Direct Link Networks: Encoding and Framing

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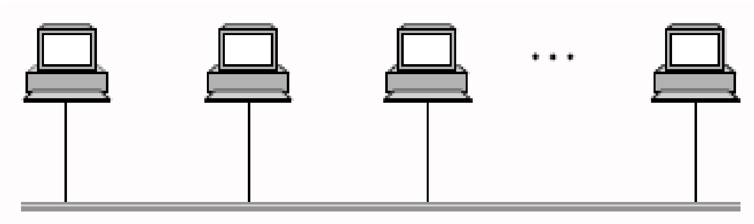
Direct Link Networks

- Types of Networks
  - Point-to-point
  - Multiple access



- What problems do we need to solve to build a direct link network?

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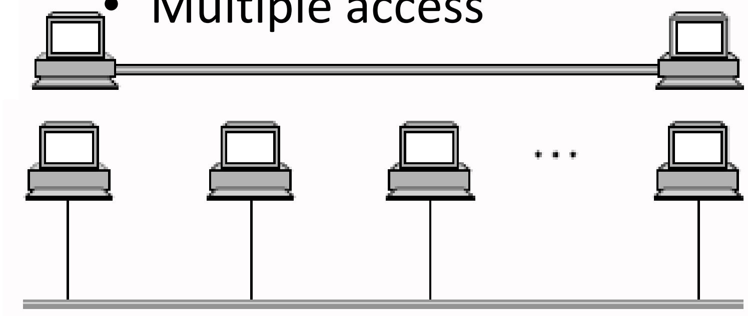
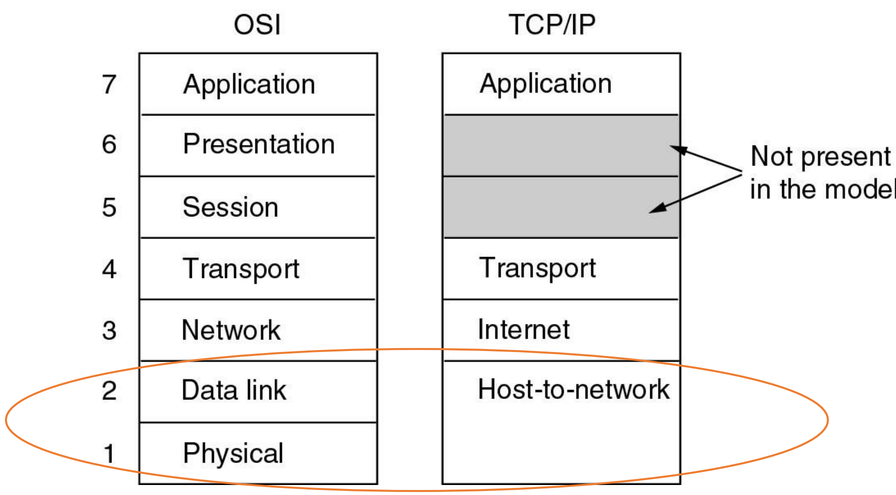
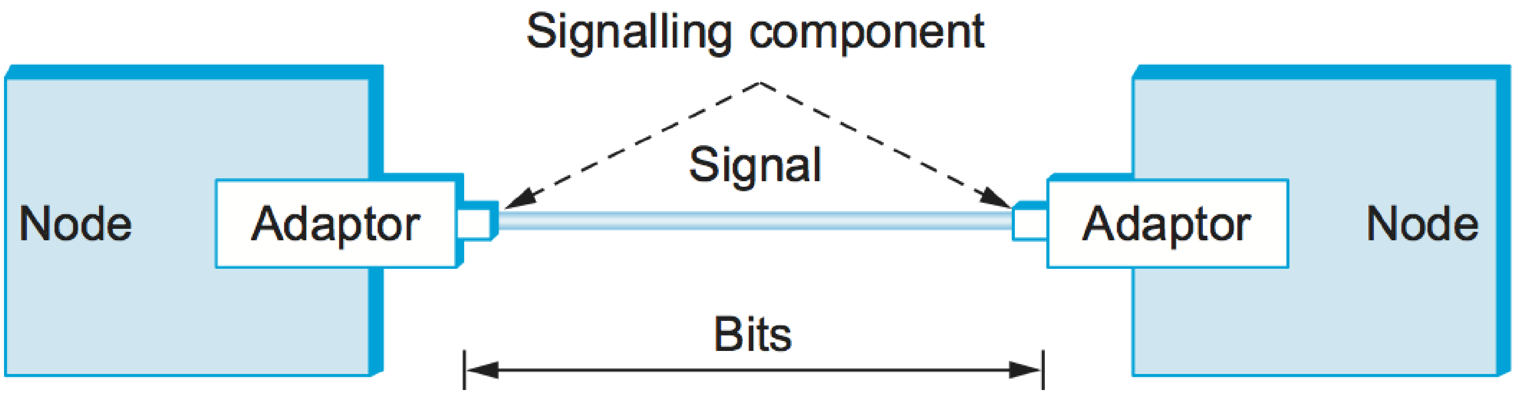




- **Encoding**
  - **Encoding bits onto transmission medium**
- Framing
  - Delineating sequence of bits into messages
- Error detection
  - Detecting errors and acting on them
- Reliable delivery
  - Making links appear reliable despite errors
- Media access control
  - Mediating access to shared link

Encoding

- Encoding
  - Encode bits (binary data) into the signals
  - Modulation is not our focus
  - Assume working with two discrete signals: high and low

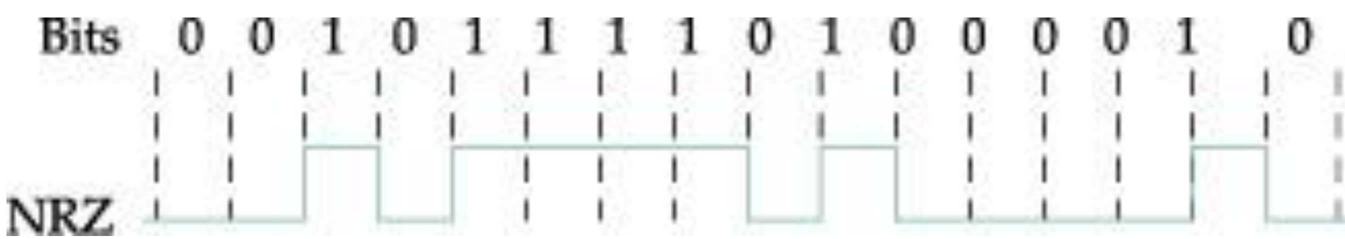


Comparing Encoding Schemes

- Nonreturn-to-zero (NRZ)
- Nonreturn-to-zero-inverted (NRZI)
- Manchester
- 4B/5B

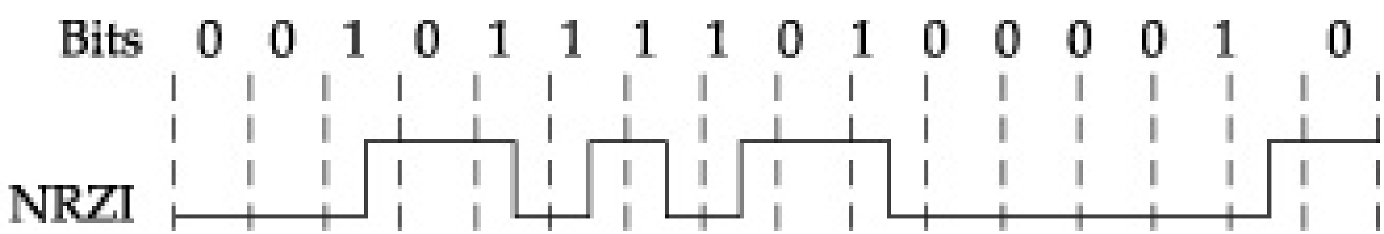
Non-Return-to-Zero (NRZ)

- Method
  - Low → 0
  - High →1
- Shortcoming
  - Long strings of 1s or 0s
    - Baseline wander
    - Difficult to recover clock



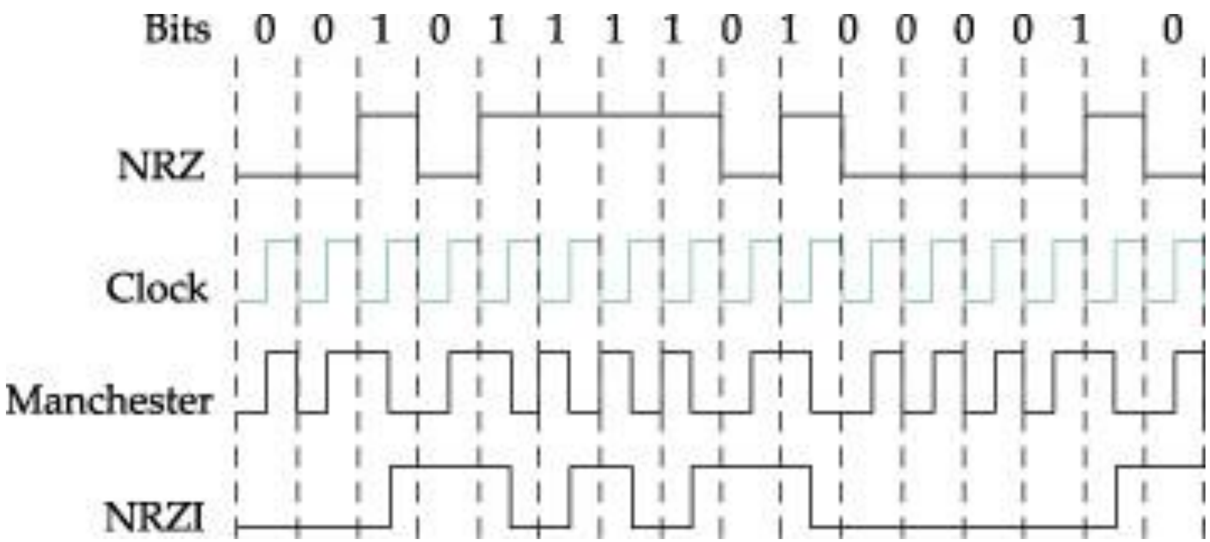
Non-Return-to-Zero-Inverted (NRZI)

- Method
  - Signal transition → 1
  - No transition → 0
- Solve the problem caused by consecutive 1's
  - But, the problem caused by consecutive 0's remains



Manchester

- Method
  - 0 → low-to-high transition 1 → high-to-low transition
  - That is, NRZ signal ⊕ Clock signal
- Solve the problems caused by both consecutive 1's and 0's
- New problem
  - 50% efficient: Two samples per clock cycle to detect a transition, bit rate is 50% of baud rate (rate of signal changes)



Exercise

- Encode bit sequence 01101
  - using the NRZ, NRZI, Manchester encodings
  - indicating bits and by drawing clock, NRZ, NRZI, and Manchester signals
- (example in the previous slide)

4B/5B

- Motivations
  - To cope with baseline wander
  - To ease clock recovery
  - To increase encoding efficiency (bit rate/baud rate)

4B/5B

- Break long strings of repeated 0's and 1's
  - before transmission: 4 bits → 5 bits
    - Every 4 bits of actual data are encoded in a 5-bit code
    - 4 bits data symbols: $2^4 = 16$
    - 5 bits codes: $2^5 = 32$
    - No more than 1 leading 0's in codes and no more than 2 trailing 0's
    - No pair of 5-bit codes results in more than 3 consecutive 0's
    - 11111: line is idle   01101: control symbols
  - Transmit codes using NRZI: 80% efficiency

4B/5B Encoding

4-Bit Data Symbol	5-Bit Code
0000	11110
0001	01001
0010	10100
0011	10101
0100	01010
0101	01011
0110	01110
0111	01111

4-Bit Data Symbol	5-Bit Code
1000	10010
1001	10011
1010	10110
1011	10111
1100	11010
1101	11011
1110	11100
1111	11101

Exercise

- Encode bit sequence 01011000 using 4B/5B encoding by showing the conversion between 4-bit sequences of data and their 5-bit sequences of codes and drawing clock and 4B/5B signals

4-Bit Data Symbol	5-Bit Code
0000	11110
0001	01001
0010	10100
0011	10101
0100	01010
0101	01011
0110	01110
0111	01111

4-Bit Data Symbol	5-Bit Code
1000	10010
1001	10011
1010	10110
1011	10111
1100	11010
1101	11011
1110	11100
1111	11101

Summary: Encoding

- Encoding problem
- Solutions
    - NRZ
    - NRZI
    - Manchester
    - 4B/5B
- Advantages/disadvantages?

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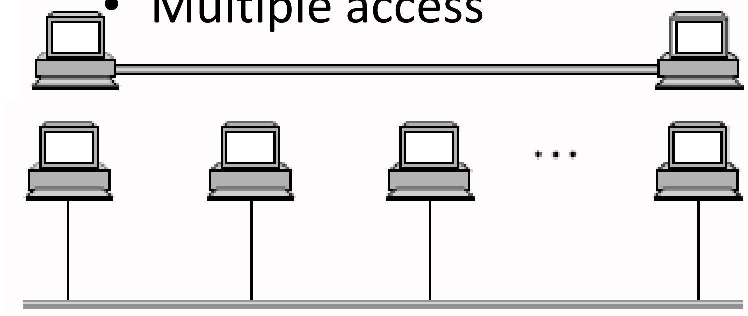

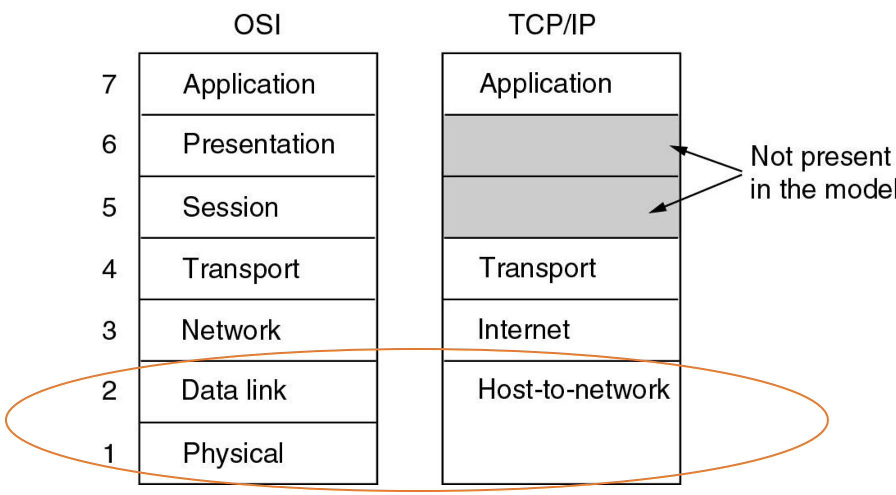

- Encoding
  - Encoding bits onto transmission medium
- **Framing**
  - **Delineating sequence of bits into messages**
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Framing

- Packet-switched networks → block of data are exchanged between nodes
  - Breaking bits into frames (packets)
- Key issue: identity where a frame begins and the ends
- *Why do we need it?*
- To discuss in the context of point-to-point links
  - Byte-oriented framing: frame as a collection of bytes
  - Bit-oriented framing: frame as a collection of bits
  - Clock-based framing (vs. sentinel-based approaches)
- Framing is a fundamental problem that must be addressed in multiaccess networks as well.

Byte-Oriented Framing

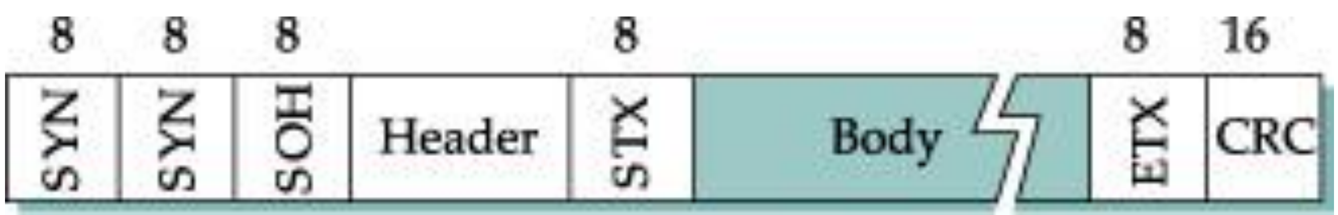
- Each frame as a collection of bytes.
- Examples
  - Binary Synchronous Communication (BISYNC) protocol
  - Digital Data Communication Message Protocol (DDCMP)
  - Point-to-Point Protocol (PPP)
    - widely used today

Sentinel vs Length

- Using sentinels
  - Use special characters to indicate where frames start and end.
    - e.g., BISYNC
      - SYN (synchronization), STX (start of text), ETX (end of text)
      - Need “escaping”*/character stuffing* : special characters might appear in the data portion of the frame (DLE, or data link escape)
- Using a length value
  - include the number of bytes in the frame at the beginning of the frame, i.e., in the frame header.
  - Example: DDCMP
  - A transmission error could corrupt the count field, in which case the end of the frame would not be correctly detected.
  - *framing error*

BISYNC

- Uses special characters known as *sentinel characters* to indicate whether frames begins and ends
- The beginning of a frame: SYN
- The data portion of the frame is contained between STX and ETX
- The start of header: SOH

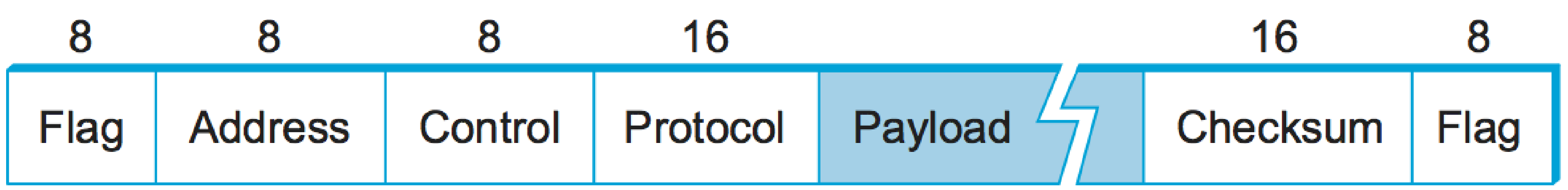


BISYNC Character Stuffing

- Problem: ETX may appear in the data
- Solution: escaping
  - ETX → DLE ETX
  - DLE → DLE DLE

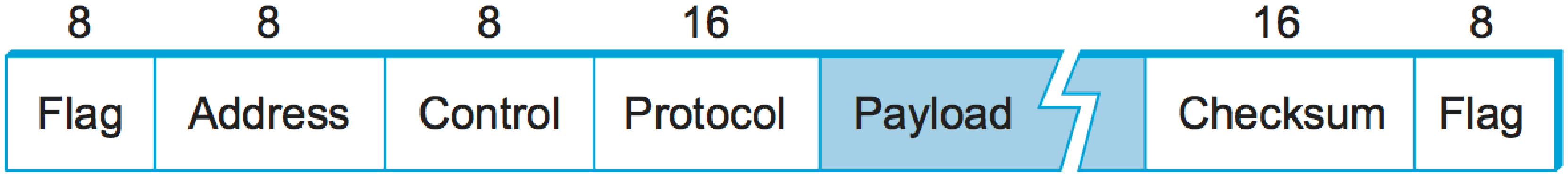
Point-to-Point Protocol (PPP)

- Commonly used to carry Internet Protocol packets over various sorts of point-to-point links
- Uses sentinels and character stuffing.

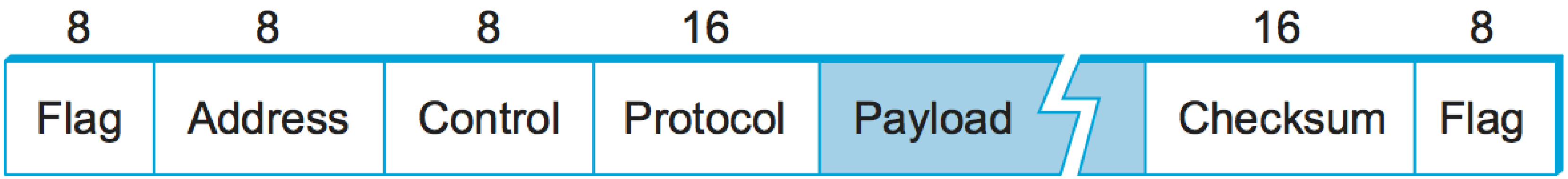


Illustrating Frame Format

- A frame is illustrated as a sequence of labeled fields
  - Above each field is a number indicating the length of that field in bits.
  - Note that the packets are transmitted beginning with the leftmost field.
  - Often we can find more detailed explanation of each field



Illustrating Frame Format: Fields



- The special start-of-text character, denoted as the Flag field is 01111110.
- The Address and Control fields usually contain default values.
- The (Protocol) field is used for demultiplexing; it identifies the high-level protocol, such as IP.
- The frame payload size can be negotiated, but it is 1500 bytes by default.
- The Checksum field is either 2 (by default) or 4 bytes long.
- The PPP frame format is unusual in that several of the field sizes are negotiated rather than fixed.
    - This negotiation is conducted by a protocol called the Link Control Protocol (LCP). PPP and LCP work in tandem
    - LCP sends control messages encapsulated in PPP frames

Exercise

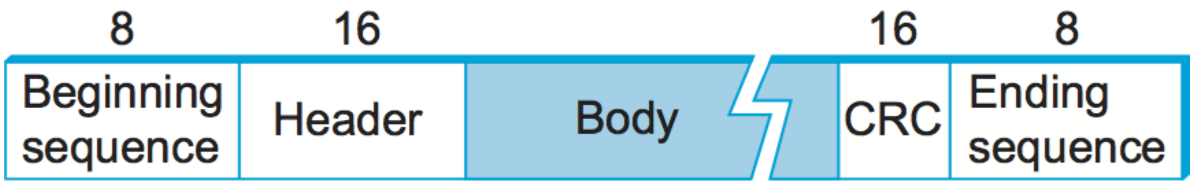
- Use the sentinels in the ASCII table.
  - (Linux manual page) man ascii
- DATA = 1A E2 02 2A 16 10 20. What would be the bytes in the *body* of the frame using BISYNC?
- In the *body* of a frame using BISYNC, is it possible to see the following byte sequence and why?

  4A 10 51 6B

Bit-Oriented Framing

- View a frame as a collection of bits
  - The Synchronous Data Link Control (SDLC) protocol
  - High-Level Data Link Control (HDLC) protocol

HDLC

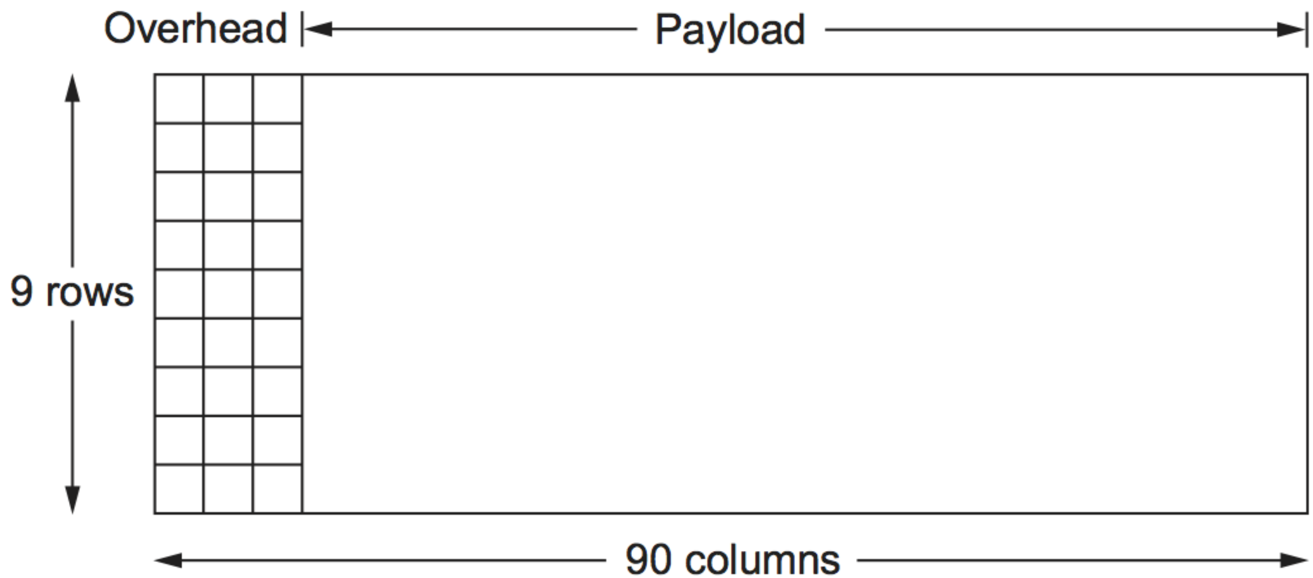


- Beginning and ending sequence: 01111110
- 01111110 may appear in the body of the frame → bit stuffing
    - Sender: any time five consecutive 1s have been transmitted from the body of the, the sender inserts a 0 before transmitting the next bit.
        - 11111 → 111110 → no 6 1's in a row in the body
    - Receiver: three scenarios
        - Bit stuffed; end of frame marker; error

Clock-based Framing

- Versus sentinel-based approaches
  - Due to bit stuffing or character stuffing, it is in fact not possible to make all frames exactly the same size,
- Clock-based framing
  - Frame can be of fixed length
- Example: framing in SONET
  - Popular in network backbone
  - Has a close tie with telephony systems
  - Specification takes entire book
  - Frame is of fixed length
    - 125 μs for STS-1 (51.84 Mbps)
      - Q: How big is a Mega (sidebar in page 45)
      - 125 μs = ? Bytes
  - Detect the frame header at each interval of frame size

SONET STS-1 Frame



- Each frame is 9 x 90 = 810 bytes long
- The first 2 bytes of the frame contain a special bit pattern
- When the special pattern turns up in the right place enough times, the receiver concludes that it is in sync and can then interpret the frame correctly.

Summary

- Bits/Bytes → frames
  - Framing
- Q: What if the link is not error free? In other words, what if a frame is corrupted?
  - Error detection
  - Reliable transmission