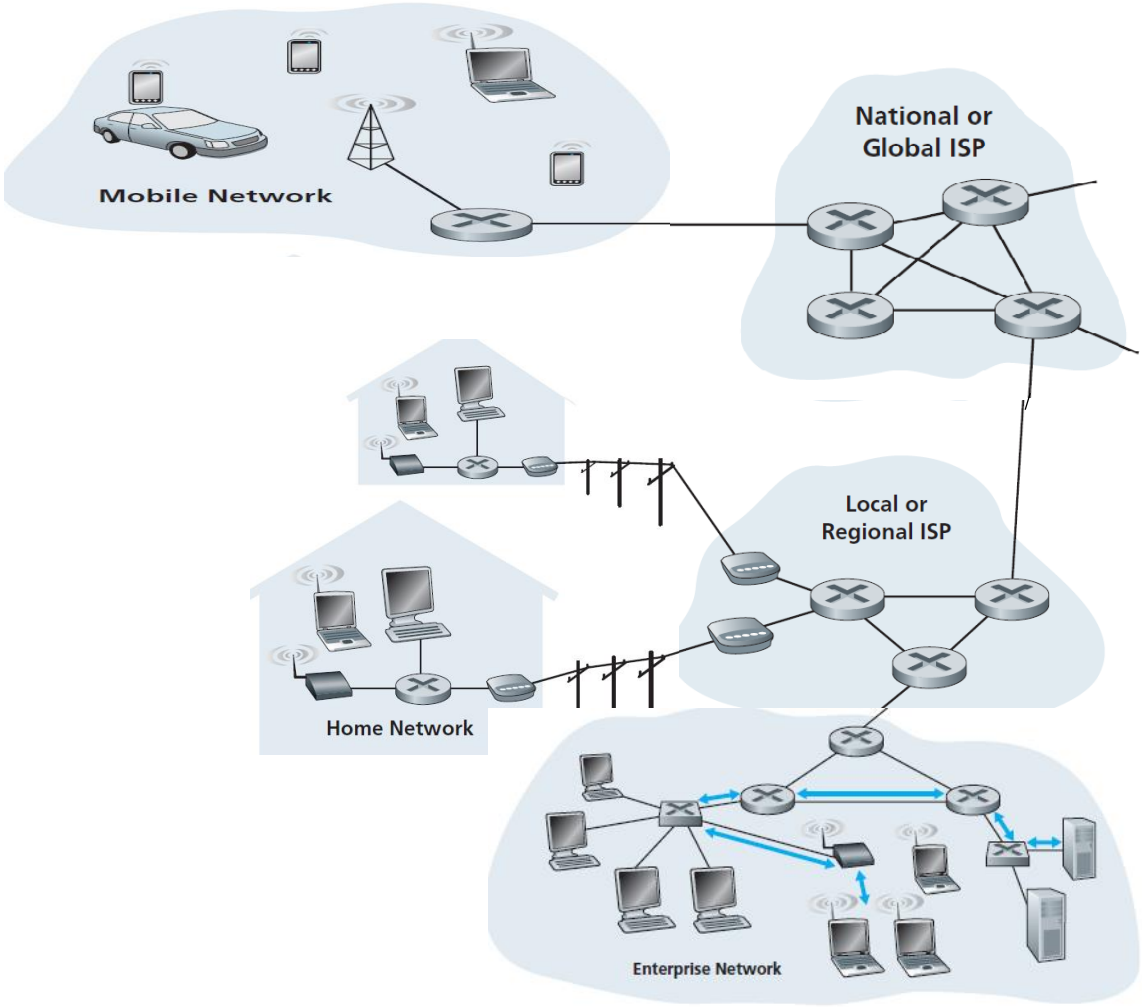
Introduction to the Link Layer

- We will refer any device that runs a link layer (i.e., layer 2) protocol as a node.
- Nodes include hosts, routers or switches, and Wi-Fi access points.
- We will also refer to the communication channels that connect adjacent nodes along the communication path as links.
- In order for a datagram to be transferred from source host to destination host, it must be moved over each of the individual links in the end-to-end path.
- Over a given link, a transmitting node encapsulates the datagram in a link layer frame and transmits the frame into the link.

Introduction to the Link Layer



Services Provided by the Link Layer

- Data Link layer has number of specific functions it can carry out. These include:
  - Framing:
    - Almost all link layer protocols encapsulate each network layer datagram within a link layer frame before transmission over the link.
    - A frame consists of a data field, in which the network layer datagram is inserted, and a number of header fields.
    - The structure of the frame is specified by the link layer protocol.

Services Provided by the Link Layer

- Data Link layer has number of specific functions it can carry out. These include:
  - Reliable delivery:
    - When a link layer protocol provides reliable delivery service, it guarantees to move each network layer datagram across the link without error.
    - A link layer reliable delivery service is often used for links that are prone to high error rates, such as a wireless link.
    - A link layer reliable delivery service can be achieved with acknowledgments and retransmissions.

Services Provided by the Link Layer

- Data Link layer has number of specific functions it can carry out. These include:
  - Link access:
    - A medium access control (MAC) protocol specifies the rules by which a frame is transmitted onto the link.
    - For point to point links that have a single sender at one end of the link and a single receiver at the other end of the link, the MAC protocol is simple – the sender can send a frame whenever the link is idle.
    - When multiple nodes share a single broadcast link the MAC protocol serves to coordinate the frame transmissions of the many nodes.

Services Provided by the Link Layer

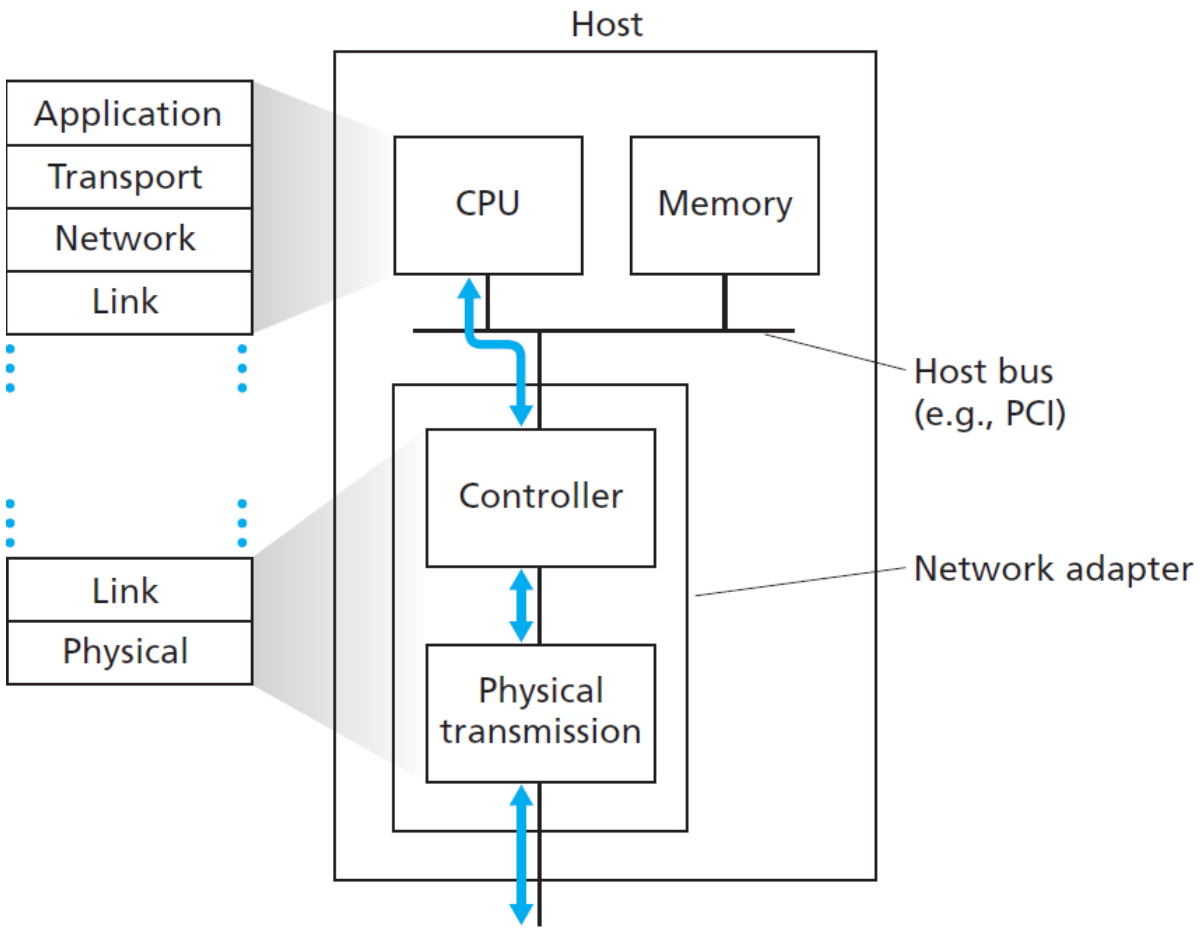
- Data Link layer has number of specific functions it can carry out. These include:
  - Error detection and correction:
    - The link layer hardware in a receiving node can incorrectly decide that a bit in a frame is zero when it was transmitted as a one, and vice versa.
    - Such bit errors are introduced by signal attenuation and electromagnetic noise. Because there is no need to forward a datagram that has an error, many link layer protocols provide a mechanism to detect such bit errors.
    - This is done by having the transmitting node include error detection bits in the frame, and having the receiving node perform an error check.
    - Error detection in the link layer is usually implemented in hardware.
    - Error correction is similar to error detection, except that a receiver not only detects when bit errors have occurred in the frame but also determines exactly where in the frame the errors have occurred (and then corrects these errors).

Services Provided by the Link Layer

- Data Link layer has number of specific functions it can carry out. These include:
  - Flow Control:
    - The nodes on each side of a link have a limited amount of buffering capacity.
    - This is a potential problem, as a receiving node may receive frames at a rate faster than it can process the frames (over some time interval).
    - Without flow control, the receiver's buffer can overflow and frames can get lost.
    - Similar to the transport layer, a link layer protocol can provide flow control in order to prevent the sending node on one side of a link from overwhelming the receiving node on the other side of the link.

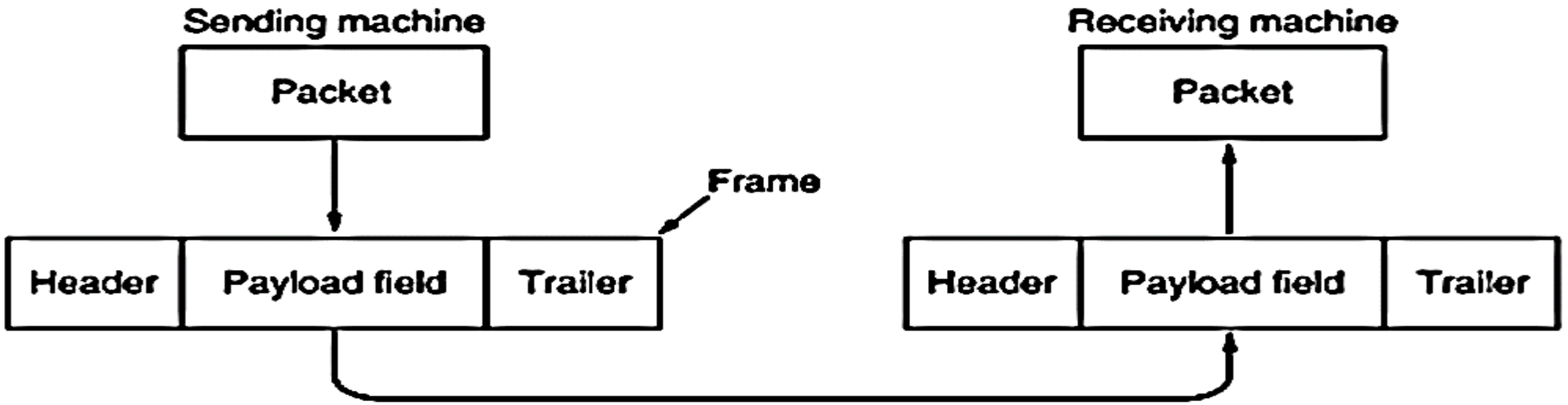
Where is Link Layer Implemented

- It is implemented in a network adapter, or sometimes known as a network interface card (NIC).
- The controller in the NIC , is usually a single, special-purpose chip that implements many of the link-layer services (framing, link access, error detection, etc.).



Framing

- The data Link layer takes the packet from the network layer and encapsulates them in frames for transmission.
- Each frame contains a frame header, a payload field for holding the packet, and a frame trailer.



Types of Frames

- Frames can be of two types.
  - Fixed size frames:
    - No need for defining the boundaries of the frames.
    - The size itself can be used as a delimiter.
    - Frame in ATM wide area network, which uses frames of fixed size called cells.
  - Variable size frames:
    - Define the end of the frame and the beginning of the next.
    - Prevalent in local area network.

How it is done?

- The data link layer breaks the bit stream up into discrete frames and compute the checksum for each frame.
- When a frame arrives at the destination, the checksum is recomputed.
- If the newly computed checksum is different from the one contained in the frame, the data link layer knows that an error has occurred and takes steps to deal with it.
- One way to achieve this framing is to insert time gaps between frames, much like the spaces between words in ordinary text.
- However, networks rarely make any guarantees about timing, so it is possible these gaps might be squeezed out or other gaps might be inserted during transmission.

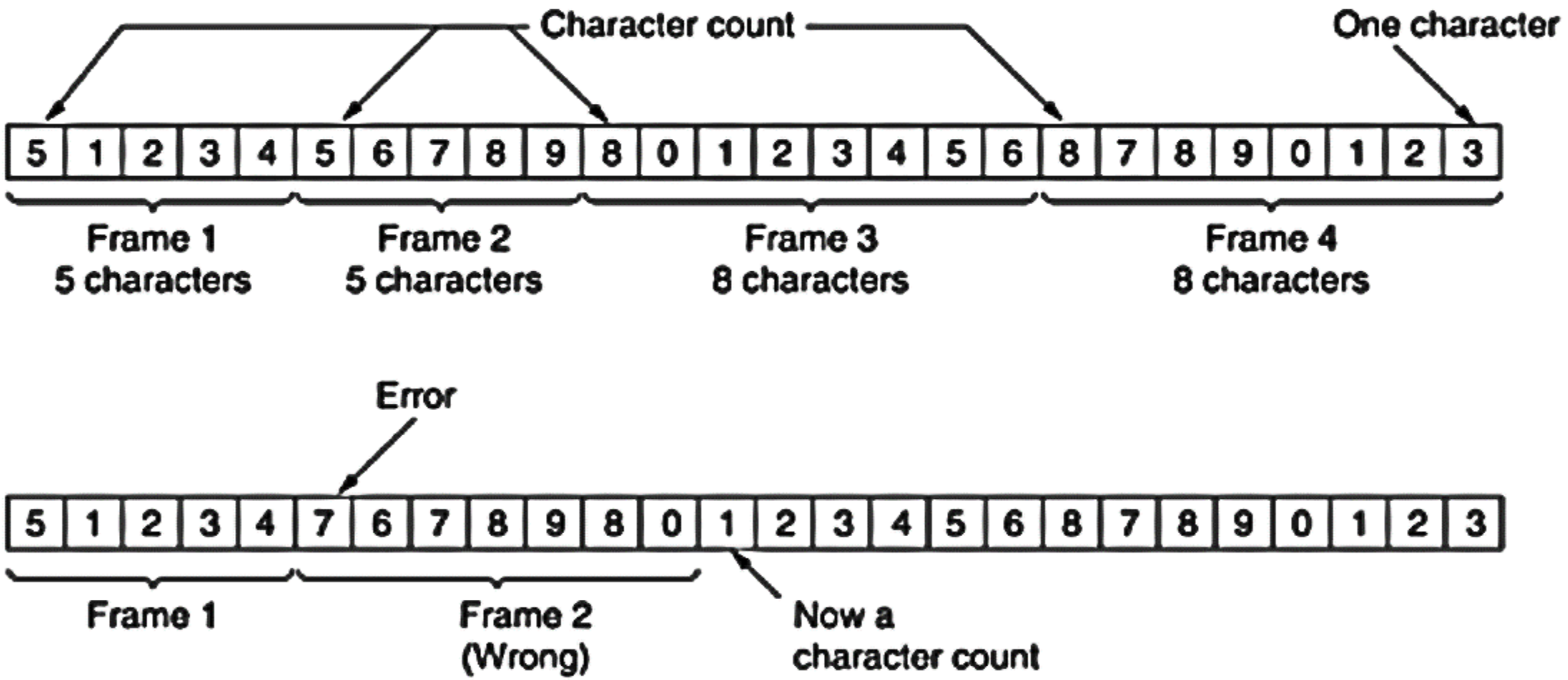
Framing Techniques

- Common methods used are:
  - Character Count
  - Flag bytes with byte stuffing – Character Oriented Protocol
  - Starting and ending flags, with bit stuffing - Bit Oriented Approach

Character Count

- Number of character in the frame is specified in the header field.
- When the data link layer at the destination sees the character count, it knows how many characters follow and hence where the end of the frame is.

Character Count



Character Count

- The count can be garbled by a transmission error. - Problem
- Even if the checksum is incorrect so the destination knows that the frame is bad, it still has no way of telling where the next frame starts.
- Sending a frame back to the source asking for a retransmission does not help either, since the destination does not know how many characters to skip over to get to the start of the retransmission.
- For this reason, the character count method is rarely used.

Flag Bytes with byte stuffing

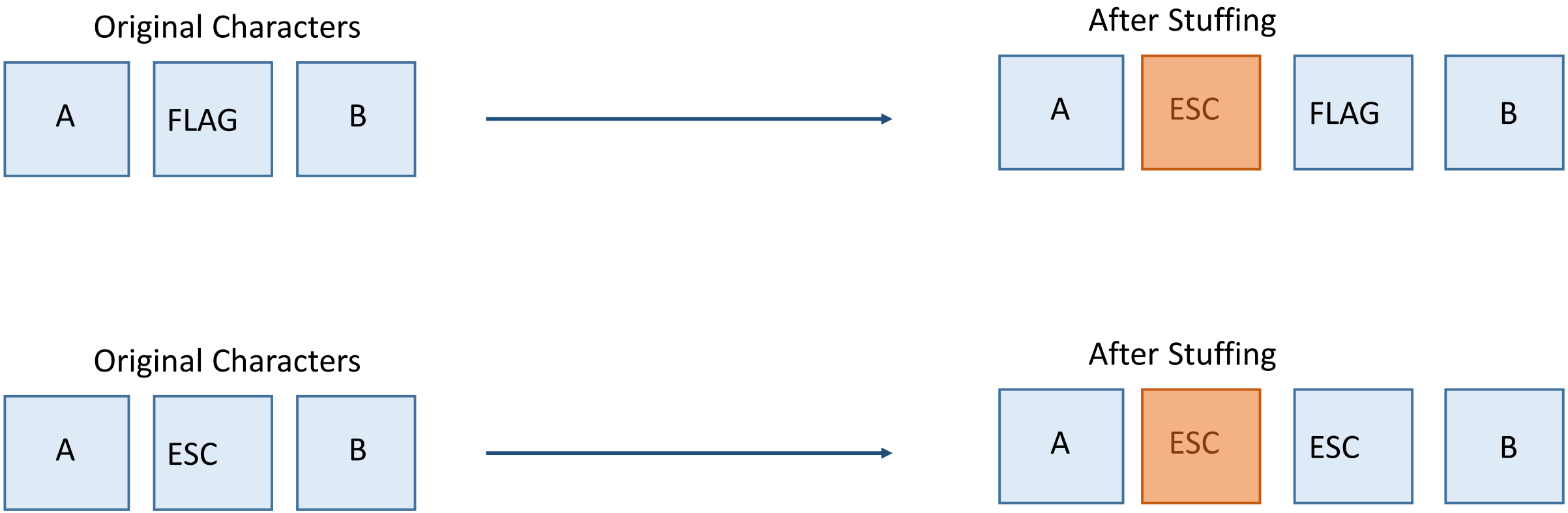
- Each frame starts and ends with special byte called a flag byte, as both the starting and ending delimiter.

- If the receiver ever loses synchronization, it can just search for the flag byte to find the end of the current frame.
- Two consecutive flag bytes indicate the end of one frame and start of the next one.

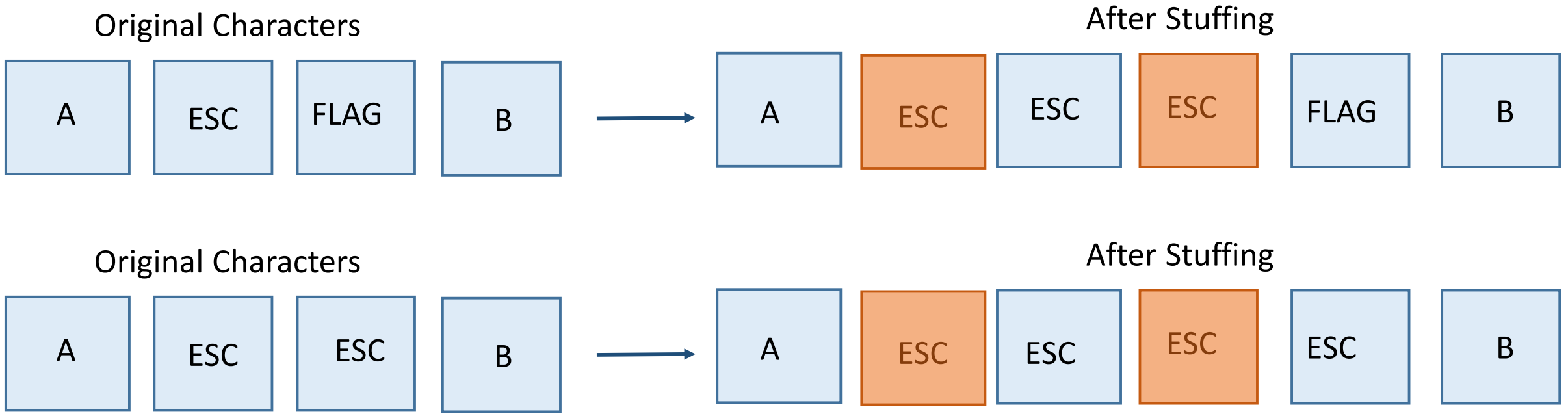
Flag Bytes with byte stuffing

- Flag byte's bit pattern may occur in the data. - Problem
- Insert a special escape byte (ESC) just before each "accidental" flag byte in the data at the sender side.
- The data link layer on the receiving end removes the escape byte before the data are given to the network layer.
- This technique is called byte stuffing or character stuffing.

Flag Bytes with byte stuffing

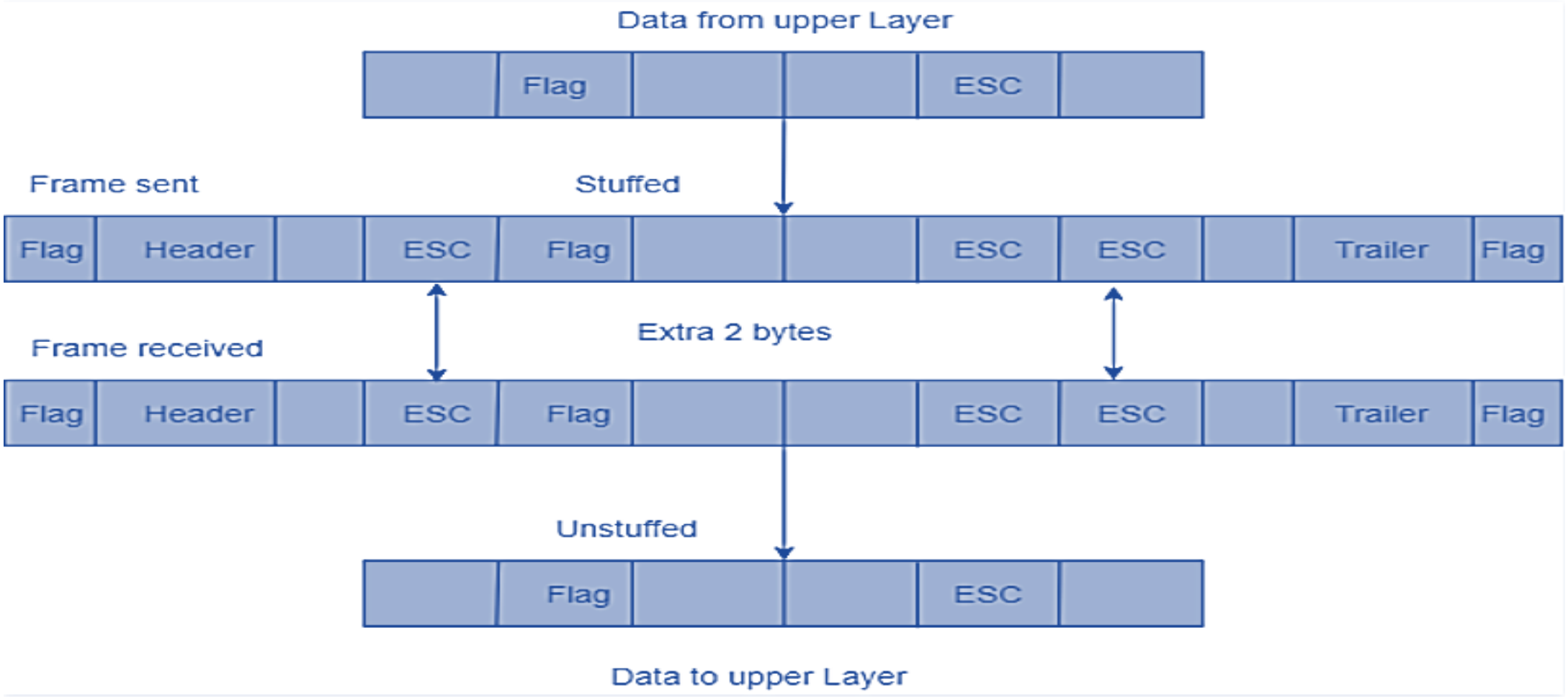


Flag Bytes with byte stuffing



- In all cases, the byte sequence delivered after destuffing is exactly the same as the original byte sequence.

Flag Bytes with byte stuffing



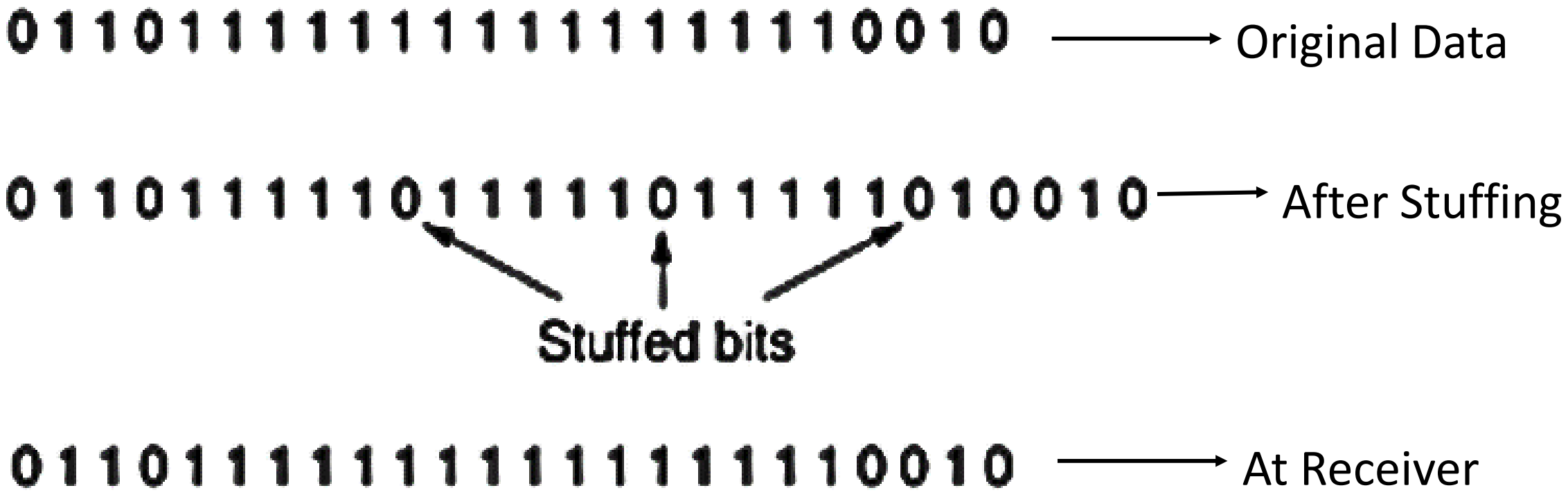
Flag Bytes with byte stuffing

- This method is tied to the use of 8-bit characters only.
- Not all character codes use 8-bit characters. For example. UNICODE uses 16-bit characters.
- There is need of a new technique to allow arbitrary sized characters.

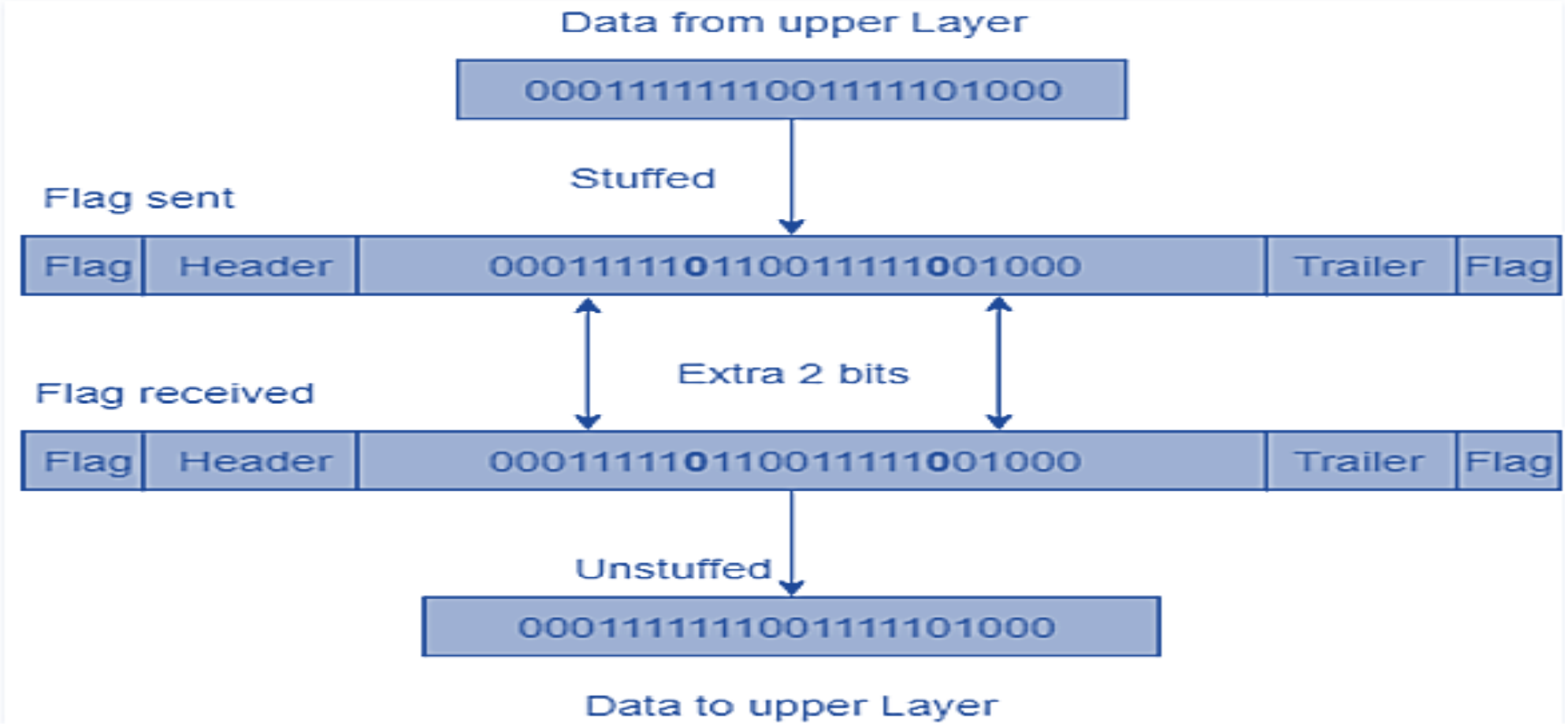
Bit Stuffing

- Bit stuffing allows data frames to contain an arbitrary number of bits and allows character codes with an arbitrary number of bits per character.
- Each frame begins and ends with a special bit pattern, 01111110 (in fact, a flag byte).
- Whenever the sender's data link layer encounters five consecutive 1s in the data, it automatically stuffs a 0 bit into the outgoing bit stream.
- This is called bit stuffing.
- When the receiver sees five consecutive incoming 1 bits, followed by a 0 bit, it automatically destuffs (i.e., deletes) the 0 bit.
- If the user data contain the flag pattern, 01111110, this flag is transmitted as 011111010 but stored in the receiver's memory as 01111110.

Bit Stuffing



Bit Stuffing



Bit Stuffing

- With bit stuffing, the boundary between two frames can be recognized by the flag pattern.
- Thus, if the receiver loses track of where it is, all it has to do is scan the input for flag sequences, since they can only occur at frame boundaries and never within the data.
- As a final note on framing, many data link protocols use a combination of a character count with one of the other methods for extra safety.