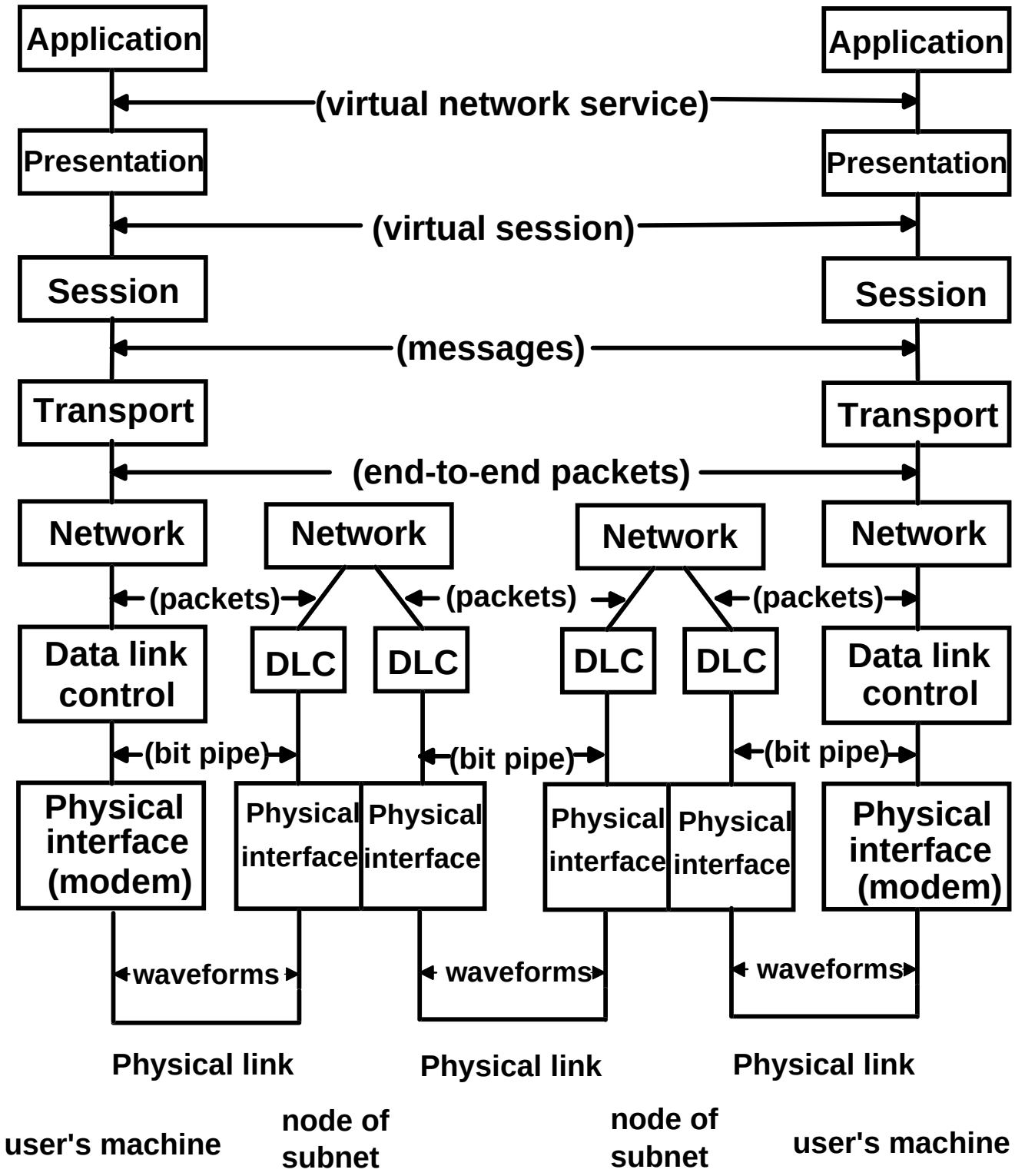
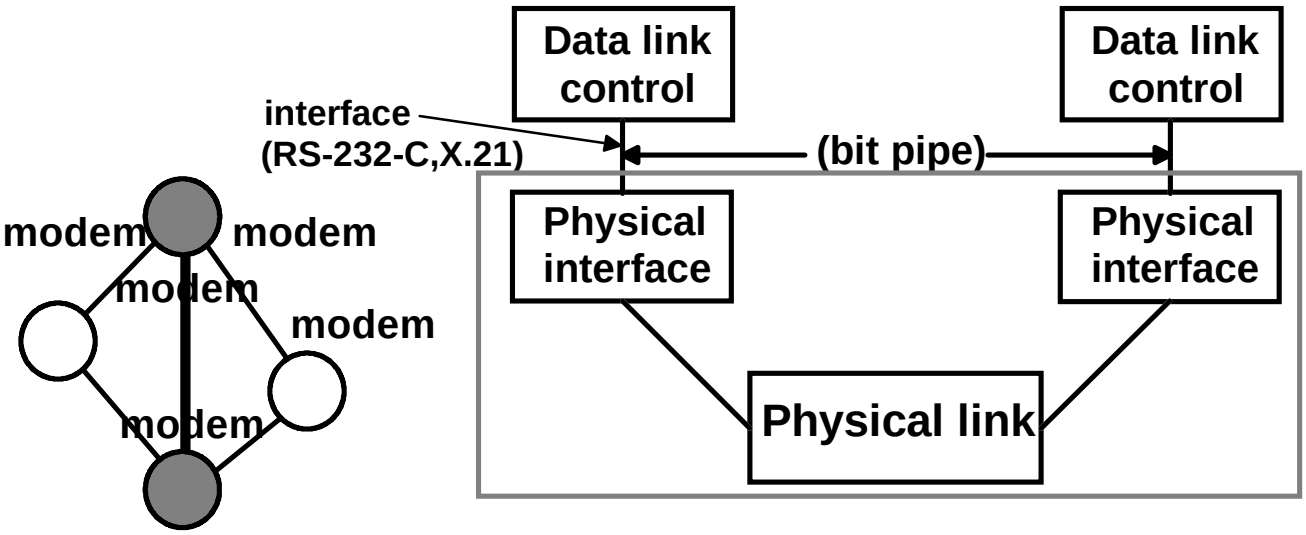
Reference Model



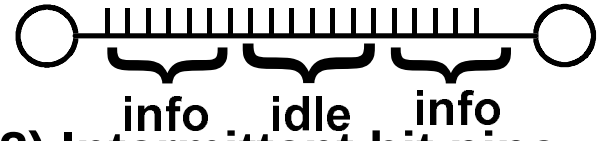
Physical layer (modem)

modulator & demodulator



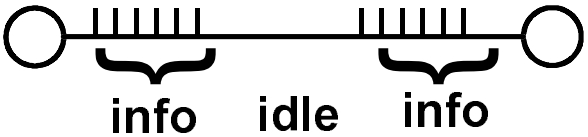
Service provided to DLC: (unreliable) bit pipe.
Function: waveform design
Timing of the bit sequence

(1) Synchronous bit pipe



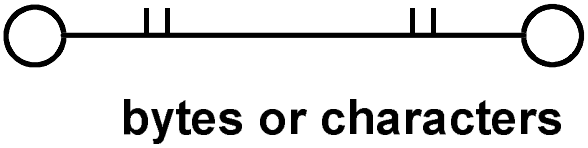
(usually the case in high-speed network)

(2) Intermittent bit pipe



(local area networks)

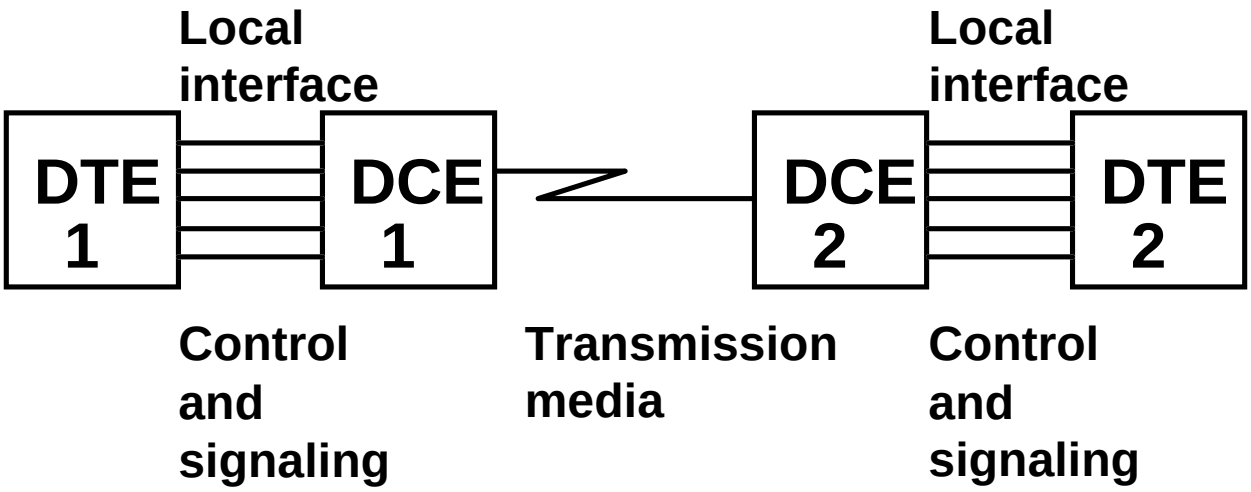
(3) Asynchronous characters



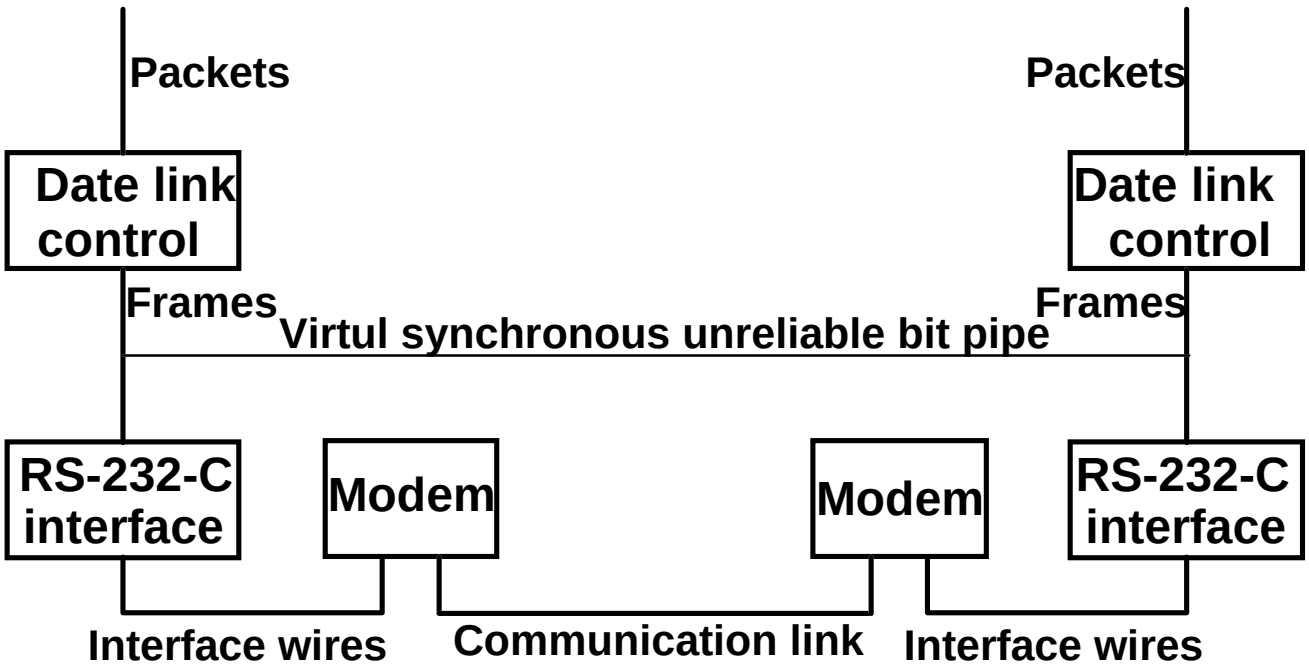
(slow communication, e.g. terminal to computer)

Interface between the DLC module & modem

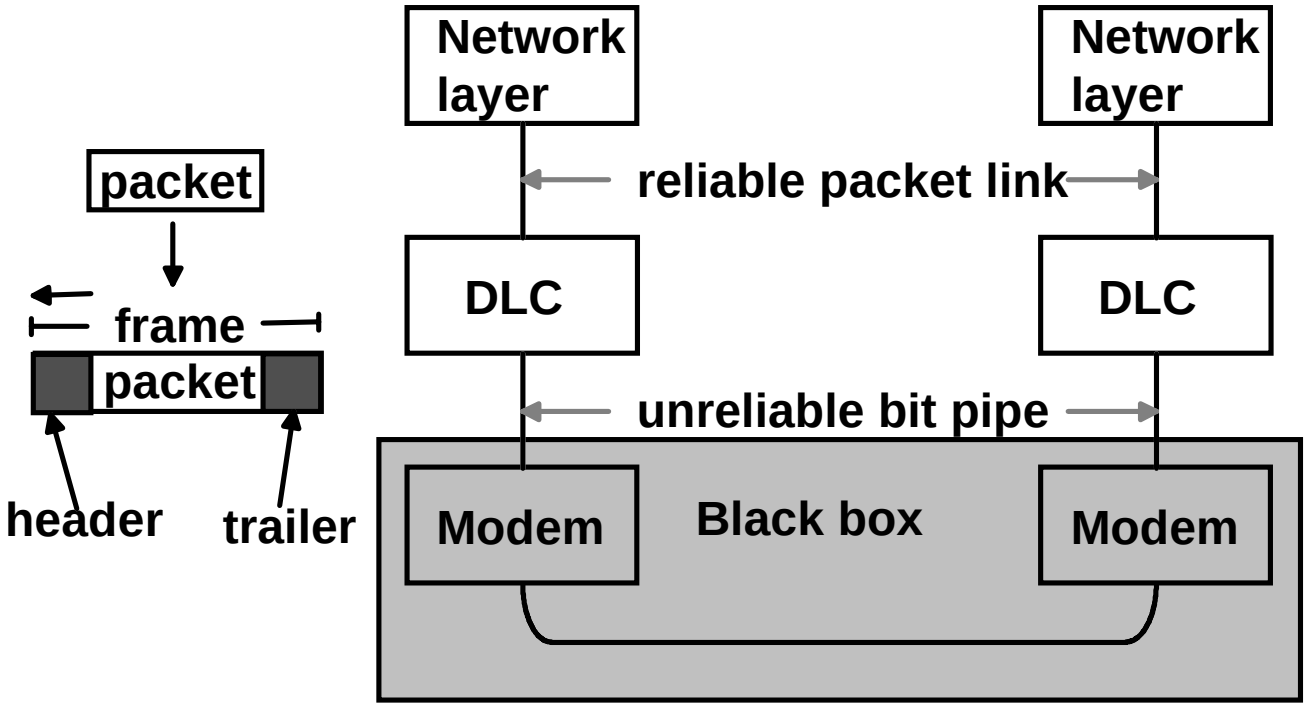
DTE to DCE communications



DTE = Data Termination Equipment
DCE = Data Communications Equipment



Data link control layer (DLC)

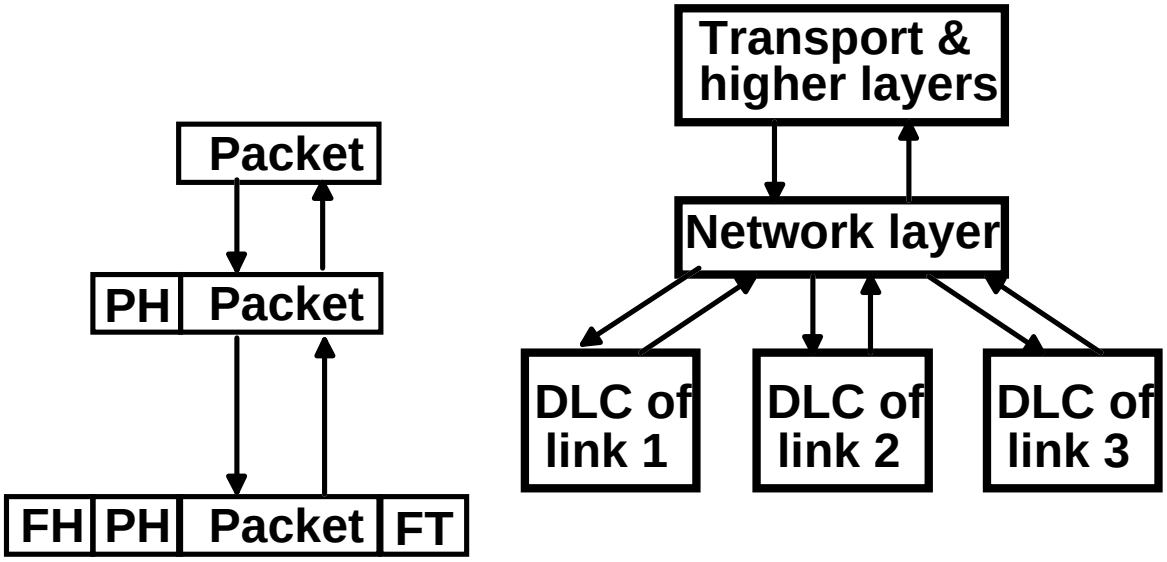


Function: framing, error control, retransmissions.

- Packets are accepted from the network layer
- DLC adds header & trailer to form a frame
- DLC supplies frames (and idle fill for a synchronous bit pipe) to lower layer
- DLC also detects error and requests retransmission.

Network layer

Each network node (PSE) or host (external site) has a network layer module, plus one DLC module for each part.



PH = Packet Header
FH = Flame Header
FT = Frame Trailer

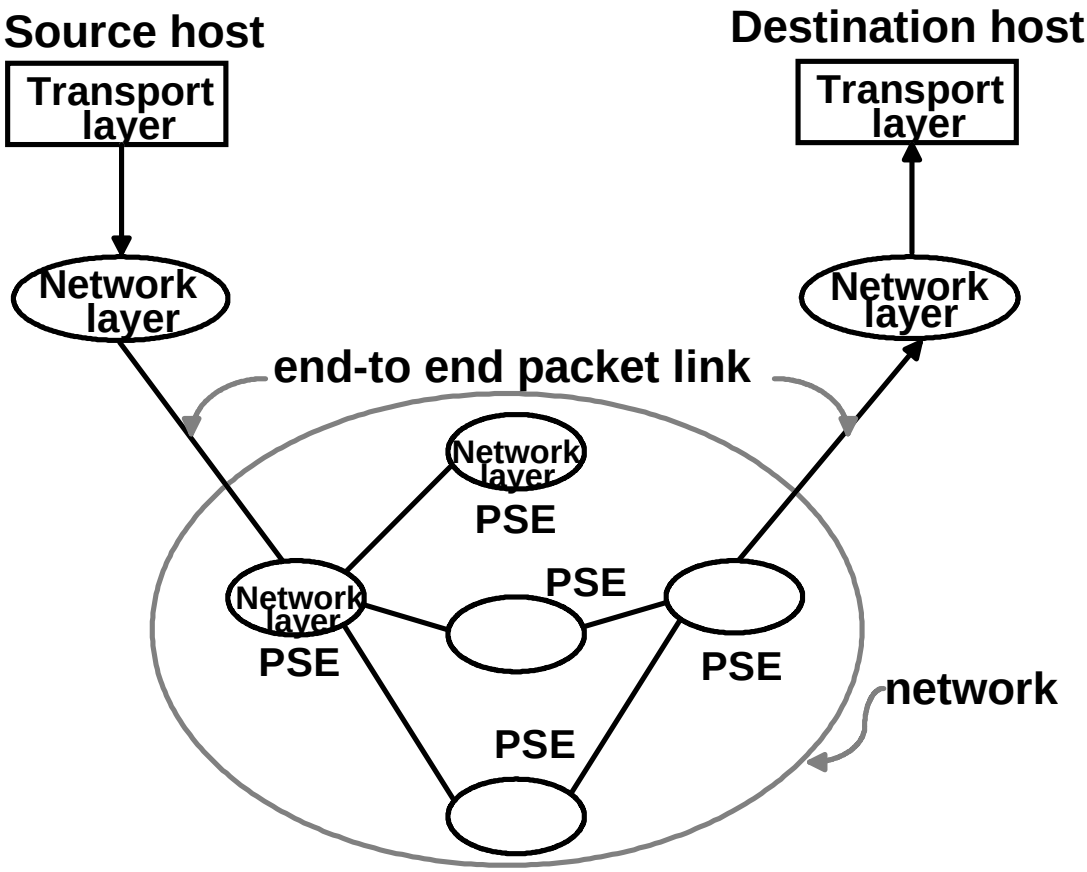
Service it provides: end-to end packet transfer.

Functions: routing & flow control.

- **Network layer can also generate its own packets**
- **The network layer may be missing (e.g. in multiaccess communication systems.)**

Function of network layer

Routing:

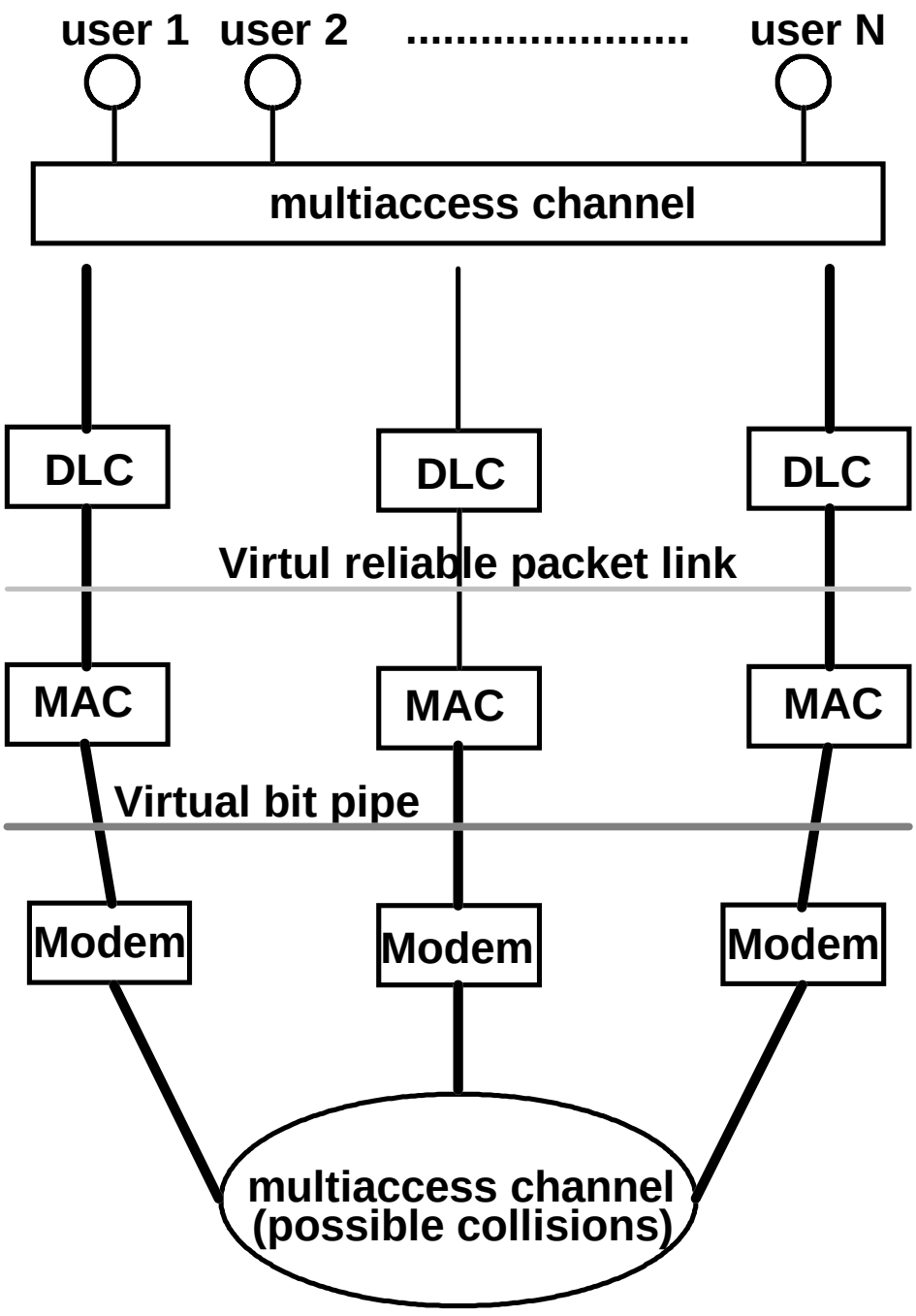


Packets may be delivered to the higher layers in the correct order (virtual circuit service) or out of order (datagram service).

FLOW CONTROL: make sure the destination can absorb packets; withhold flow of packets when congestion arises.

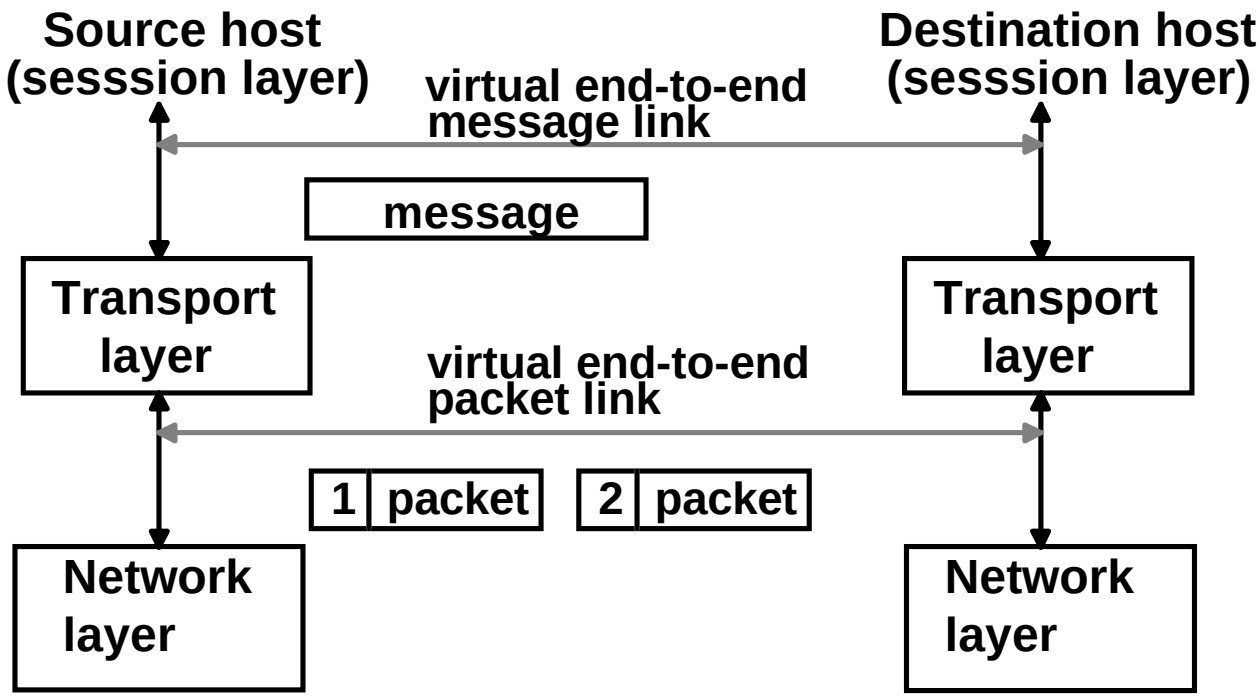
INFORMATION BROADCAST: congestion + queueing delays, status of links and node, etc..

MAC sublayer (Medium Access Control)



Service: intermittent synchronous bit pipe.
Function: MAC sublayer allocates the channel to each node, resolves collision, etc..

Transport layer

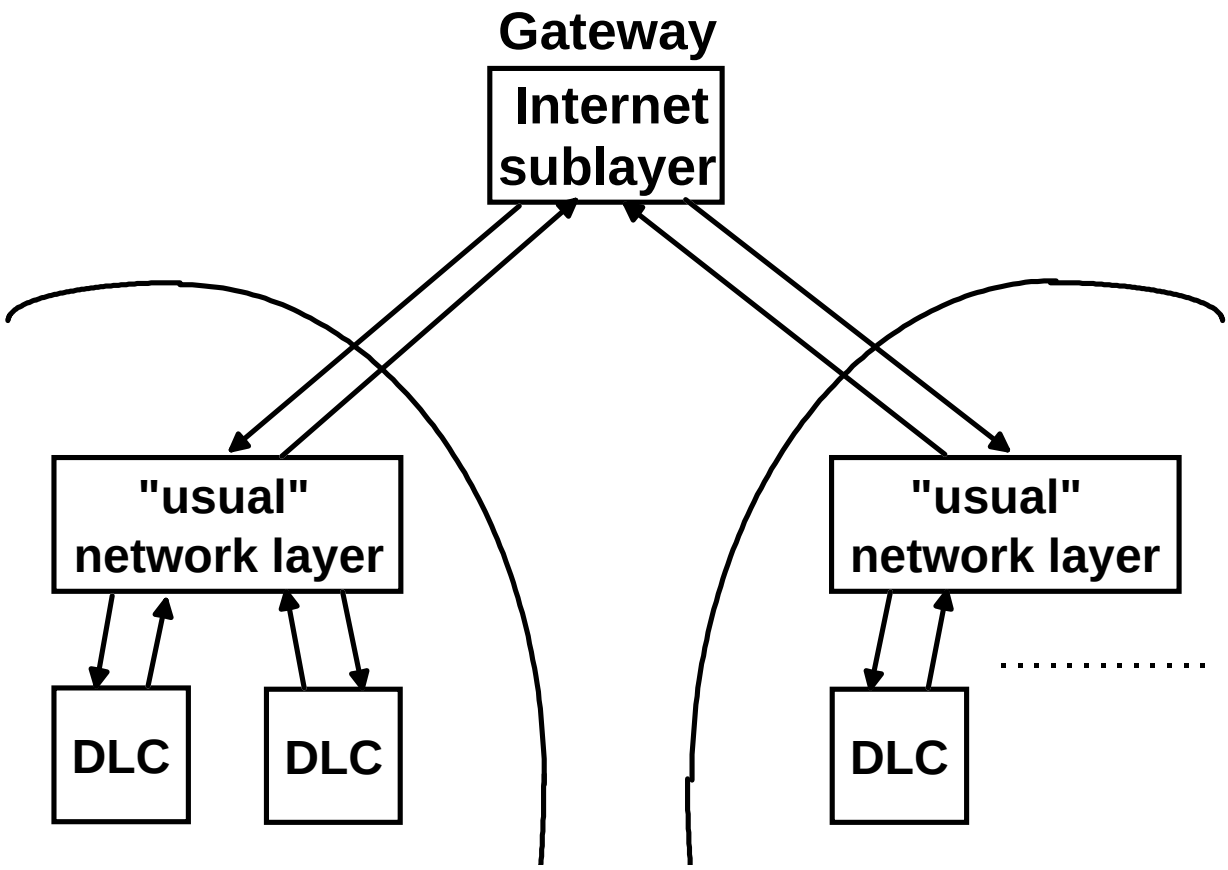


Functions:

1. Break messages into packets (and reassemble at the destination).
2. Multiplex sessions with same destination node.
3. Split high rate sessions into multiple sessions.
4. Error control.
5. Flow control.

Internet sublayer

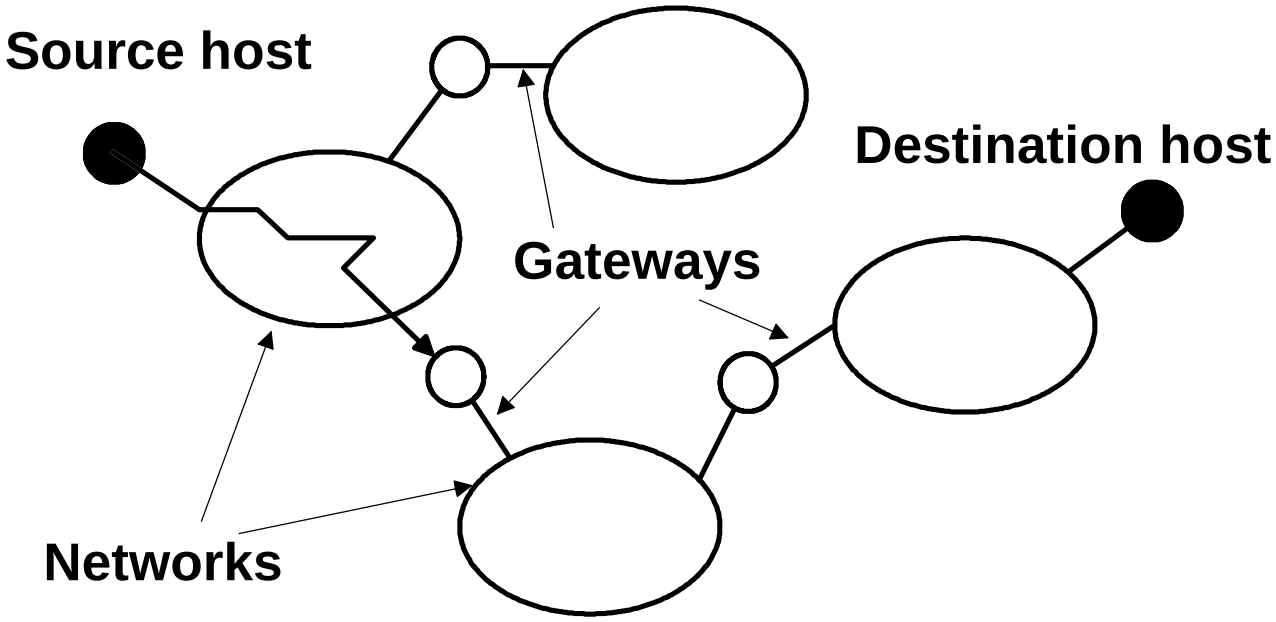
Needed at node (called “gateways”) where two incompatible networks are joined together.



Function: routing and flow control between networks, conversion of packet format etc.

- **Usually viewed as the top part of the network layer**
- **If gateways connect two LANs of the same type they are called “bridges”**

Routing in an internet

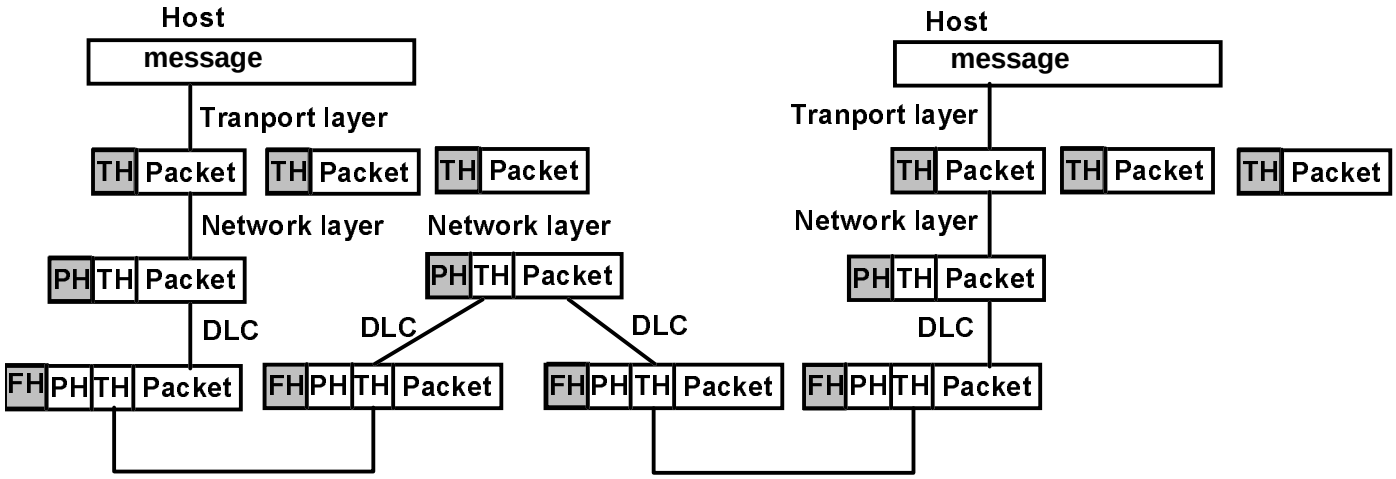


Session layer: provides billing, access right, login functions.

Presentation layer: provides character code conversion, data encryption, data compression.

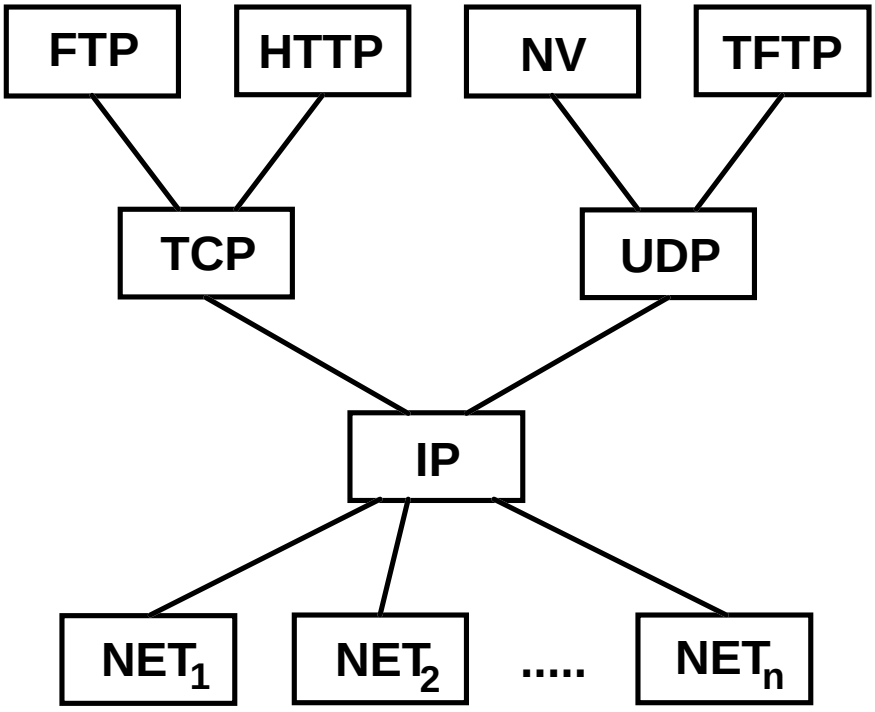
Application layer: provides specific information transfer services to user (e.g. ftp, rlogin, e-mail, telnet, etc)

Headers at each layer



Each layer looks only at its own header.

Internet's protocol graph



FTP = File Transfer Protocol
HTTP = Hyper-Text Transport Protocol
NV = Network Video
TFTP = Trivial File transport Protocol
TCP = Transport Control Protocol
UDP = User Datagram Protocol
IP = Internet Protocol

ARQ: Retransmission Strategies

ARQ = Automatic Repeat reQuest.

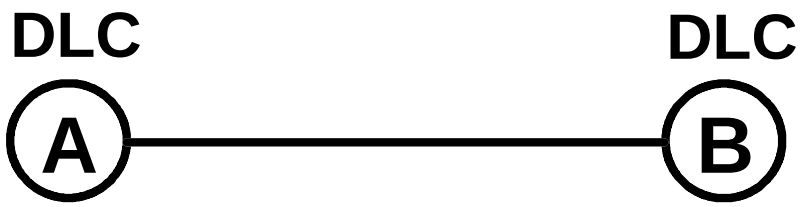
DLC layer (transport layer)

Assume: 1. Error detection is infallible.

2. Channel preserves order of packets.

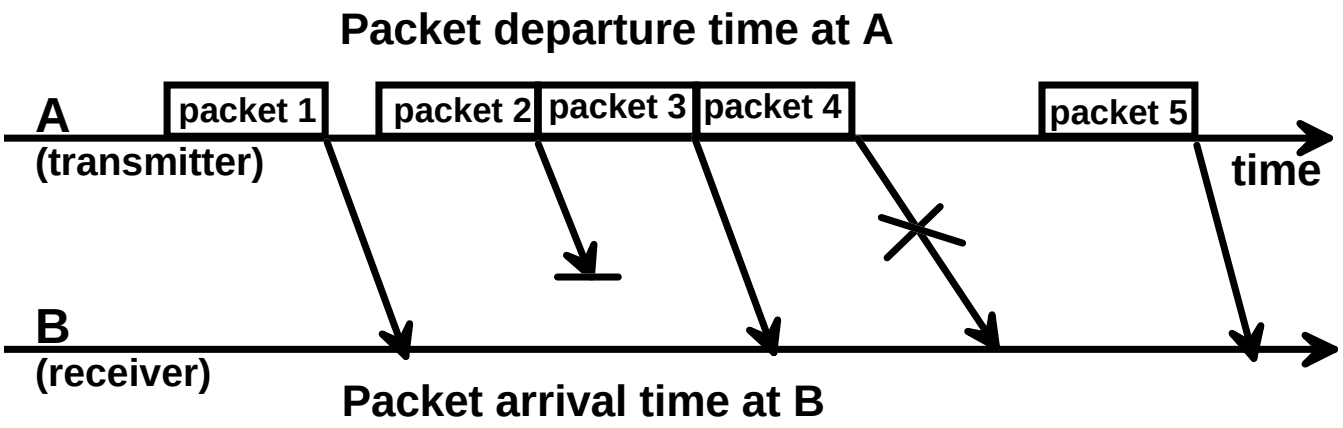
3. Packets may be arbitrarily delayed or even lost.

4. Feedback channel is error prone also.



We want B to accept all packets sent by A only once, and in the correct order.

Model of frame transmission

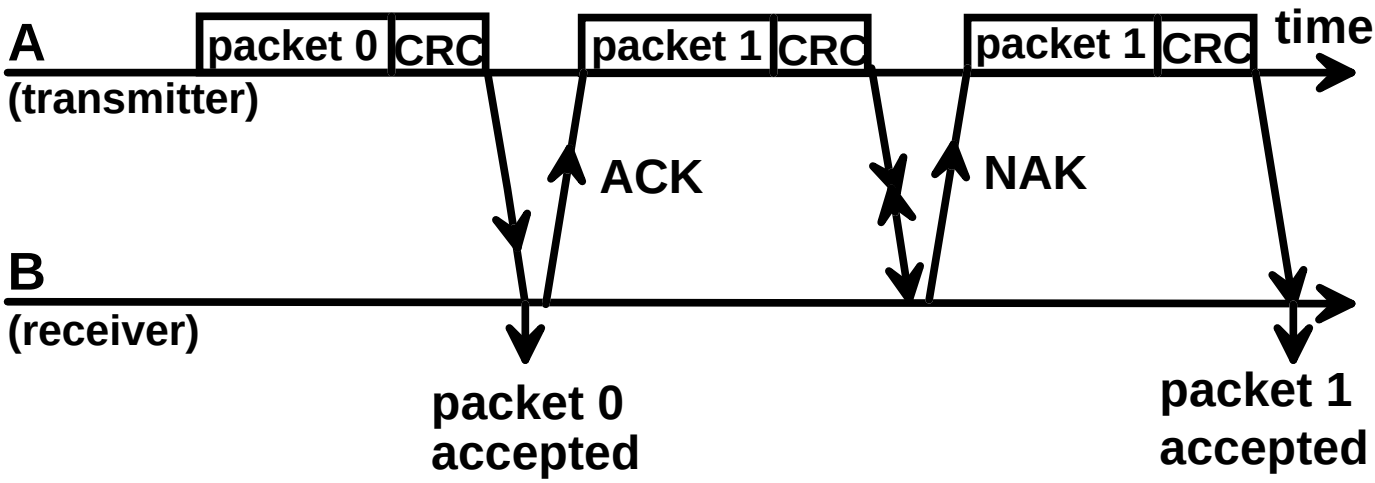


Packet 2 is lost.

Packet 4 contains errors.

Packet 1, 3, 5 are accepted by node B.

Pure Stop and Wait Protocol



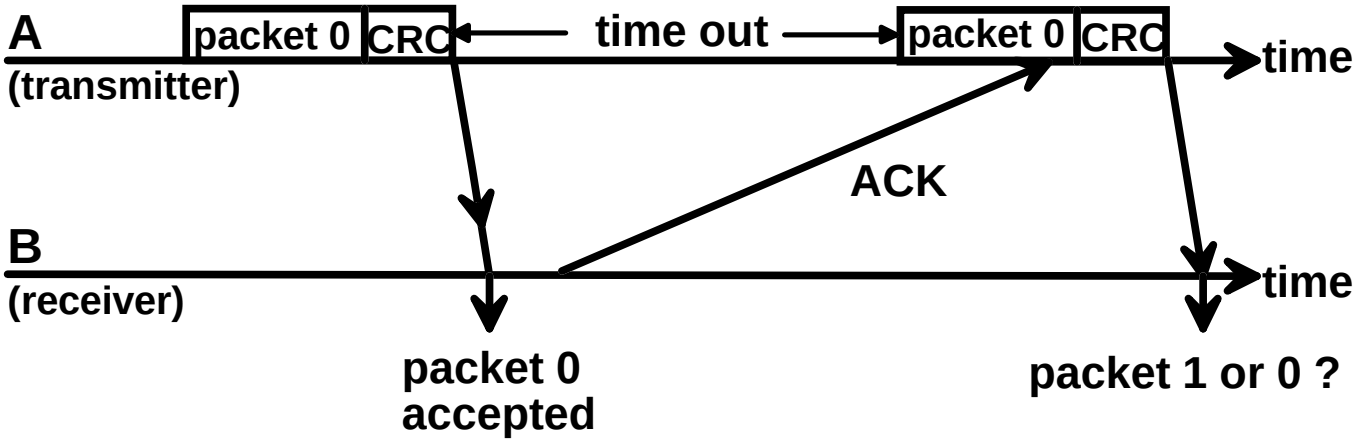
After sending a packet, A waits for ACK or NAK.

- **if ACK received, A sends next packet.**
- **if NAK received, A sends same packet.**

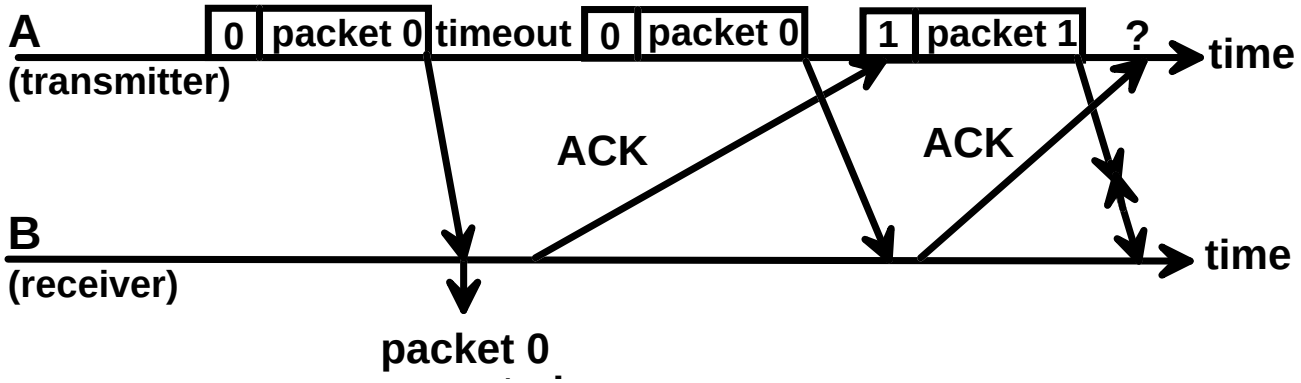
If neither ACK or NAK arrives, A times-out and retransmits same packet(frame).

ACK = acknowledge
NAK = negative acknowledge
CRC = cyclic redundancy check code

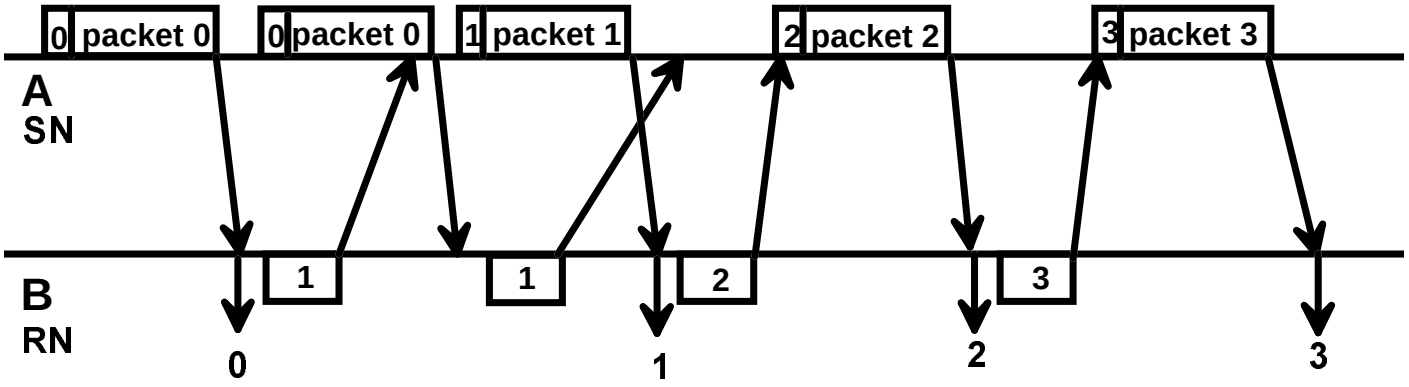
The use of timeouts for lost packets requires sequence numbers.



Request numbers are required on ACKs to distinguish packet asked:

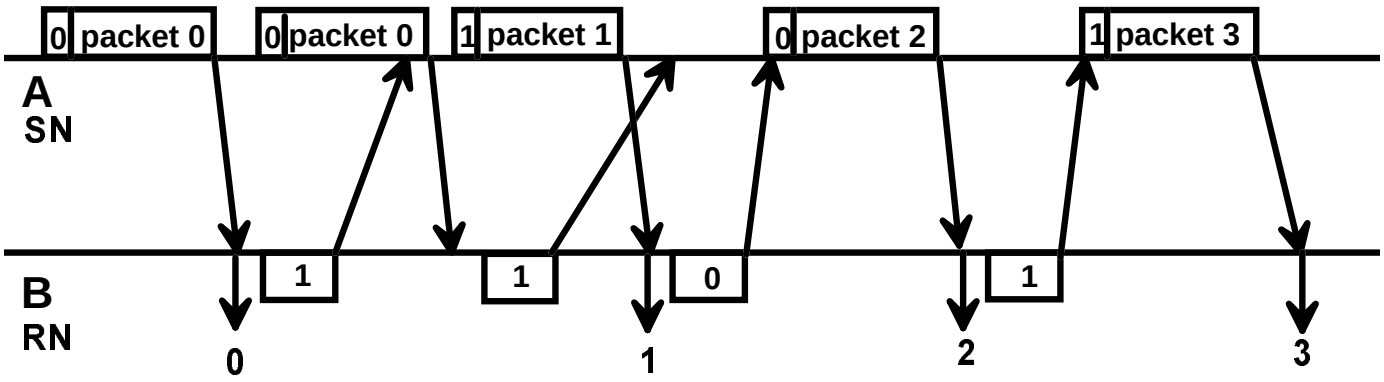


Example using sequence number



Request Numbers

- **Instead of sending “ACK” or “NAK”, the receiver sends the number of the packet currently awaited.**
- **Sequence numbers and request numbers can be sent module 2 (because packets n & n+2 cannot be simultaneously in the system.)**



- **This works correctly for all combinations of delay and timeout assuming that:**
  1. **packets travel in order on links.**
  2. **CRC never fails to detect errors.**
  3. **The system is correctly initialized**