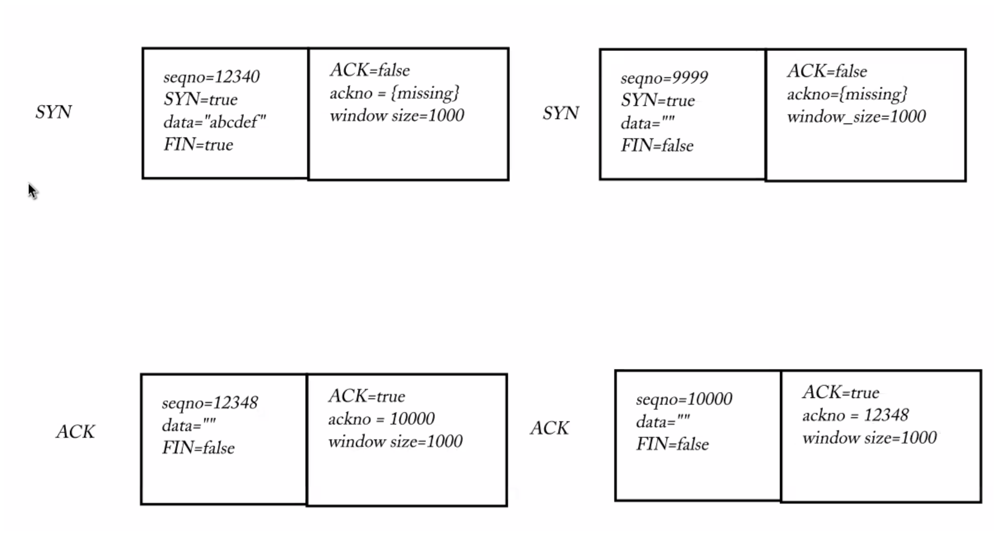
- Last week:
    - the Internet's service abstraction as a host-to-host datagram
    - Build on top of that: User Datagram
    - Reliable services on top of User Datagram: host, DNS, DHCP, … (idempotent short get)
    - TCP: convert datagrams to reliable byte streams
        - Sender Message: first_index, data, FIN
        - Receiver Message: next needed index, window size
        - "User Datagram" info (for multiplexing, and part of the TCP datagram port): source port (16 bits), destination port (16 bits), checksum
        - Internet datagram (v4): source address(32 bits), destination address (32 bits), checksum
        - source IP + source port + destination IP + destination port define a connection
        - There can be 2^32 * 2^16 * 2^16 simultaneous connections from one computer.
        - e.g. ByteStream: "abcdef"
            - Sender message: {first_index=0, data: "abcdef", FIN=true}
            - Or {first_index=0, data="abcdef", FIN=false} and {first_index=6, data:"", FIN=true}
            - Receiver message: {next_needed=6, window_size=0}, {next_needed=6, window_size=3} (FIN flag also consumes a sequence number}, {next_needed=7, window_size=2}
            - Ordering of messages:
                - sender: {first_index=0, data="abcdef", FIN=false}
                - receiver: {next_needed=6, window_size=0}
                - After the reader pops 3 bytes: {next_needed=6, window_size=3}
                - sender: {first_index=6, data:"", FIN=true}
                - receiver: {first_index=6, data:"", FIN=true}
- What happens when a stream ends?
    - My sender has ended its outgoing bytestream, but the incoming bytestream from the peer may not be ended.
    - When a stream ends, can the same pair of ports be used? Reusing the same pair of ports makes it not clear to tell whether a datagram belongs to the old stream or the new stream.
    - We want a new INCARNATION of the connection (new connection on the same pair of ports)
    - **Sequence number**: start from a random big number + **SYN**: this sequence number should be viewed as the beginning of a stream
        - If the sequence number doesn't make sense on the old stream, and the SYN flag is true, the receiver knows this is a new incarnation of the connection.

        - e.g. {sequnce_no=12345, data=”abcdef”, SYN=true, FIN=true}, and {sequence_no=99999, data=”xyz”, SYN=true, FIN=true}
    - First seqno belongs to SYN flag, next seqnos belong to each byte of stream, final seqno belongs to FIN flag.
        - It is very important to have SYN flag and FIN flag delivered reliably, so therefore receiver need to acknowledge SYN seqno and FIN seqno
- What happens to TCP receiver message’s next_needed_idx field before receiving the SYN flag from the peer?
    - Without seqno:
        - I: {{first_index=0, data=”abcdef”, FIN=true}, {next_needed=0, window_size=1000}}
        - Peer: {{first_index=0, data=””, FIN=true}, {next_needed=7, window_size=1000}}
        - I: {{first_index=7, data=””, FIN=false}, {next_needed=1, window_size=1000}}
    - With seqno and SYN:
        - I: {{seqno=12340, SYN=true, data=”abcdef”, FIN=true}, {**What should this be? (before seeing 9999 from the Peer**)}}
        - Peer: {{seqno=9999, SYN=true, data=””, FIN=true}, {next_needed=12348, window_size=1000}}
        - I: {{next_needed=10001, window size =1000}}
    - ackno = optional<int> (a pair of ACK flag and ackno int)
        - I: {{seqno=12340, SYN=true, data=”abcdef”, FIN=true}, {ACK=false, ackno={missing}, window_size=1000}} (SYN)
        - Peer: {{seqno=9999, SYN=true, data=””, FIN=true}, {ACK=true, ackno=12348, window_size=1000}} (SYN+ACK)
        - I: {{ACK=true, ackno=10001, window size =1000}} (ACK)
    - (SYN) + (SYN+ACK) + (ACK) = “the three-way handshake”
    - What if the two SYN messages are sent at the same time?



SYN | seqno=12340, SYN=true, data="abcdef", FIN=true | ACK=false, ackno = {missing}, window size=1000

SYN | seqno=9999, SYN=true, data="", FIN=false | ACK=false, ackno={missing}, window_size=1000

ACK | seqno=12348, data="", FIN=false | ACK=true, ackno = 10000, window size=1000

ACK | seqno=10000, data="", FIN=false | ACK=true, ackno = 12348, window size=1000

        -

        - Not a classic “three-way handshake” but still a valid way of starting a TCP connection.
- Standardized TCP Message:
    - Sender: {sequence number, SYN, data, FIN}
    - Receiver: {ackno: optional<int>, window_size}
    - “User Datagram” info

https://www.rfc-editor.org/rfc/rfc9293.html#name-header-format

```
Unset
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |          Source Port          |       Destination Port        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                        Sequence Number                        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    Acknowledgment Number                      |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |  Data |       |C|E|U|A|P|R|S|F|                               |
   | Offset| Rsrvd |W|C|R|C|S|S|Y|I|            Window             |
   |       |       |R|E|G|K|H|T|N|N|                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |           Checksum            |         Urgent Pointer        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                           [Options]                           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                                                               :
   :                             Data                              :
   :                                                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
          Note that one tick mark represents one bit position.
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- Wireshark tool