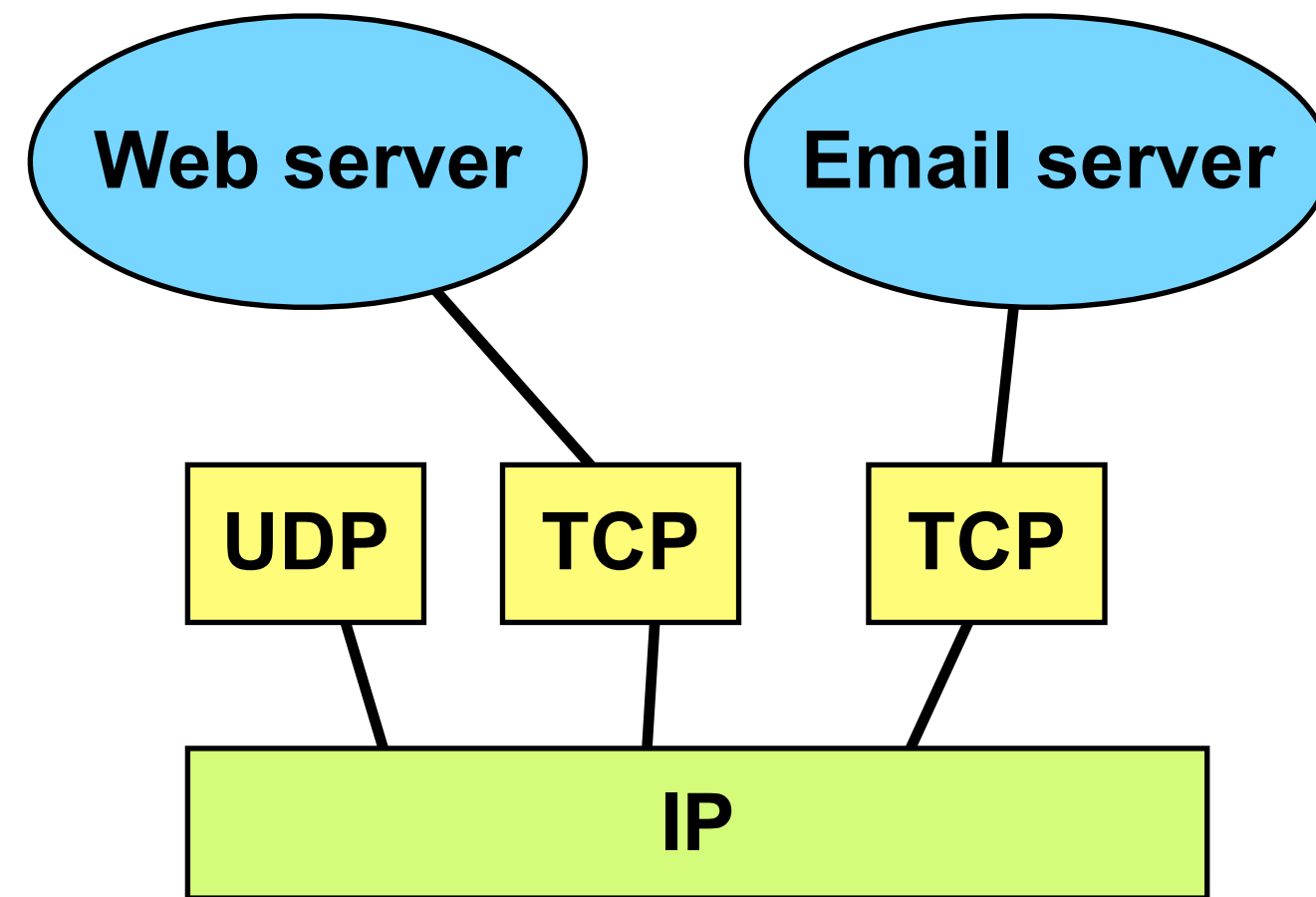


The Transport Layer

- Concepts
- UDP
- TCP
- Congestion control

TCP and UDP Transport

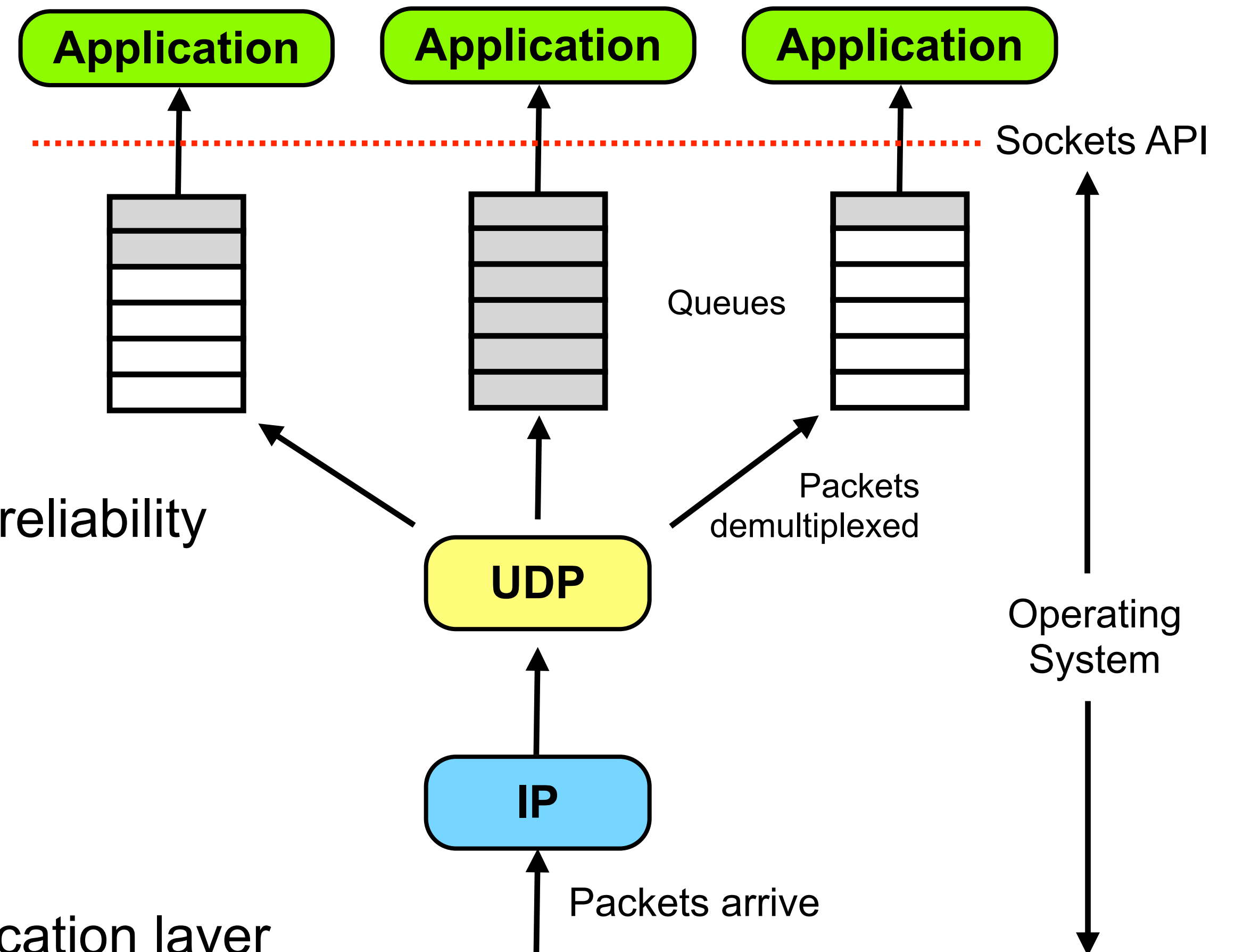


- IP network provides best effort service
 - Packets can be lost, duplicated, delayed, or re-ordered
- Transport isolates applications from the network
 - Demultiplexes traffic for different applications
 - Enhances network quality of service to offer appropriate reliability
 - Performs congestion control, adapts to network capacity

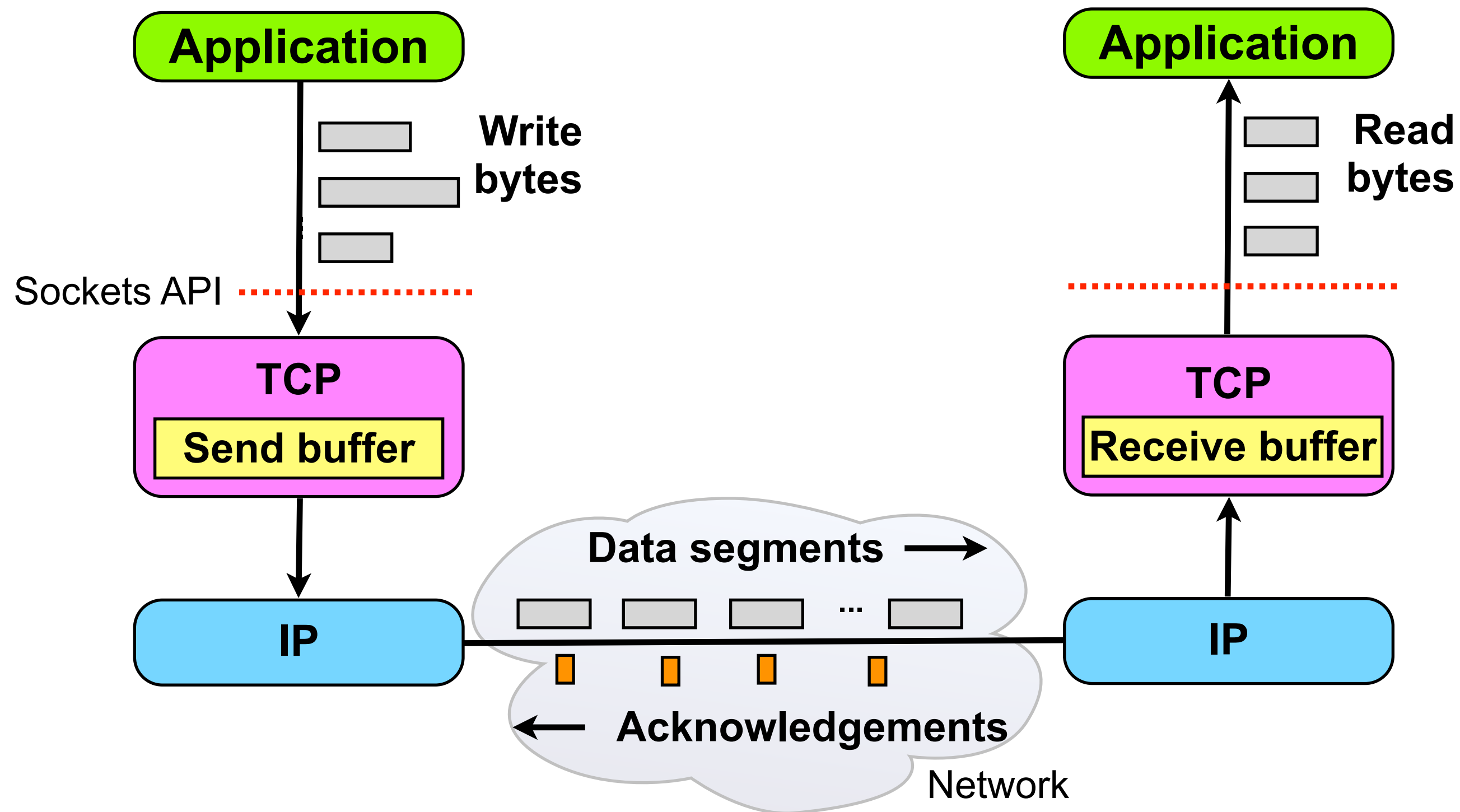
- Only two deployable transport protocols in the Internet:
 - **UDP** - user datagram protocol
 - **TCP** - transmission control protocol

UDP

- Simplest transport protocol
- Exposes raw IP service to applications
 - Connectionless, best effort packet delivery: framed, but unreliable
 - No congestion control
 - Adds 16 bit port number to identify services
- Used by applications preferring timeliness over reliability
 - Voice-over-IP
 - Streaming video
 - Gaming
- Must be able to tolerate some loss of data
- Must be able to adapt to congestion in the application layer

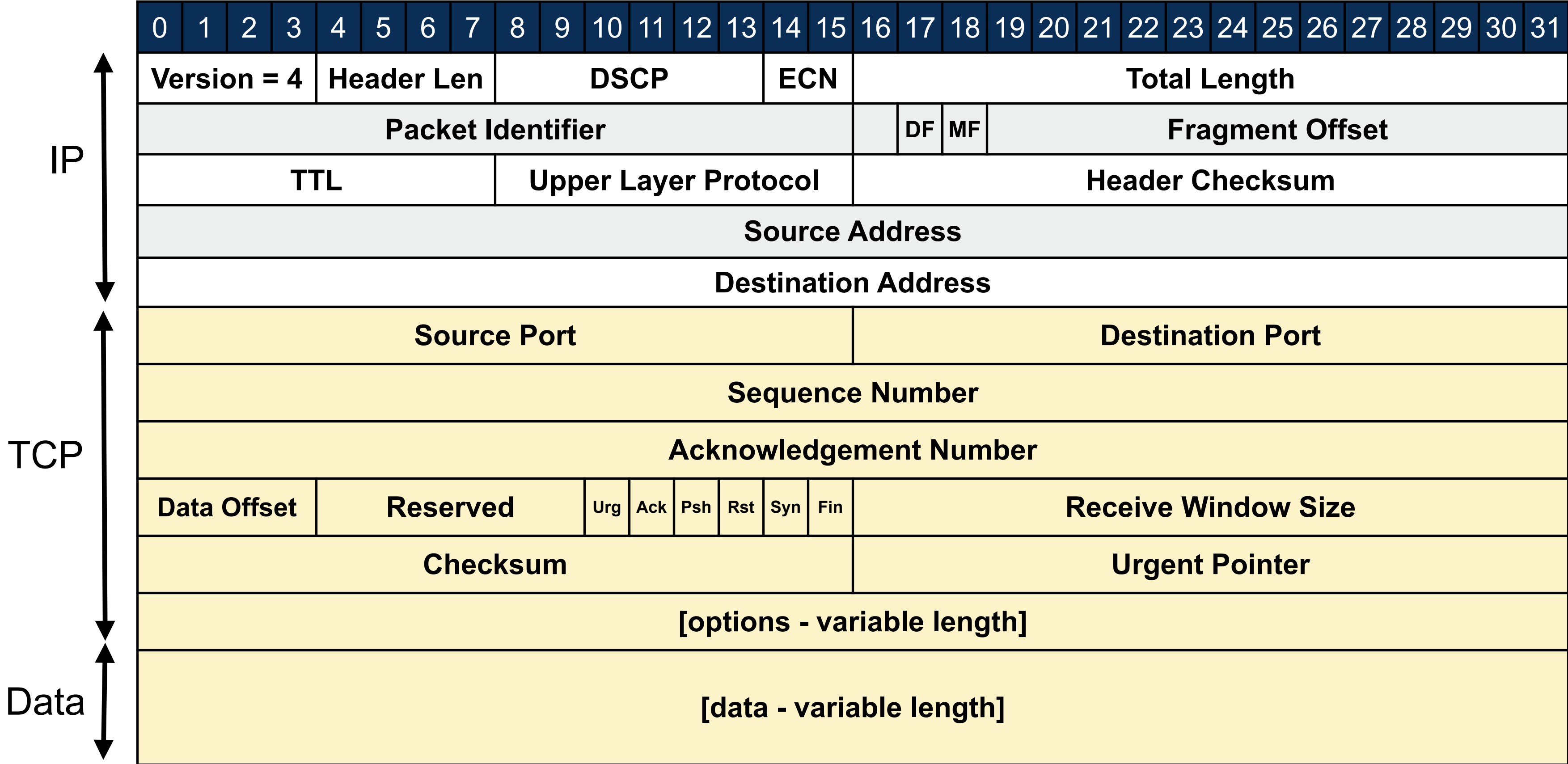


TCP

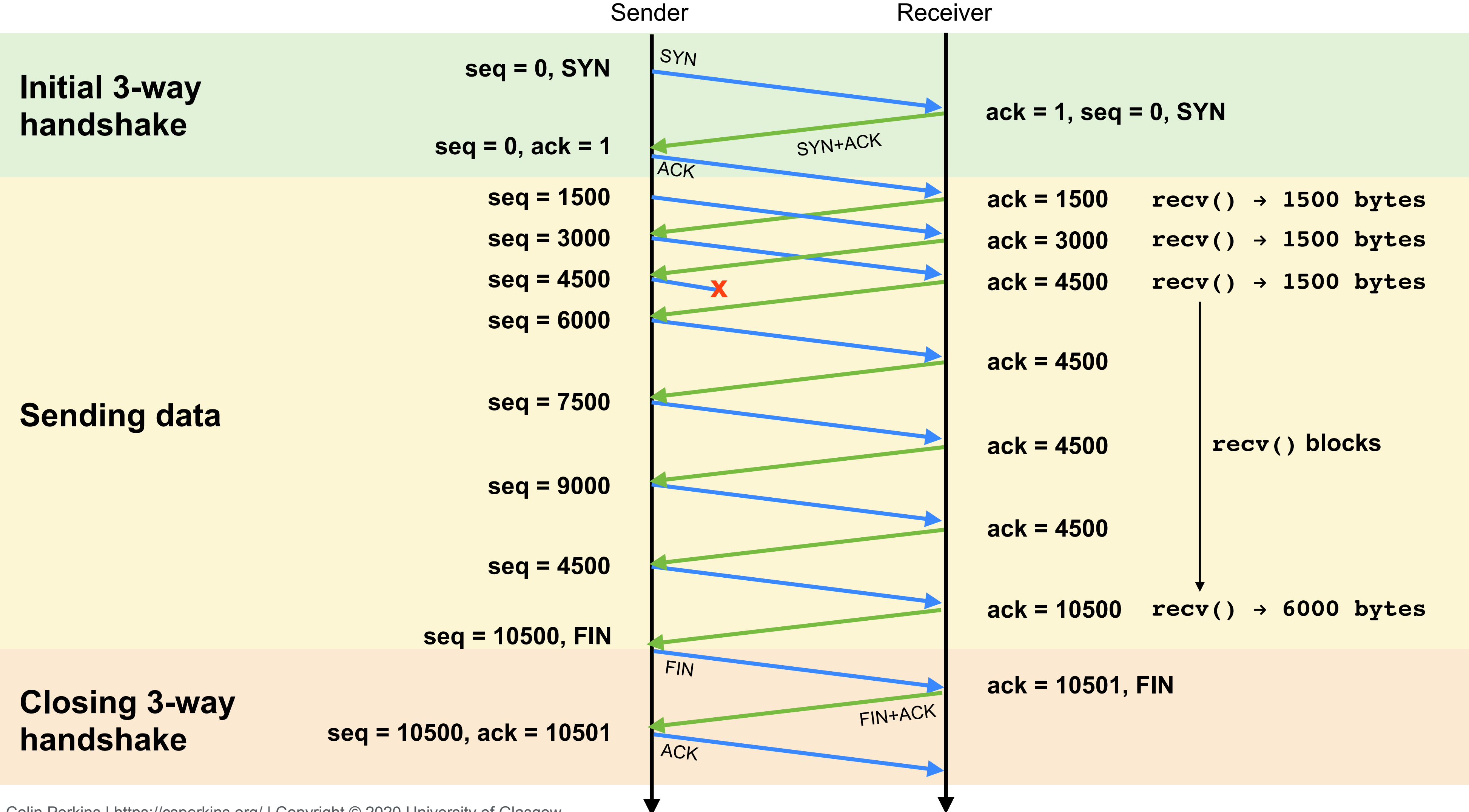


- Reliable, ordered, byte stream delivery service running over IP
- Lost packets are retransmitted; ordering is preserved; message boundaries **are not** preserved
- Adapts sending rate to match network capacity → congestion control
- Adds port number to identify services
- Used by applications needing reliability → default choice for most applications

TCP Packet Format

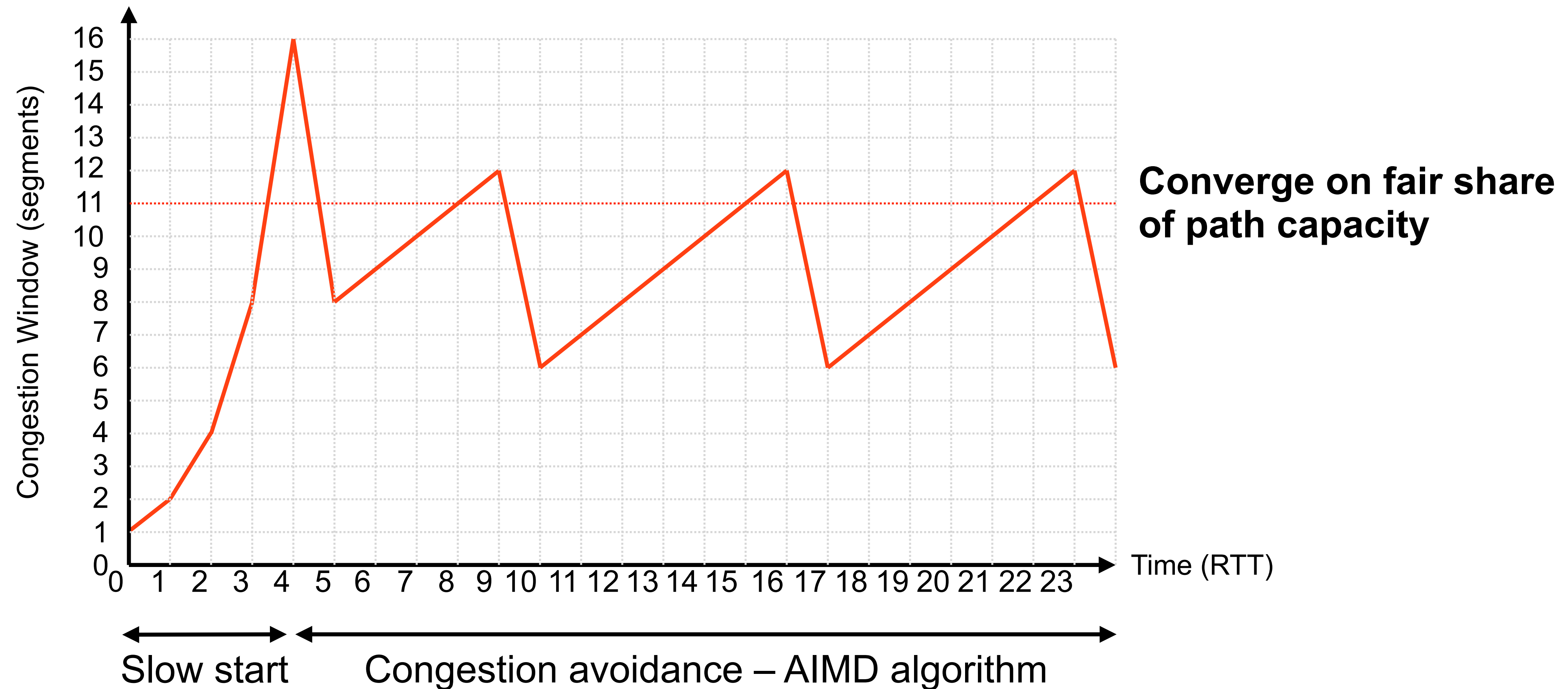


TCP Connection Timeline (Example)



TCP Congestion Control

Typical evolution of TCP window, assuming $W_{init} = 1$



The Transport Layer

- Concepts
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