CS 725/825 & IT 725

Lecture 16

Transport Layer

October 30, 2023

Filling the pipe…

- Stop and Wait protocol
  - wait for acknowledgment before sending next packet
- Sliding Window protocols
  - send up to W (window size) packets/bytes before waiting for acknowledgment
  - when a packet is lost:
    - retransmit the packet (*Selective-Reject ARQ*)
    - retransmit all un-acknowledged packets (*Go-Back-N ARQ*)
- Measure: utilization (a.k.a. normalized throughput)
  - the ratio between *goodput* and *maximum theoretical capacity*

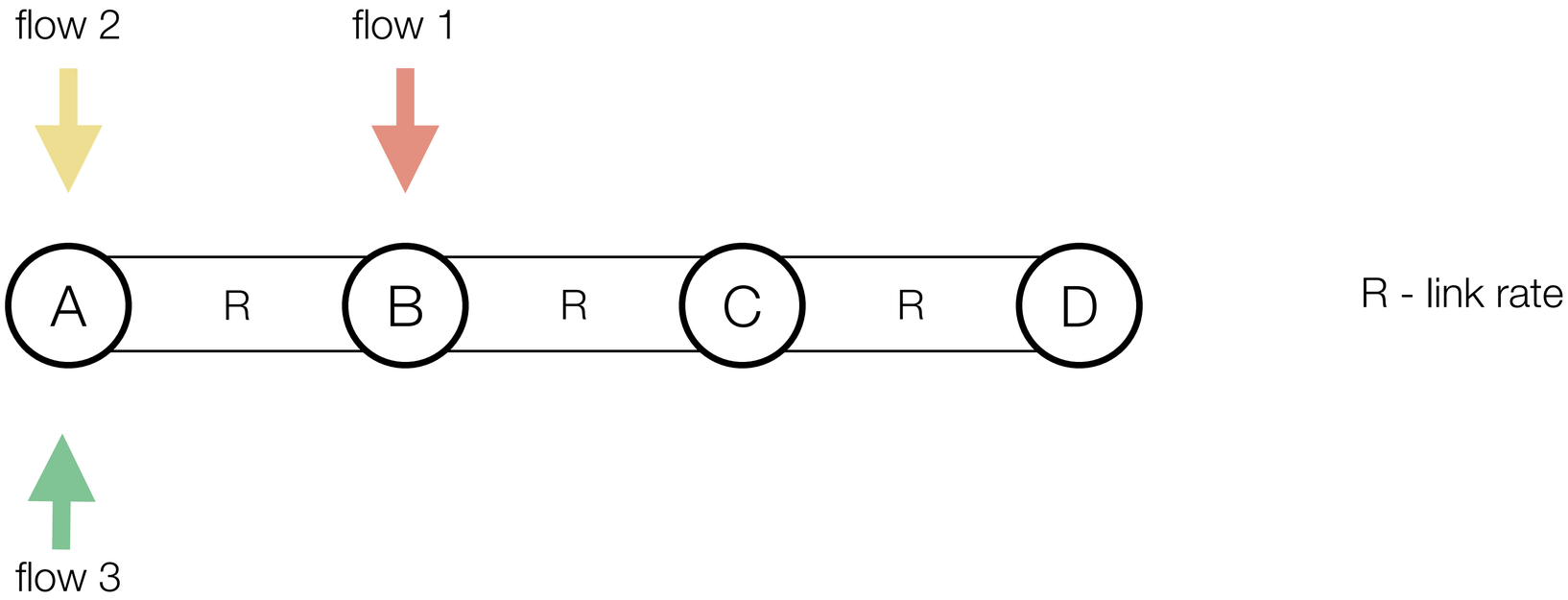
Flow/congestion control

- Goal: Make the most effective use of the network capacity
  - avoid congestion
  - maximize utilization
  - maintain fairness (or deliver promised service level)
- Method: Controlling the rate with which traffic is injected into the network by the transmitter

Flow/congestion control

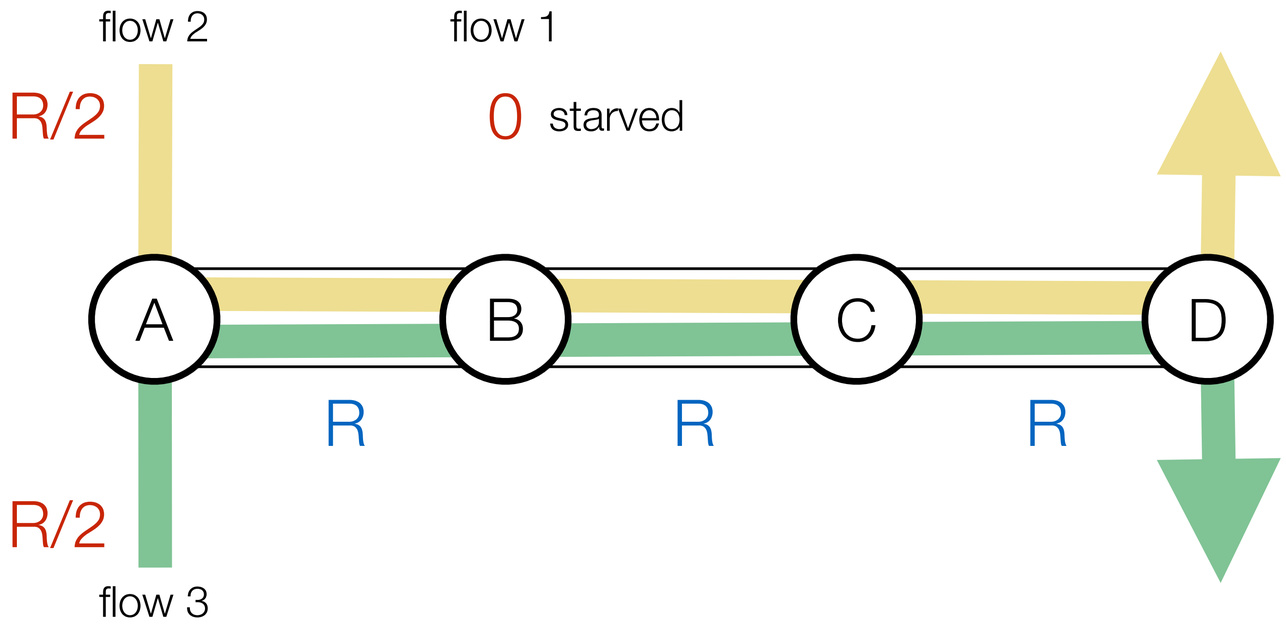
- Reasons why congestion control mechanisms are critical for the stable operation of the Internet [RFC 8085]:
- Prevention of congestion collapse
  - i.e., a state where an increase in network load results in a decrease in useful work done by the network
- Establishment of a degree of fairness
  - i.e., allowing multiple flows to share the capacity of a path reasonably equitably.

Utilization vs fairness



R - link rate

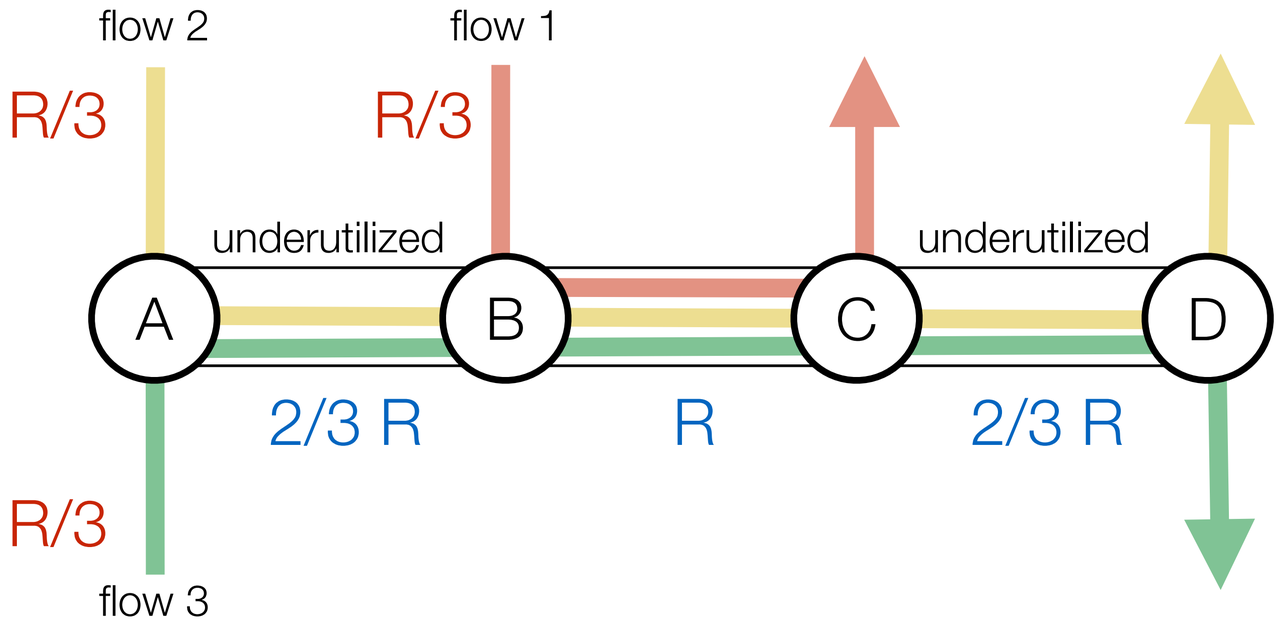
Utilization vs fairness



	Max utilization	Max fairness
flow 1	0	R/3
flow 2	R/2	R/3
flow 3	R/2	R/3

R - link rate

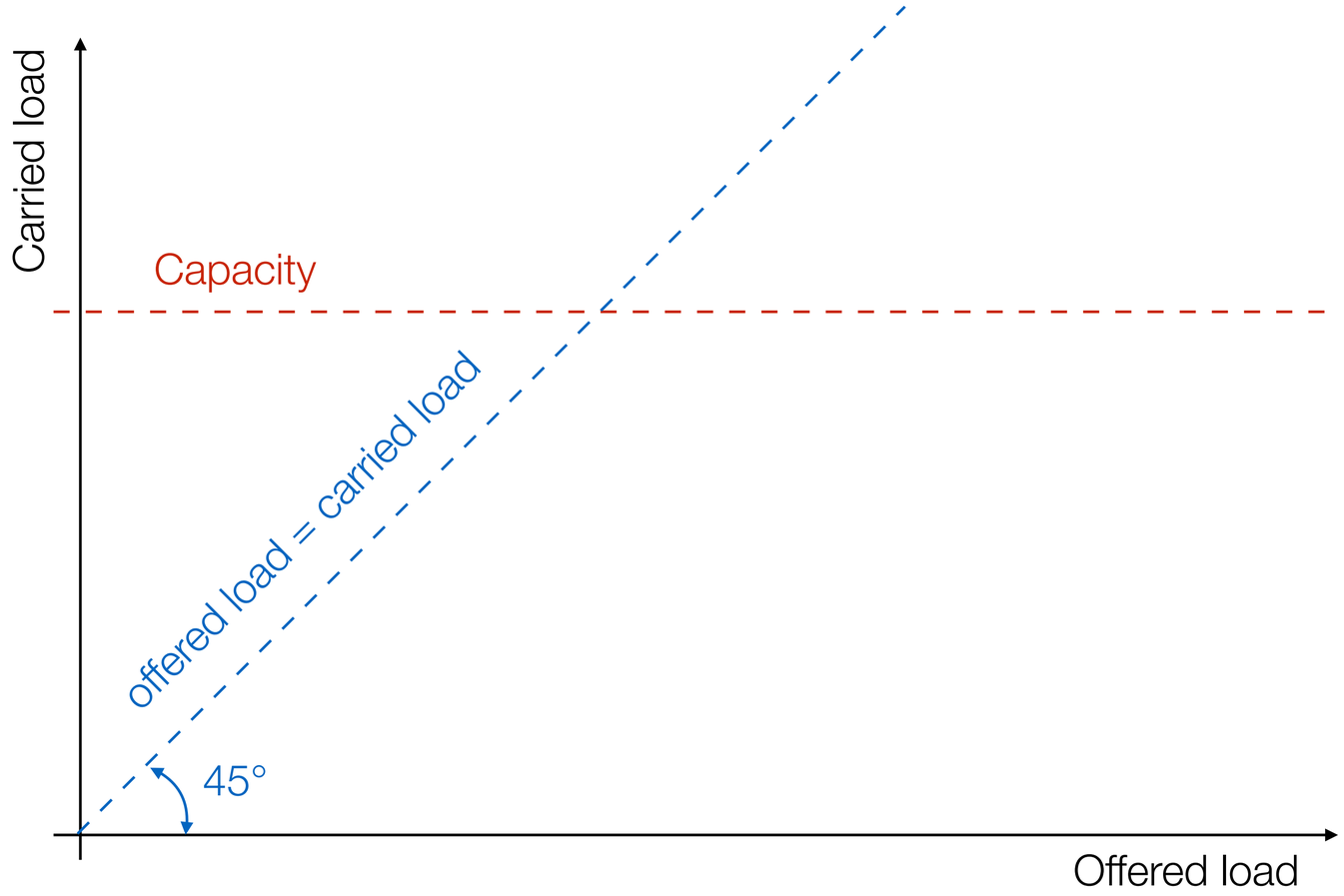
Utilization vs fairness



	Max utilization	Max fairness
flow 1	0	R/3
flow 2	R/2	R/3
flow 3	R/2	R/3

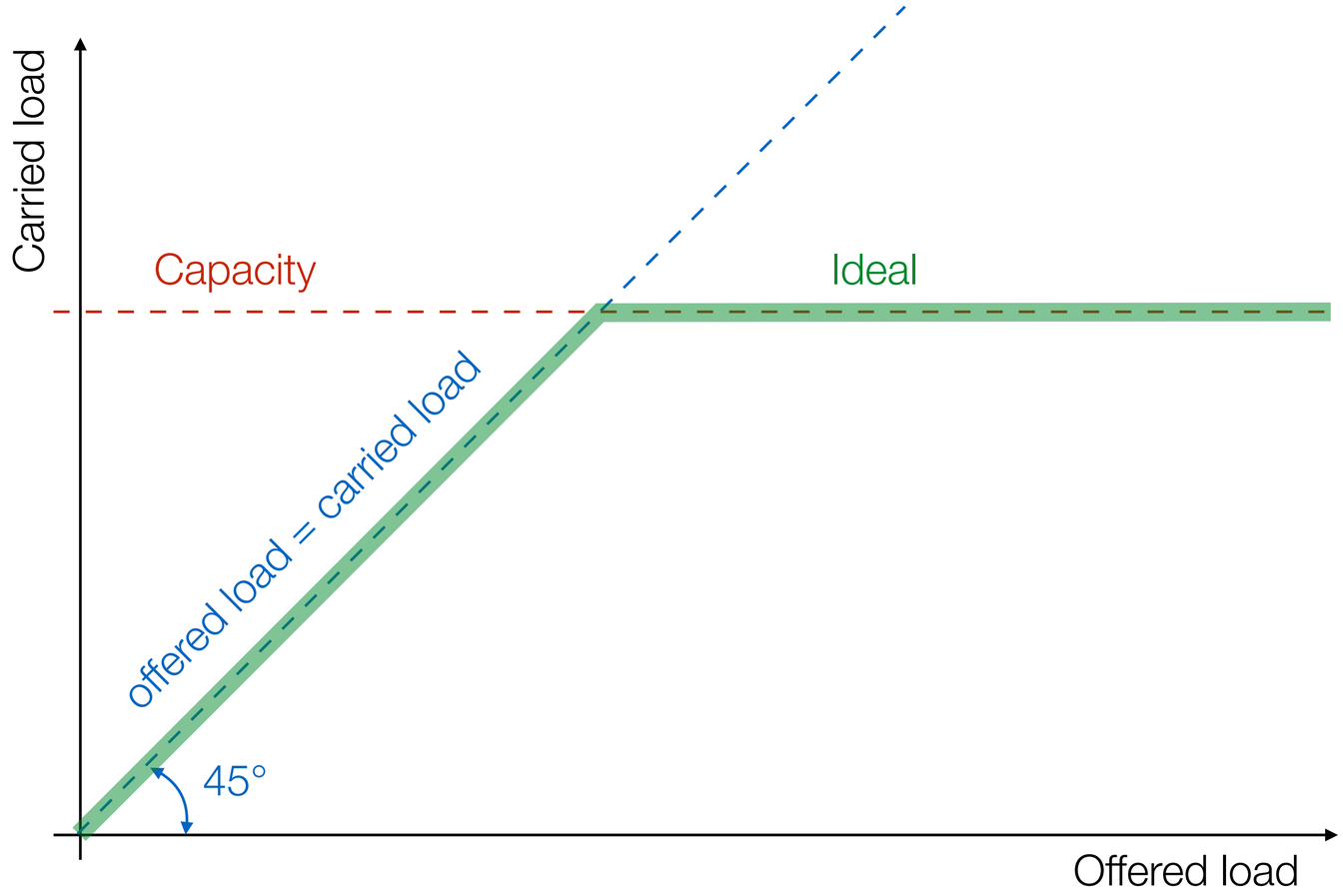
R - link rate

Impact of Congestion

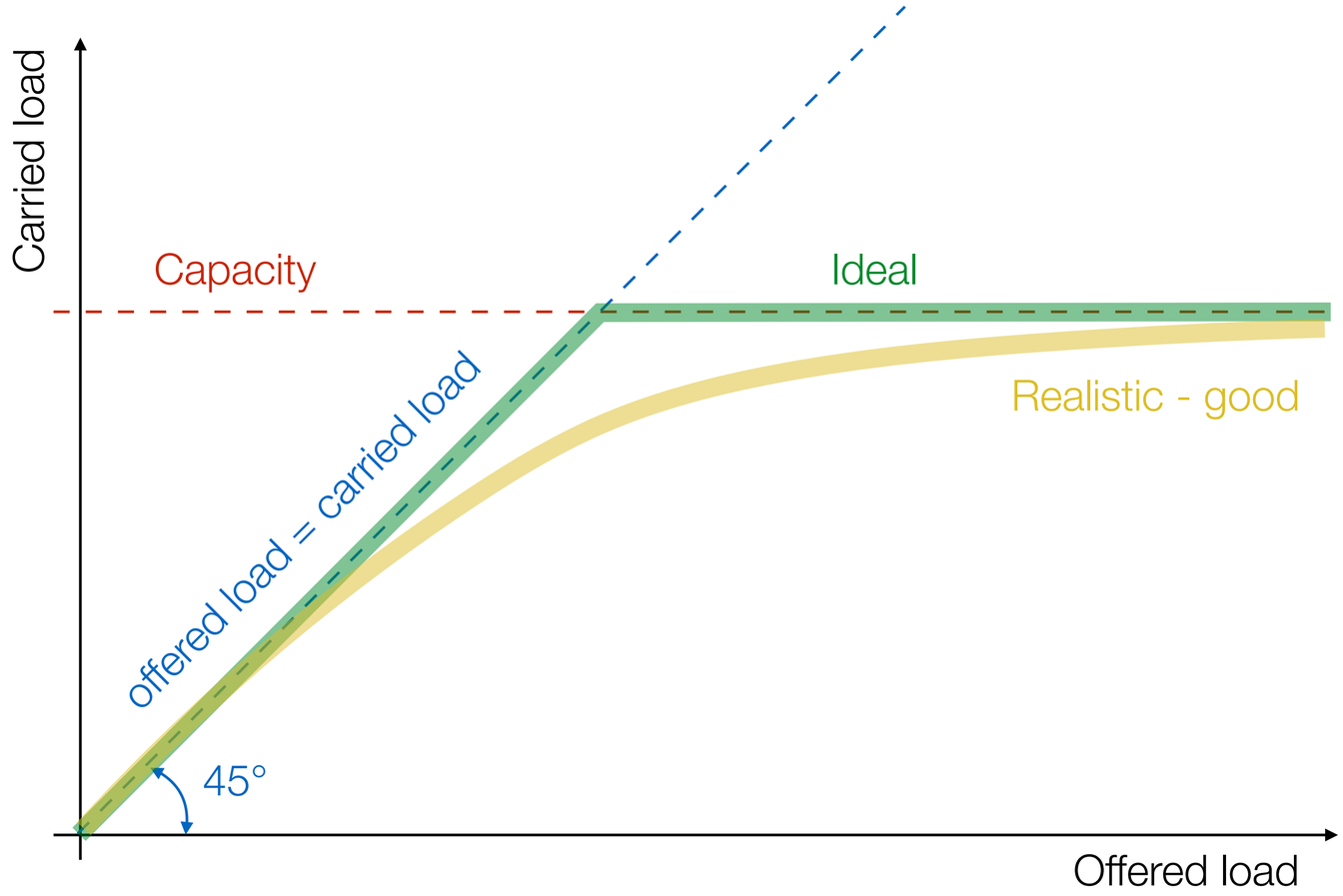


Offered vs carried load graph

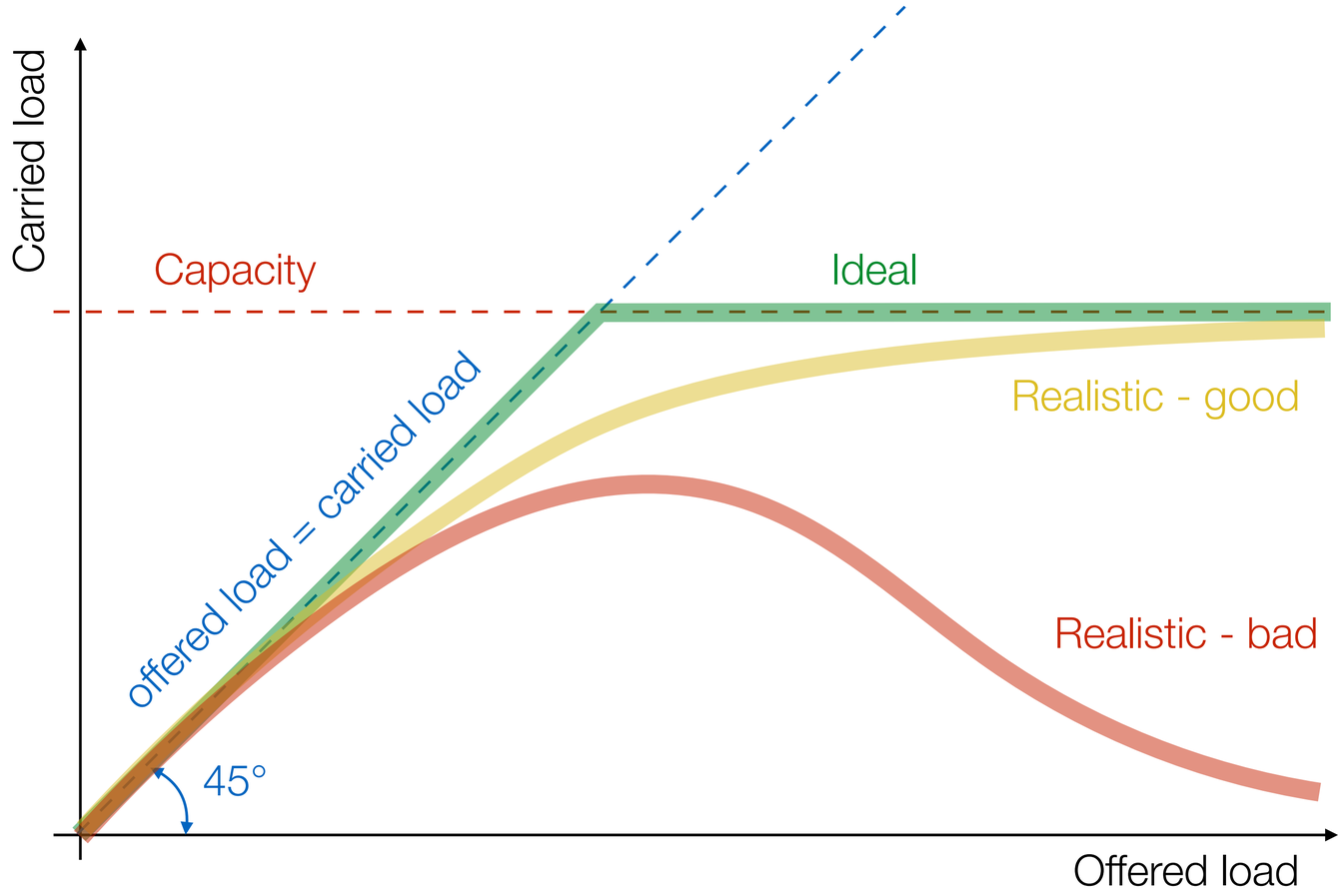
Impact of Congestion



Impact of Congestion



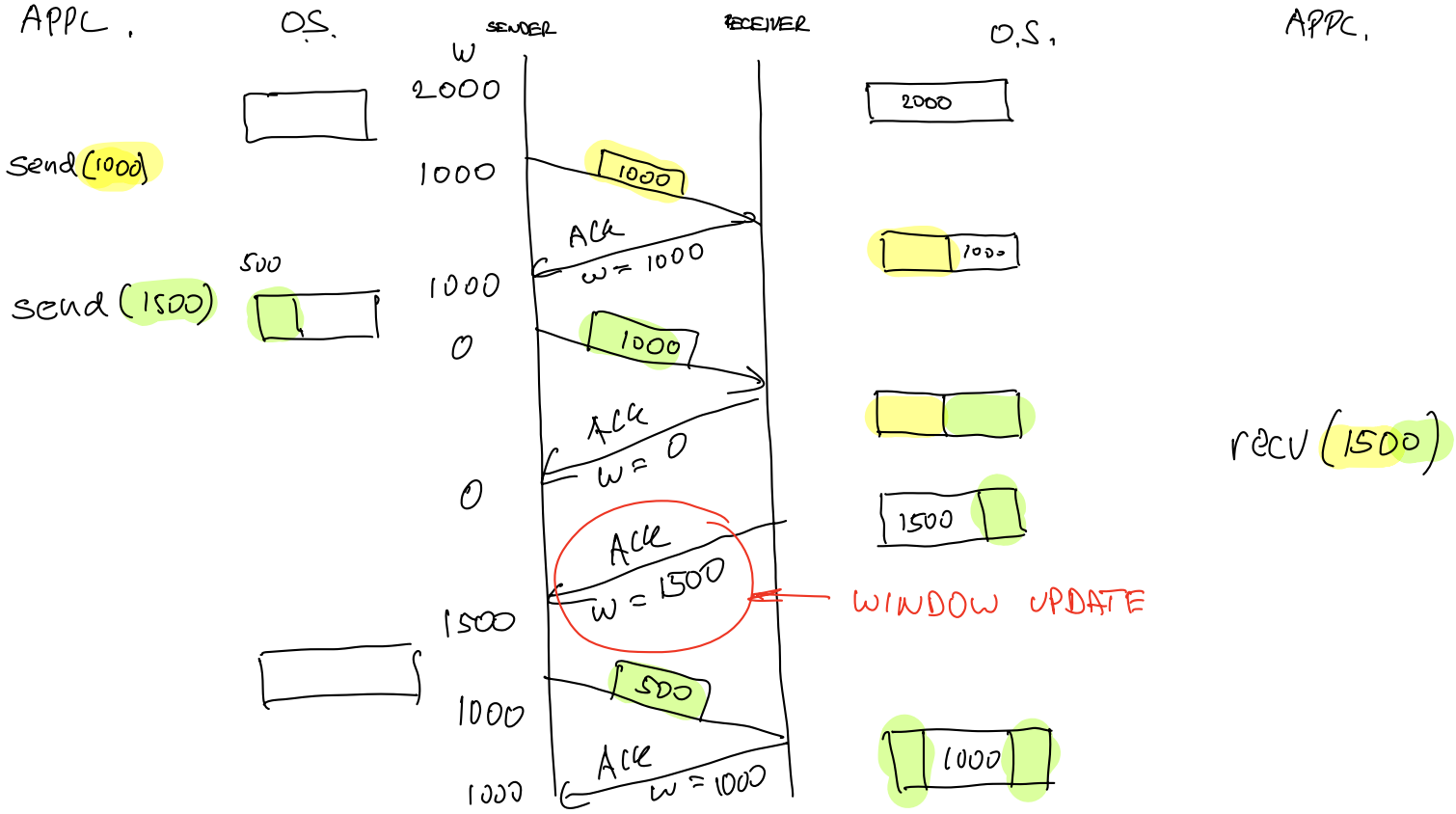
Impact of Congestion



Two Types of Congestion

- Receiver Congestion
  - receiver is unable to keep up with incoming data
  - solved by explicit feedback from receiver to sender
- Network Congestion
  - nodes or links of the network are overloaded
  - explicit congestion notification (few technologies)
  - implicit congestion notification (Internet)

FLOW CONTROL (REC. CONG CONTROL)



TCP

- Transport Control Protocol
- Design parameters and objectives
  - used by most popular applications, majority of Internet traffic is transported over TCP
  - significant impact on congestion behavior of the Internet
  - must operate over networks with widely-varying characteristics
  - must be robust and (relatively) simple to implement