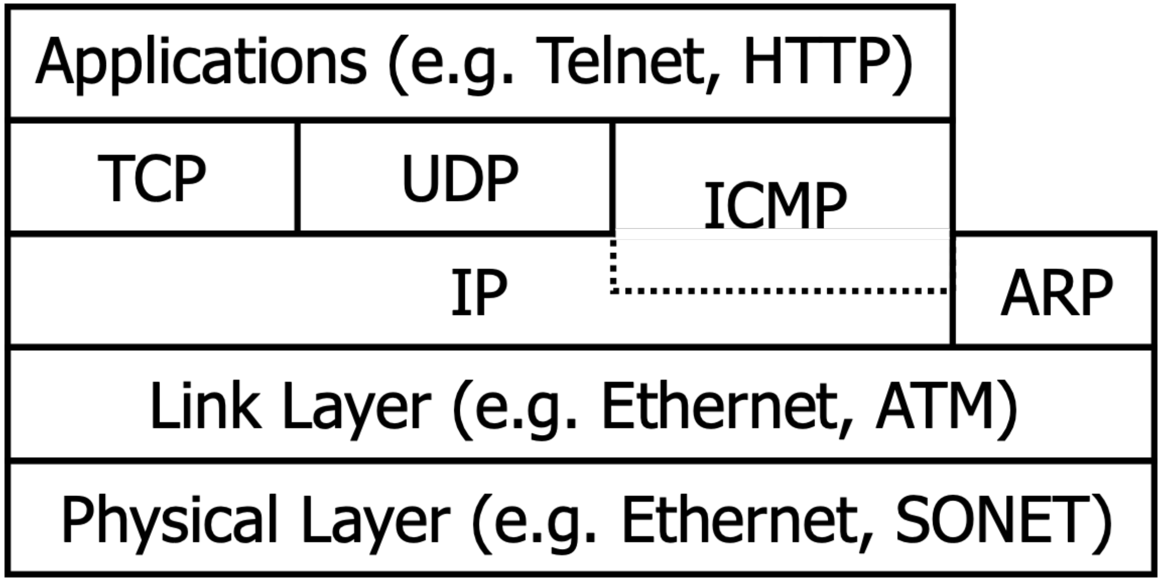
Technical Issues in Wireless Networking
- Wireless Transport -

Kyunghan Lee
Networked Computing Lab (NXC Lab)
Department of Electrical and Computer Engineering
Seoul National University
https://nxc.snu.ac.kr
kyunghanlee@snu.ac.kr

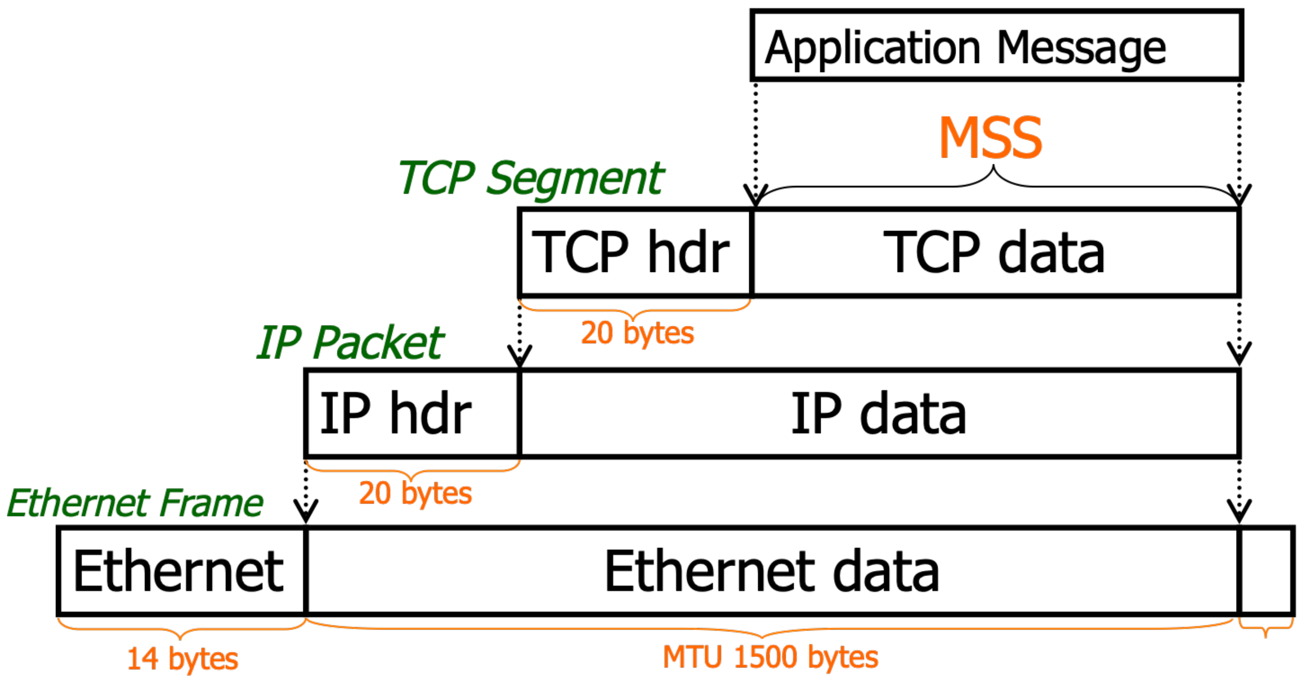
TCP Overview

TCP/IP Protocol Stack
(5 Layer Architecture)



TCP Overview

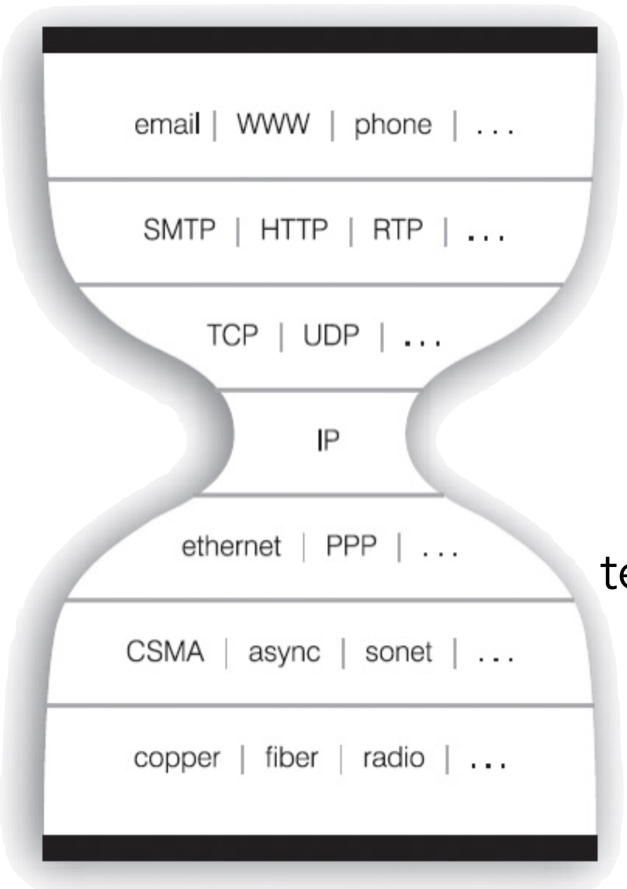
TCP/IP Packet Structure



MSS: Maximum Segment Size
MTU: Maximum Transmission Unit

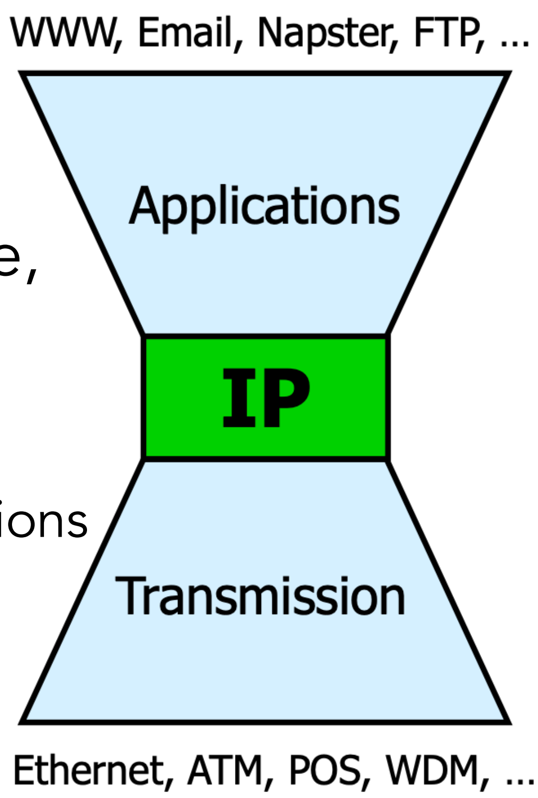
TCP Overview

IP Hourglass: End-to-End Semantic

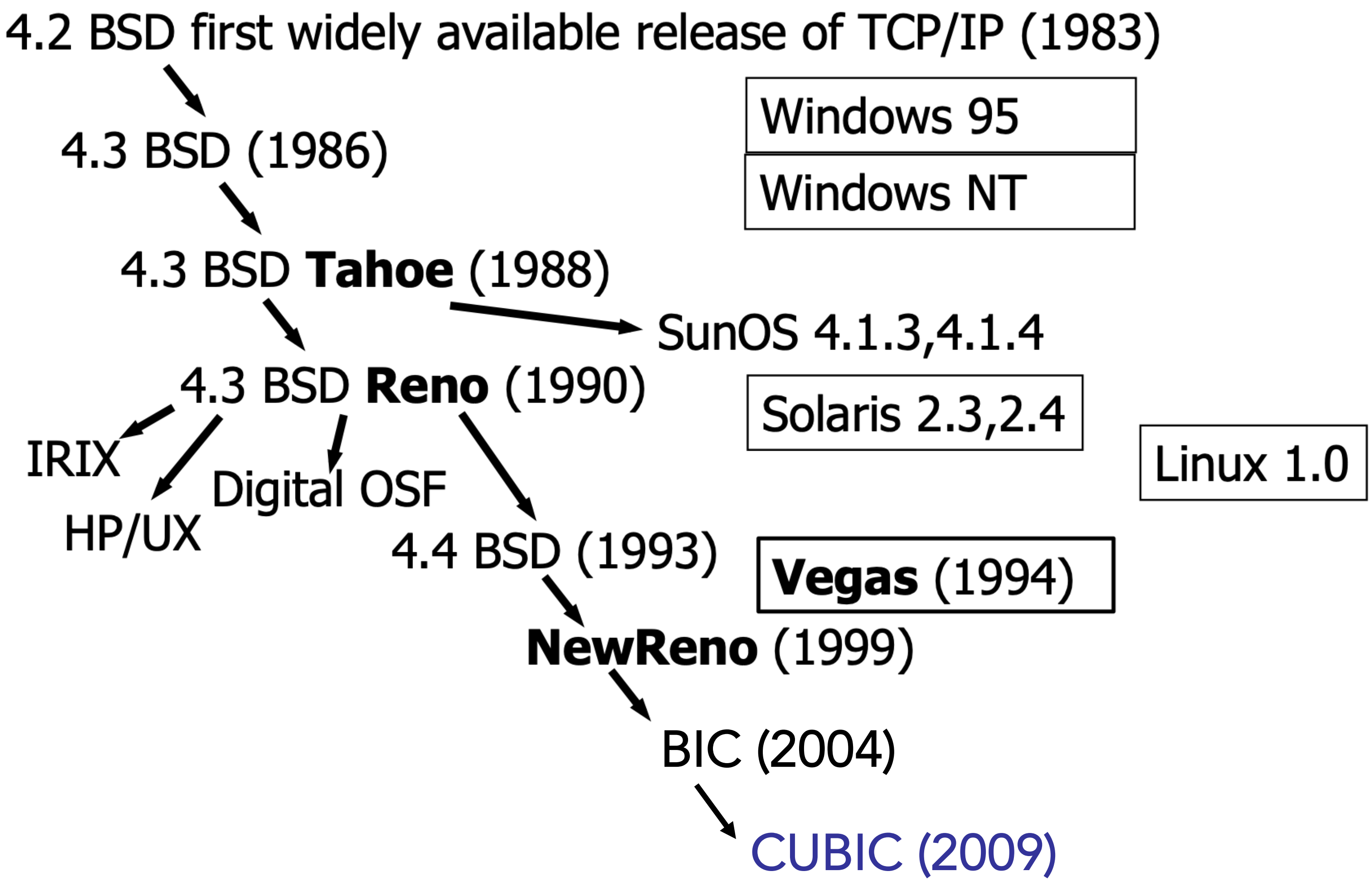


Intelligent Edge,
Dumb Core

Robust against
technological evolutions

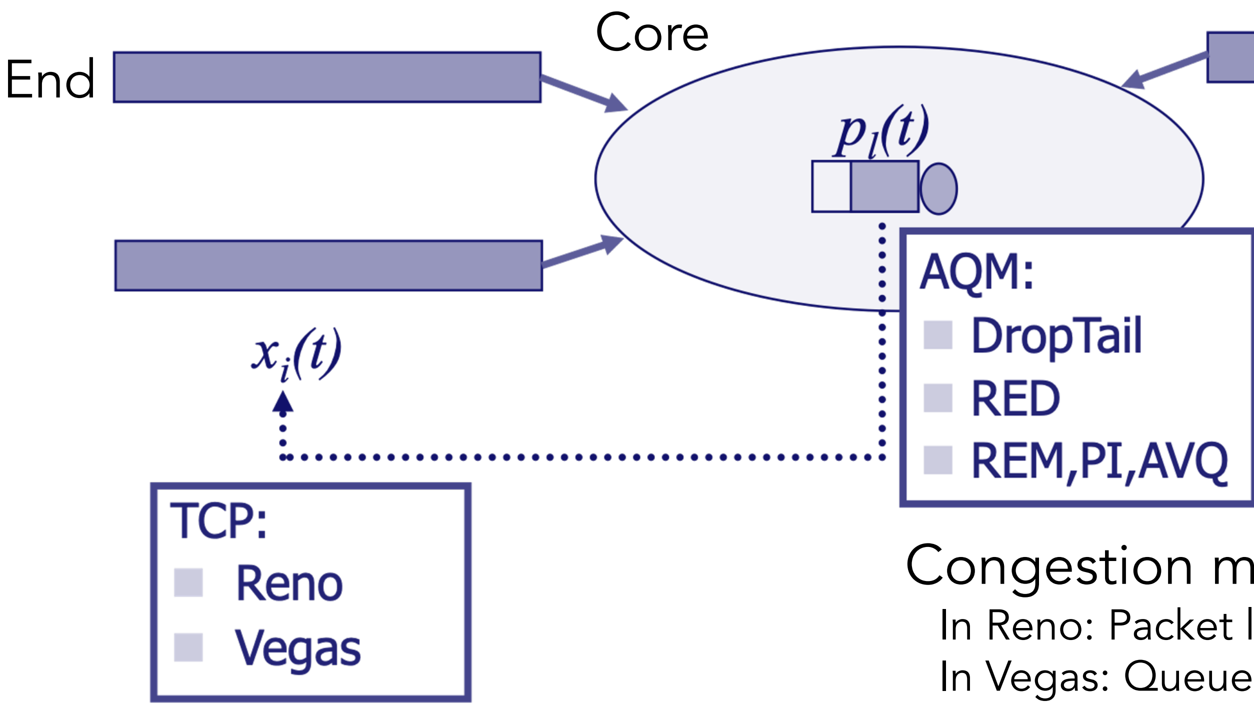


TCP Version History in BSD



TCP & AQM Control Approach

AQM: Active Queue Management



Congestion measure of link l: $p_l(t)$

In Reno: Packet loss

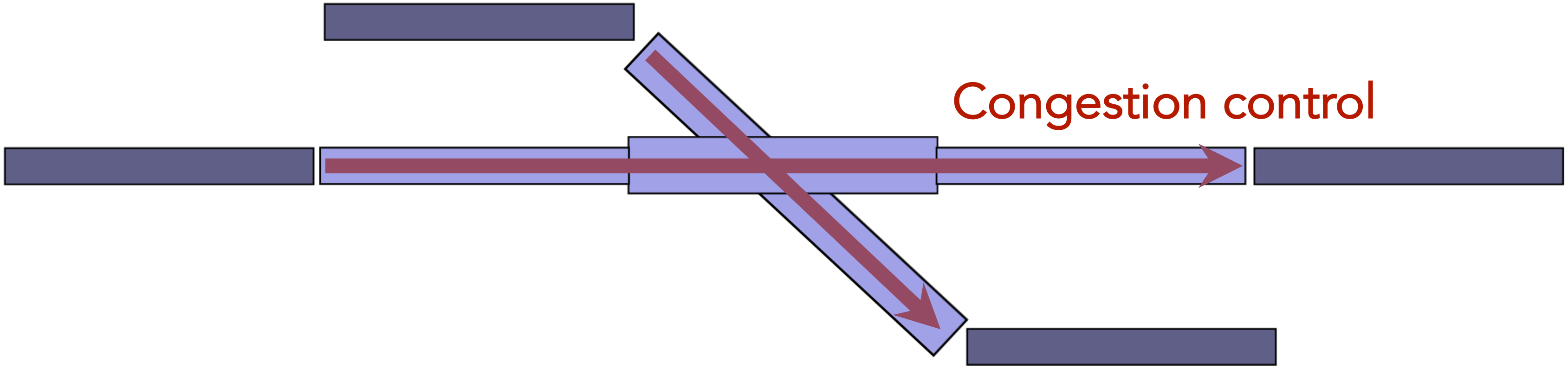
In Vegas: Queueing delay

Data rate of source i: $x_i(t)$

TCP Overview - Flow & Congestion control

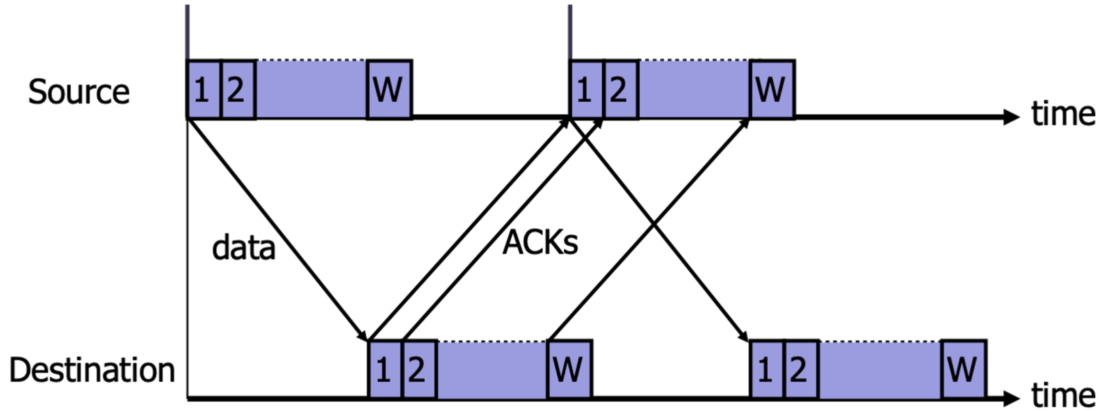
What is the capacity of my end-to-end connection?

What is the fair-share of my end-to-end connection?



TCP Overview

Baseline algorithm

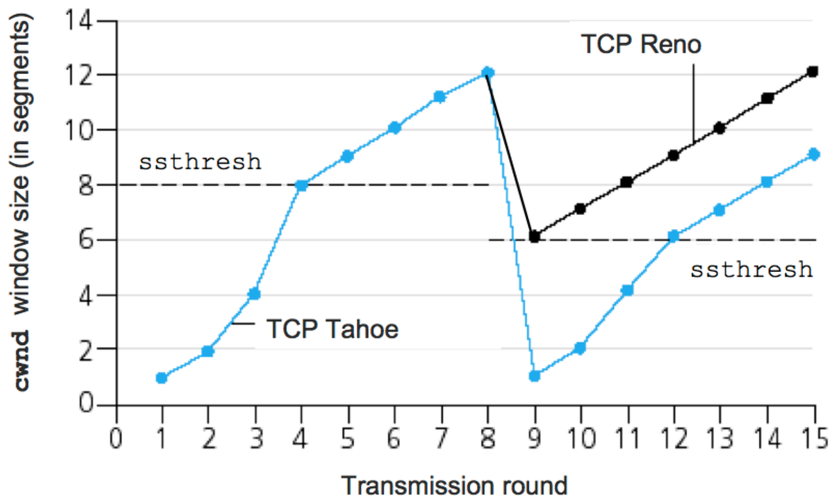


Control W to be

$$\frac{W \cdot MSS}{RTT} \sim BW$$

TCP Tahoe, Reno

```
for every ACK {
     if (W < ssthresh) then W++ (SS)
     else  W += 1/W              (CA)
}
for every loss {
     ssthresh = W/2
           W  = 1    (or   W  = W/2)
}
```



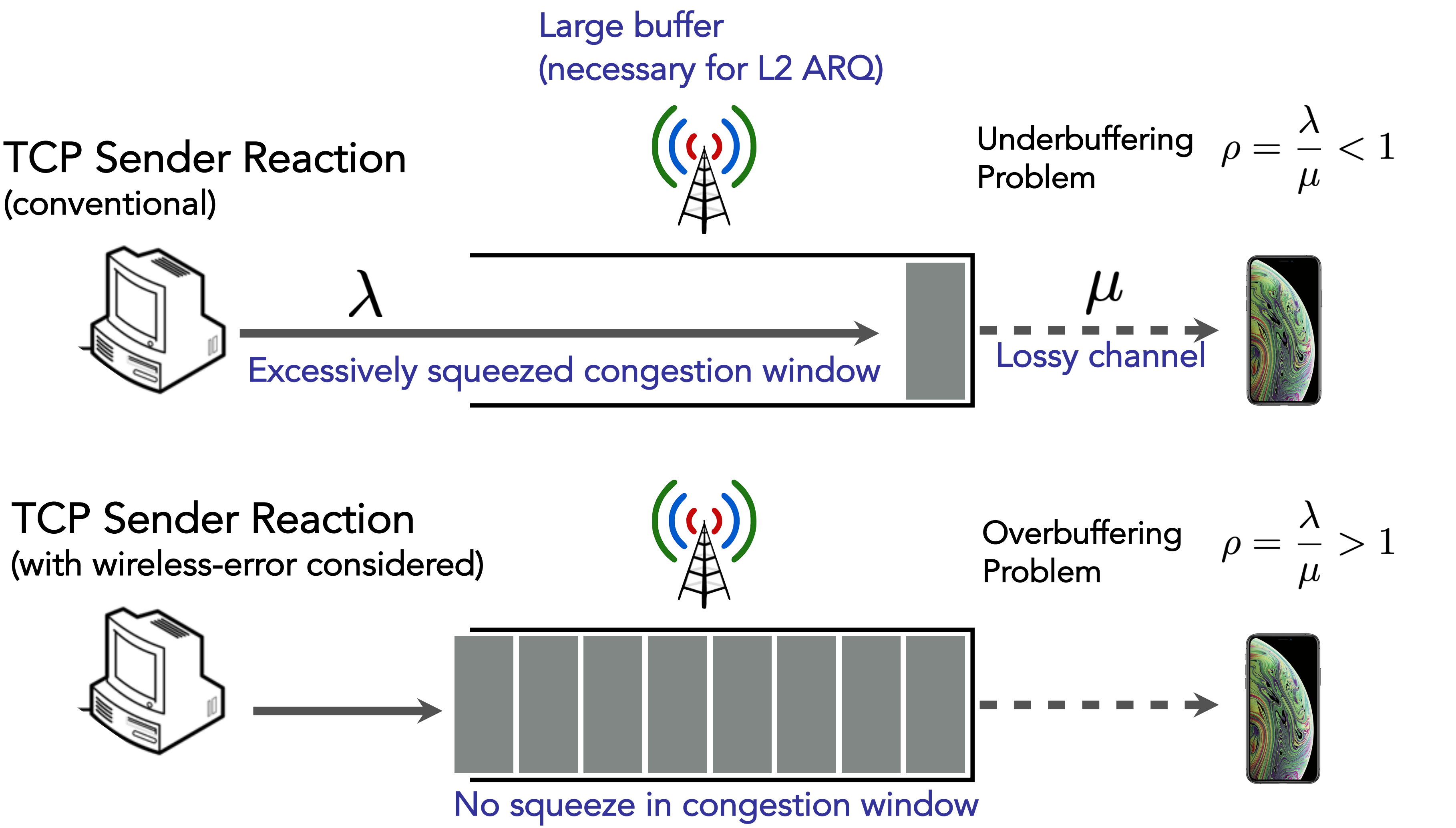
Problems in Wireless Transmission

- Packet loss in wireless networks
  - Bit errors (channel degradation)
  - Handoffs (mobility)
  - Congestion and timeout
  - Reordering

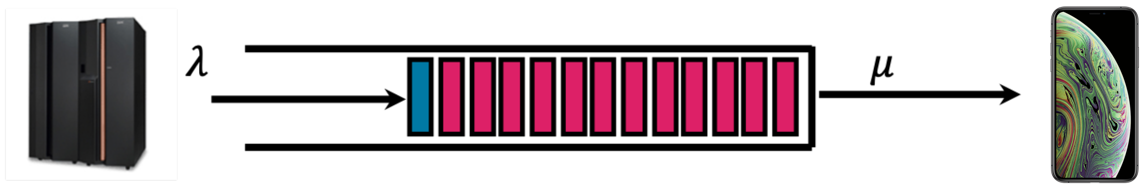
- TCP always assumes that "packet loss" is due to
  - Congestion (+ Reordering)

- TCP reactions to wireless problems
  - Reducing packets in flight (data rates)
  - Consecutive losses make the data rate almost ZERO

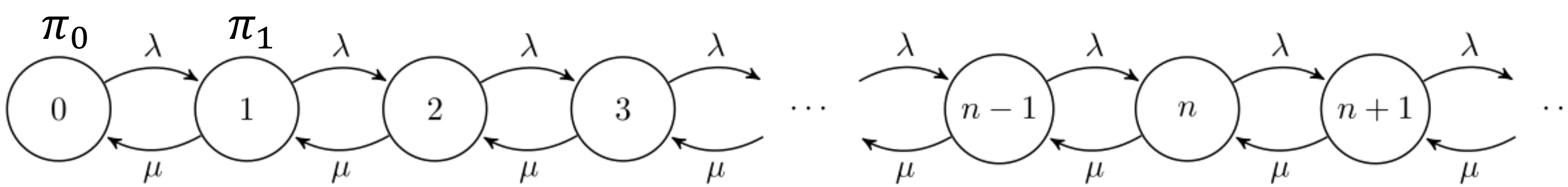
Problems in Wireless Transmission



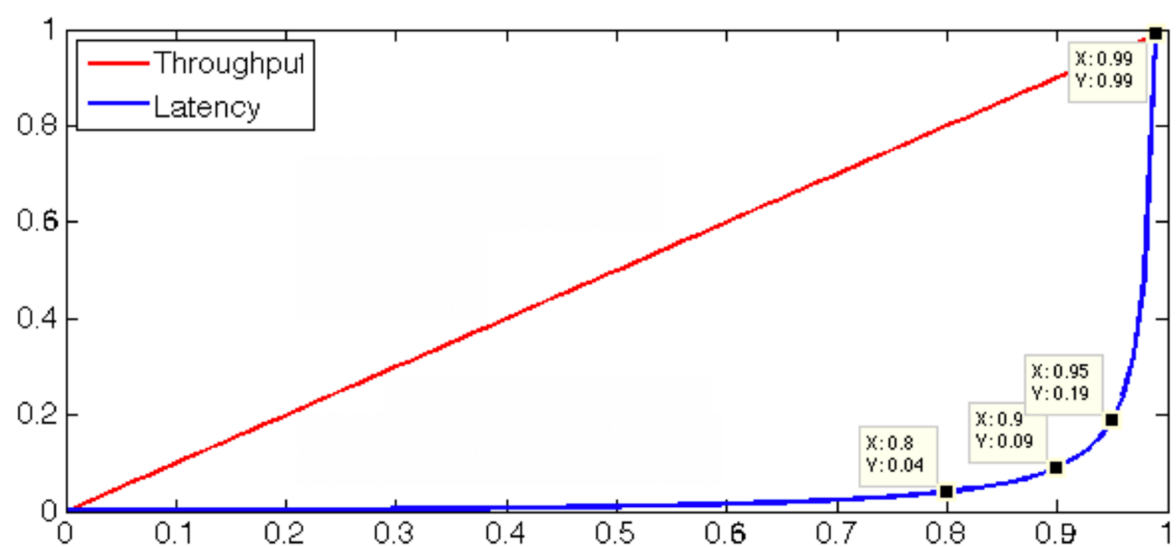
Problems in Wireless Transmission



M/M/1



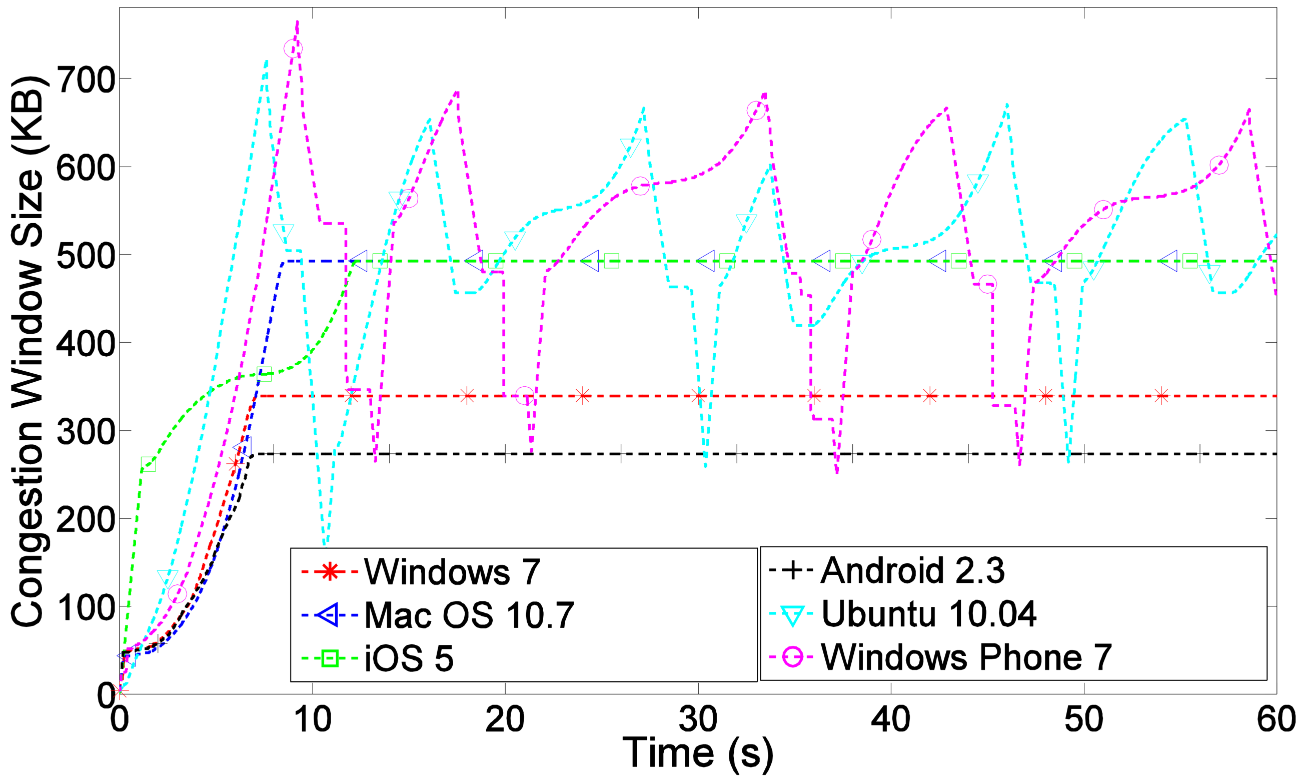
$$\pi_i = (1-\rho)\rho^i$$



$$\rho = \lambda/\mu$$

Problems in Wireless TCP

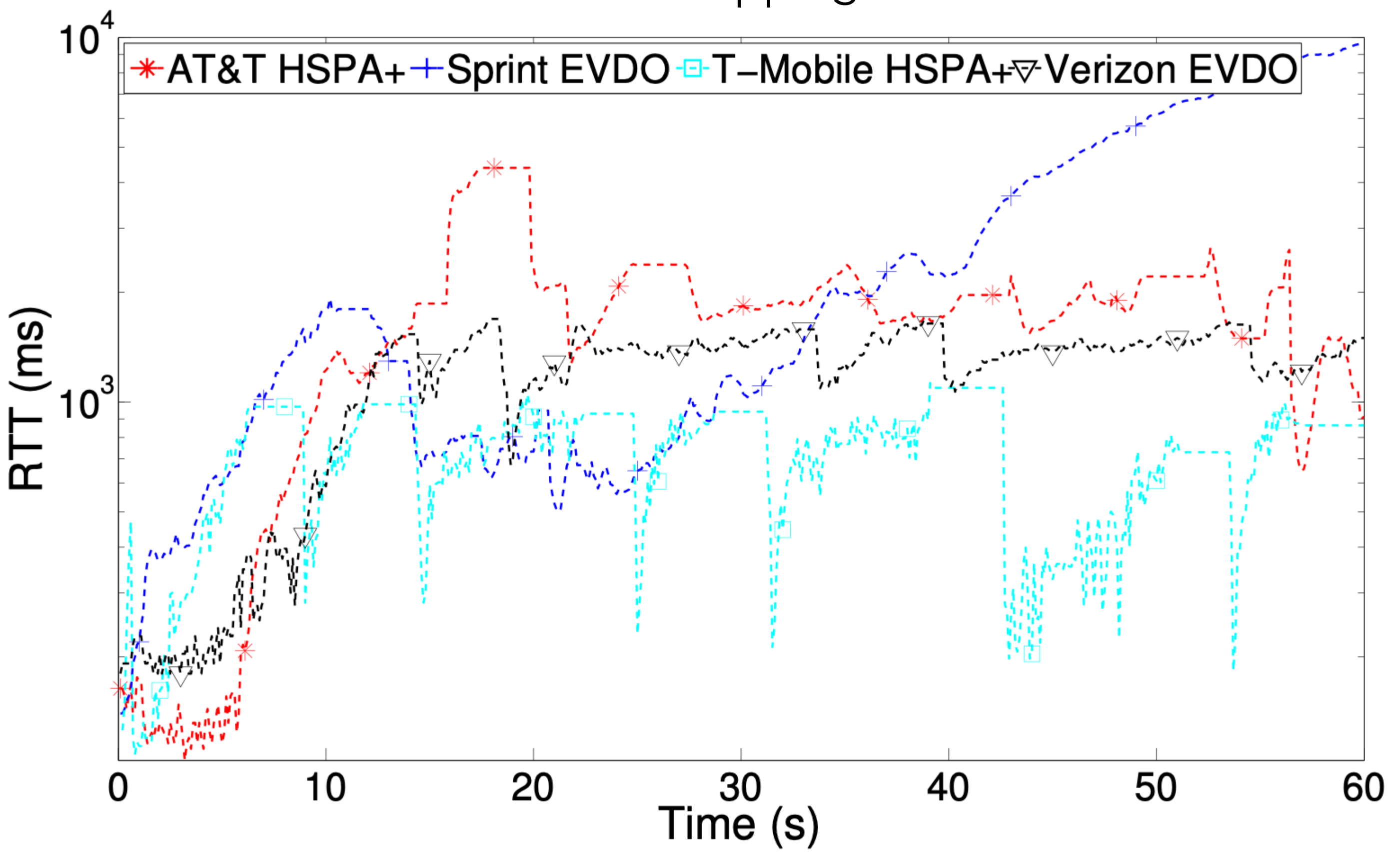
Flat TCP congestion window observed in cellular networks



rwnd
cropping

Problems in Wireless TCP

If there is no RWND cropping in cellular networks



Potential Solutions

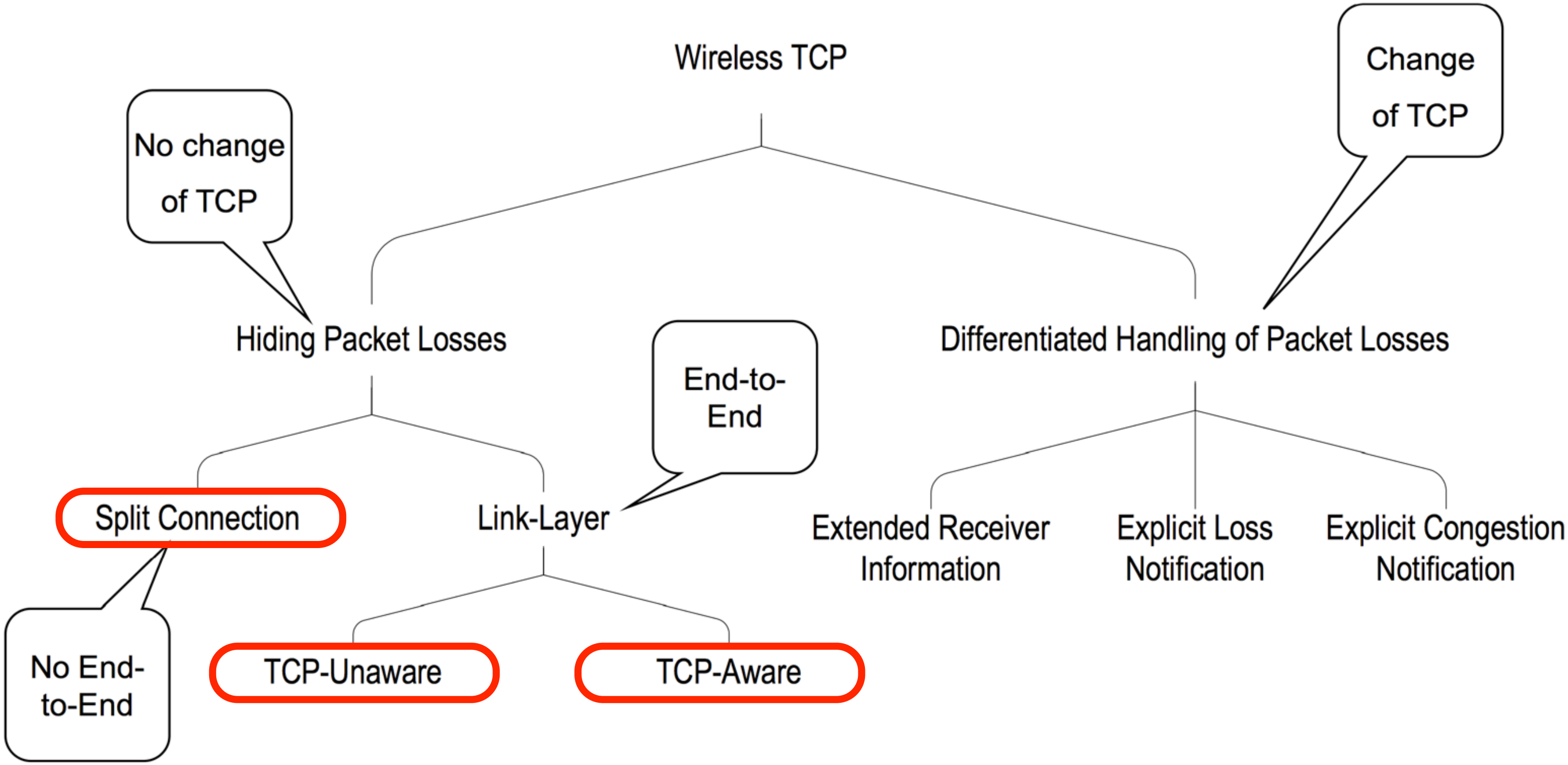
- Entirely new transport protocol
  - Hard to widely deploy
  - End-to-end protocol should also efficiently work in wired networks
- Modifications to TCP mechanism
  - Maintain end-to-end semantics
  - Add new wireless-related features to TCP
  - May not be backward compatible
- Splitting a connection into wireless and wired
  - Breaks end-to-end nature
  - May be backward compatible with end hosts
  - New issues in migration of TCP states when doing handoffs
  - Extra TCP processing burden is given to base-stations

Potential Solutions

- Link-layer protocols
  - Invisible to higher-level protocols (hide lower-level problems)
  - Does not break end-to-end semantics (in high-level)
  - May negatively affect delay-sensitive applications
  - May bring algorithmic failures which need another fix

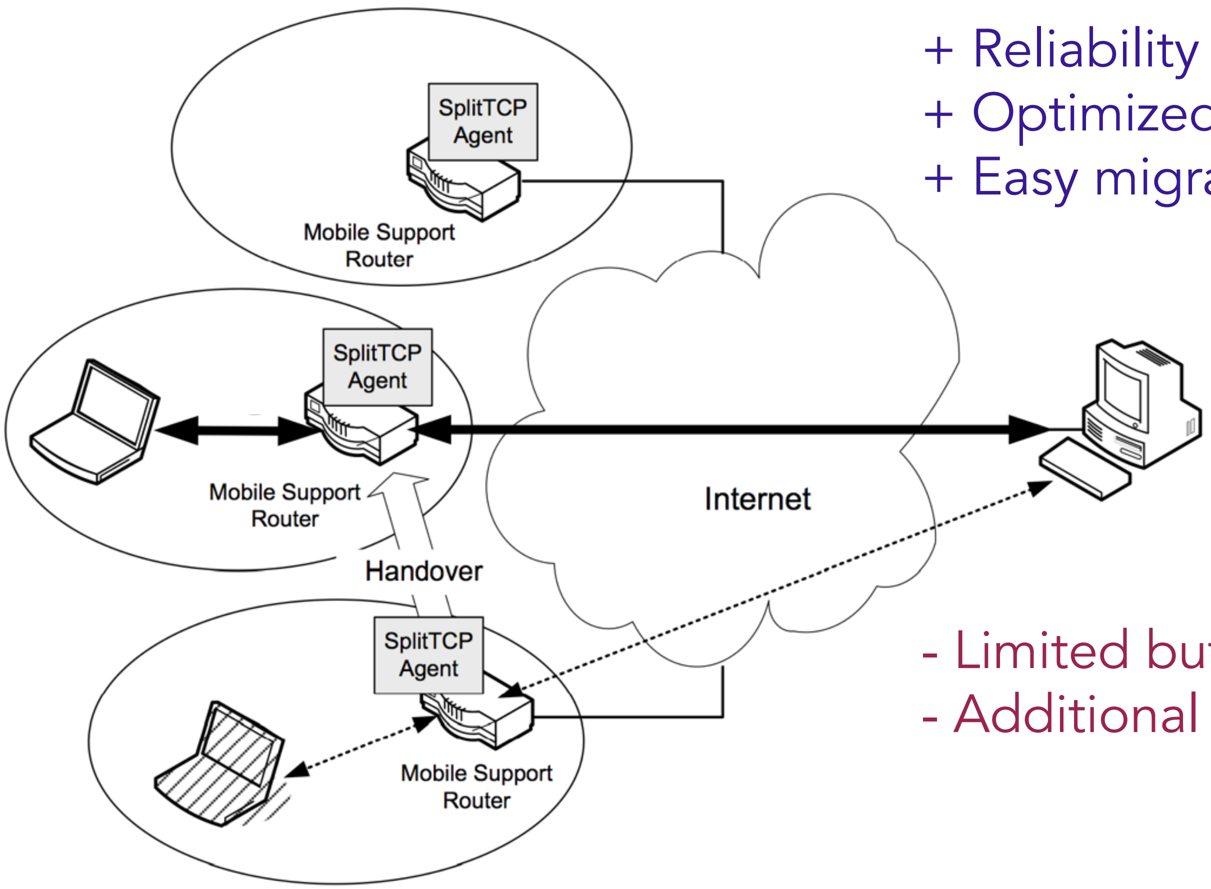
- Snoop protocol
  - Does not break end-to-end semantics
  - Like a link-layer protocol, some algorithmic failures follow
  - No termination but soft states are maintained at base stations

Potential Solutions



From Dr. Ing. Thomas Springer's slide

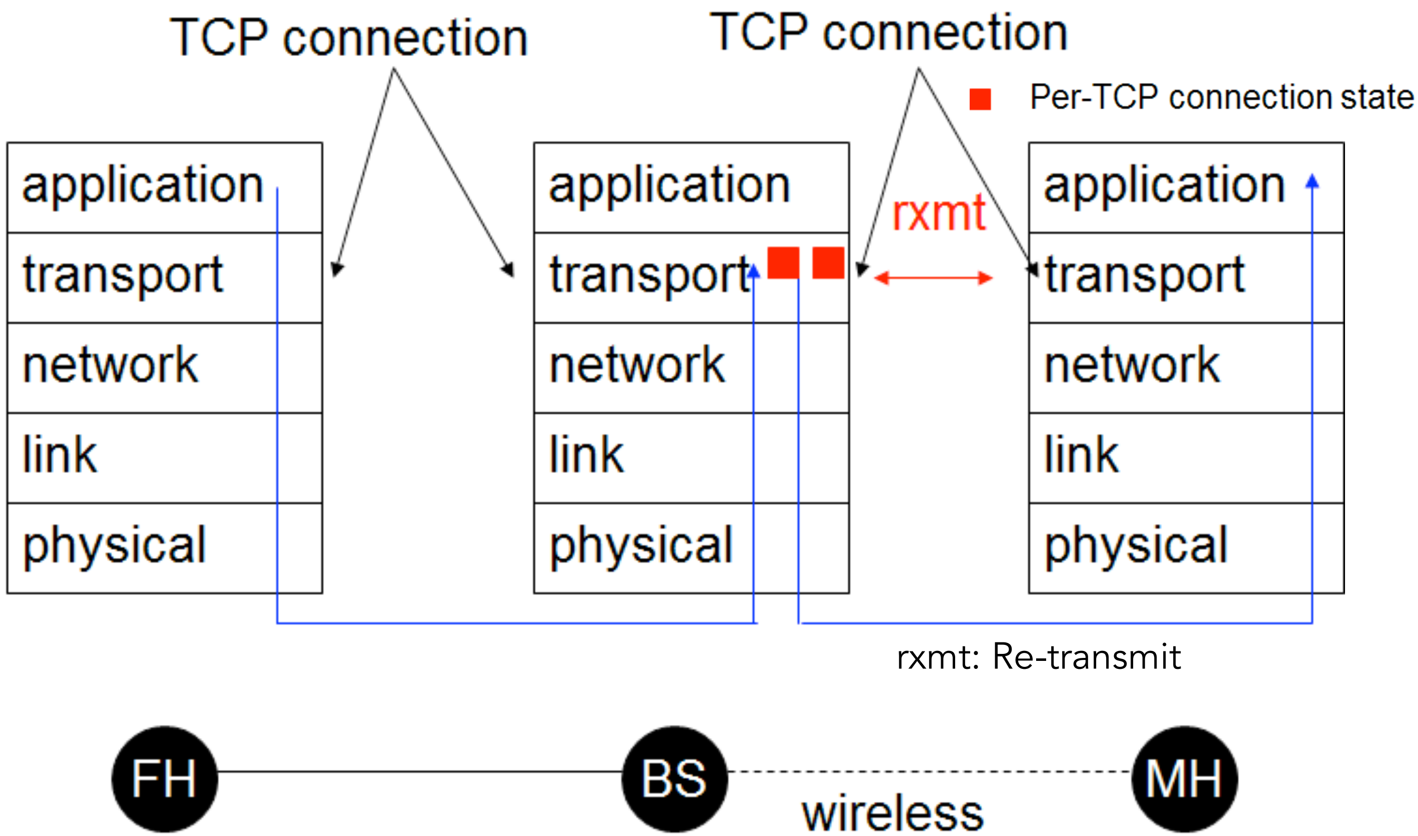
Split TCP



+ Reliability in wired portion
+ Optimized wireless control
+ Easy migration among base-stations

- Limited buffer in base station
- Additional delay

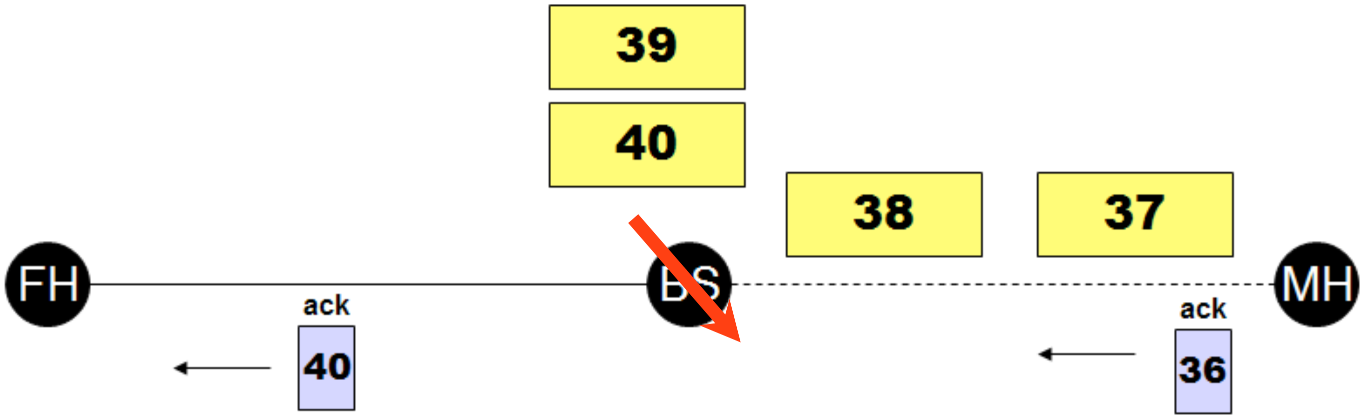
Split TCP



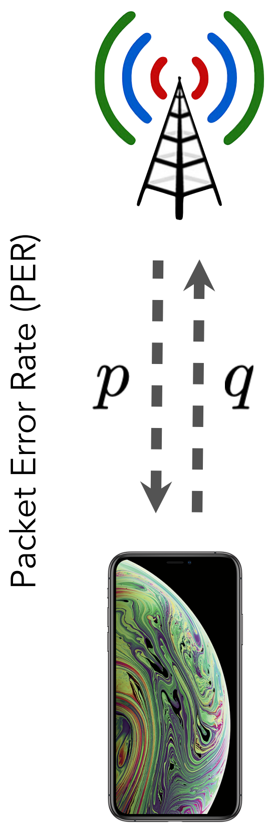
TCP connection
TCP connection
Per-TCP connection state
application
transport
network
link
physical
application
transport
network
link
physical
rxmt
application
transport
network
link
physical
rxmt: Re-transmit
FH
BS
wireless
MH

Split TCP

- *Critical Issue (BS Failure)*
  - *For those packets buffered and already ack'ed by BS*
  - *If BS fails, those packets already removed from the sender are not recoverable (price for discarding end-to-end semantic)*



Link-Layer Recovery

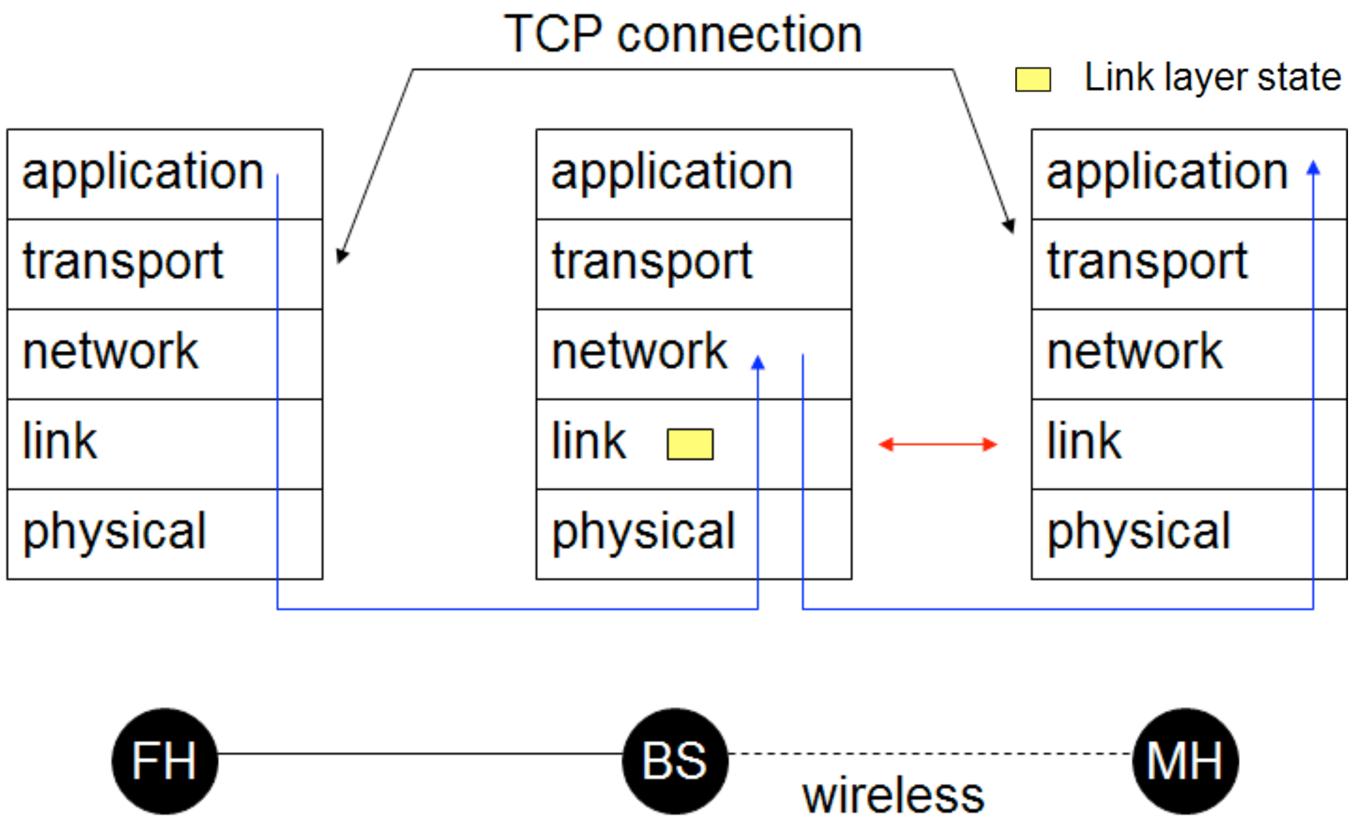


- *Expected Transmission Count: E[X]*

$$E[X] = 1(1-p) + 2p(1-p) + 3p^2(1-p) + \cdots$$
$$= \frac{1}{1-p}$$

- *Effective wireless bandwidth*
  - *Nominal data rate* $\times(1-p)$
- *Link Layer Recovery*
  - *Makes the link slower*
  - *But, makes the link robust (similarly to wired)*

Link-Layer Recovery



Snoop Protocol

- *TCP Hacking (Eavesdropping) at BS*

- *Snoop protocol buffers data packets at BS*
  - *for link layer retransmission*
  - *but not breaks end-to-end semantic*

- *When Duplicated ACKs received by BS from MH*
  - *BS retransmits buffered packets*
  - *And drop the dupacks to hide them to the TCP sender*

Snoop Protocol