Mobilitate la nivel transport

- recapitulare TCP
- comportare TCP la delay și loss
- PEP (Performance Enhancing Proxies)
- MPTCP

Mobility and transport

1. Performance
   – TCP is averse to loss, delay

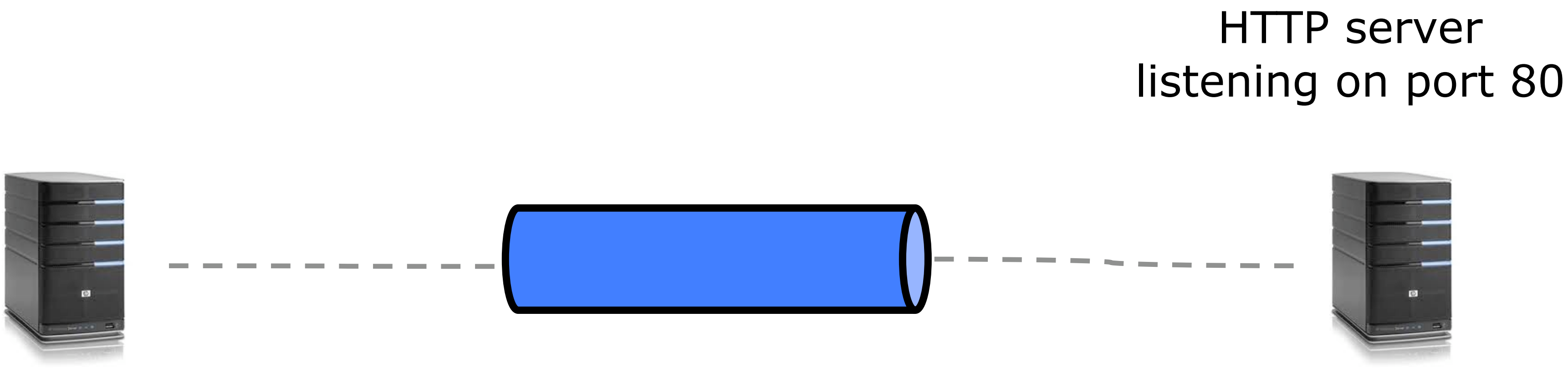
2. Functionality
   – TCP is tied to IP

TCP refresher

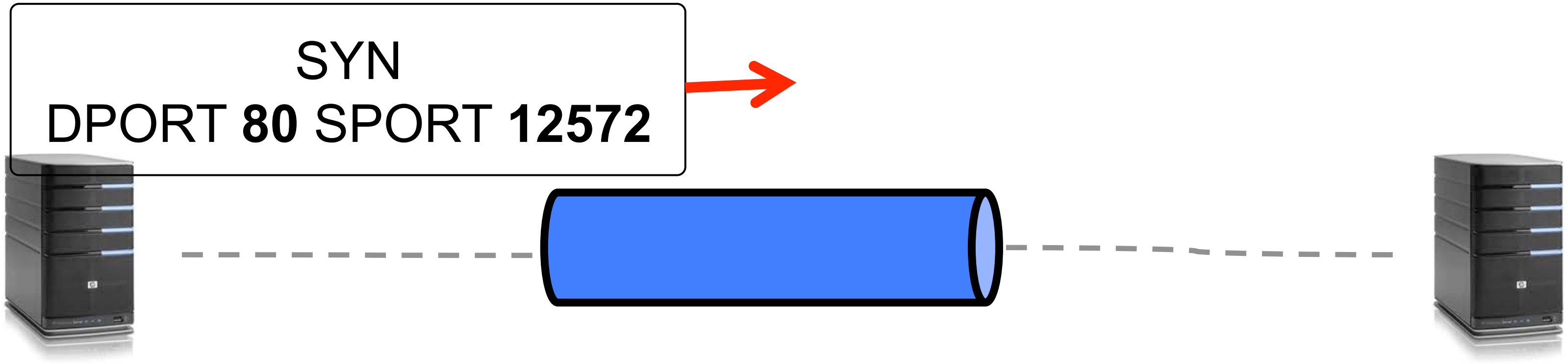
- TCP provides two functions:
  - reliable delivery
  - congestion control

- How does it react to
  - Loss?
  - Delay?
  - Mobility?

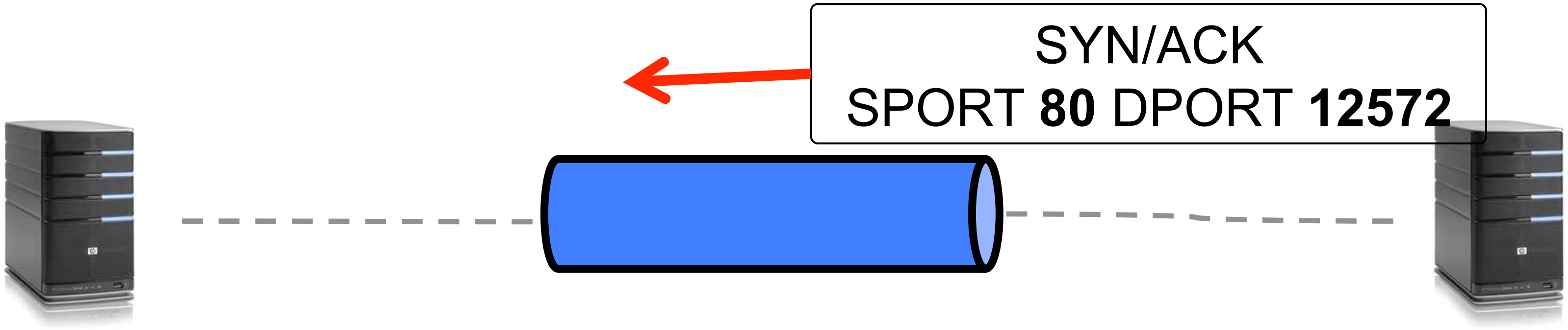
TCP Connection Setup



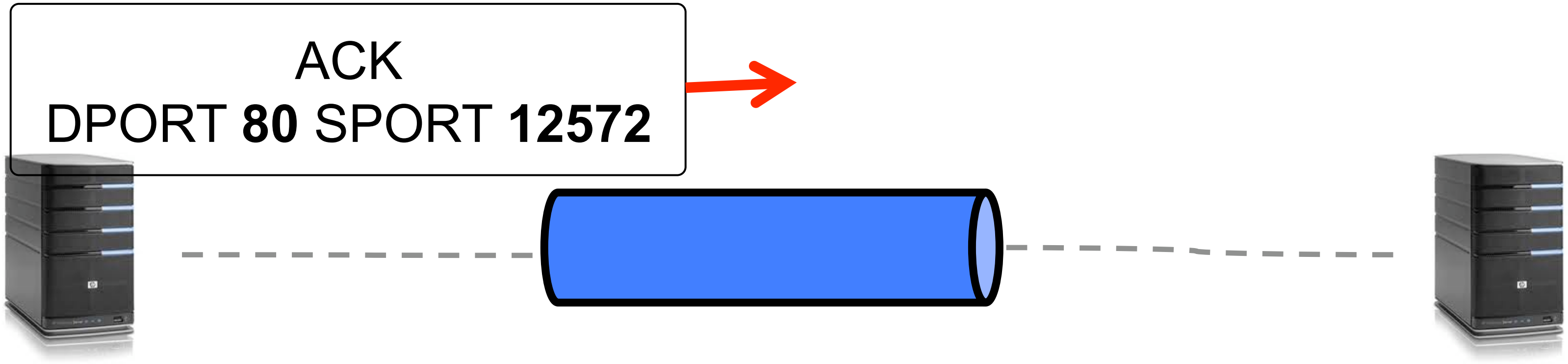
TCP Connection Setup



TCP Connection Setup


SYN/ACK
SPORT **80** DPORT **12572**

TCP Connection Setup

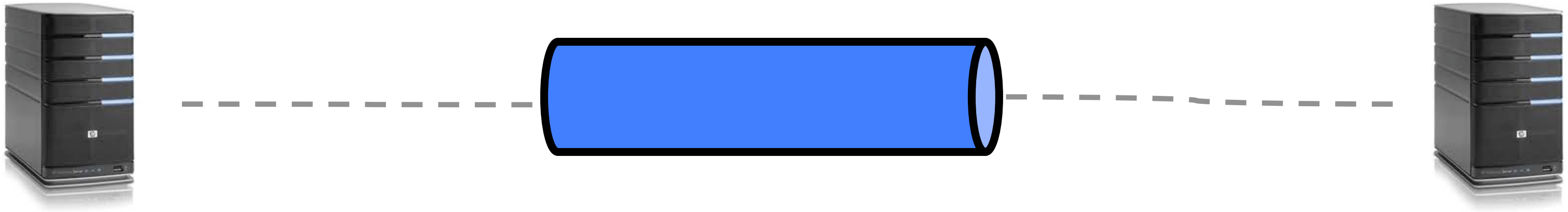


ACK
DPORT **80** SPORT **12572**

reliable in order byte stream delivery

- Apps send any numbers of bytes
  - Say 100.000B
- TCP split bytes into segments
  - Because network works with limited-size packets
- Sends them over the network
  - Segments can be lost/reordered
- TCP receiver MUST read data in order

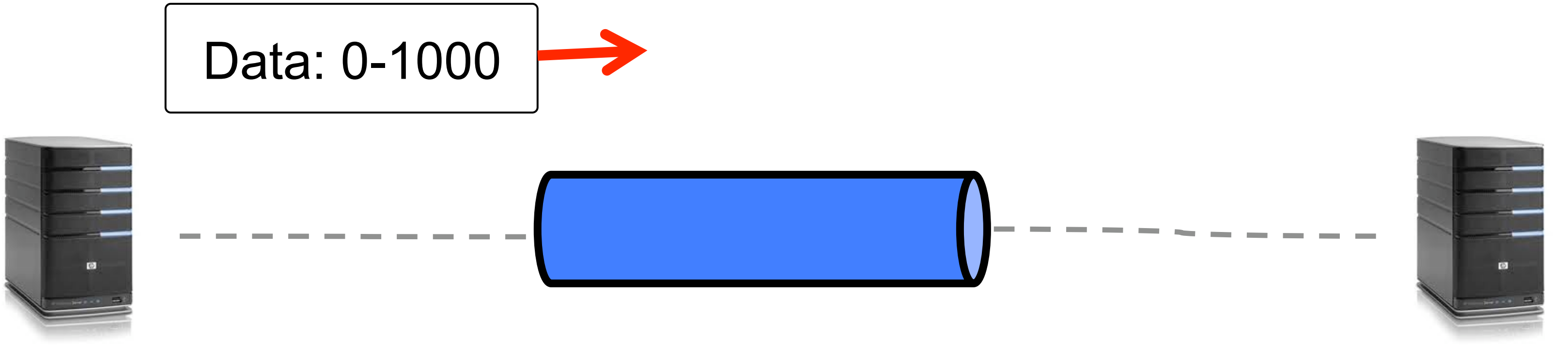
TCP Data Transmission



Browser: Send 3KB of data

HTTP Server:
Read Request

TCP Data Transmission

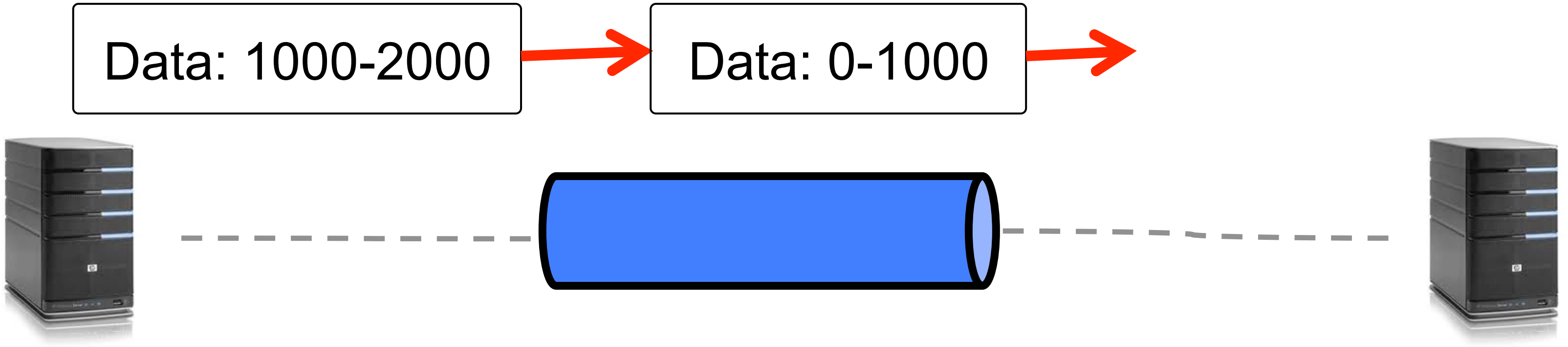


Data: 0-1000

Browser: Send 3KB of data

HTTP Server:
Read Request

TCP Data Transmission



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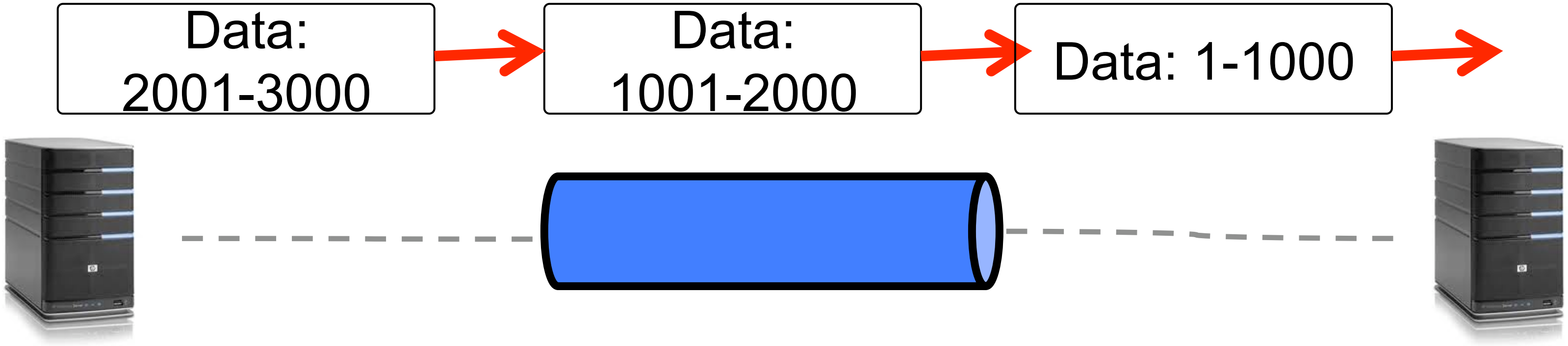
TCP Data Transmission



Data: 2001-3000

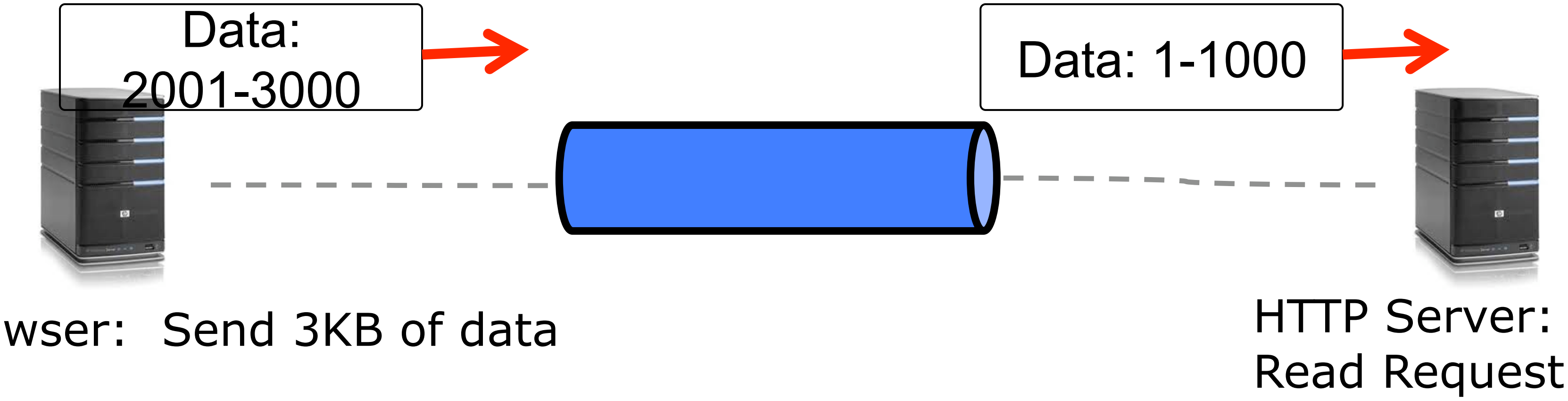
Data: 1001-2000

Data: 1-1000

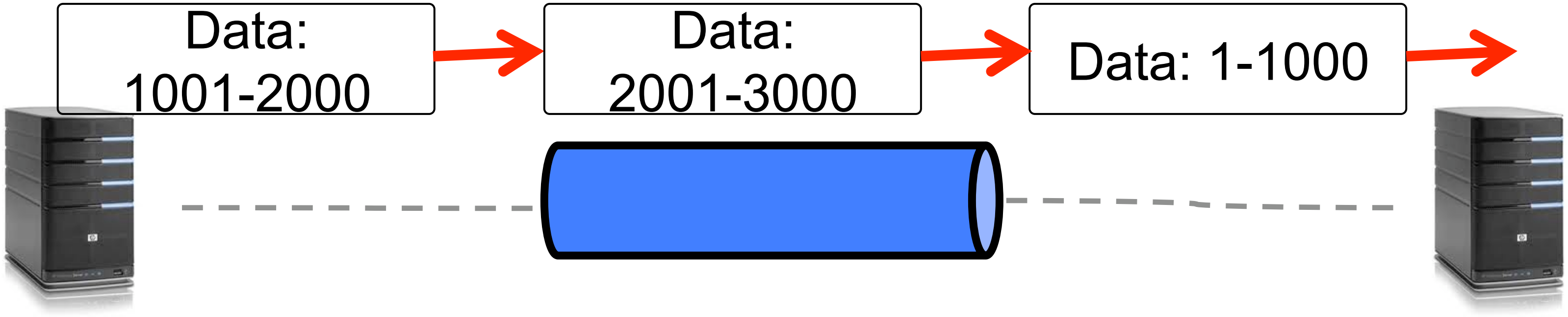
Browser: Send 3KB of data

HTTP Server: Read Request

TCP Data Transmission: Lost Packets



TCP Data Transmission: Reordering



Data: 1001-2000

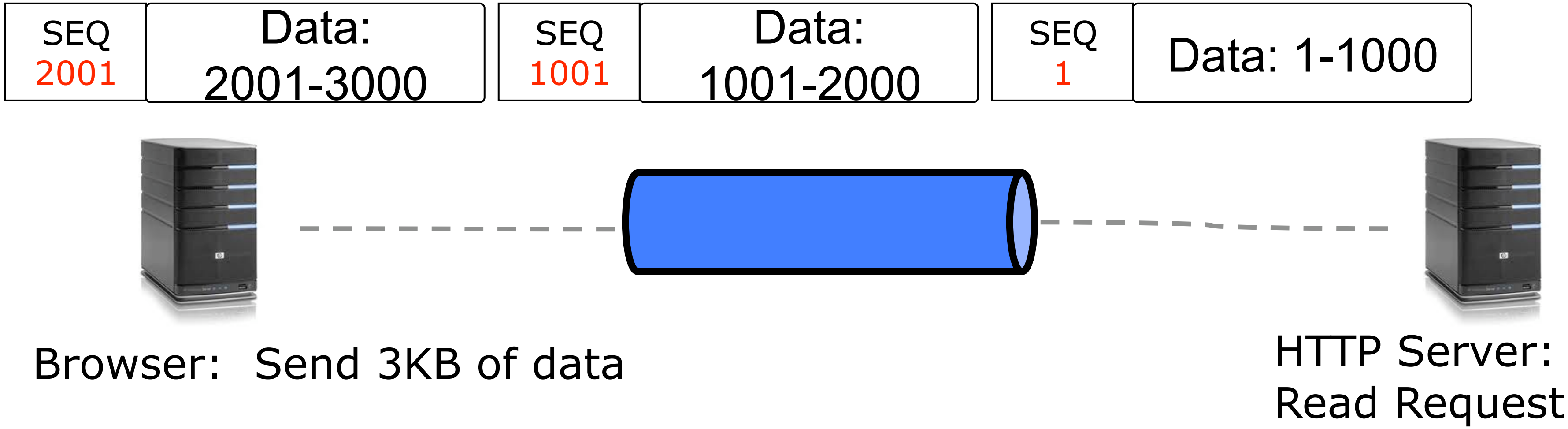
Data: 2001-3000

Data: 1-1000

Browser: Send 3KB of data

HTTP Server:
Read Request

Sequence Numbers and ACKs



SEQ 2001 | Data: 2001-3000

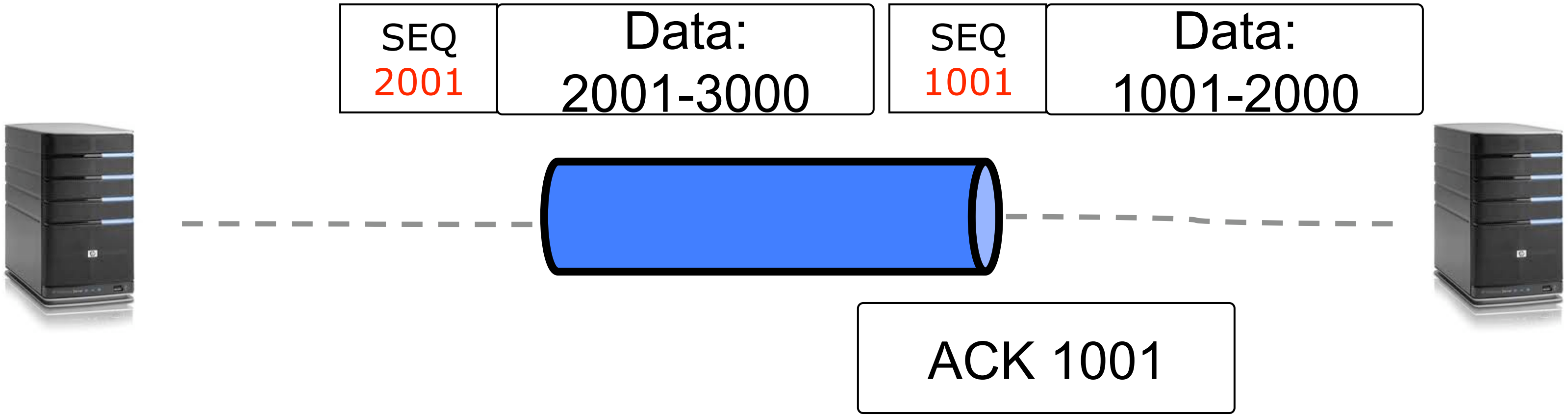
SEQ 1001 | Data: 1001-2000

SEQ 1 | Data: 1-1000

Browser: Send 3KB of data

HTTP Server:
Read Request

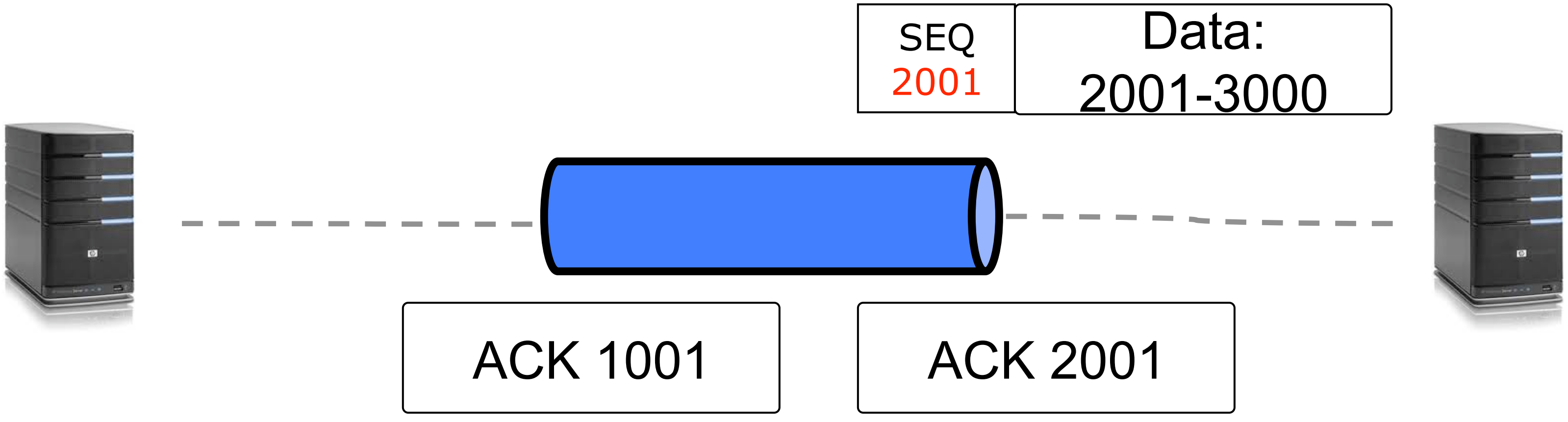
Sequence Numbers and ACKs



Browser: Send 3KB of data

HTTP Server:
Read Request

Sequence Numbers and ACKs



SEQ
2001

Data:
2001-3000

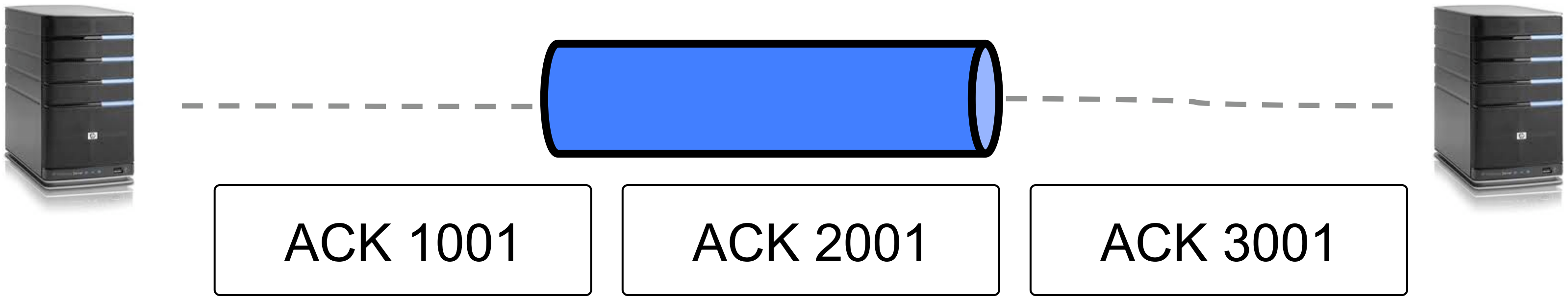
ACK 1001

ACK 2001

Browser: Send 3KB of data

HTTP Server:
Read Request

Sequence Numbers and ACKs



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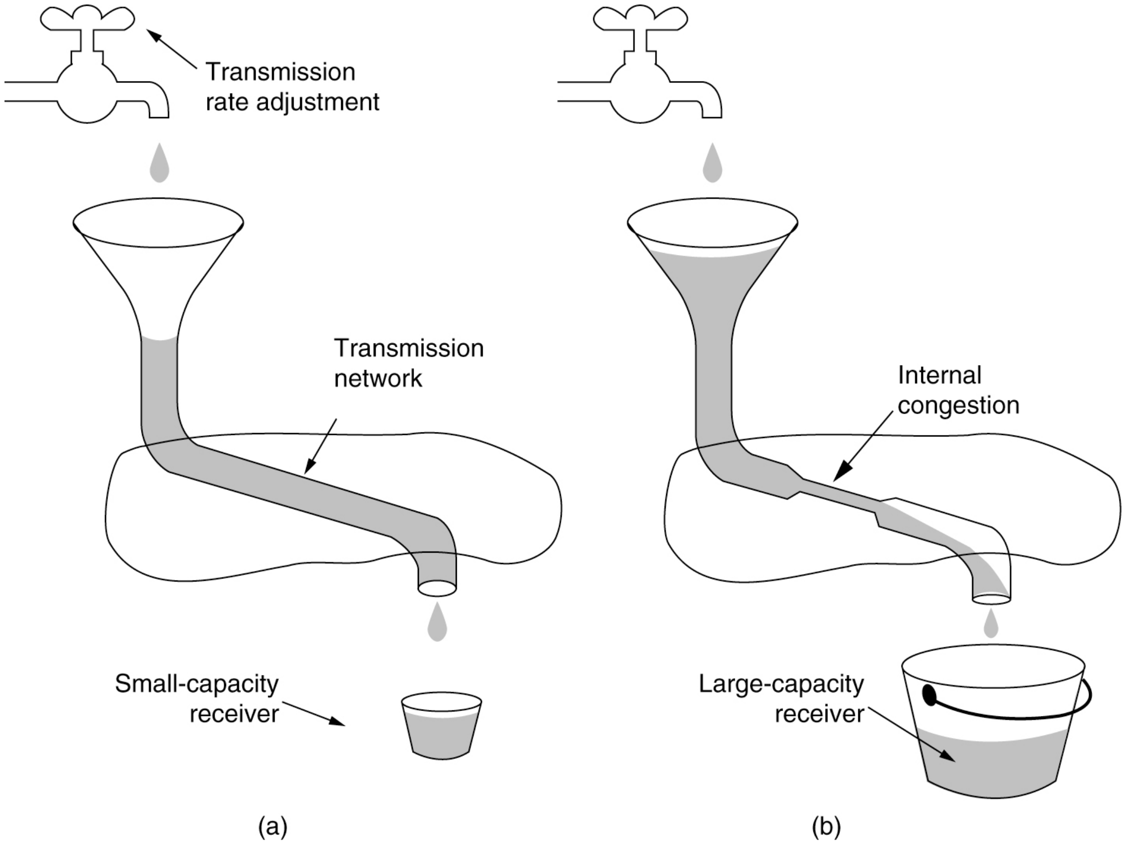
Read Request

TCP congestion control



(a) Fast network feeds a slow receiver

(b) Slow network feeds a fast receiver.

What is the optimal window? …

… BDP = bandwidth delay product

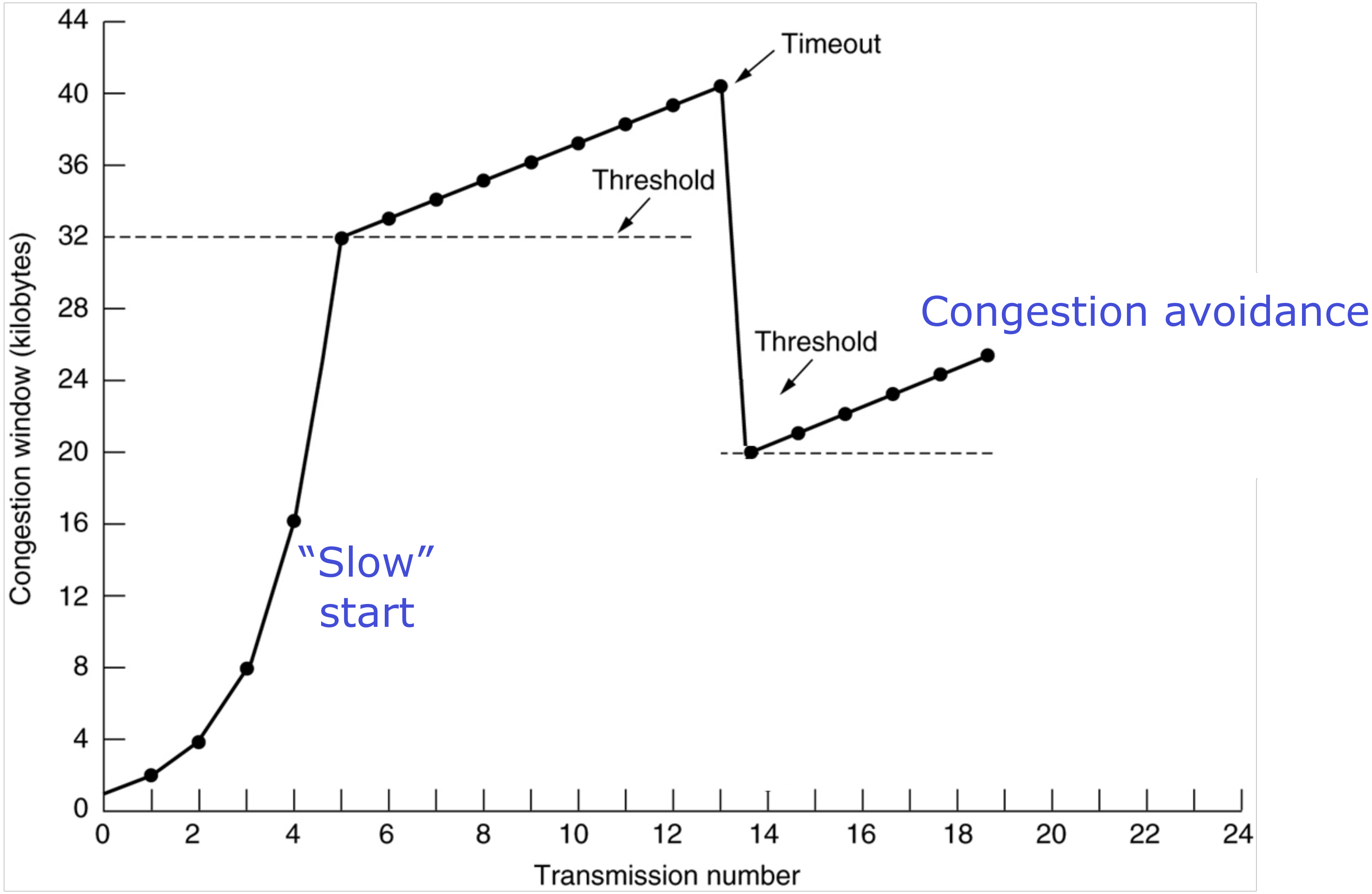
TCP congestion control

- Sender uses minimum of two windows
  - AW (advertised window) = receiver capacity, in each ACK segment
  - CW (congestion window) = network capacity, estimated by sender
  - CW crows in two phases
- “slow start”, actually exponential
  - Up to a threshold
- “congestion avoidance” (prevention), liniar increase
  - After threshold
- Threshold
  - Inițially 64K
  - Cut in half after a timeout
- fast recovery, fast retransmit

TCP slow start

- Used at the beginning, and after a timeout
- "slow" compared to selective repeat
- Used to discover capacity
  - Initially CW = 1 segment
  - After each ACK, CW increases by 1
  - Exponential!

TCP congestion control



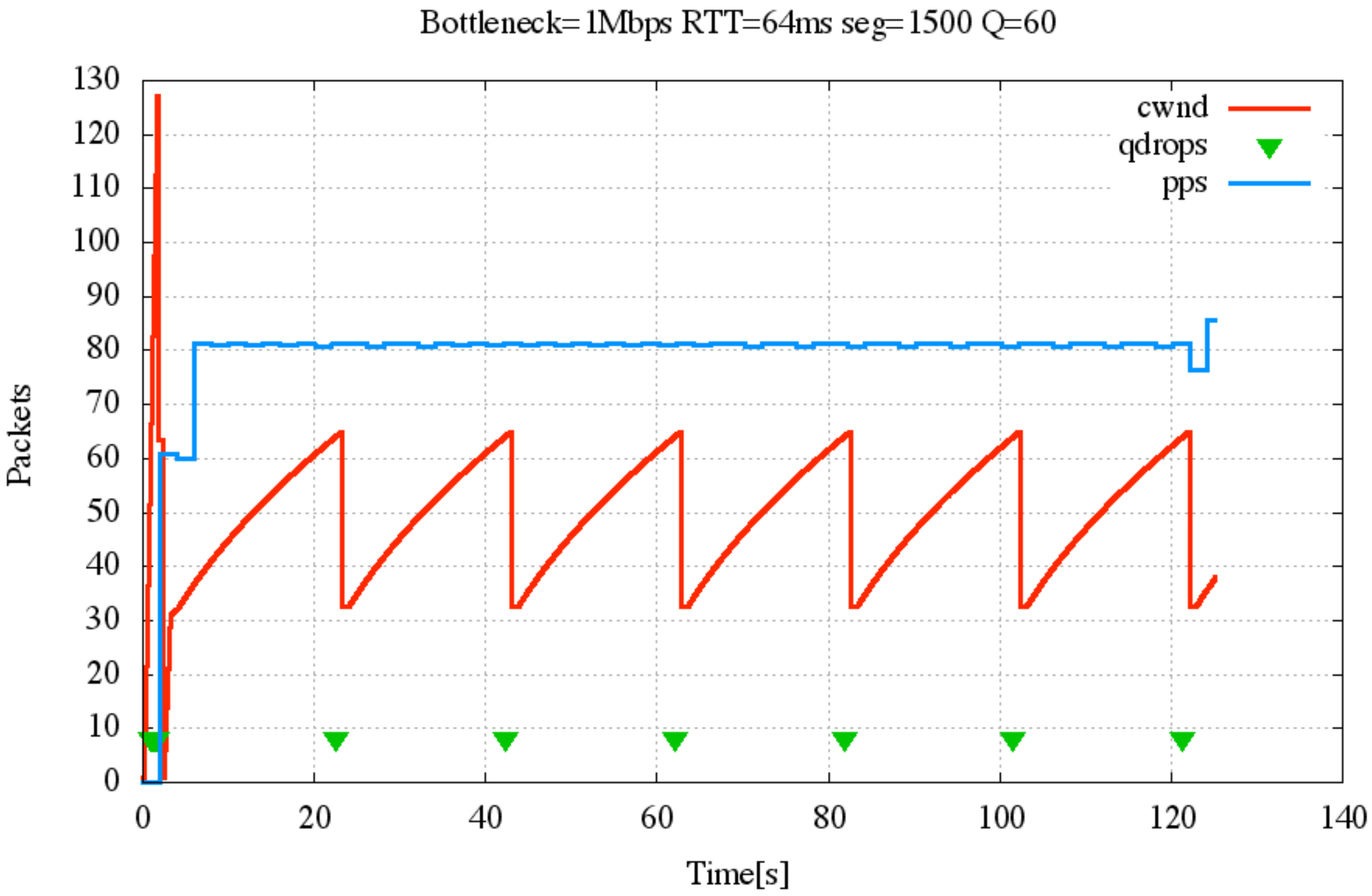
Example MSS=1024 bytes

TCP congestion avoidance

1. TCP slow start
   - Increment CW with each ACK
   - (exponențial)
2. TCP congestion avoidance
   - Increase CW with 1/CW at each ACK
   - Effect: grows with 1 segment per RTT, liniarly

ACK duplicate 3 times:

- CW = CW/2 (fast recovery)
- retransmit segment (fast retransmit)
- stay in congestion avoidance

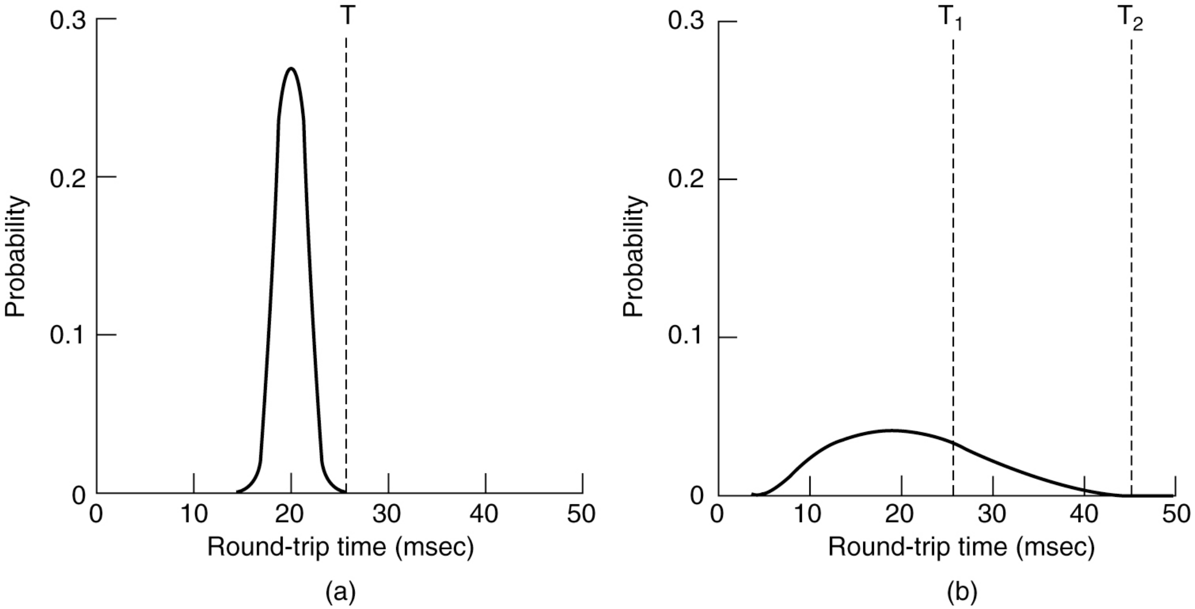


- CW oscillates around optimum
- Lost segment
    - repeat ACK
    - fast retransmit
- Throughput stays constant

TCP timers

Retransmission timer – started with each segment sent

- What is the expiration interval?
- RTT hard to estimate over internet



(a) ACK time distribution at layer 2

(b) ACK time distribution at layer 4

timer = T1 => useless retransmissions

timer = T2 => wait too much for most segments

TCP – dynamic timers

Jacobson: adjust RTT based on continuous measurements

- RTT = current estimate, M = last measurement
- $RTT = \alpha\, RTT + (1 - \alpha) M$, $\alpha = 7/8$

How long to wait?

- Estimate standard deviation of RTT (also called “jitter”)
- Estimate $D = \alpha\, D + (1 - \alpha)|RTT - M|$
- **Timeout= RTT + 4D**

TCP performance

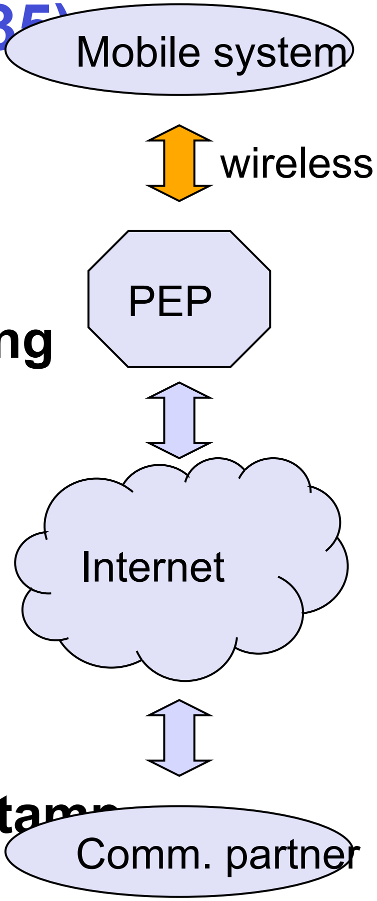
- How TCP reacts to
  - Loss
    - Covered by layer 2 (FEC, ARQ)? => delay
    - Uncovered? => fast retransmit, timeout :-(
  - Delay
    - Reduced throughput (high BDP)
    - timeout :-(
- TCP interprets loss as congestion

Design bug!

- “Solutions”
  - SACK = selective acknowledgments
  - ECN = Explicit congestion notification
  - PEP = Performance enhancing proxies

TCP “improvements”

- Performance enhancing proxies (PEP, RFC 3135)
  - Transport layer
    - Local retransmissions and acknowledgements
  - Additionally on the application layer
    - Content filtering, compression, picture downscaling
    - Web service gateways?
  - Big problem: breaks end-to-end semantics
    - Disables use of IP security
    - Choose between PEP and security!
- More open issues
  - RFC 3150 (slow links) header compression, no timestamp
  - RFC 3155 (links with errors)
    - States that explicit congestion notification cannot be used
  - In contrast to 2.5G/3G recommendations!



Mobility and transport

- Performance
  - TCP is averse to loss, delay

- Functionality
  - TCP is tied to IP

Mobile IP reminder

- IP address = location identifier & host identity
- MobileIP
  - Home Agent
  - Foreign Agent, Care of Address
  - tunneling, triangle routing
- MobileIP problems
  - Security – FA, HA authentication
  - Firewalls
    - needs reverse tunneling
  - NAT
- instead, would like to use multiple IPs….

MPTCP (multipath TCP)

- Why?
  - Most web servers are multi-homed
  - Smart phones have multiple wireless connections
  - Data centers have multiple paths between hosts

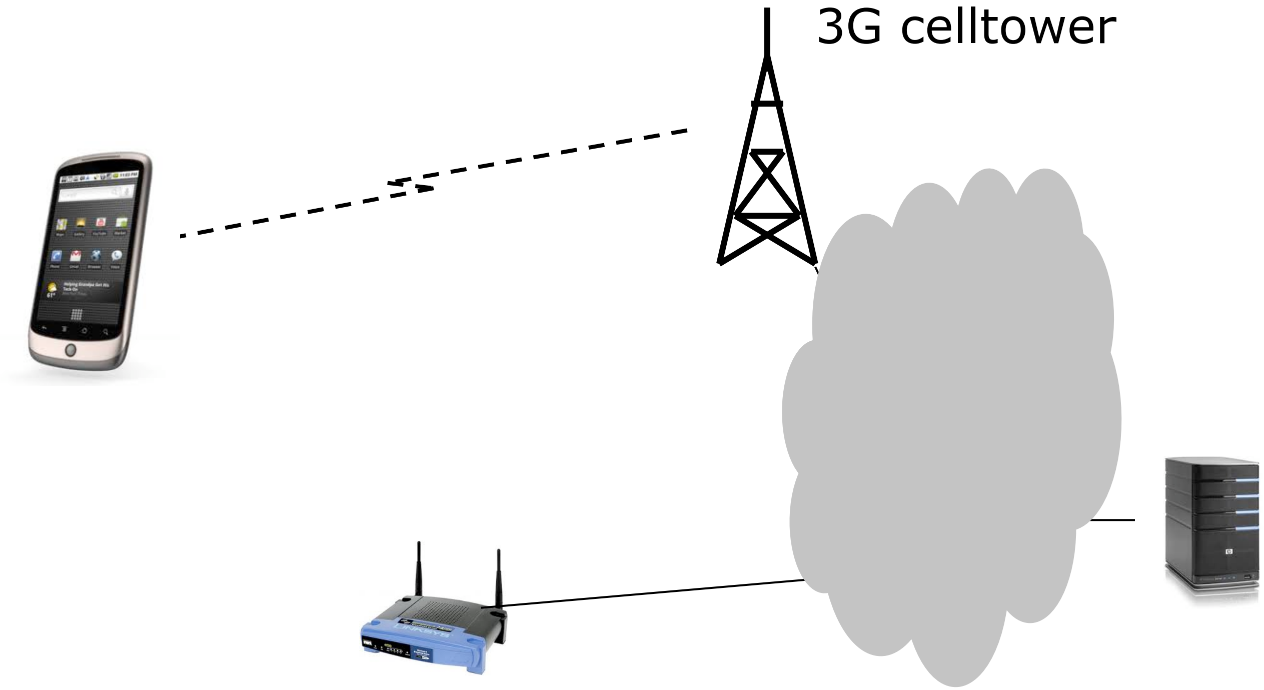
- Advanced adoption stage (2015)
  - RFC 6824
  - Linux kernel patch
  - Android kernel
  - Apple SIRI

- Costin Raiciu
  UPB

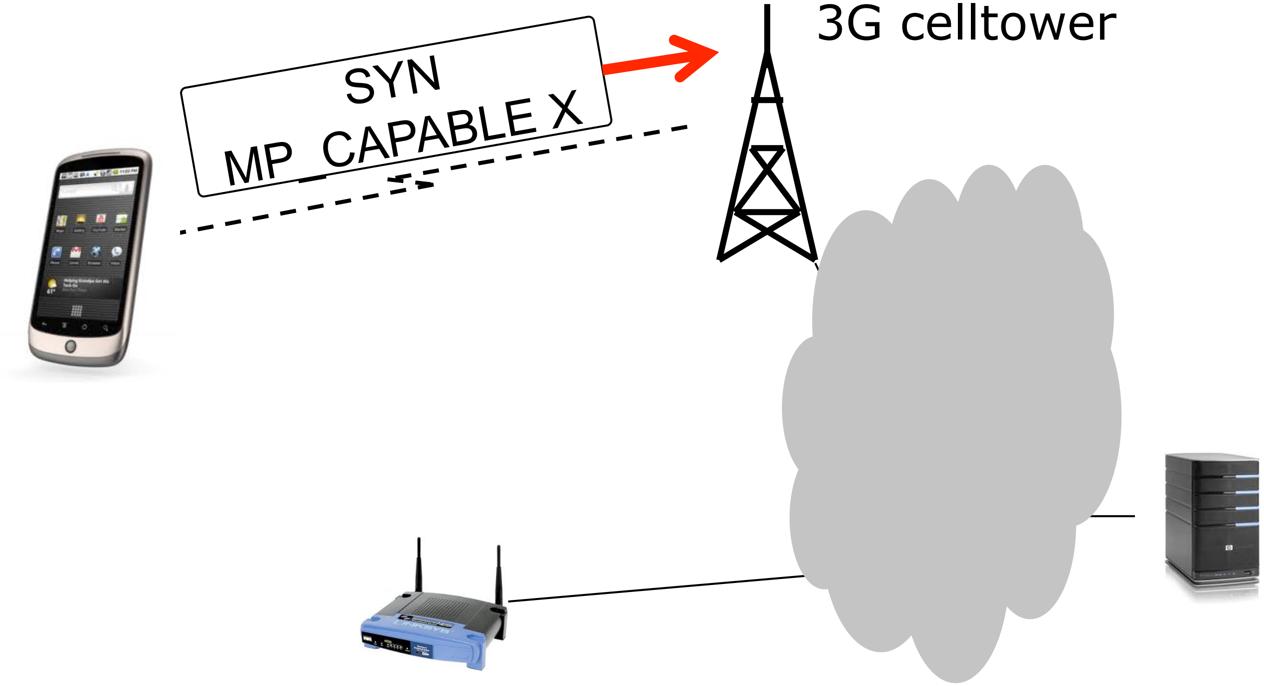
Octavian Purdilă
Intel/UPB

4/27/15

MPTCP Mobile Architecture



MPTCP Mobile Architecture



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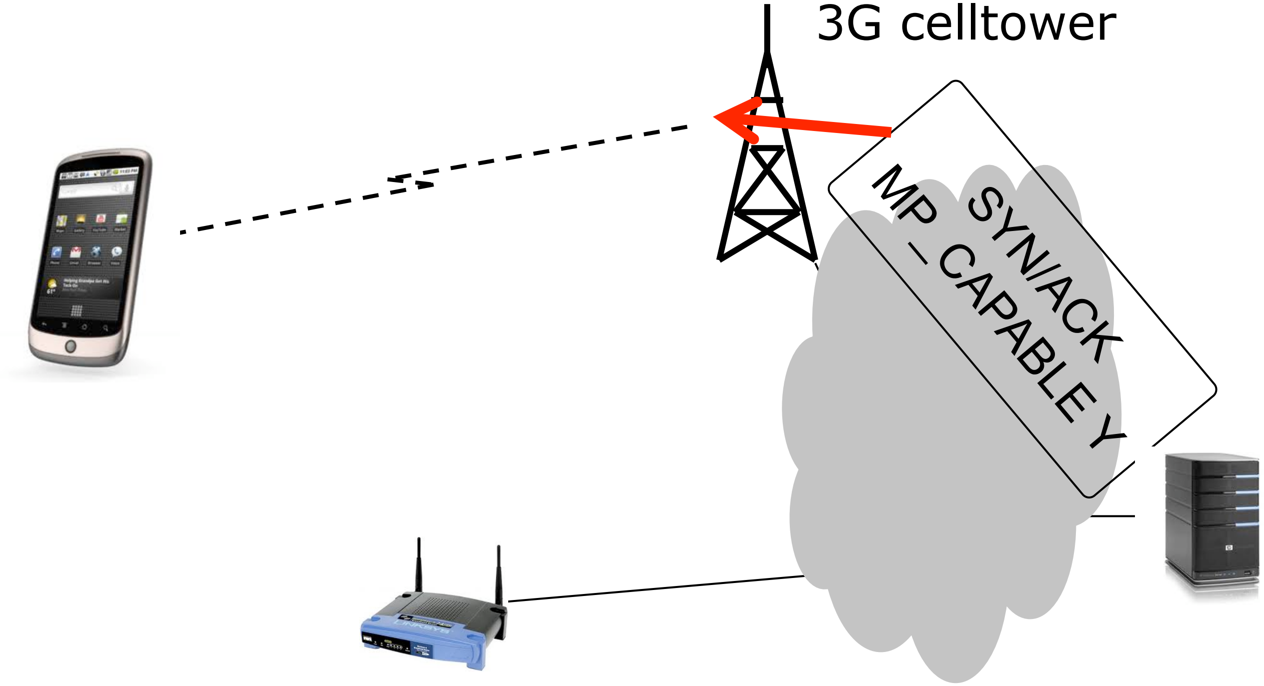

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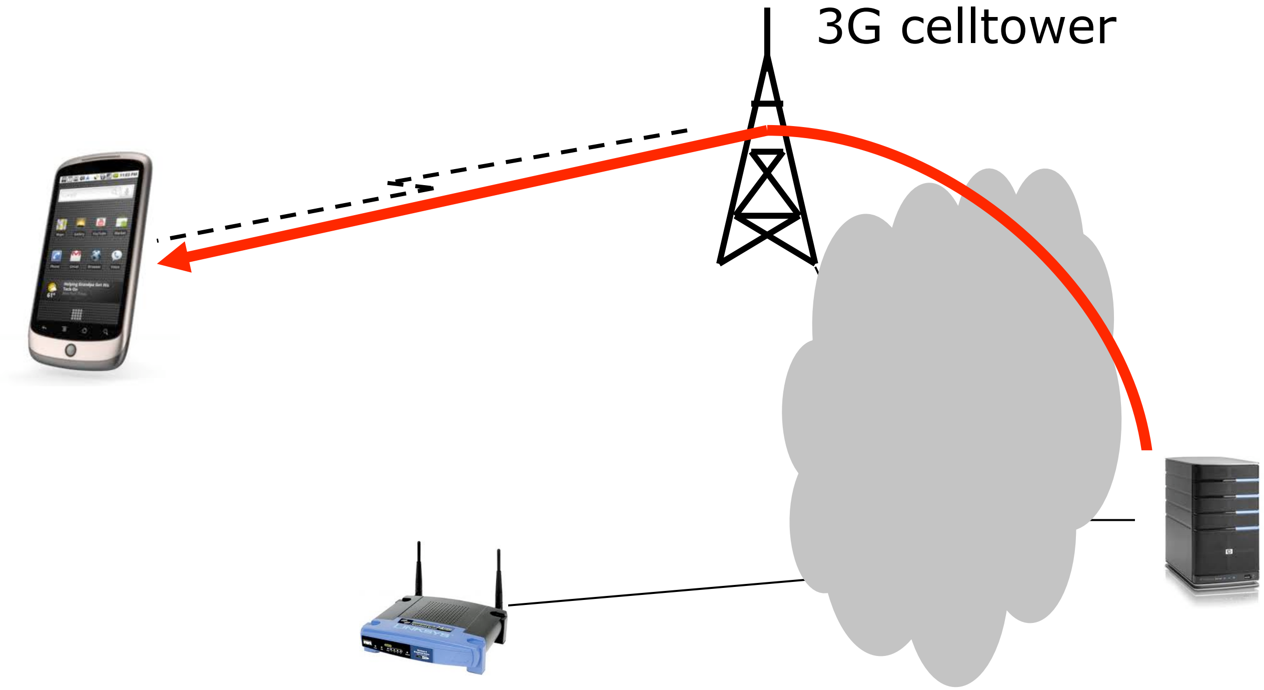

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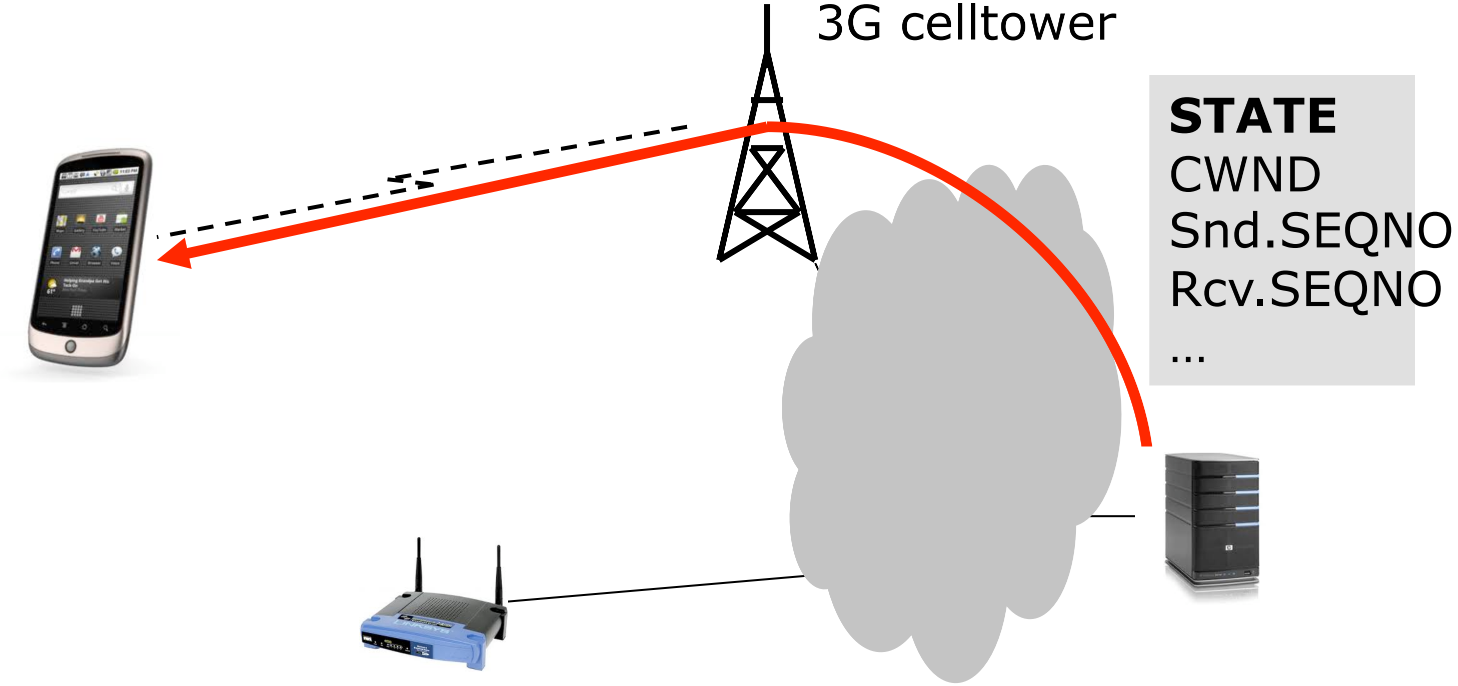
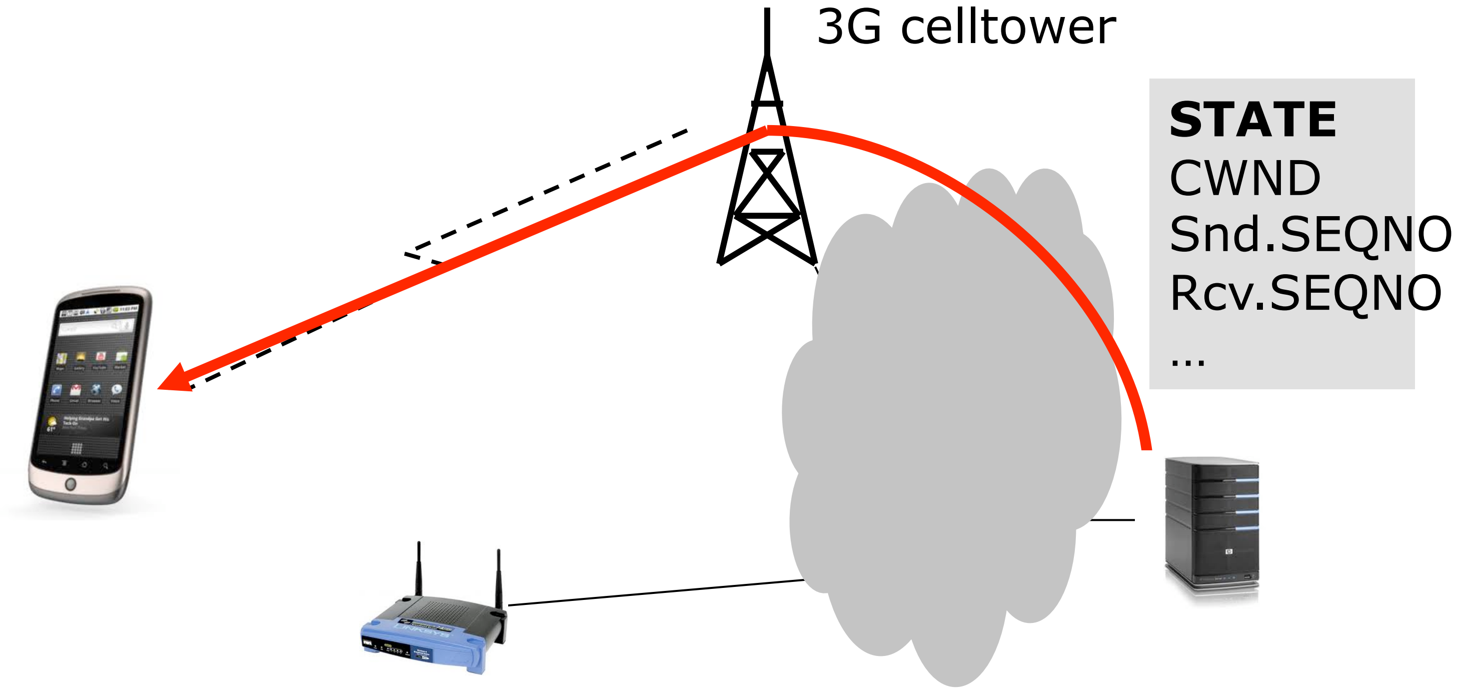


STATE
CWND
Snd.SEQNO
Rcv.SEQNO
...

MPTCP Mobile Architecture



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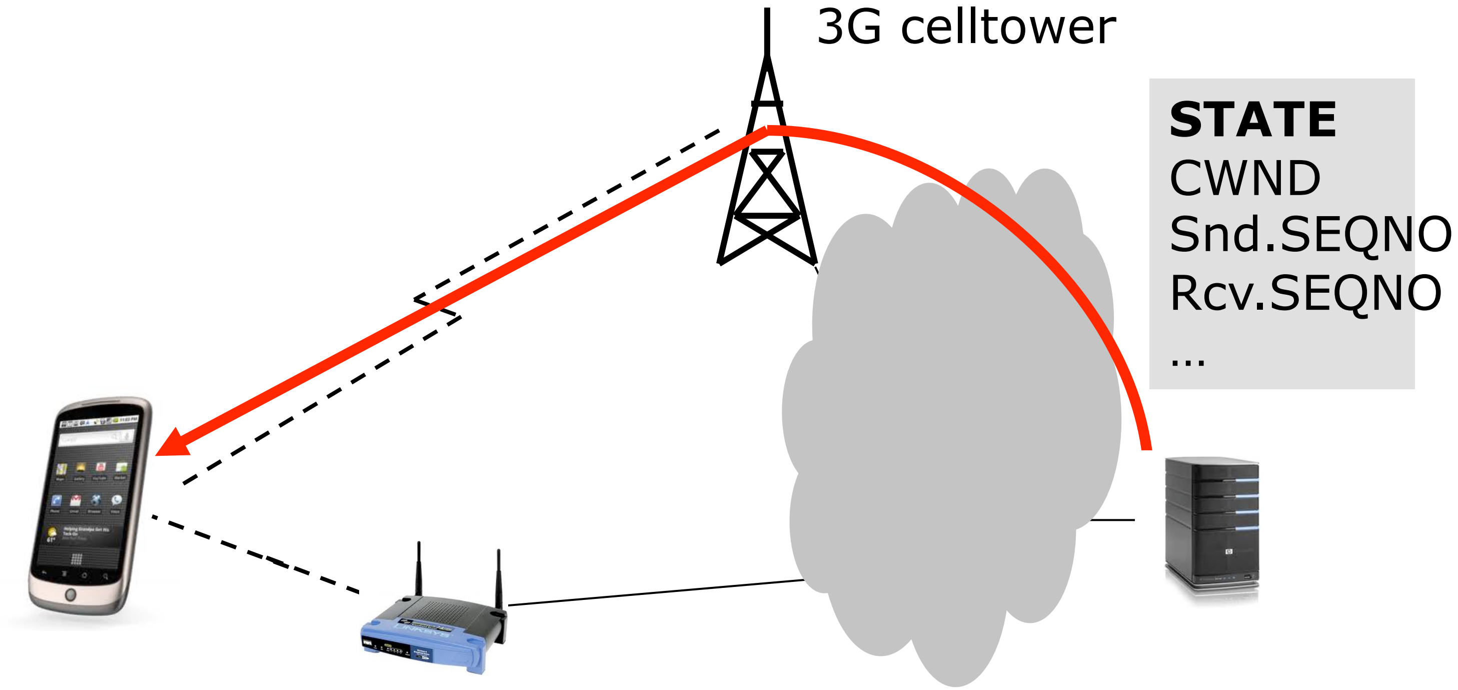
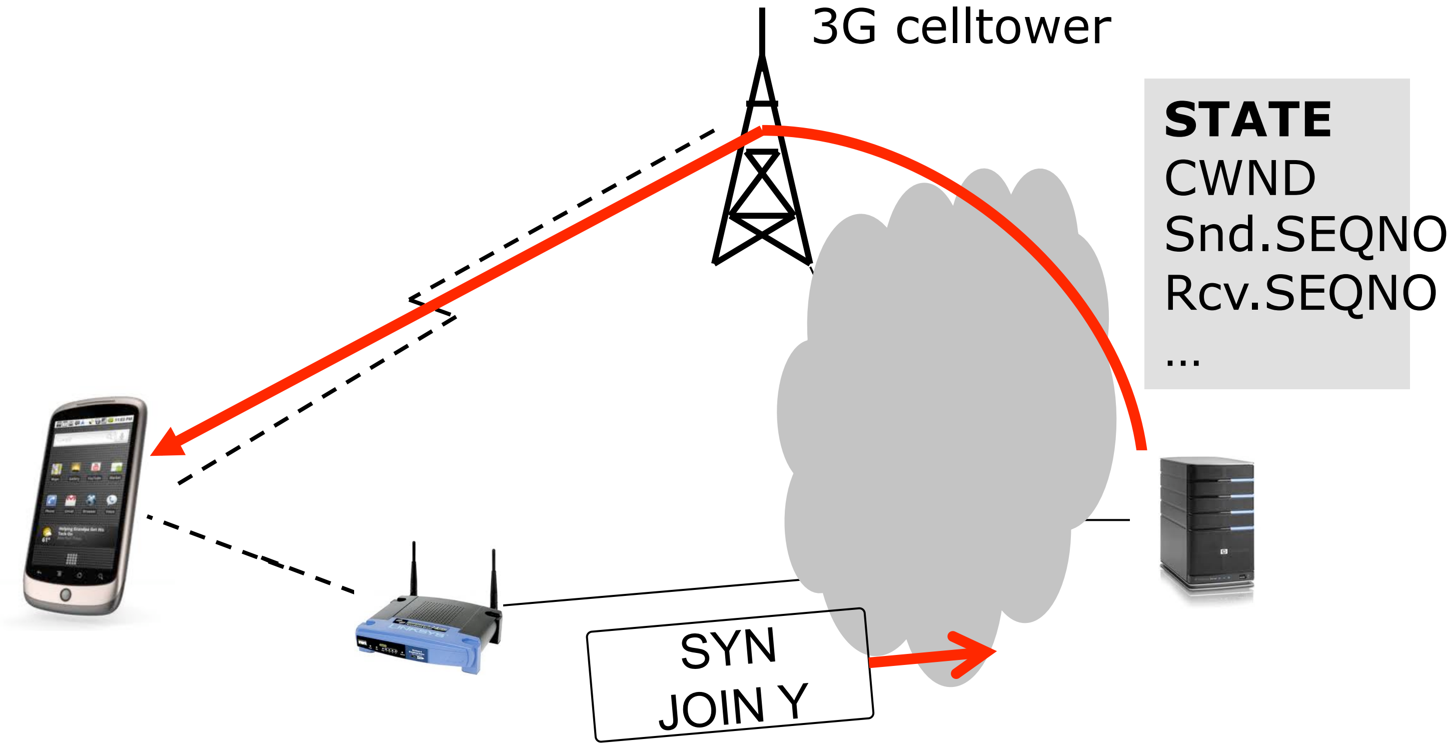
MPTCP Mobile Architecture



STATE
CWND
Snd.SEQNO
Rcv.SEQNO
...

MPTCP Mobile Architecture

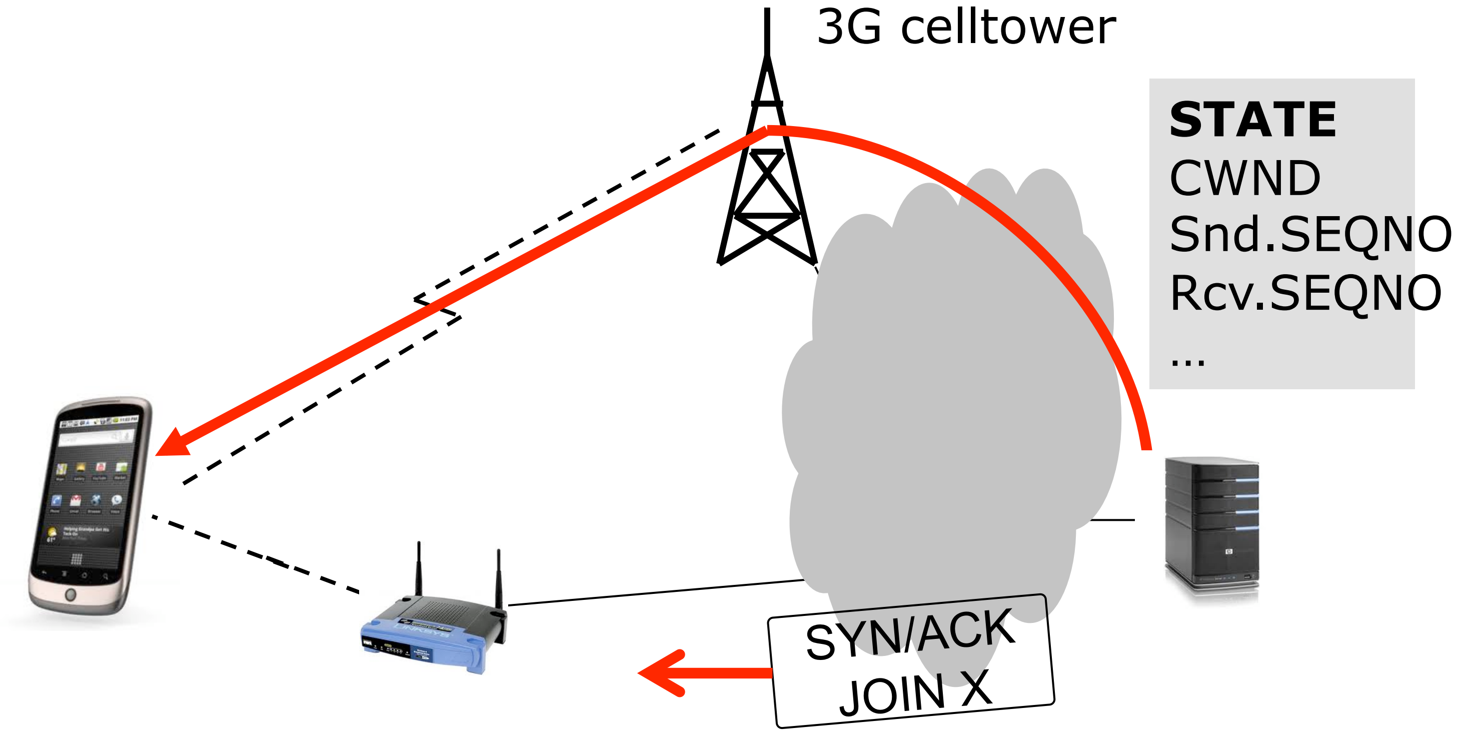


3G celltower

STATE
CWND
Snd.SEQNO
Rcv.SEQNO
...

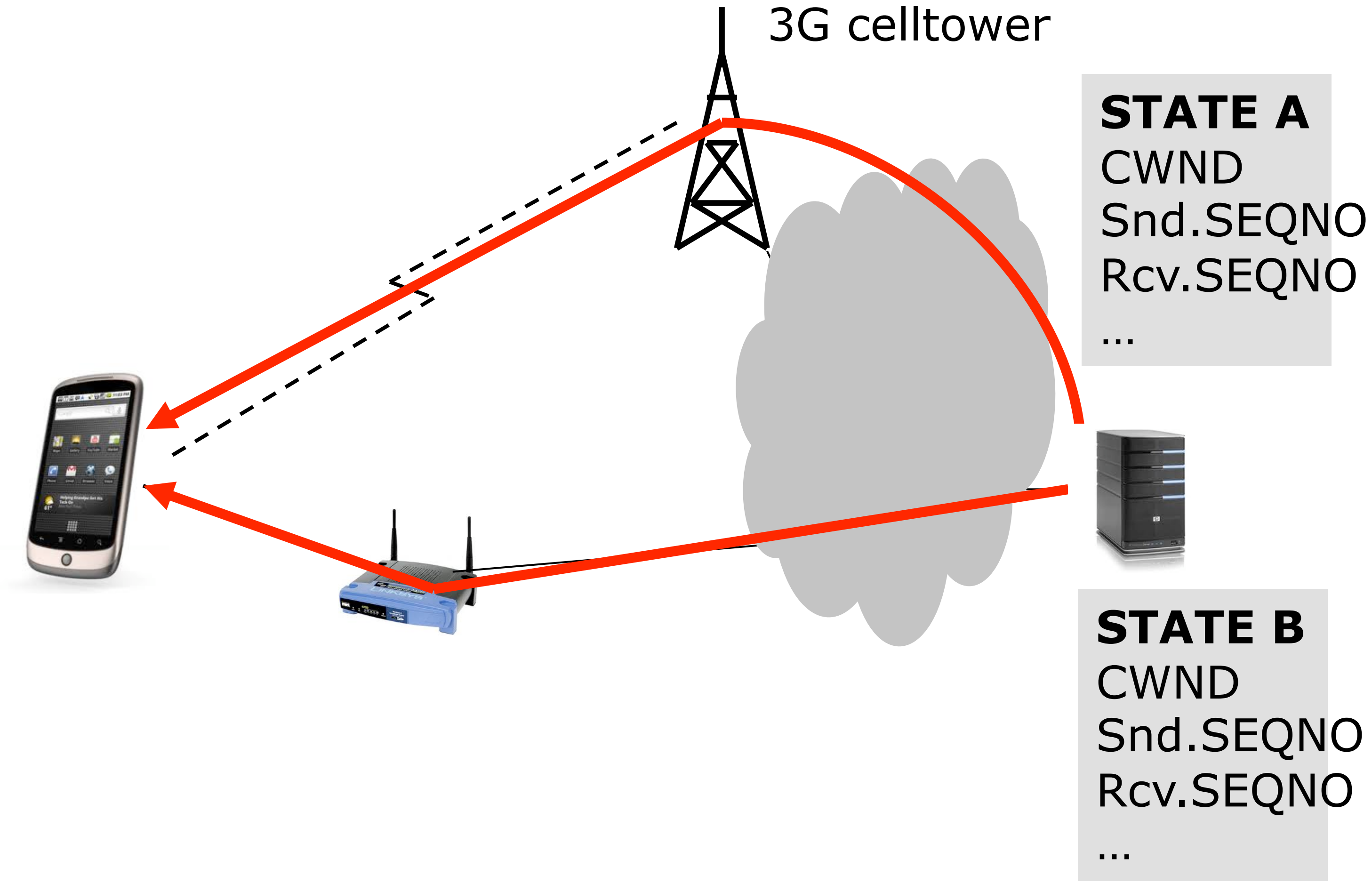
SYN
JOIN Y

MPTCP Mobile Architecture



STATE
CWND
Snd.SEQNO
Rcv.SEQNO
...

MPTCP Mobile Architecture

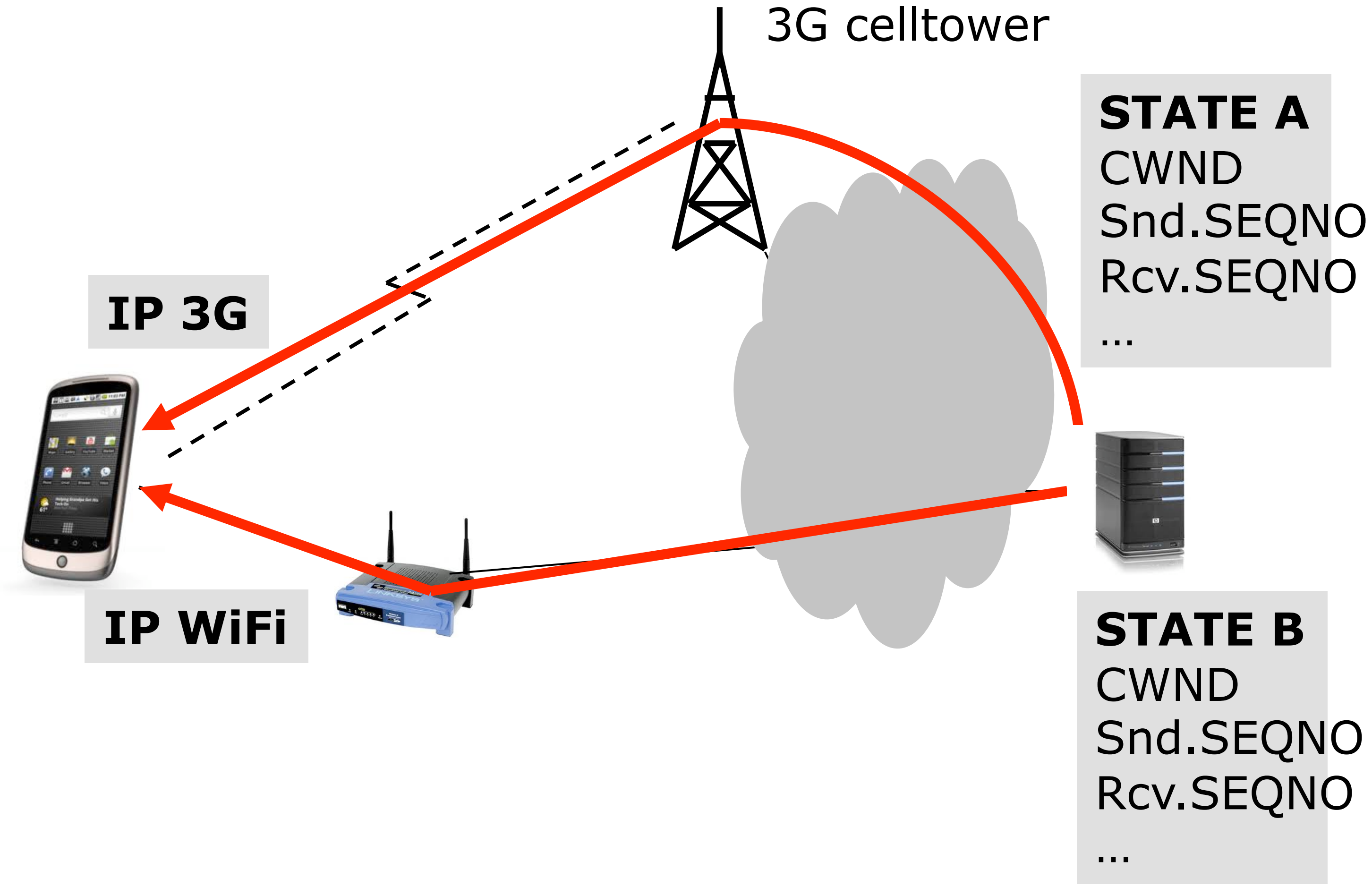


3G celltower

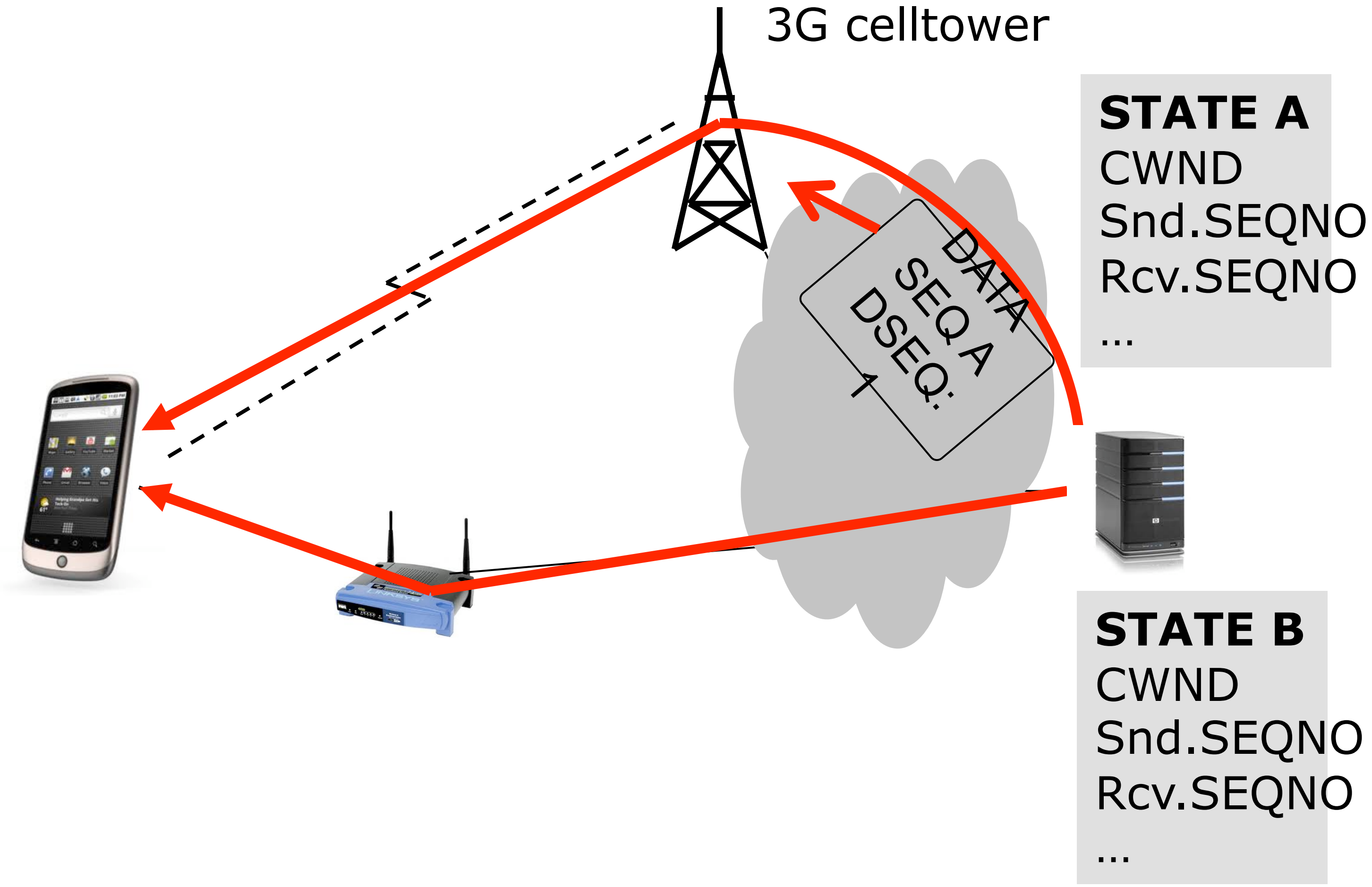
STATE A
CWND
Snd.SEQNO
Rcv.SEQNO
…

STATE B
CWND
Snd.SEQNO
Rcv.SEQNO
…

MPTCP Mobile Architecture



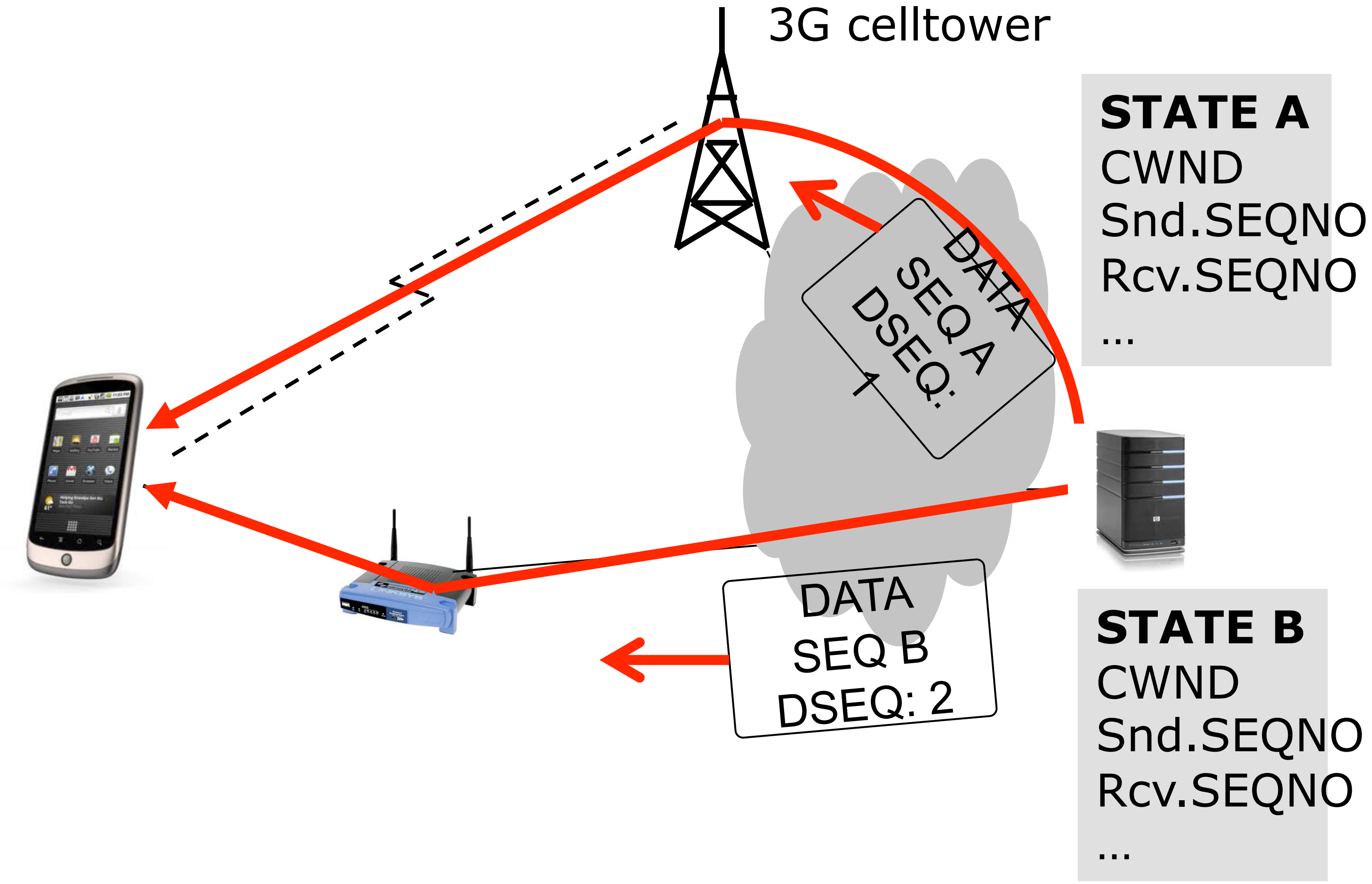
MPTCP Mobile Architecture



STATE A
CWND
Snd.SEQNO
Rcv.SEQNO
...

STATE B
CWND
Snd.SEQNO
Rcv.SEQNO
...

MPTCP Mobile Architecture



3G celltower

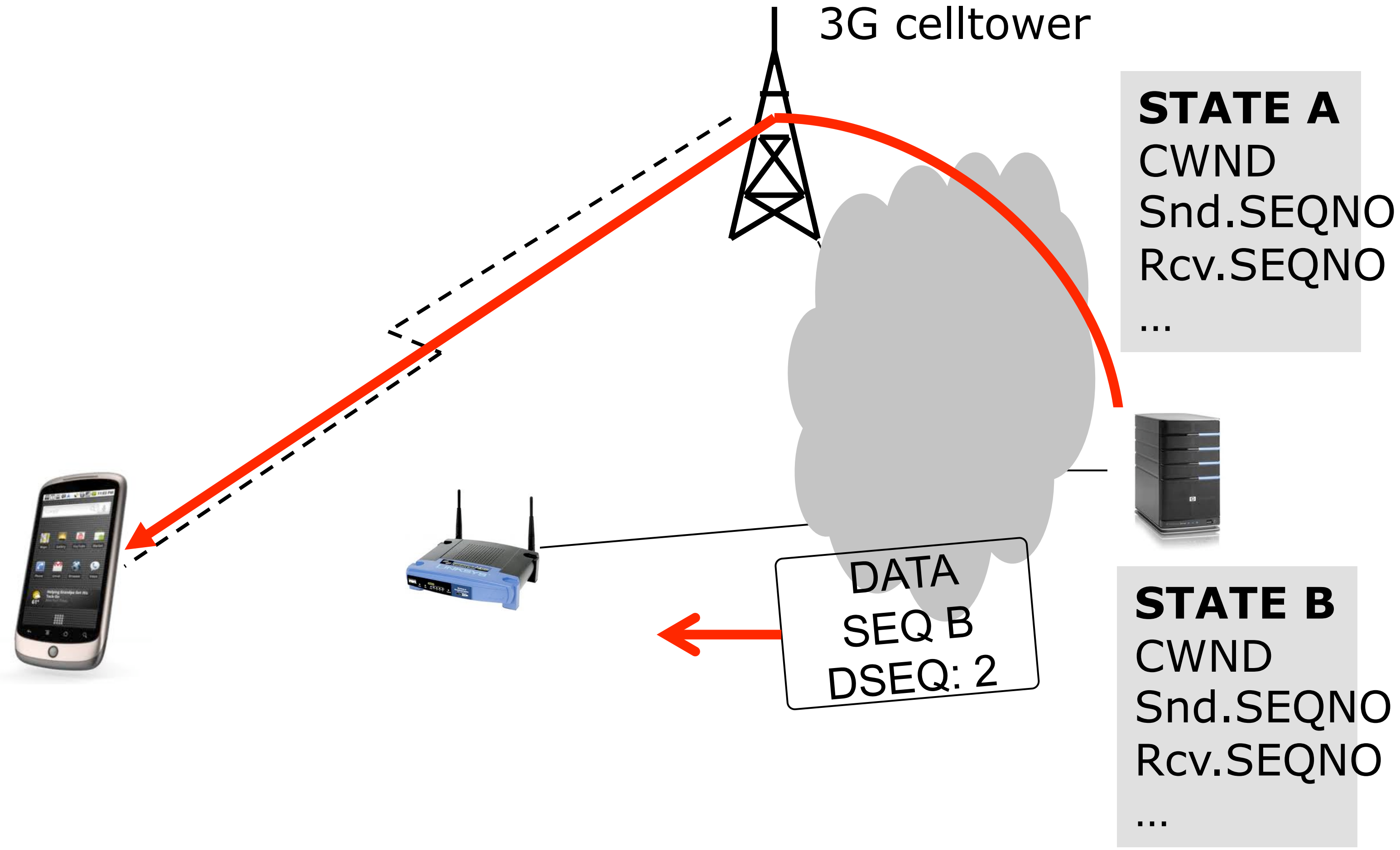
STATE A
CWND
Snd.SEQNO
Rcv.SEQNO
...

DATA
SEQ A
DSEQ: 1

DATA
SEQ B
DSEQ: 2

STATE B
CWND
Snd.SEQNO
Rcv.SEQNO
...

MPTCP Mobile Architecture



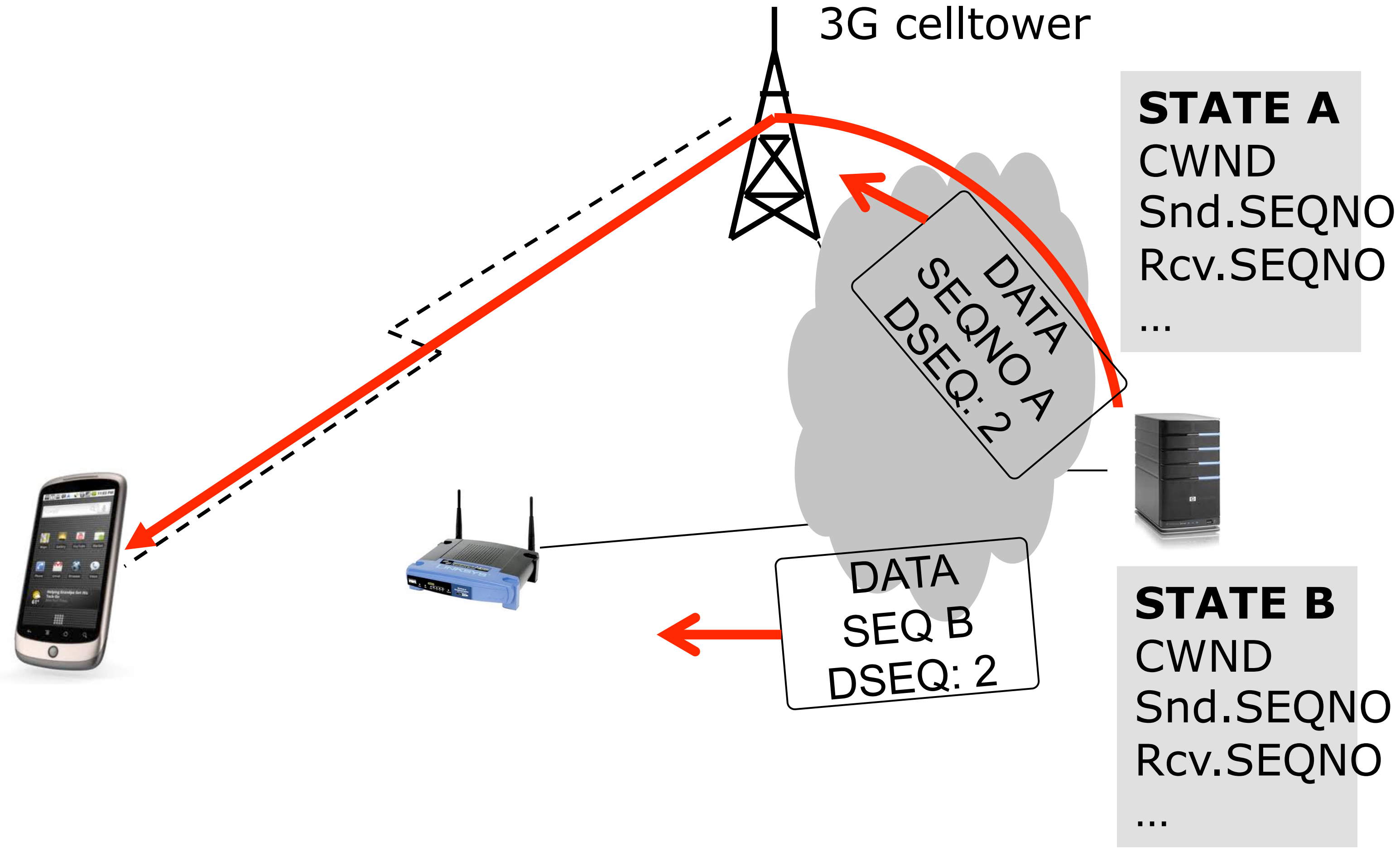
3G celltower

STATE A
CWND
Snd.SEQNO
Rcv.SEQNO
...

DATA
SEQ B
DSEQ: 2

STATE B
CWND
Snd.SEQNO
Rcv.SEQNO
...

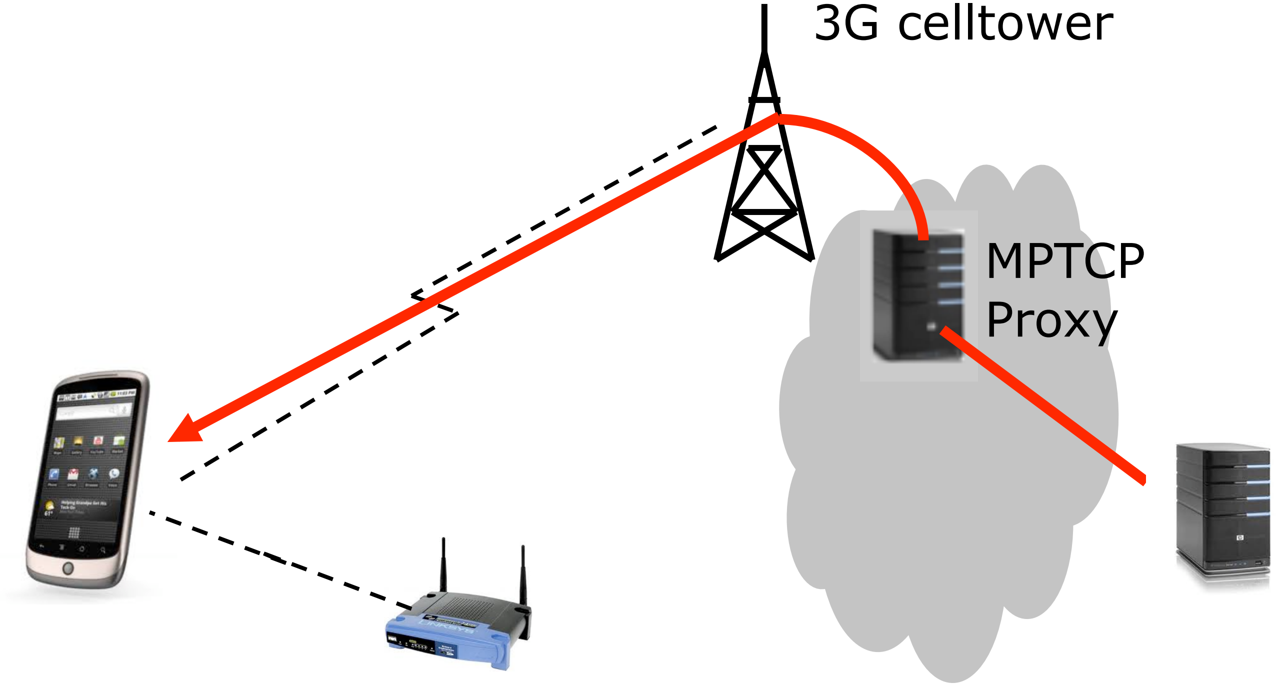
MPTCP Mobile Architecture



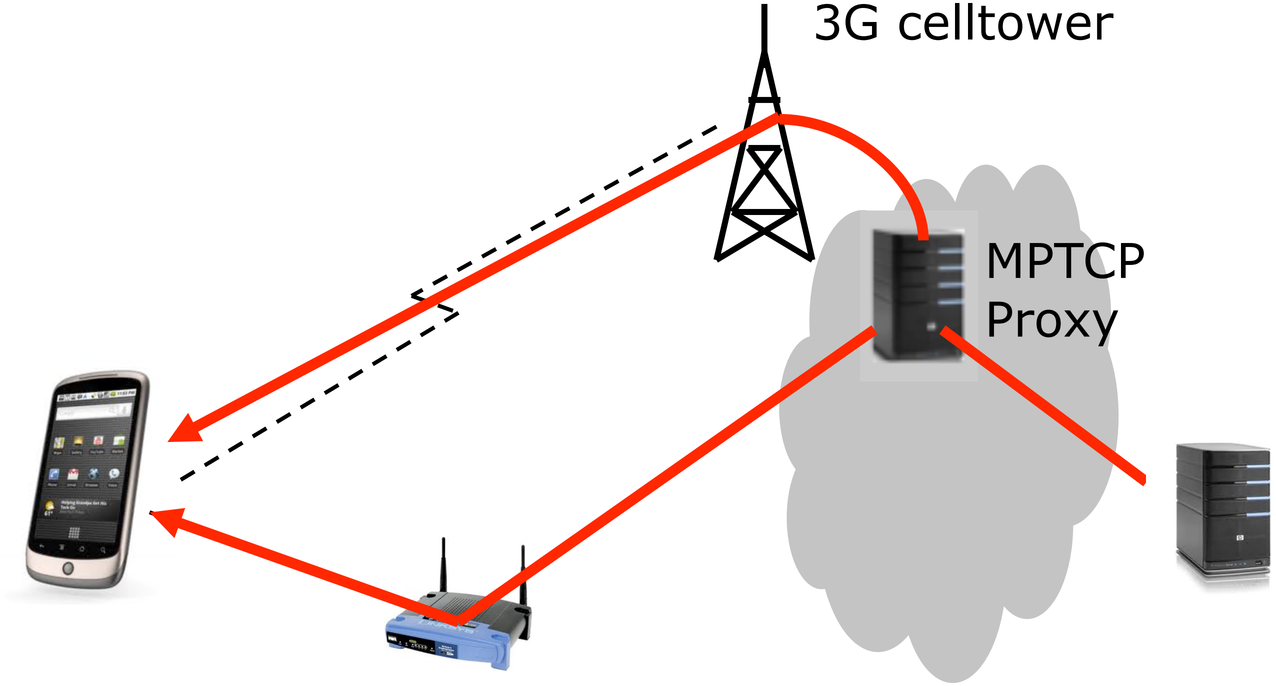
What if the remote server is not MPTCP enabled?

- This will be the case for initial deployment
- Solution: use an MPTCP proxy
  - Will be deployed by the mobile operator
  - Phones will be configured with the proxy's address via DHCP
- The proxy can also help with:
  - Simultaneous move
  - Peer to peer operation

Proxy: Server Does Not Speak MPTCP



Proxy: Server Does Not Speak MPTCP



Middleboxes: problems, problems, problems...

- TCP offload engines may re-segment TCP packets, replicating options on all segments.
- Firewalls may drop packets with options.
- Firewalls may remove options from packets.
- Proxies may ack data before it’s received by receiver.
- Proxies may report their window, not the receiver’s.
- Proxies/NATs may rewrite/extend/shrink payload and fix up sequence numbers accordingly.
- Normalizers may ensure retransmissions are consistent with the original data.
- Firewalls may rewrite sequence numbers in packets.

MPTCP is deployable

- Unmodified apps and network
  - Socket API not changed
- Protocol works at least as well as regular TCP
- Always works when a regular TCP would work
  - Falls back to TCP when path/endpoint not MPTCP capable
- Plays nicely with all the strange middleboxes out there
- Allows transport layer mobility!

Summary

- Network layer mobility
  - IP address = Identity & location ☹
  - Mobile IP, triangle routing, NAT ☹

- Transport layer mobility
  - TCP endpoint = IP address ☹
  - TCP sensitive to loss, delay ☹
  - Performance enhancing proxies 😐
  - MPTCP ☺