TCP in Wireless Mobile Networks

3/27/2004

TCP

- Reliable ordered delivery
- Implements congestion avoidance and control
- Reliability achieved by means of retransmissions if necessary
- End-to-end semantics
  - Acknowledgements sent to TCP sender confirm delivery of data received by TCP receiver
  - Ack for data sent only **after** data has reached receiver

TCP Basics

- Cumulative acknowledgements
- An acknowledgement ack's all contiguously received data
- TCP assigns byte sequence numbers
- For simplicity, we will assign packet sequence numbers
- Also, we use slightly different syntax for acks than normal TCP syntax
  - In our notation, *ack i* acknowledges receipt of packets through packet *i*

Cumulative Acknowledgements

- A new cumulative acknowledgement is generated only on receipt of a **new in-sequence** packet

Delayed Acknowledgements

- An ack is delayed until
  - another packet is received, or
  - delayed ack timer expires (200 ms typical)
- Reduces ack traffic

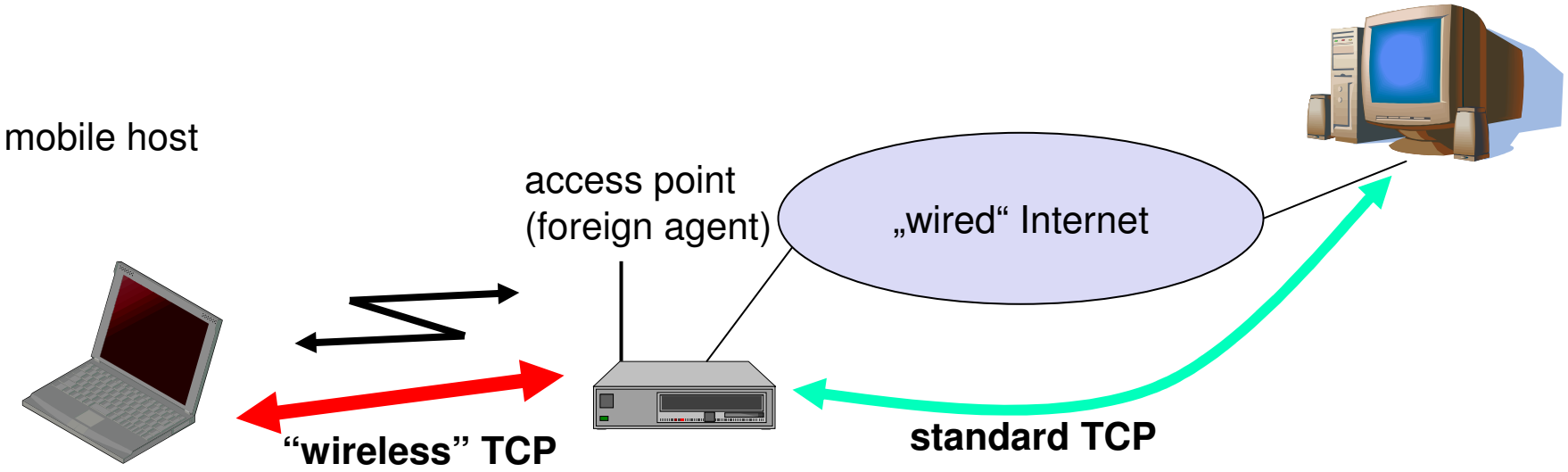
Duplicate Acknowledgements

- A dupack is generated whenever an out-of-order segment arrives at the receiver
- What may cause packets to arrive OOO?
  - Dropped segment: all the segments after the dropped segment are OOO.
  - Re-ordering the packets in the network.
  - Replication of ACK or data segments by the network.
- TCP uses fast retransmit/fast recovery for dupack.

Outline

- Classical TCP improvement
- Indirect TCP
- Snooping TCP
- Mobile TCP
- Fast retransmission, fast recovery
- Freezing
- Selective retransmission

Indirect-TCP

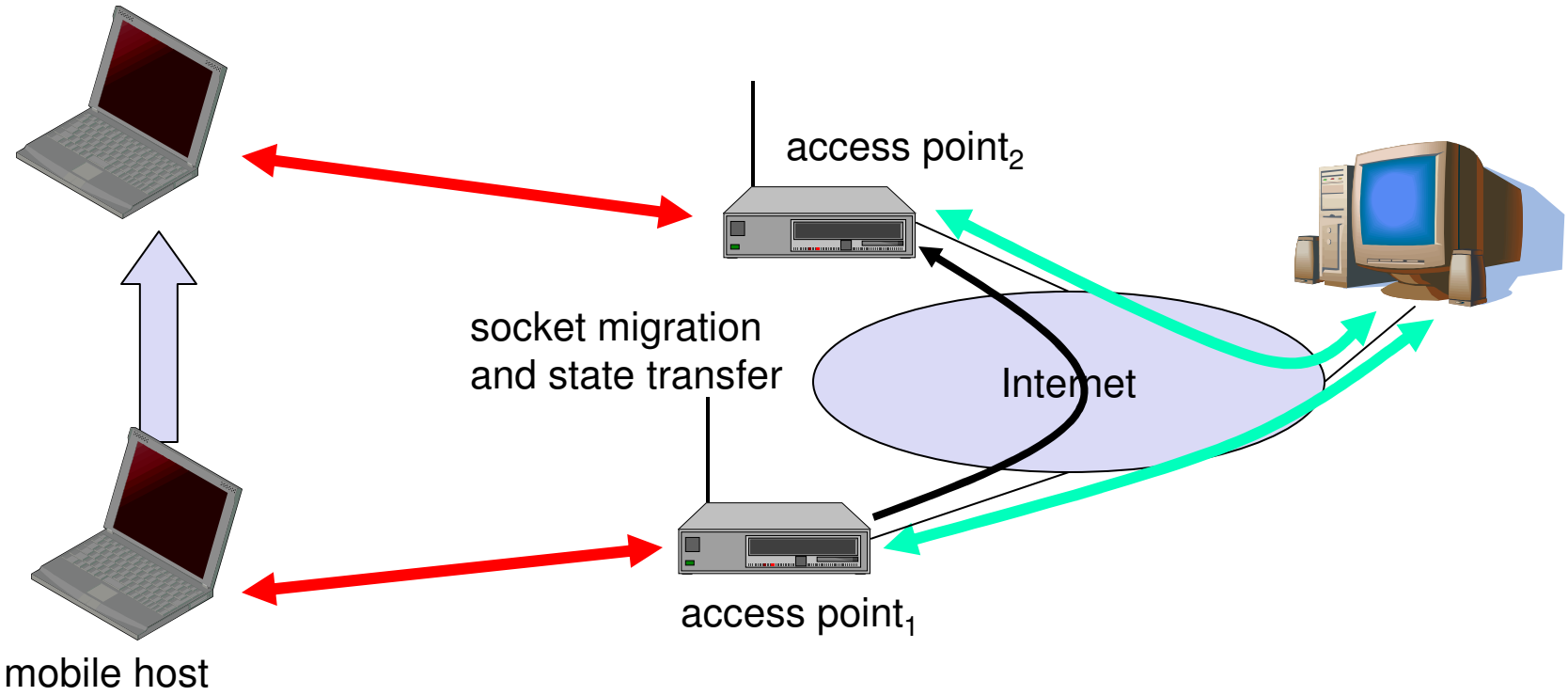


- Split a TCP connection at the foreign agent into 2 TCP connections
  - hosts in the fixed part of the network do not notice the characteristics of the wireless part
    - no changes to the TCP protocol for hosts connected to the wired Internet, millions of computers use (variants of) this protocol
  - optimized TCP protocol for mobile hosts

Indirect TCP

- The access point acts as proxy in both directions.
- AP acknowledges to both the sender and receiver.
- Re-transmission on wireless links is handled locally.
- During handover, the buffered packets, as well as the system state (packet sequence number, acknowledgements, ports, etc), must migrate the new agent.

I-TCP Socket and State Migration



Advantages of I-TCP

- No changes in the fixed network necessary, no changes for the hosts (TCP protocol) necessary, all current optimizations to TCP still work
- Simple to control, mobile TCP is used only for one hop between, e.g., a foreign agent and mobile host
  - transmission errors on the wireless link do not propagate into the fixed network
  - therefore, a very fast retransmission of packets is possible, the short delay on the mobile hop is known

Advantages of I-TCP

- It is always dangerous to introduce new mechanisms in a huge network without knowing exactly how they behave.
  - New optimizations can be tested at the last hop, without jeopardizing the stability of the Internet.
- It is easy to use different protocols for wired and wireless networks.

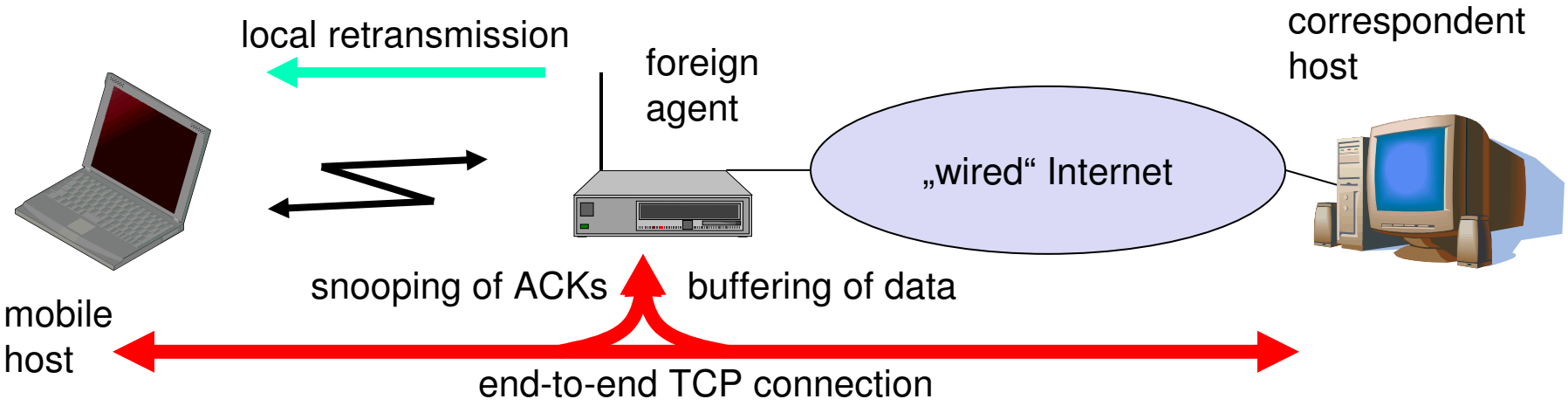
Disadvantages of I-TCP

- Loss of end-to-end semantics
  - an acknowledgement to a sender no longer means that a receiver really has received a packet --- foreign agents might crash.
- Higher latency possible
  - due to buffering of data within the foreign agent and forwarding to a new foreign agent
- Security issue
  - The foreign agent must be a trusted entity.

Snooping TCP

- Indirect TCP
  - 2 TCP sessions.
- Snooping TCP
  - One TCP session.
  - The access point snoops into the traffic and buffers packets for fast re-transmission.

Snoop TCP



- Transparent extension of TCP within the foreign agent
  - changes of TCP only within the foreign agent
  - buffering of packets sent to the mobile host
  - lost packets on the wireless link (both directions!) will be retransmitted immediately by the mobile host or foreign agent, respectively (so called "local" retransmission)
  - the foreign agent therefore "snoops" the packet flow and recognizes acknowledgements in both directions, it also filters ACKs

Snooping TCP

- Data transfer to the mobile host
  - FA buffers data until it receives ACK of the MH, FA detects packet loss via duplicated ACKs or time-out
  - fast retransmission possible, transparent for the fixed network
- Data transfer from the mobile host
  - FA detects packet loss on the wireless link via sequence numbers, FA answers directly with a NACK to the MH
  - MH can now retransmit data with only a very short delay

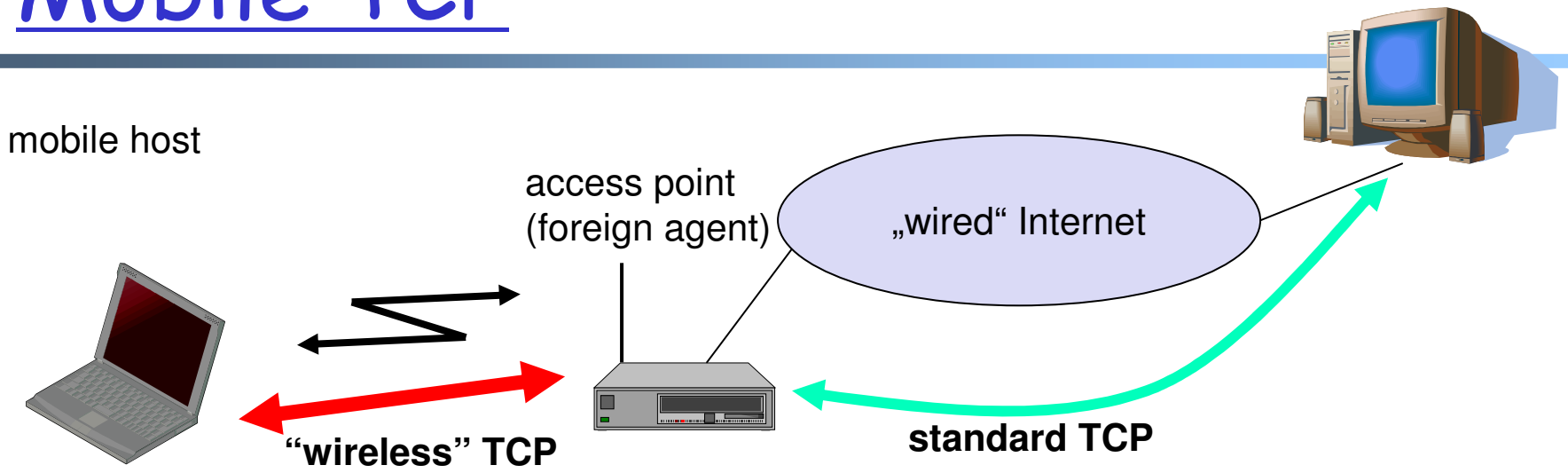
Snooping TCP

- Advantages
  - End-to-end semantics is preserved.
  - Handover is easy. I-TCP requires a careful handover of the system state. Here it falls back to the standard solution if no enhancements.
- Problems
  - snooping TCP does not isolate the wireless link as good as I-TCP
  - snooping might be useless depending on encryption schemes

Mobile TCP

- What if the mobile node is disconnected?
- I-TCP
  - more packets are buffered at AP.
- Snooping TCP
  - no more snooping
  - Missing acknowledgement, TCP goes to slow-start.
- Mobile TCP
  - Improve efficiency.
  - Special handling of lengthy and/or frequent disconnections.

Mobile TCP



- M-TCP splits as I-TCP does
  - unmodified TCP fixed network to supervisory host (SH)
  - optimized TCP SH to MH
- Supervisory host
  - no caching, no local retransmission
  - monitors all packets, if disconnection detected
    - set sender window size to 0
    - sender automatically goes into persistent mode
  - old or new SH reopen the window

Mobile TCP

- Advantages:
  - End-to-end semantics.
  - When mobile host is disconnected, it avoids useless retransmissions and slow-start.
  - No buffering, handover is easy.
- Disadvantages:
  - Packet loss at the wireless link propagates back to sender.
  - Not a good idea for heavy traffic.

Fast retransmit/fast recovery

- Change of foreign agent often results in packet loss
  - TCP reacts with slow-start although there is no congestion
- Forced fast retransmit
  - as soon as the mobile host has registered with a new foreign agent, the MH sends duplicated acknowledgements on purpose
  - this forces the fast retransmit mode at the communication partners
  - additionally, the TCP on the MH is forced to continue sending with the actual window size and not to go into slow-start after registration

Fast retransmit/fast recovery

- Advantage
  - simple changes result in significant higher performance
- Disadvantage
  - further mix of IP and TCP, no transparent approach

Time-out freezing

- Mobile hosts can be disconnected for a longer time
  - no packet exchange possible, e.g., in a tunnel, disconnection due to overloaded cells or mux. with higher priority traffic
  - TCP disconnects after time-out completely
- TCP freezing
  - MAC layer is often able to detect interruption in advance
  - MAC can inform TCP layer of upcoming loss of connection
  - TCP stops sending, but does now not assume a congested link
  - MAC layer signals again if reconnected

Time-out freezing

- Advantage
  - scheme is independent of data
- Disadvantage
  - TCP on mobile host has to be changed, mechanism depends on MAC layer

Selective retransmission

- TCP acknowledgements are often cumulative
  - ACK n acknowledges correct and in-sequence receipt of packets up to n
  - if single packets are missing quite often a whole packet sequence beginning at the gap has to be retransmitted (go-back-n), thus wasting bandwidth
- Selective retransmission as one solution
  - RFC2018 allows for acknowledgements of single packets, not only acknowledgements of in-sequence packet streams without gaps
  - sender can now retransmit only the missing packets

Selective retransmission

- Advantage
  - much higher efficiency
- Disadvantage
  - more complex software in a receiver, more buffer needed at the receiver

Transaction oriented TCP

- TCP phases
  - connection setup, data transmission, connection release
  - using 3-way-handshake needs 3 packets for setup and release, respectively
  - thus, even short messages need a minimum of 7 packets!
- Transaction oriented TCP
  - RFC1644, T-TCP, describes a TCP version to avoid this overhead
  - connection setup, data transfer and connection release can be combined
  - thus, only 2 or 3 packets are needed

Transaction oriented TCP

- Advantage
  - efficiency
- Disadvantage
  - requires changed TCP
  - mobility not longer transparent
  - Security issue.

Comparison

Approach	Mechanism	Advantages	Disadvantages
Indirect TCP	splits TCP connection into two connections	isolation of wireless link, simple	loss of TCP semantics, higher latency at handover
Snooping TCP	“snoops” data and acknowledgements, local retransmission	transparent for end-to-end connection, MAC integration possible	problematic with encryption, bad isolation of wireless link
M-TCP	splits TCP connection, chokes sender via window size	Maintains end-to-end semantics, handles long term and frequent disconnections	Bad isolation of wireless link, processing overhead due to bandwidth management
Fast retransmit/ fast recovery	avoids slow-start after roaming	simple and efficient	mixed layers, not transparent
Transmission/ time-out freezing	freezes TCP state at disconnect, resumes after reconnection	independent of content or encryption, works for longer interrupts	changes in TCP required, MAC dependant
Selective retransmission	retransmit only lost data	very efficient	slightly more complex receiver software, more buffer needed
Transaction oriented TCP	combine connection setup/release and data transmission	Efficient for certain applications	changes in TCP required, not transparent

Summary

- Classical TCP improvement
- Indirect TCP
- Snooping TCP
- Mobile TCP
- Fast retransmission, fast recovery
- Freezing
- Selective retransmission