Mobile Transport Layer

- TCP-mechanisms
- Classical approaches
  - Indirect TCP
  - Snooping TCP
  - Mobile TCP
- Additional optimizations
  - Selective retransmission
  - Transaction oriented TCP

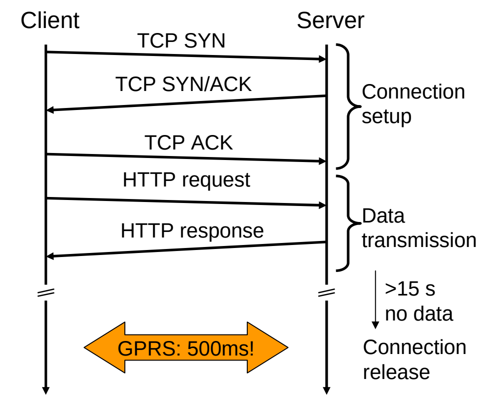
Transport Layer

E.g. HTTP (used by web services) typically uses TCP
- Reliable transport between client and server required

TCP
- Steam oriented, not transaction oriented
- Network friendly: time-out
  ➔ congestion
  ➔ slow down transmission

Well known – TCP guesses quite often wrong in wireless and mobile networks
- Packet loss due to transmission errors
- Packet loss due to change of network

Result
- Severe performance degradation



Motivation

Congestion control mechanisms of TCP typically designed for
- Fixed end-systems
- Fixed, wired networks

Research activities
- Performance
- Congestion control
- Efficient retransmissions

TCP congestion control
- packet loss in fixed networks typically due to (temporary) overload situations
- router have to discard packets as soon as the buffers are full
- TCP recognizes congestion only indirect via duplicate ACKs or retransmission timer expirations

Influences of mobility on TCP-mechanisms

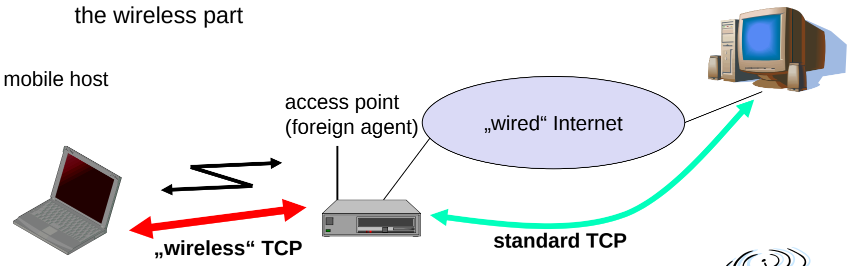
TCP assumes congestion if packets are dropped
- typically wrong in wireless networks, here we often have packet loss due to *transmission errors*
- furthermore, *mobility* itself can cause packet loss, if e.g. a mobile node roams from one access point (e.g. foreign agent in Mobile IP) to another while there are still packets in transit to the wrong access point and forwarding is not possible

The performance of an unchanged TCP degrades severely
- however, TCP cannot be changed fundamentally due to the large base of installation in the fixed network, TCP for mobility has to remain compatible
- the basic TCP mechanisms keep the whole Internet together

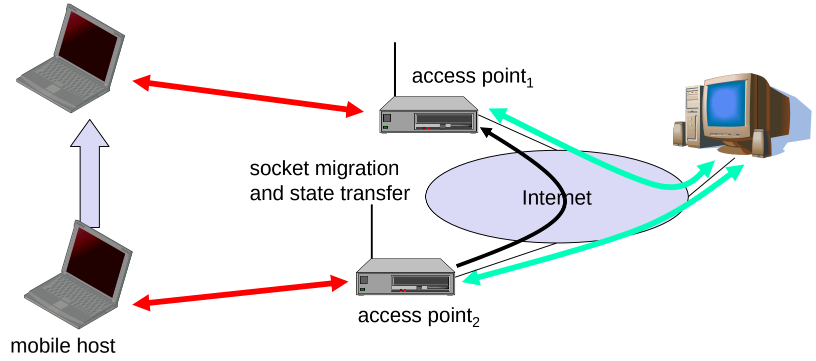
Early approach: Indirect TCP I

Indirect TCP or I-TCP segments the connection

- 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
- splitting of the TCP connection at, e.g., the foreign agent into 2 TCP connections, no real end-to-end connection any longer
- hosts in the fixed part of the net do not notice the characteristics of the wireless part



I-TCP socket and state migration



Indirect TCP II

Advantages

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

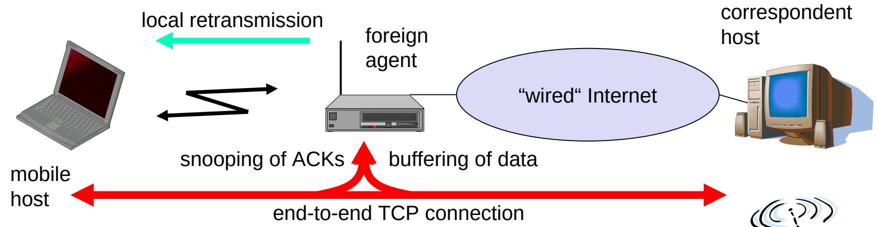
Disadvantages

- loss of end-to-end semantics, an acknowledgement to a sender does now not any longer mean that a receiver really got 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

Early approach: Snooping TCP I

"Transparent" extension of TCP 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
- changes of TCP only within the foreign agent



Snooping TCP II

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 (which is needed to be modified)
- 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

Integration of the MAC layer
- MAC layer often has similar mechanisms to those of TCP
- thus, the MAC layer can already detect duplicated packets due to retransmissions and discard them

Problems
- snooping TCP does not isolate the wireless link as good as I-TCP
- snooping might be useless depending on encryption schemes

Early approach: Mobile TCP

Special handling of lengthy and/or frequent disconnections

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 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

Advantages
- supports disconnection, no buffer forwarding

Disadvantages
- violation of end-to-end arguments
  - single TCP connection broken into 2; SH maintains connection state
- loss on wireless link propagated into fixed network
- adapted TCP on wireless link

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

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

Advantage
- efficiency

Disadvantage
- requires changed TCP
- mobility not longer transparent

Comparison of different approaches for a "mobile" TCP

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	handles long term and frequent disconnections	bad isolation of wireless link, processing overhead due to bandwidth management
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

TCP Improvements I

$$BW \le \frac{0.93 * MSS}{RTT * \sqrt{p}}$$

- max. TCP **B**and**W**idth
- **M**ax. **S**egment **S**ize
- **R**ound **T**rip **T**ime
- loss **p**robability

Initial research work

- Indirect TCP, Snoop TCP, M-TCP, T/TCP, SACK, Transmission/time-out freezing, …

TCP over 2.5/3G wireless networks

- Fine tuning today's TCP
- Learn to live with
  - Data rates: 64 kbit/s up, 115-384 kbit/s down; asymmetry: 3-6, but also up to 1000 (broadcast systems), periodic allocation/release of channels
  - High latency, high jitter, packet loss
- Suggestions (but some of them are contradictory to general wireless environment)
  - Large (initial) sending windows, large maximum transfer unit, selective acknowledgement, explicit congestion notification, time stamp, no header compression
- Already in use
  - i-mode running over FOMA
  - WAP 2.0 ("TCP with wireless profile")

TCP Improvements II

Performance enhancing proxies (PEP, RFC 3135)

- Transport layer
  - Local retransmissions and acknowledgements
- Additionally on the application layer
  - Content filtering, compression, picture downscaling
  - E.g., Internet/WAP gateways
  - 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)
  - Recommends header compression, no timestamp
- RFC 3155 (links with errors)
  - States that explicit congestion notification cannot be used
- In contrast to 2.5G/3G recommendations!