TCP over Wireless Links © Dr. Ayman Abdel-Hamid, CS6504

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Mobile Computing

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TCP over Wireless Links
Outline

TCP over wireless Links

• Taxonomy of Schemes to improve TCP’s performance
• An example of an ELN scheme
• I-TCP: Indirect TCP
• Snoop Protocol (TCP-aware LL protocol)
Improving TCP’s Performance

• Non-congestion related losses effects on TCP performance
  ➢ Significant throughput degradation

• Schemes to improve TCP performance
  ➢ End-to-End proposals: Make TCP sender handle losses through
    ✓ SACK (Selective ACK- allow sender to recover from multiple packet
      losses in a window without restoring to a smaller timeout)
    ✓ ELN (Explicit Loss Notification- allow sender to distinguish between
      congestion and other forms of losses)
  ➢ Split-connection proposals
    ✓ Hide wireless links from sender by terminating TCP connection at BS
    ✓ Separate reliable connection between BS and MH
  ➢ Link-layer proposals
    ✓ Hide link-related losses from TCP sender by using local
      retransmissions
ELN: Example of End-to-End Proposals

• Add an ELN option to TCP ACKs [BPS+97]

• When a packet dropped on wireless link, future cumulative ACKs corresponding to lost packet are marked to identify that a non-congestion related loss has occurred

• Sender might retransmit (after receiving 3 dup ACKs) without invoking associated congestion control schemes

• An enhancement  → Sender can retransmit upon receiving first dup ACK with ELN option set

• Problems  → Which packets are lost due to errors on wireless link?

  ➢ At the receiver, if a partially corrupted packet is received
  ➢ Entire packet is dropped  → BS generates ELN with ACK stream when observe dup ACKs from MH
I-TCP: Indirect TCP for Mobile Hosts

• Any interaction from a MH to a fixed host is split into 2 separate interactions
  ➢ One between MH and BS over wireless medium
  ➢ Another between BS and fixed host over fixed network

• Advantages
  ➢ Separate flow and congestion control functionality on wireless and wired network
  ➢ Allows using a separate transport protocol for wireless link

• Disadvantages
  ➢ Breaks TCP end-to-end semantics
  ➢ Maintenance of TCP state at BS per TCP connection (effect on handoff procedure)
I-TCP Connection Setup

MSR: Mobility Support Router (the BS)

FH: Fixed Host
Snoop Protocol (TCP-aware LL Protocol) 1/2

• A TCP-aware link protocol, running at BS

• Snoop agent at BS monitors every TCP packet that passes through connection in either end

• Agent maintains a cache of TCP packets sent from fixed host that have not been ACKed by MH (Why this works?)

• Agent keeps track of all ACKs sent by MH

• Detect loss of packets either by arrival of a number of duplicate ACKs, or by a local timeout (*local timeout < TCP timeout*)

• Upon detecting packet loss, retransmit lost packets to MH if cached

• Hide packet loss from sender by not propagating duplicate ACKs
Snoop Protocol (TCP-aware LL Protocol) 2/2

• From fixed host to MH

  ➢ Cache unACKed TCP data and perform local transmissions based on some policies for ACKs and timeouts
  ➢ Use duplicate ACKs from MH to identify packet loss and perform local transmissions as soon as loss is detected

• From MH to fixed host

  ➢ Detect missing packets at BS and generate negative ACKs for them
  ➢ Negative ACKs sent to MH which then retransmits the missing packets
  ➢ Need to modify FH and MH
From FH to MH 1/3

- BS routing code is modified by adding a snoop module (monitor every packet through connection in either direction)
- No transport layer code runs at BS
- Snoop maintains a cache of TCP packets sent from FH that are not yet ACKed by MH
- Keep track of all ACKs sent from MH
- When a packet loss is detected (arrival of duplicate ACK, or local timeout) retransmit lost packet is cached
- Do not propagate duplicate ACK to FH (unnecessary congestion control mechanisms invocations avoided)
- Two modules: snoop_data() and snoop_ack()
Snoop_data()

• Processes data from fixed host
• A new packet in normal TCP sequence
• An out-of-sequence packet that has been cached earlier
  ➢ Seq # > last Acked → forward
  ➢ Seq# < last Acked → generate TCP Ack with last ACK seen at BS to sender (on behalf of MH)
• An out-of-sequence packet that has not been cached earlier
  ➢ Congestion loss on wired network or out-of-order delivery by network
  ➢ Forward to MH
  ➢ Mark as been retransmitted by sender

Figure 1. Flowchart for snoop_data().
Snoop_ack()

- Monitors ACKs sent by MH
- New ACK
- Spurious ACK → discard
- Duplicate ACK
  - Dup Ack for a packet not in snoop cache or marked as having been retransmitted by sender
    - Route dup Ack to FH
  - First dup Ack
    - Retransmit at high priority
  - Not first dup Ack
    - discard
From MH to FH

• At BS, keep track of packets lost in a transmission window, and generate negative ACKs for those packets back to MH

• NACKs generated when a threshold number of packets (from a single window) reach the BS, or when a certain amount of time has expired without any new packets from MH

• Implementation based on using SACK option in TCP

• Need to enable SACK processing at MH
Routing Protocol 1/3

• Handoffs use *multicast* and *intelligent buffering* in nearby BSs

• MH assigned a home address and a multicast address

• HA intercepts packets destined to MH and encapsulate to the corresponding multicast group

• Members of multicast group are BSs in vicinity of MH, but not MH itself

• MH uses statistics such as received signal strength of BS beacons and communication quality to identify nearby BSs

• MH determines which cells it should join and which cells it is likely to handoff to in near future
Routing Protocol 2/3

• One primary BS in system to forward packets to MH

• Other BSs (likely handoff targets) are asked to join multicast group, but do not forward packets to MH

• Instead, last several packets from HA are buffered

• When handoff to a previously buffering BS, can start sending packets to MH from buffered packets, hence reducing packet loss during handoff

Figure 4. Home Agent to Mobile Host Routing.
Routing Protocol 3/3

Includes a list of unique identifiers of last several packets received by MH (Why?)

Figure 5. Typical handoff messaging.