18-452/18-750
Wireless Networks and Applications
Lecture 14: Wireless and the Internet

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http://www.cs.cmu.edu/~prs/wirelessS18/

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Wireless and the Internet Challenges

- **IP addresses are used both to forward packets to a host and to identify the host**
    - » **Active session break when a host moves**
    - » **Mobile hosts are hard to find**
- **TCP congestion control interprets packet losses as a sign of congestion**
    - » **Assumes links are reliable, so packet loss = full queue**
    - » **Not true for wireless links!**
- **Applications generally assume that they are continuously connected to the Internet**
    - » **Can access servers, social networks, …**
    - » **Mobile apps must support "disconnected" operations**

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Outline

- **The Internet 102**
- **Wireless and the Internet**
- **Mobility: Mobile IP**
- **TCP and wireless**
- **Disconnected operation**
- **Disruption tolerant networks**

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Mobile IP Goals

- **Communicate with mobile hosts using their "home" IP address**
    - » **Target is "nomadic" devices: do not move while communicating, i.e., laptop, not cellphone**
    - » **Allows any host to contact mobile host using its "usual" IP address**
- **Mobility should be transparent to applications and higher level protocols**
    - » **No need to modify the software**
- **Minimize changes to host and router software**
    - » **No changes to communicating host**
- **Security should not get worse**

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Mobile IP Operation

- **Agents advertise their presence.**
  - » Using ICMP or mobile IP control messages
  - » Mobile host can solicit agent information
  - » Mobile host can determine where it is
- **Registration process: mobile host registers with home and foreign agent.**
  - » Set up binding valid for *registration lifetime*
- **Tunneling**
  - » forward packets to foreign agent
  - » foreign agent forwards packets to mobile host
- **Supporting mobility**
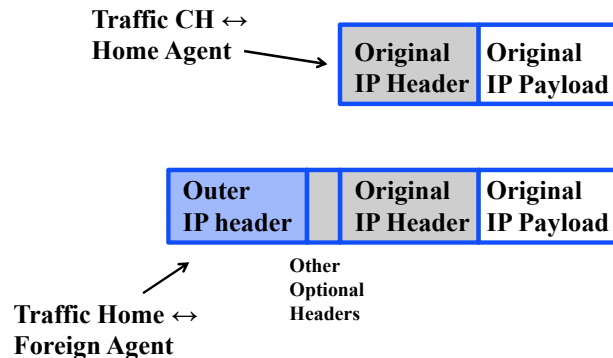 - » invalidating old caches in a lazy fashion
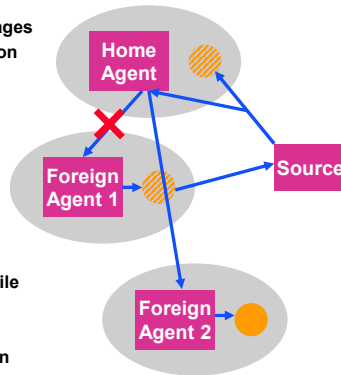
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Mobile IP

- **Home network has a home agent that is responsible for intercepting packets and forwarding them to the mobile host.**
  - » E.g. router at the edge of the home network
  - » Forwarding is done using tunneling
- **Remote network has a foreign agent that manages communication with mobile host.**
  - » Point of contact for the mobile host
- **Binding ties IP address of mobile host to a "care of" address.**
  - » binding = (IP address, foreign agent address)
  - » binding includes time stamp

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Tunneling
IP-in-IP Encapsulation

Traffic CH ↔ Home Agent

Original IP Header	Original IP Payload

Outer IP header		Original IP Header	Original IP Payload

Other Optional Headers

**Traffic Home ↔ Foreign Agent**

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Optimizations

- **Mobile host can be its own the foreign agent.**
  - » Mobile host acquires local IP address
  - » performs tasks of the mobile agent
- **Short circuit the home location by going directly to the foreign agent.**
  - » Routers in the network store cache bindings and intercept and tunnel packets before they the mobile host's home network
  - » Need a protocol to update/invalidate caches
  - » Raises many security questions and is not in the standard

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Registration via Foreign Agent

Mobile Host — **Foreign Agent** — **Home Agent**
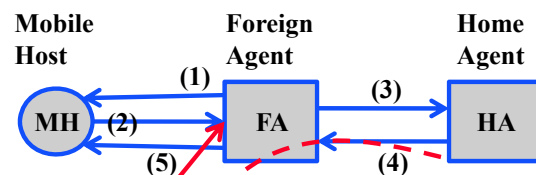
MH — (1) — FA — (3) — HA
(2) (4)
(5)
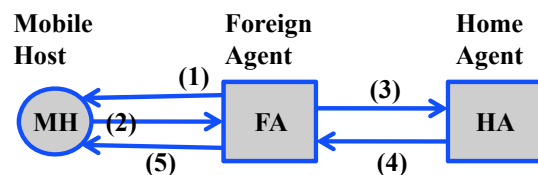
1. FA advertizes service
2. MH requests service
3. FA relays request to HA
4. HA accepts (or denies) request and replies
5. FA relays reply to MH

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Authentication

Mobile Host — **Foreign Agent** — **Home Agent**

MH — (1) — FA — (3) — HA
(2) (4)
(5)

Dr. Evil will receive all the traffic destined to the mobile host

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Mobile IP Authentication

- **Without security, a "bad guy" on any network with a FA could issue a registration request for a host on any network (with a HA)**
  - » HA would begin to forward datagrams to the bad guy
- **Registration messages between a mobile host and its home agent must be authenticated**
  - » Uses mobile-home authentication extension
- **Mobile hosts, home agents, and foreign agents must maintain a mobility security association for mobile hosts, indexed by…**
  - » Security Parameter Index (SPI)
  - » IP address (home address for mobile host)

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Discussion

- **Mobile IP not used in practice**
- **Not designed for truly mobile users**
  - » Designed for nomadic users, e.g. visitors to a remote site
  - » Only solves the initial contact problem, but …
- **Mobile devices are typically clients, not servers, i.e., they initiate connections**
  - » Problem Mobile IP solves is rare in practice
- **IETF defined solutions that are more efficient**
  - » But they are move heavy weight: effectively creates overlay with tunnels and special "routers"
- **Ultimately all solutions are similar: need a "relay" that knows location of the device**

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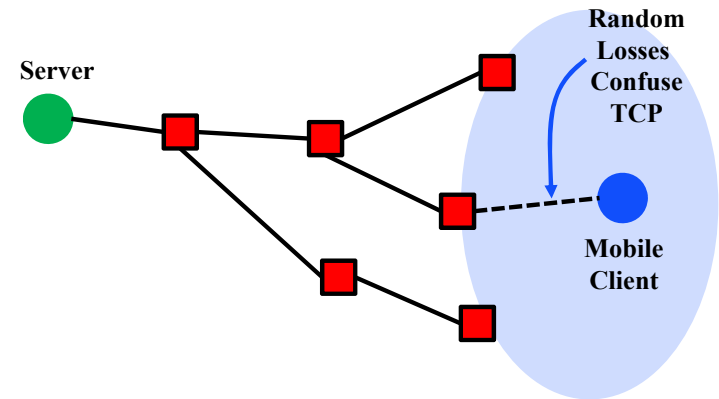## Outline

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Solution Ideas?

Server

Random Losses Confuse TCP
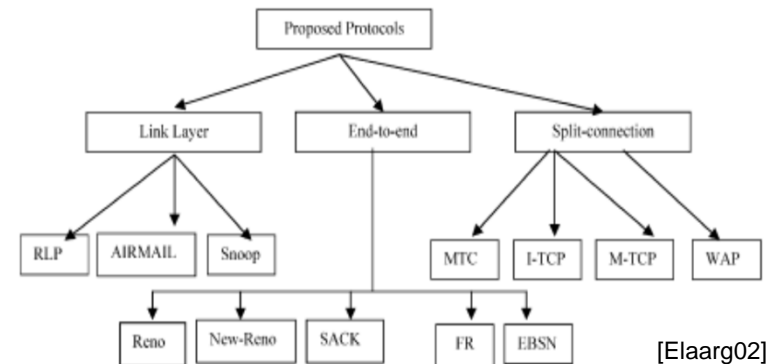
Mobile Client

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Solution Space

- **Modify TCP for wireless paths**
  - » **Would maintain status quo for wired paths**
  - » **What would wireless TCP look like?**
  - » **Difficult to do: there are many Internet hosts**
  - » **Traditionally, hosts have no information about path properties**
- **Modify TCP for all paths**
  - » **Not clear what that modification would be!**
  - » **Similar problems: need to modify many hosts**
- **Modify TCP only on the mobile host**
  - » **A more practical idea – but what would the change be?**
- **Keep end hosts the same but tweak things at the wireless gateway**
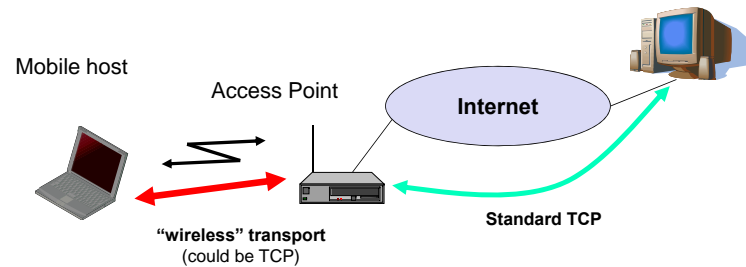 - » **Keep end-end TCP happy despite wireless links**

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Possible Classification of Solutions

Proposed Protocols

Link Layer — End-to-end — Split-connection

RLP   AIRMAIL   Snoop   MTC   I-TCP   M-TCP   WAP

Reno   New-Reno   SACK   FR   EBSN

[Elaarg02]

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I-TCP

Mobile host

Access Point

Internet

"wireless" transport
(could be TCP)

Standard TCP

Connection Split: Indirect TCP or I-TCP

- **Do not change TCP on the wire-line part**
- **Split the TCP connection at the wireless gateway into two parts**
  - » **One optimized for the wireless link**
  - » **The second for the wire-line communication (TCP)**
- **No real transport-layer end-to-end connection**
  - » **Although host on wired network does not know this**
- **Wired host should not notice the characteristics of the wireless part**
  - » **This is a challenge since wireless gateway is limited in what it can send and when, e.g. cannot prematurely acknowledge data**
  - » **Certain things cannot be hidden: delay, dramatic throughput variations**
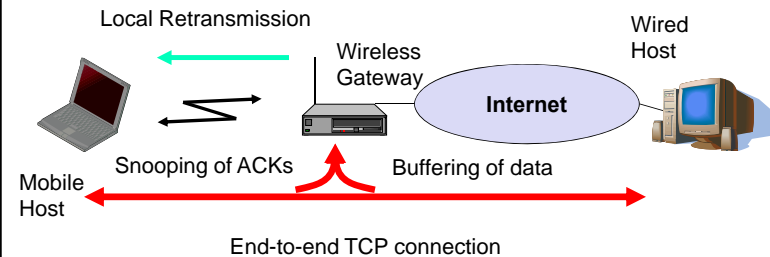

I-TCP Discussion

- **I-TCP Advantages**
  - » **No changes in the fixed network or hosts (TCP protocol), so all current TCP optimizations still work**
  - » **Wireless transmission errors do not "propagate" to the wire-line network**
  - » **Simple, effective (in the best case)**
- **I-TCP Disadvantages**
  - » **End-to-end semantics become less clear, e.g. what happens if the wireless gateway crashes?**
  - » **Higher end-to-end delays due to buffering and forwarding to the gateway**

Snooping TCP

Local Retransmission

Wired Host

Wireless Gateway

Internet

Snooping of ACKs

Buffering of data

Mobile Host

End-to-end TCP connection

Snooping TCP

- "Transparent" extension of TCP within the wireless gateway
  - » End hosts are not modified
- Hides wireless losses from wired host
  - » Buffer packets sent to the mobile host
  - » Local retransmission: Lost packets on the wireless link, for both directions, are retransmitted immediately by the mobile host or foreign agent
- Wireless gateway "snoops" the packet flow so it can cover up signs of packet loss
  - » E.g. recognizes acknowledgements in both directions and suppresses duplicate ACKs

Snooping TCP Discussion

- **Data transfer to the mobile host**
  - » FA buffers data until it receives ACK from the MH
  - » FA detects packet loss via duplicated ACKs or time-out
- **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
- **Integration of the MAC layer**
  - » MAC layer often has similar mechanisms to those of TCP
- **Problems**
  - » Snooping TCP does not isolate the wireless (as I-TCP)
  - » Snooping might be useless if encryption is used

An Internet Style Approach

- **Use aggressive retransmission in the wireless network to hide retransmission losses**
  - » Most deployed wireless network in fact do that already
  - » Would sell few products if they did not
- **Wireless losses translate into increased delay**
  - » But TCP roundtrip time estimation is very conservative, e.g. increases if variance is high
- **Also: persistent high loss rate results in reduced available bandwidth → congestion response is appropriate and needed**
- **Works remarkably well!**
- **Other solutions only needed for "challenged" networks**

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Disconnected Operation

- **Mobility means that devices will occasionally be disconnected from the network**
  - » Seconds ... Minutes … Hours .. Days
  - » Mostly an issue for clients
- **This can confuse systems and applications that assume a wired/stationary model**
  - » Clients cannot access servers, e.g., mail, calendar applications, …
  - » Distributed file systems
  - » Systems for back up or systems management
- **Must adapt the applications and systems to make them "disconnection aware"**

Two Examples

- **E-mail: users must be able to "work on" e-mail offline and operations are performed when the mobile client is redirected**
  - » Compose, read and delete e-mail
  - » Possibly others: manage folders, etc.
- **Calendars and tasks are similar: operations performed offline must be executed later**
  - » Adding or removing appointment and tasks, …
- **Must sometimes resolve conflicts when multiple clients are used offline**
  - » E.g., mail is deleted on one client and moved to another folder on another – delete or keep?
  - » Tend to be minor – ask user for help if needed

More Complex Case: File System

- **A distributed file system can be accessed from many computers**
  - » Files tend to be cached in the computers
- **Creates opportunities for inconsistencies**
  - » E.g., a file is modified on two different computers – how do you merge the changes? Who is responsible?
- **The consistency model depends on the file system**
  - » Stronger consistency requires that the system can keep track of all copies and remove/lock them if needed
- **Disconnected operation makes the consistency problem harder!**
  - » Some file copies my be inaccessible for long periods!

Mobility is Common Today

- **Many applications are designed to work on mobile clients so they deal properly with disconnections**
  - » Many apps on mobile devices are designed for mobility
  - » Most clients server applications can work offline with at least partial functionality
- **Does not work for interactive applications**
  - » Games, etc.
- **Disconnection can still be very inconvenient**
  - » Need state that is not cached on your client device
  - » Things like back ups cannot be performed
  - » Unpredictable delays in communication

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Challenged Networks

- **Violate one or more of Internet's assumptions**
  - » **End-points may rarely/never be online at the same time**
  - » **Very long delay path, frequent disconnections, …**
  - » **Have naming semantics for their particular application domain**
  - » **Not be well served by the current end-to-end TCP/IP**
- **Examples**
  - » **Terrestrial mobile networks**
  - » **Some ad-hoc networks**
  - » **Sensor/actuator networks**
- **Goals for "disruption tolerant" networks**
  - » **Achieve interoperability between very diverse types networks**
  - » **Sometimes also called disruption tolerant**

Background
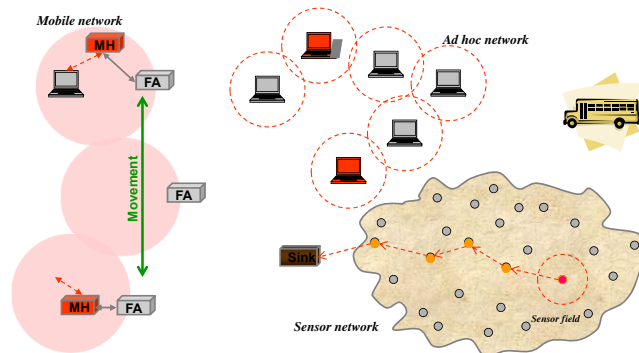
High-level Architecture

- **Characteristics:**
  - » **Operate as an overlay above the existing transport layers**
  - » **Based on an abstraction of message switching**
    - – **Bundle**
    - – **Bundle forwarder (DTN gateway)**
    - – **Store-and-forward gateway function between different networks**

source   DTN gateway   DTN gateway   destination
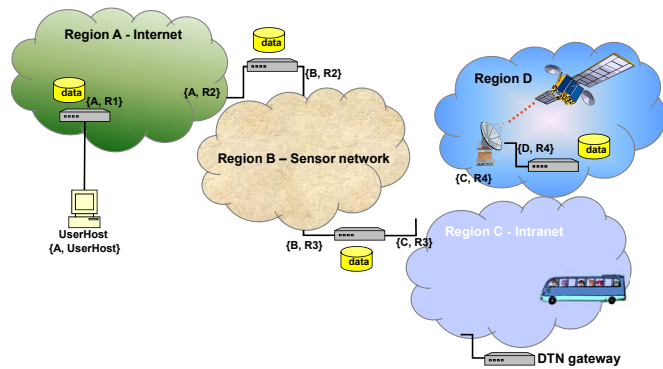
- **Constituent of DTN architecture**
  - » **Region: internally homogenous, i.e. same network stack, addressing, …**
  - » **DTN gateway: Interconnection point between region boundaries**
  - » **Name Tuple: {Region name, Entity name}**

Example DTN

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