15-441 15-641 Computer Networking

Lecture 27: Wireless and the Internet

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Overview

- Internet mobility
- TCP over noisy links

Routing to Mobile Nodes

- Obvious solution: have mobile nodes advertise route to mobile address/32
  - Should work!!!
- Why is this bad?
  - Consider forwarding tables on backbone routers
    - Would have an entry for each mobile host
    - Not very scalable
- What are some possible solutions?

How to Handle Addressing for Mobile Nodes?

- Simple existing solution: Dynamic Host Configuration (DHCP)
- Host gets new IP address in new locations
  - No impact on Internet routing
- Problems for the mobile host
  - Host does not have constant name/address → how do others contact host?
  - What happens to active transport connections when the host moves?

We Can Fix the Naming Problem

- Use DNS and update name-address mapping whenever host changes address
  - An awkward solution, at best
  - Increases “write” load on DNS
  - Also raises security issues
- Fixes contact problem but the broken transport connection problem remains

5

How to Handle Transport Connections for Mobile Nodes?

- TCP currently uses 4 tuple to describe connection
  - <Src Addr, Src port, Dst addr, Dst port>
- Modify TCP to allow peer’s address to be changed during connection
- Security issues
  - Can someone easily hijack connection?
- Difficult deployment → both ends must support mobility

6

How about Link Layer Mobility?

- Link layer mobility is easier
- Learning bridges can handle mobility → this is how it is handled at CMU
- Wireless LAN (802.11) also provide some help to reduce impact of handoff
  - Reduce latency, packet loss
- Problem is with inter-network mobility, i.e. Changing IP addresses
  - Need to make it look as if we stay in the same network

7

Mobile IP: Supporting Host Mobility in the Internet

- Allow mobile node to keep same address and name
- Solution? Same as for many project in CS: add a level of indirection
- Keep some entity in the network informed about current location
  - Packets must travel through this location (interception)
  - Today often called a “rendez-vous” service
- Need to forward packets from this location to mobile host (delivery)

8

Mobile IP Goals

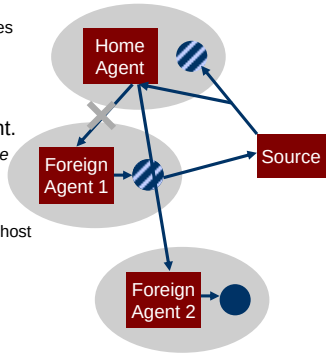
- Communicate with mobile hosts using their “home” IP address
  - Target is “nomadic” devices: do not move while communicating, i.e., laptop, not cellphone
  - Allows any host to contact mobile host using its “usual” IP address, as if it where in its “normal” location
- Mobility should be transparent 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

Mobile IP Overview

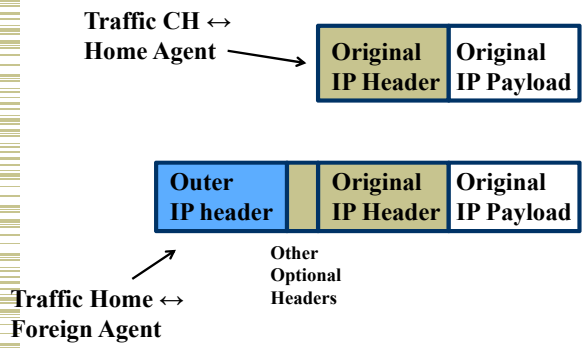
- Home network has a home agent that is responsible for intercepting packets and forwarding them to the mobile host.
  - E.g., router at the edge of the home network
  - Forwarding is done using tunneling
- Remote network has a foreign agent that manages communication with mobile host.
  - Point of contact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

Mobile IP Operation

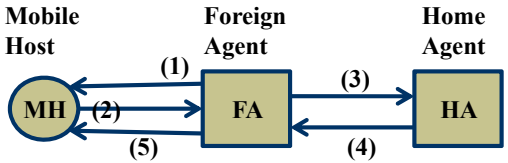
- Agents advertise their presence.
  - Using ICMP or mobile IP control messages
  - Mobile host can solicit agent information
  - Mobile host can determine where it is
- Registration process: mobile host registers with home and foreign agent.
  - Set up binding valid for *registration lifetime*
- Tunneling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



Tunneling IP-in-IP Encapsulation



Registration via Foreign Agent

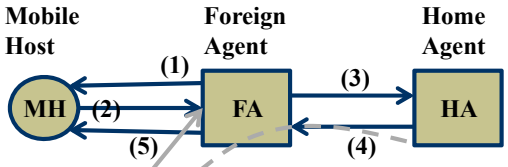


1. FA advertizes service
2. MH requests service
3. FA relays request to HA
4. HA accepts (or denies) request and replies
5. FA relays reply to MH

Optimizations

- Mobile host can be its own the foreign agent.
  - Mobile host acquires local IP address using DHCP
  - 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

Authentication



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

Mobile IP Authentication

- Without security, an adversary 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)

Discussion

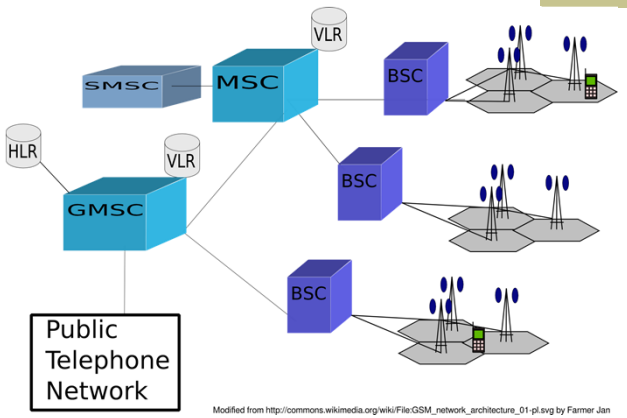
- Mobile IP not used in practice
- Not designed for truly mobile users
  - Designed for nomadic users, e.g. visitors to a remote site
  - Only solves the initial contact problem, but …
- Mobile devices are typically clients, not servers, i.e., they initiate connections
  - Problem Mobile IP solves not common 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

Mobility with GSM

- Mobile Station – MS
  - A device connecting to the cellular network
- Base Station Controller - BSC
  - In charge of a group of cells
  - Sometimes called a Location Area (LA)
- Mobile Switching center – MSC
  - In charge of several clusters of cells
- Gateway Mobile Switching center – GMSC
  - Connects to the wired telephone networks
- Location registries
  - Home Location Registry (HLR)
  - Visitor Location Registry (VLR)

18

GSM Core Architecture



Modified from http://commons.wikimedia.org/wiki/File:GSM_network_architecture_01-pl.svg by Farmer Jan

19

Home Location Register

- One per “operator”
- Contains entries for every subscriber and every mobile ISDN number that is homed in the respective network
- Permanent subscriber data and relevant temporary information
- Current location of the mobile station
- All administrative activities of the subscriber happen here!

Visitor Location Register

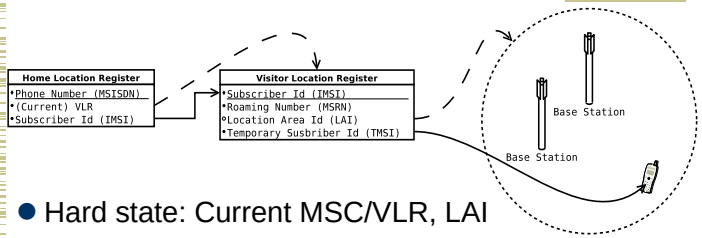
- Stores data on all mobile stations that are currently in the administrative area of the MSC
  - Roughly a large region
- 1 VLR could be responsible for more than 1 MSC
- A roaming MS will be registered in a VLR of its home network or the foreign network depending on its location
- MS registers upon entering a LA. The MSC passes the identities of the MS and LA to VLR

GSM Addressing Hierarchy

- Device
  - IMEI (International Mobile Equipment Identifier)
- User
  - IMSI (International Mobile Subscriber Identifier)
  - MSISDN (Mobile Subscriber IDSN Number)
    - "Real phone number"
  - MSRN (Mobile Station Roaming Number)
  - TMSI (Temporary Mobile Subscriber Identity
  - LMSI (Local Mobile Subscriber Identity)
- Other
  - LAI (Location Area Identity)
  - CI (Cell Identity)

Just for your entertainment – do not memorize

GSM Address Lookup ("registers")



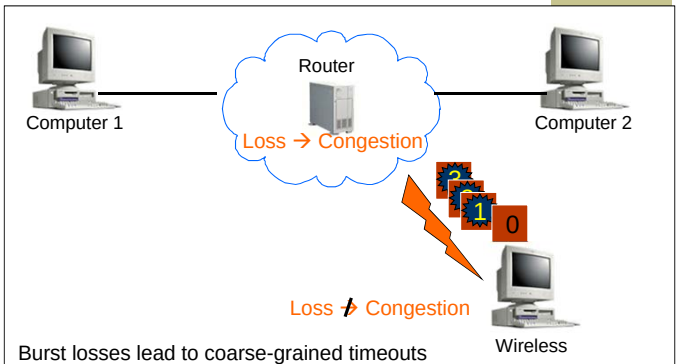
- Hard state: Current MSC/VLR, LAI
  - (Necessary to page phone, updated whenever mobile moves)
- Soft-ish state:
  - MSRN, cell ID, TMSI

Again: Grossly simplified for your safety and sanity!

Overview

- Internet mobility
- TCP over noisy links

Wireless Bit-Errors



Burst losses lead to coarse-grained timeouts
Result: Low throughput

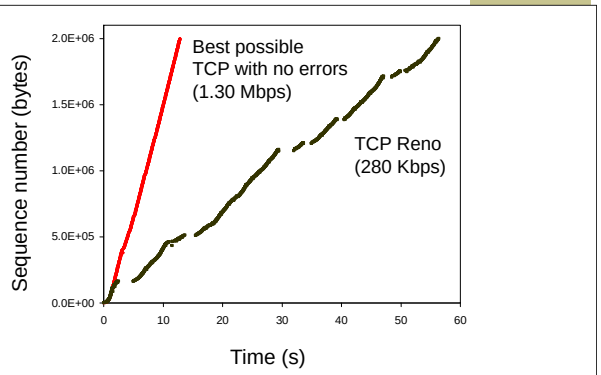
25

TCP Problems Over Noisy Links

- Wireless links are inherently error-prone
  - Fades, interference, attenuation
  - Errors often happen in bursts
- TCP cannot distinguish between corruption and congestion
  - TCP unnecessarily reduces window, resulting in low throughput and high latency
- Burst losses often result in timeouts
- Sender retransmission is the only option
  - Inefficient use of bandwidth

26

Performance Degradation



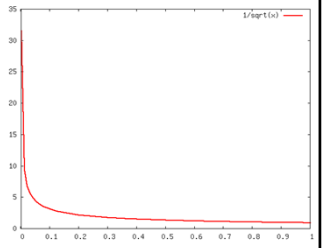
2 MB wide-area TCP transfer over 2 Mbps Lucent WaveLAN

27

Performance Degradation 2

- Recall TCP throughput / loss / RTT rel:
  - BW = MSS / (rtt * sqrt(2p/3))
  - = proportional to 1 / rtt * sqrt(p)
  - == ouch!
  - Normal TCP operating range: < 2% loss

Internet loss usually < 1%



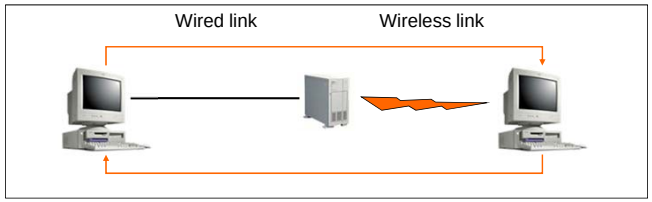
Proposed Solutions

- Error recovery by link-layer protocols
  - Solution used by today's wireless standards
  - Uses aggressive local retransmissions, possible combined with error-correcting codes
- End-to-end protocols
  - Selective ACKs and explicit loss notification can reduce impact of losses, but often not sufficient
- Split-connection protocols
  - Separate transport connections for wired path and wireless hop + fast recovery solution for wireless hop
  - Not common in practice, unless middleboxes are used for other services, e.g., caching, mobility services

29

Approach Styles (End-to-End)

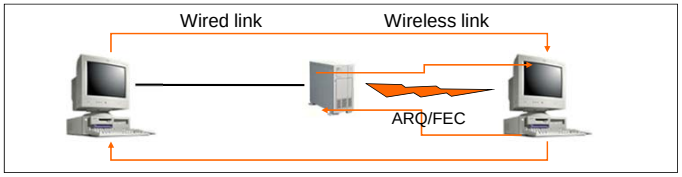
- Improve TCP implementations
  - Not incrementally deployable
  - Improve loss recovery (SACK, NewReno)
  - Help it identify congestion (ELN, ECN)
    - E.g. ACKs include flag indicating wireless loss
  - Trick TCP into doing right thing → E.g. send extra dupacks if wireless host suspects errors (e.g. mobility)



30

Approach Styles (Link Layer)

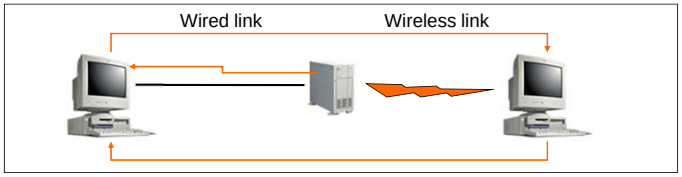
- More aggressive local rexmit than TCP
  - Approach used in 802.11
  - Bandwidth not wasted on wired links + faster recovery
- Possible adverse interactions with transport layer
  - Interactions with TCP retransmission
  - Large end-to-end RTT variation (but RTO considers variance?)
- FEC used in some wireless networks (802.11a and later)



31

Split Connection Approach

- Gateway splits connection in two segments
  - Separates congestion, error, and flow control
- Gateway tries to keep the server happy
  - Insert additional acks, change timing of acks, etc.
- Very difficult to do without modifying TCP on server
  - Especially considering the diversity of TCP implementations
  - Some proposals modify semantics, e.g. local acks



32

Important Lessons

- Many assumptions built into Internet design
  - Wireless forces reconsideration of issues
- Network
  - Mobile endpoints – how to route with fixed identifier?
  - Link layer, naming, addressing and routing solutions
    - What are the +/- of each?
- Transport
  - Losses can occur due to corruption as well as congestion
    - Impact on TCP?
  - How to fix this → hide it from TCP or change TCP
- Link-layer
  - Spatial reuse (cellular) vs wires
  - Hidden/exposed terminal
  - No collision detection

33