Mobile Network Layer

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Lecture 08

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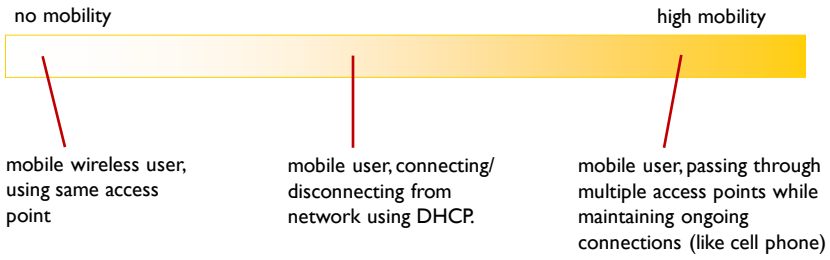
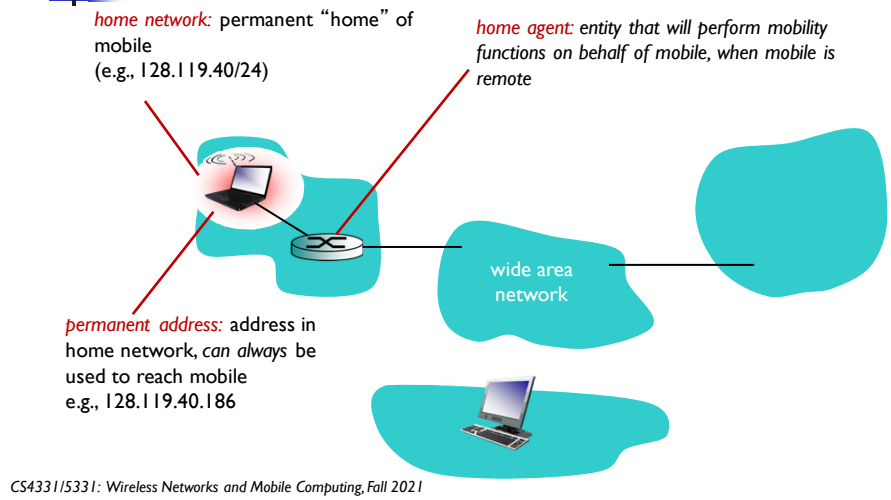
Adapted partially from Mobile Communications, J. Schiller, and Computer Networking – A Top-Down Approach, by J. F. Kurose and K. W. Ross

What is mobility?

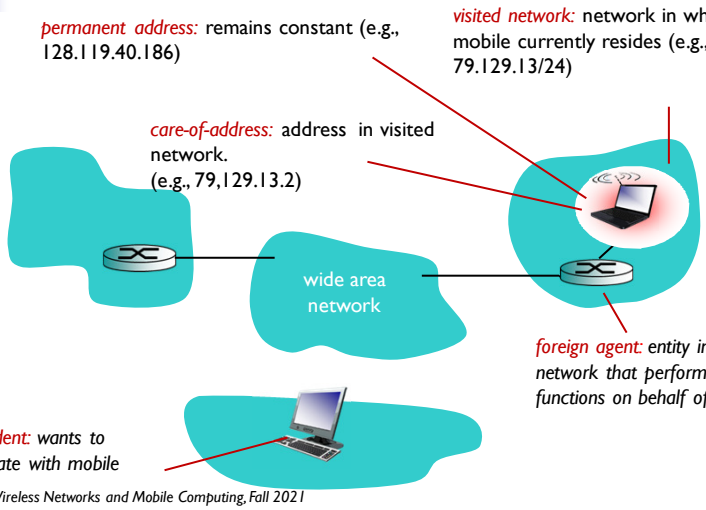
- spectrum of mobility, from the *network* perspective:



Mobility: Terminology



Mobility: More Terminology



Terminology

- Mobile Node (MN)
  - system (node) that can change the point of connection to the network without changing its IP address
- Home Agent (HA)
  - system in the home network of the MN, typically a router
  - registers the location of the MN, tunnels IP datagrams to the COA
- Foreign Agent (FA)
  - system in the current foreign network of the MN, typically a router
  - forwards the tunneled datagrams to the MN, typically also the default router for the MN

Terminology (cont.)

- Care-of-Address (COA)
  - address of the current tunnel end-point for the MN (at FA or MN)
  - actual location of the MN from an IP point of view
  - can be chosen, e.g., via DHCP
- Correspondent Node (CN)
  - communication partner

How do you contact a mobile friend?

Consider friend frequently changing addresses, how do you find her?

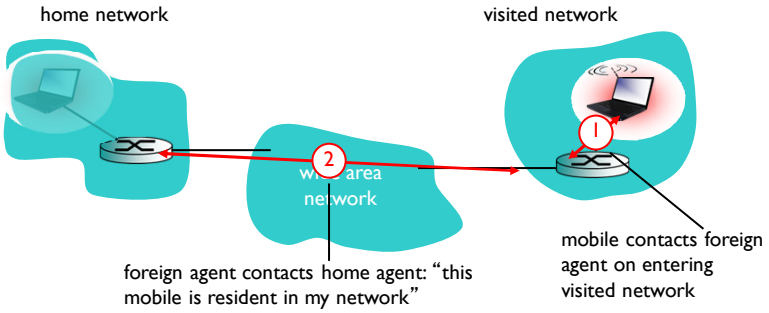
- search all phone books?
- call her parents?
- expect her to let you know where he/she is?

Mobility: Approaches

- *let routing handle it:* routers advertise permanent address of mobile-nodes-in-residence via usual routing table exchange.
  - routing tables indicate where each mobile located
  - no changes to end-systems

- *let end-systems handle it:*
  - *indirect routing:* communication from correspondent to mobile goes through home agent, then forwarded to remote
  - *direct routing:* correspondent gets foreign address of mobile, sends directly to mobile

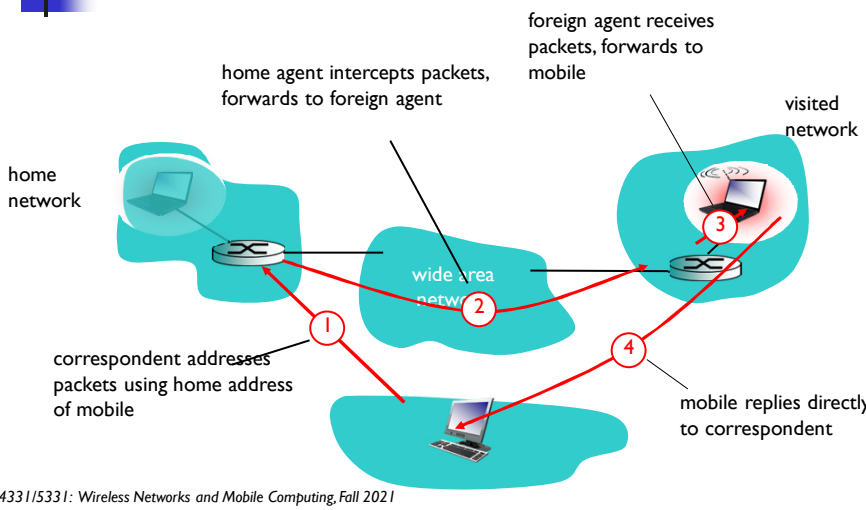
Mobility: Registration



end result:

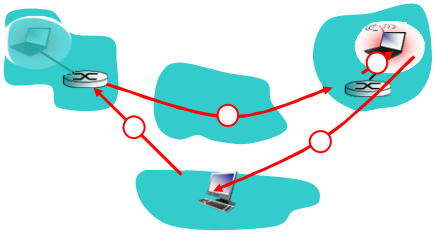
- foreign agent knows about mobile
- home agent knows location of mobile

Mobility via Indirect Routing

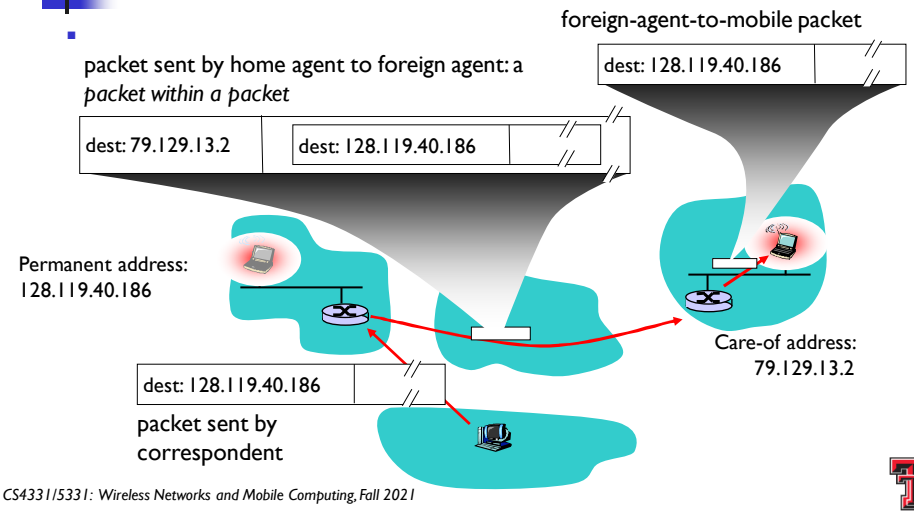


Indirect Routing: Comments

- mobile uses two addresses:
  - permanent address: used by correspondent (hence mobile location is *transparent* to correspondent)
  - care-of-address: used by home agent to forward datagrams to mobile
- foreign agent functions may be done by mobile itself
- triangle routing: correspondent-home-network-mobile
  - inefficient when correspondent, mobile are in same network



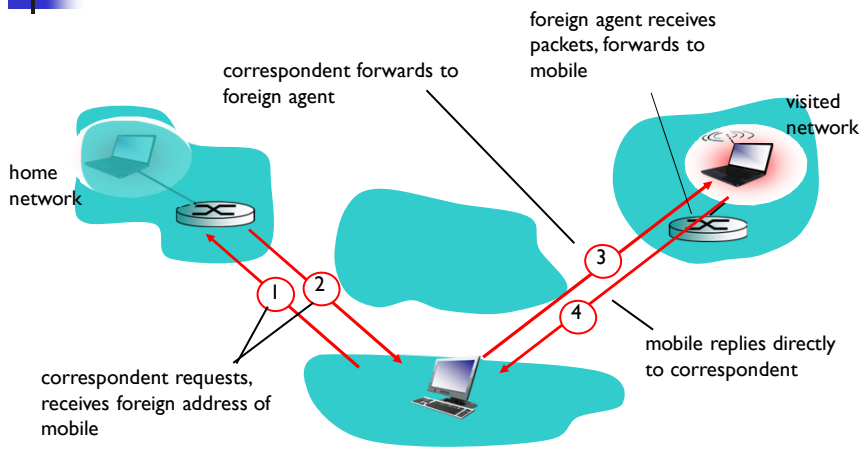
Data Transfer to the Mobile System: Indirect Routing



Indirect Routing: Moving between Networks

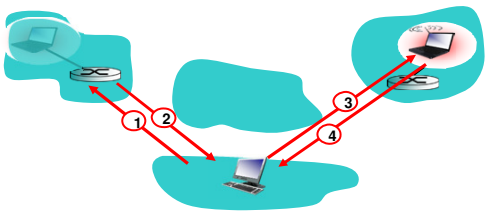
- suppose mobile user moves to another network
  - registers with new foreign agent
  - new foreign agent registers with home agent
  - home agent update care-of-address for mobile
  - packets continue to be forwarded to mobile (but with new care-of-address)
- mobility, changing foreign networks transparent: *on going connections can be maintained!*

Mobility via Direct Routing



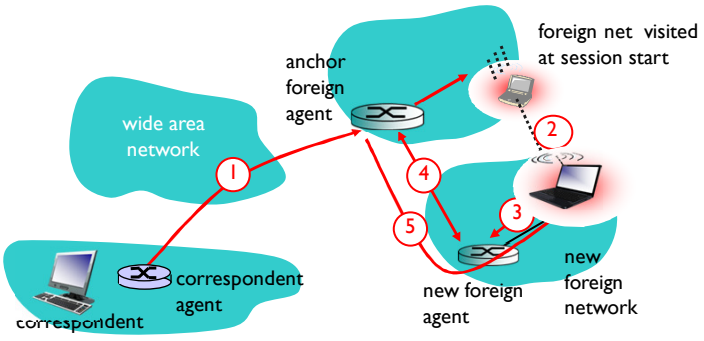
Mobility via Direct Routing: Comments

- overcome triangle routing problem
- *non-transparent to correspondent:* correspondent must get care-of-address from home agent
  - what if mobile changes visited network?



Accommodating Mobility with Direct Routing

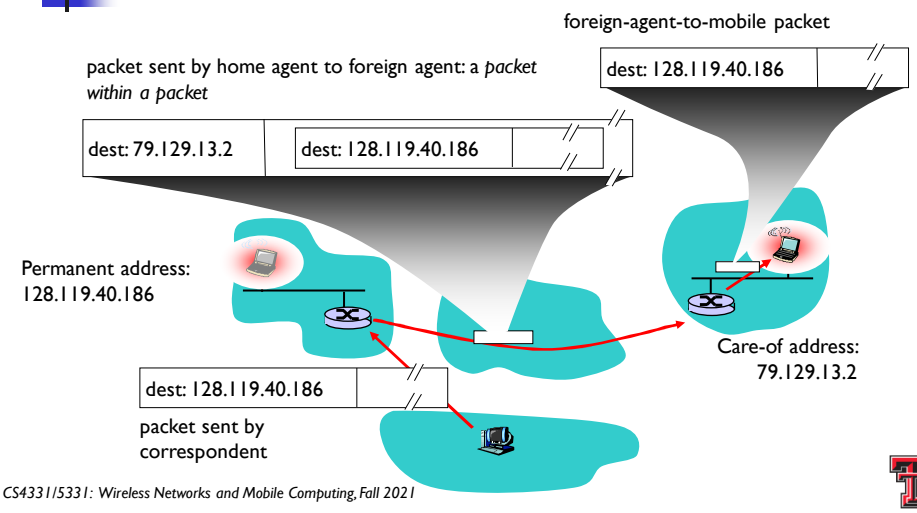
- anchor foreign agent: FA in first visited network
- data always routed first to anchor FA
- when mobile moves: new FA arranges to have data forwarded from old FA (chaining)



Mobile IP

- RFC 3344
- has many features we've seen:
  - home agents, foreign agents, foreign-agent registration, care-of-addresses, encapsulation (packet-within-a-packet)
- three components to standard:
  - indirect routing of datagrams
  - agent discovery
  - registration with home agent

Mobile IP: Indirect Routing

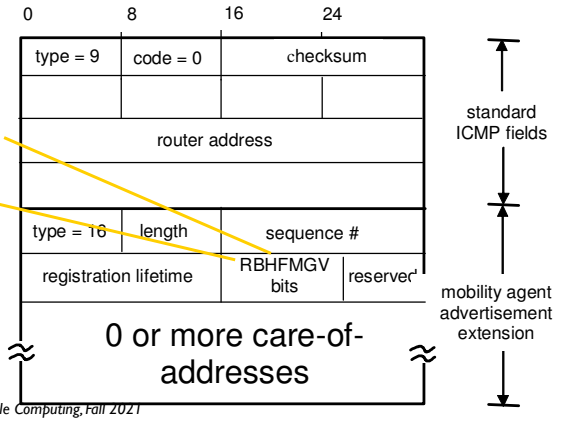


Mobile IP: Agent Discovery

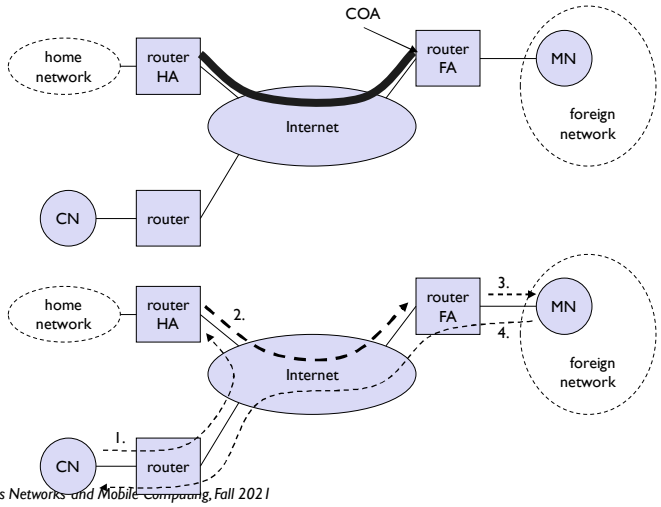
- *agent advertisement:* foreign/home agents advertise service by broadcasting ICMP messages (typefield = 9 → **router advertisement**)

H,F bits: home and/or foreign agent

R bit: registration required



Overview



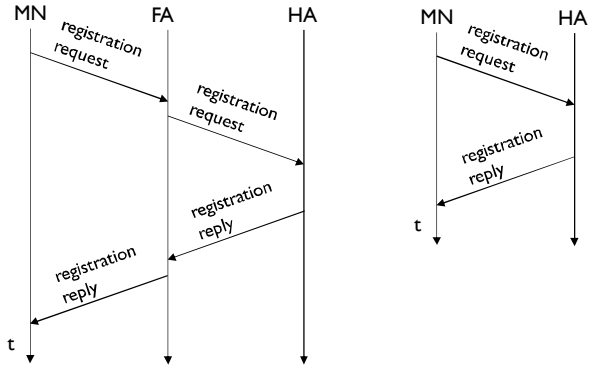
Network Integration

- Agent Advertisement:
  - HA and FA periodically send **advertisement messages** into their physical subnets
  - MN listens to these messages and detects,
    - if it is in the home or a foreign network (standard case for home network)
  - MN reads a COA from the FA advertisement messages
- Registration (always limited lifetime!):
  - MN signals COA to the HA via the FA, HA acknowledges via FA to MN
  - these actions have to be secured by authentication

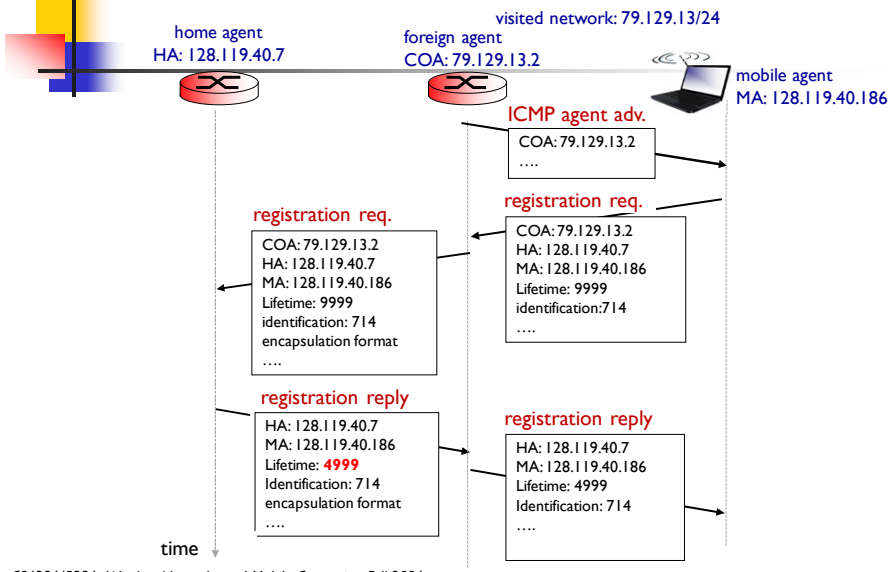
Network Integration (cont.)

- Advertisement:
  - HA advertises the IP address of the MN (as for fixed systems)
    - i.e. standard routing information
  - routers adjust their entries, these are stable for a longer time (HA responsible for a MN over a longer period of time)
  - packets to the MN are sent to the HA,
  - independent of changes in COA/FA

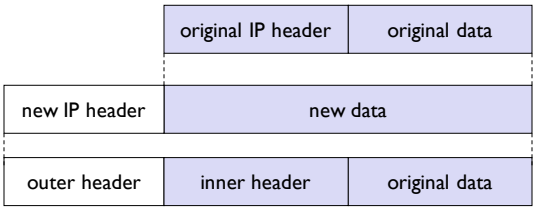
Registration with HA



Mobile IP: Registration Example



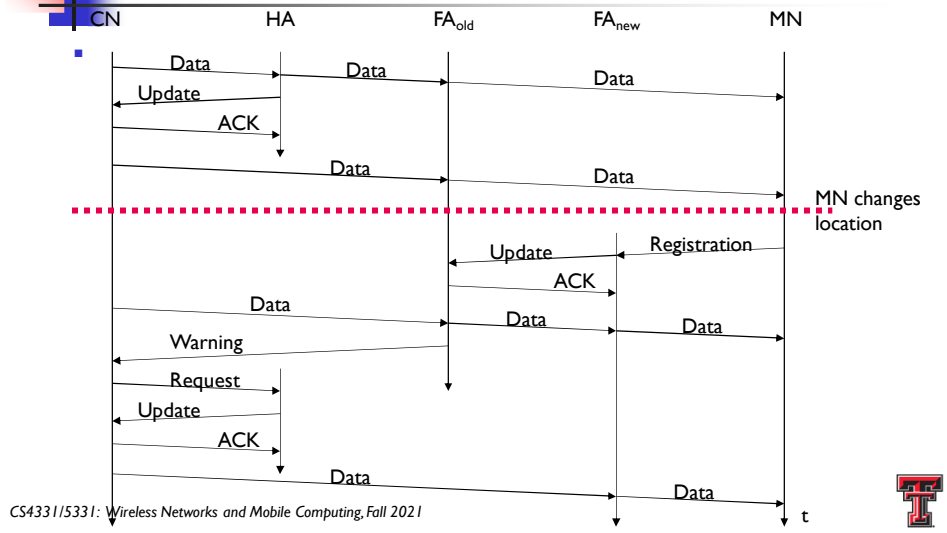
Encapsulation



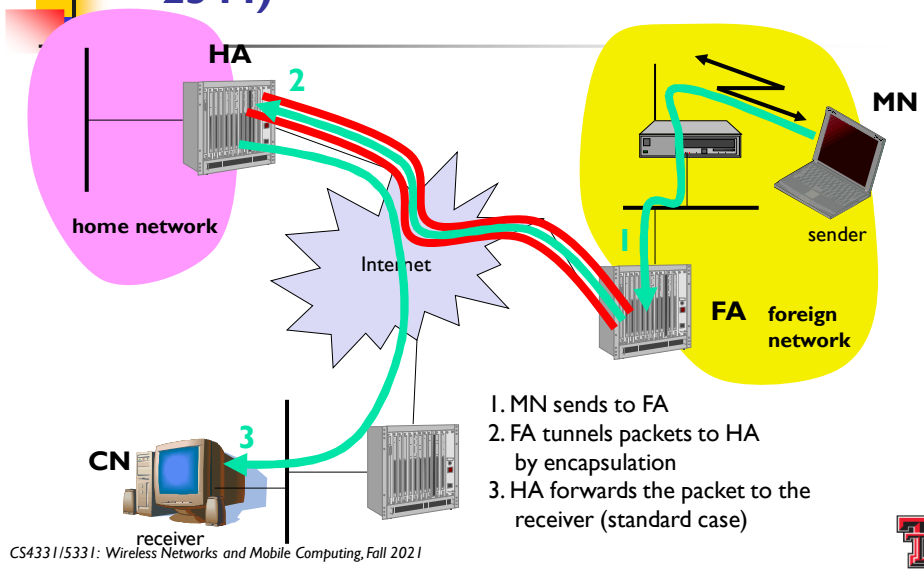
Optimization of Packet Forwarding

- Triangular Routing
  - sender sends all packets via HA to MN
  - higher latency and network load
- "Solutions"
  - sender learns the current location of MN
  - direct tunneling to this location
  - HA informs a sender about the location of MN
  - **big security problems!**
- Change of FA
  - packets on-the-fly during the change can be lost
  - new FA informs old FA to avoid packet loss, old FA now forwards remaining packets to new FA (chaining)
  - this information also enables the old FA to release resources for the MN

Change of Foreign Agent



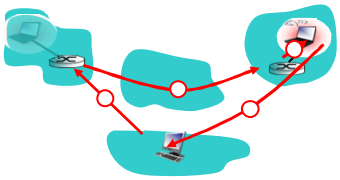
Reverse Tunneling (RFC 3024, was: 2344)



1. MN sends to FA
2. FA tunnels packets to HA by encapsulation
3. HA forwards the packet to the receiver (standard case)

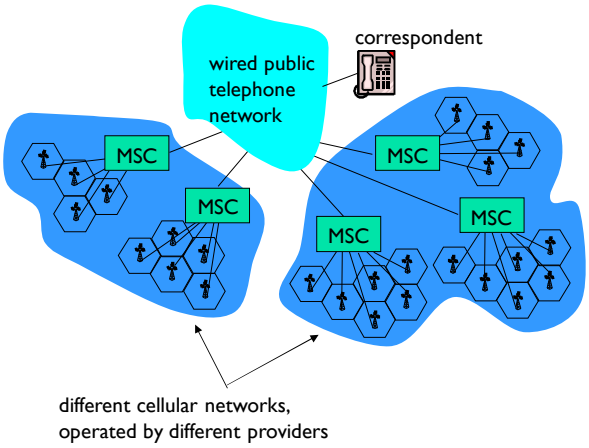
Mobile IP with Reverse Tunneling

- Router accepts often only "topological correct" addresses (firewall – filter out malicious addresses)
  - a packet from the MN encapsulated by the FA is now topological correct
  - multicast
    - participate in a multi-cast group
  - TTL (in terms of number of hops) problem
    - TTL in the home network correct, but MN is to far away from the receiver



- Reverse tunneling does not solve
  - problems with *firewalls*, the reverse tunnel can be abused to **circumvent security mechanisms** (tunnel hijacking)
  - optimization of data paths, i.e., packets will be forwarded through the tunnel via the HA to a sender (double triangular routing)

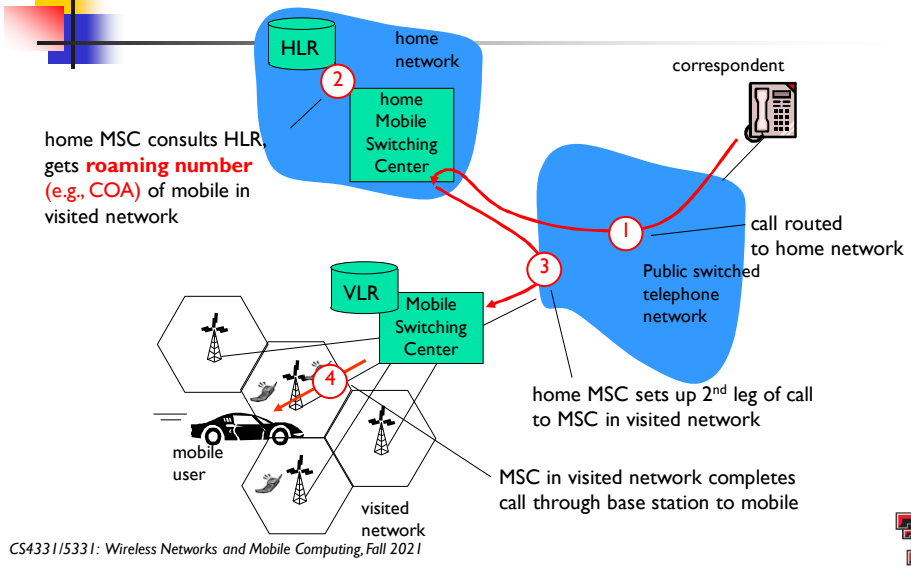
Components of Cellular Network Architecture



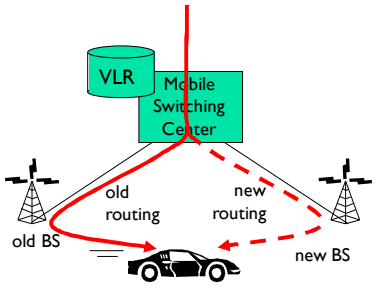
Handling Mobility in Cellular Networks

- *home network:* network of cellular provider you subscribe to (e.g., Sprint, Verizon, etc.)
  - *home location register (HLR):* **database** in home network containing permanent cell phone #, profile information (services, preferences, billing), information about current location (could be in another network)
- *visited network:* network in which mobile currently resides
  - *visitor location register (VLR):* **database** with entry for each user currently in network

GSM: Indirect Routing to Mobile

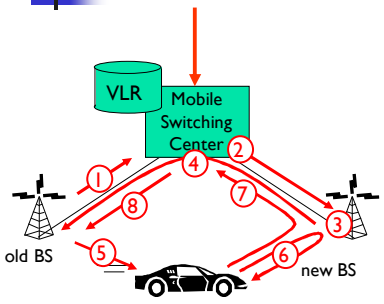


GSM: Handoff with Common MSC



- *handoff goal:* route call via new base station (without interruption)
- reasons for handoff:
  - stronger signal to/from new BS (continuing connectivity, less battery drain)
  - load balance: free up channel in current BS
  - GSM does not mandate why to perform handoff (policy), only how (mechanism)
- handoff initiated by old BS

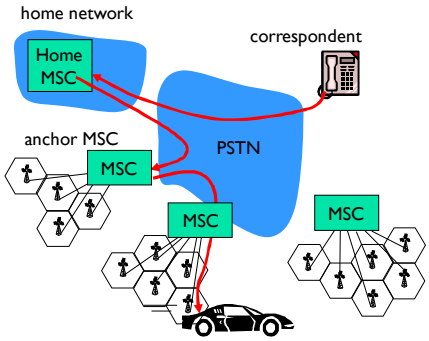
GSM: Handoff with Common MSC (cont.)



1. old BS informs MSC of impending handoff, provides list of 1+ new BSs
2. MSC sets up path (allocates resources) to new BS
3. new BS allocates radio channel for use by mobile
4. new BS signals MSC, old BS: ready
5. old BS tells mobile: perform handoff to new BS
6. mobile, new BS signal to activate new channel
7. mobile signals via new BS to MSC: handoff complete. MSC reroutes call

8 MSC-old-BS resources released

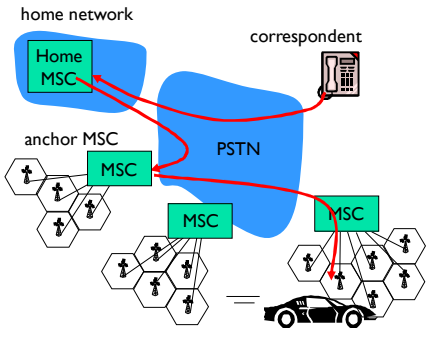
GSM: Handoff between MSCs



(a) before handoff

- *anchor MSC:* first MSC visited during call
  - call remains routed through anchor MSC
- new MSCs add on to end of MSC chain as mobile moves to new MSC

GSM: Handoff between MSCs (cont.)



(b) after handoff

- *anchor MSC:* first MSC visited during call
  - call remains routed through anchor MSC
- new MSCs add on to end of MSC chain as mobile moves to new MSC
- optional path minimization step to shorten multi-MSC chain

Mobility: GSM versus Mobile IP

Home system	Network to which mobile user's permanent phone number belongs	**Home network**
Gateway Mobile Switching Center, or "home MSC". Home Location Register (HLR)	Home MSC: point of contact to obtain routable address of mobile user. HLR: database in home system containing permanent phone number, profile information, current location of mobile user, subscription information	**Home agent**
Visited System	Network other than home system where mobile user is currently residing	**Visited network**
Visited Mobile services Switching Center. Visitor Location Register (VLR)	Visited MSC: responsible for setting up calls to/from mobile nodes in cells associated with MSC. VLR: temporary database entry in visited system, containing subscription information for each visiting mobile user	**Foreign agent**
Mobile Station Roaming Number (MSRN), or "roaming number"	Routable address for telephone call segment between home MSC and visited MSC, visible to neither the mobile nor the correspondent.	**Care-of-address**

Wireless, Mobility: Impact on Higher Layer Protocols

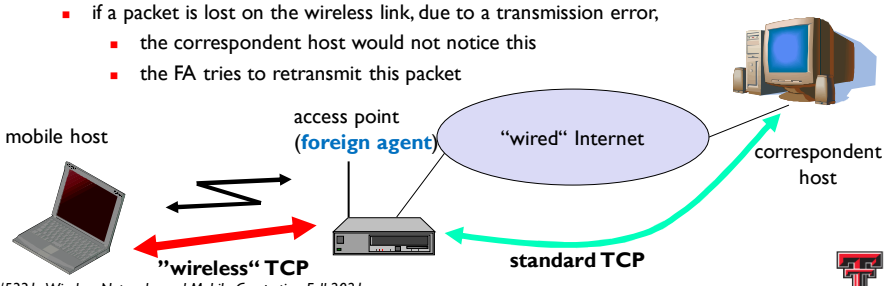
- logically, impact *should* be minimal …
  - best effort service model remains unchanged
  - TCP and UDP can (and do) run over wireless, mobile
- … but performance-wise:
  - packet loss/delay due to bit-errors (discarded packets, delays for link-layer retransmissions), and **handoff**
  - TCP interprets loss as **congestion**, will decrease congestion window un-necessarily
  - delay impairments for real-time traffic
  - limited bandwidth of wireless links

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,
    - e.g. if a mobile node roams from one access point 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

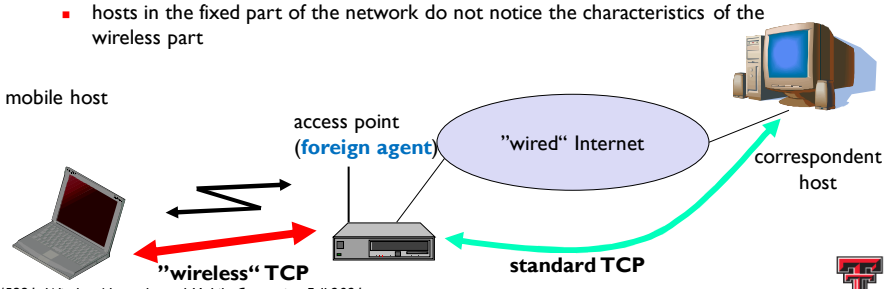
Indirect TCP

- indirect TCP (or I-TCP) segments the connection
  - FA relays all data in both directions
  - if the correspondent host sends a packet,
    - the FA acks this packet & tries to forward the packet to the mobile host
  - if the mobile host receives the packet,
    - it acks the packet, and this ack is only used by FA
  - if a packet is lost on the wireless link, due to a transmission error,
    - the correspondent host would not notice this
    - the FA tries to retransmit this packet



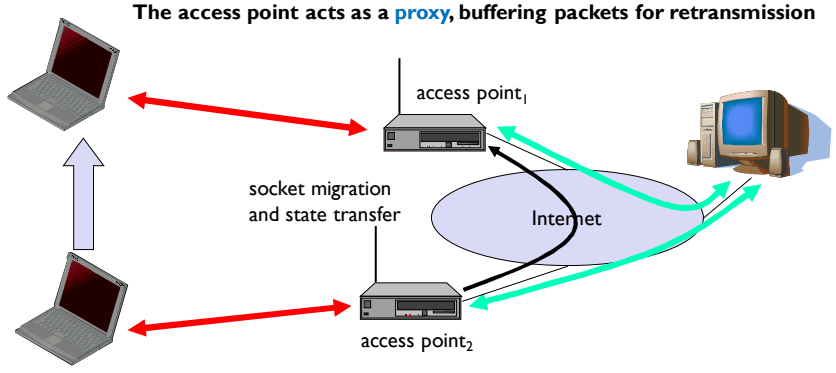
Indirect TCP (cont.)

- indirect TCP or I-TCP segments the connection (cont.)
  - 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
    - no real end-to-end connection any longer
  - hosts in the fixed part of the network do not notice the characteristics of the wireless part



I-TCP Socket and State Migration

The access point acts as a proxy, buffering packets for retransmission

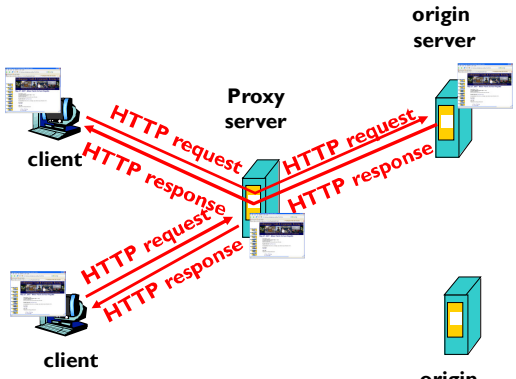


After the handoff, the old proxy must forward buffered data to the new proxy, because it has already ack the data.

Web Caches (Proxy Server)

Goal: satisfy client request without involving origin server

- user sets browser: Web accesses via cache
- browser sends all HTTP requests to cache
  - object in cache: cache returns object
  - else cache requests object from **origin server**, then returns object to client



Indirect TCP (cont.)

- 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
- 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