Cellular Networks and Mobility

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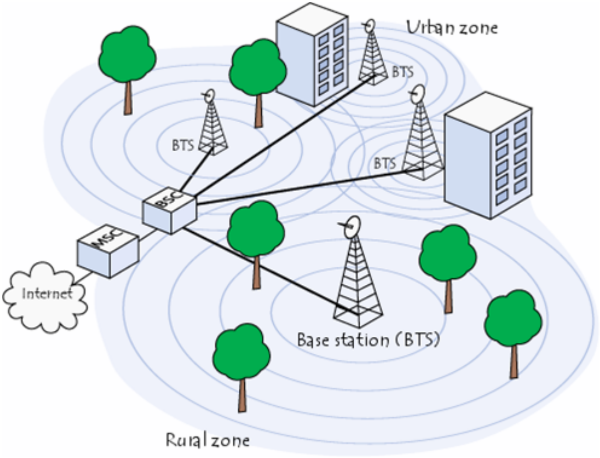
Cellular Networks


Urban zone
BTS
BTS
BTS
BSC
MSC
Internet
Base station (BTS)
Rural zone

Basic Architecture

- hierarchy
  - telephone network
  - Gateway Mobile Switching Center
  - Mobile Switching Center
  - Base Station Controller
  - Base Station Transceiver
- each BST covers a cell
  - imagined as a hexagon
  - actual coverage depends on transmission power, obstacles
  - directional antennas increase capability of a single tower

2G Standard

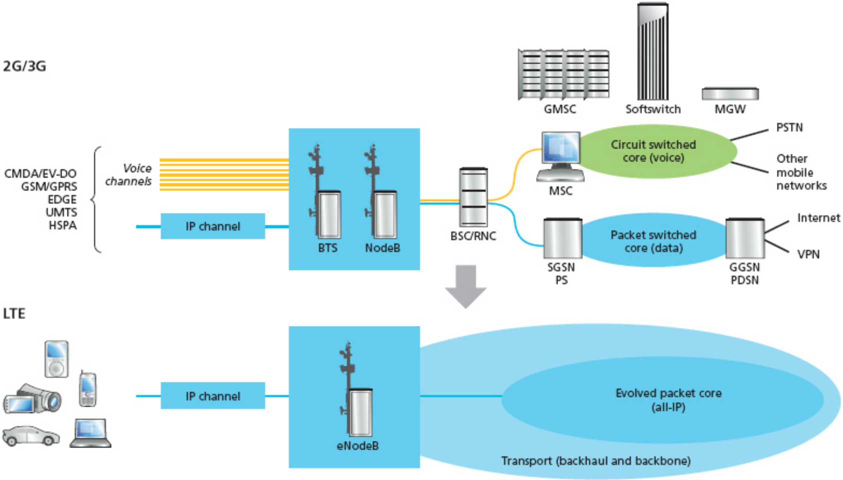
- GSM: combined FDM/TDM
  - divide into 200 kHz bands
  - each band supports 8 TDM calls
  - 13 kbps
- BSC
  - locate the cell where the phone is located
  - allocate channels to cell phones
  - perform handoff to a new BST or BSC
- MSC
  - handles about five BSCs, or 200K customers
  - call creation, teardown, handoff, authorization and accounting

3G Standard

- combine data with voice
  - developed slowly: 30 kbps - 144 kbps - 384 kbps 2 Mbps - 3 Mbps
  - UMTS has up to 14 Mbps download speeds
- replace BSC with RNC (Radio Network Controller)
  - uses circuit switching to connect to phone network, packet switching to connect to Internet
  - uses CDMA within TDMA slots, and TDMA slots available on various frequencies

4G/LTE Standard

Figure 1. LTE: Evolution from separate CS and PS core sub-domains (3GPP case shown) to one common IP core

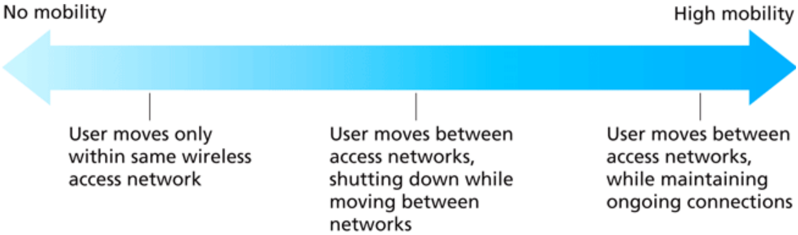


4G/LTE Standard

- Evolved Packet Core (EPC)
  - all IP core – no circuits
  - provides Quality of Service to voice calls
- LTE Radio Access Network
  - OFDM (combination of FDM and TDM) that allocates time slots to each device on one or more frequencies
  - MIMO antennas
  - 100 Mbps downstream, 50 Mbps upstream

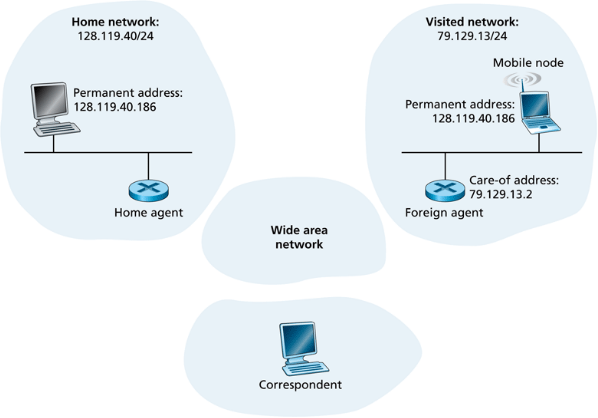
Mobility

Mobility



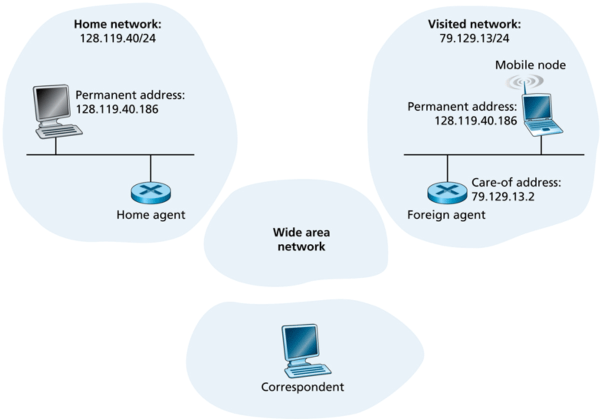
- how fast is the user moving?
- does the user need to keep her IP address?
  - cellular or high speed car vs DHCP on a laptop
  - need to maintain Internet connections when user becomes mobile: is it the application's or TCP's job?
- is infrastructure available?

Mobility Terminology



- home agent: entity that acts on behalf of mobile user while she is away
- foreign agent: entity that acts on behalf of mobile user in visited network

Mobility Terminology

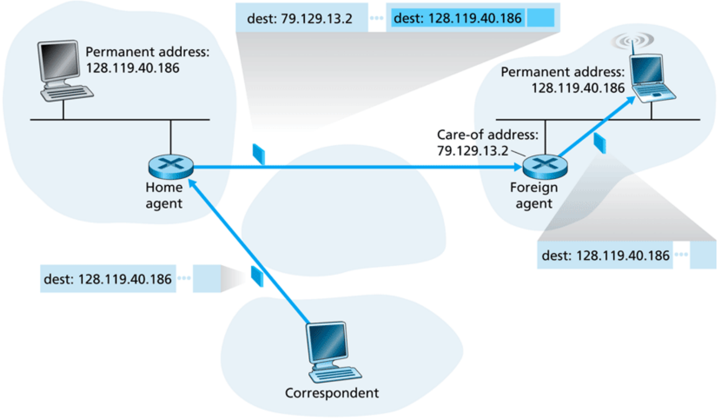


- permanent address: address in home network
- care-of-address: address in the foreign network

Approaches

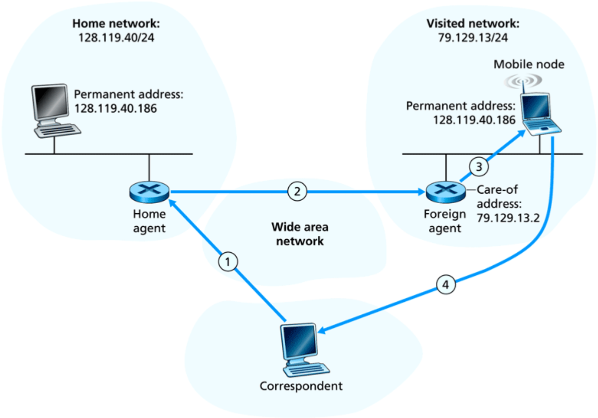
- network-layer routing
  - routers advertise permanent address of mobile nodes via usual routing algorithm
  - no changes to end systems
  - not scalable - breaks IP address aggregation
  - could separate routing from naming (Nimrod IPv6 proposal), but this requires massive Internet architecture change
- application-layer routing
  - applications register with home network when they visit a foreign network
  - indirect routing: home agent routes packets to foreign agent
  - direct routing: home agent tells correspondent about foreign agent

Indirect Routing



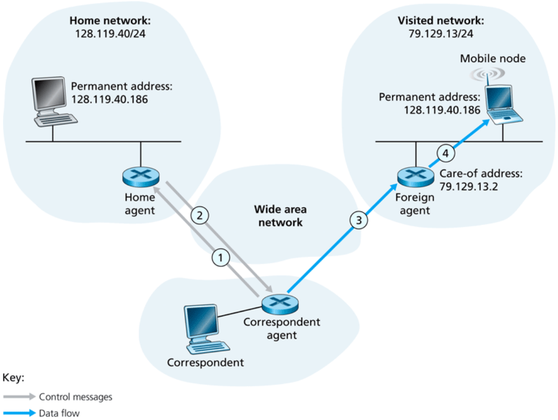
- transparent to correspondent

Indirect Routing



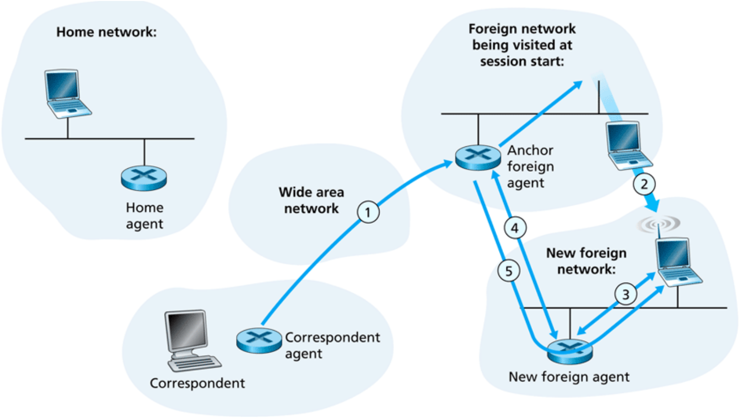
- causes a triangle routing problem: forward path is different from the reverse path, may be inefficient and may cause problems with TCP

Direct Routing



- solves triangle routing problem, but not transparent to correspondent

Direct Routing



- foreign agent chaining when mobile node moves to a new foreign network
- subsequent foreign networks just notify the anchor foreign agent
- used in GSM

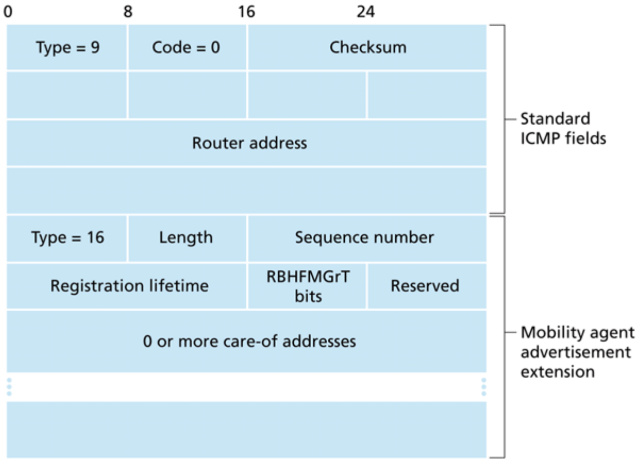
Mobile IP

Mobile IP

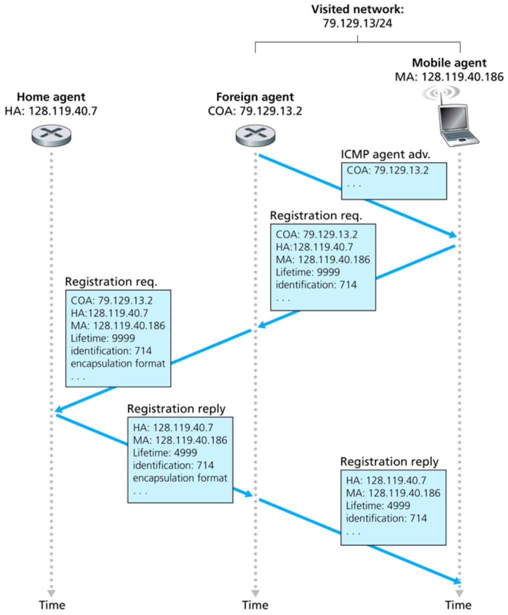
- RFC 3220
- uses home agents, foreign agents, foreign agent registration, care-of-addresses, encapsulation
- three components
  - indirect routing
  - agent discovery
  - registration with home agent

Mobile IP Agent Discovery

- foreign and home agents advertise services by broadcasting ICMP messages
- H, F bits: home and/or foreign agent
- R bit: registration required



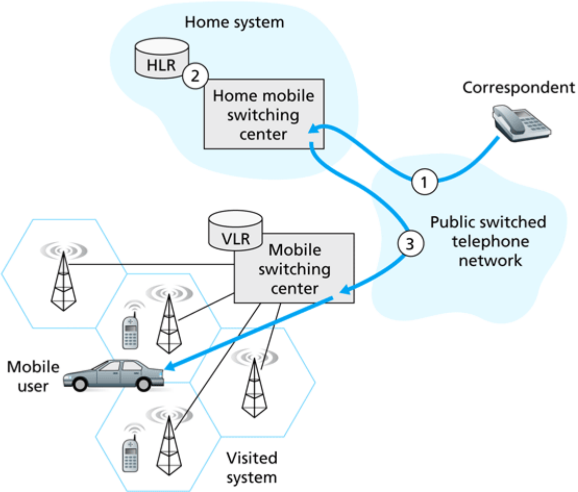
Mobile IP Registration Example



Mobile TCP

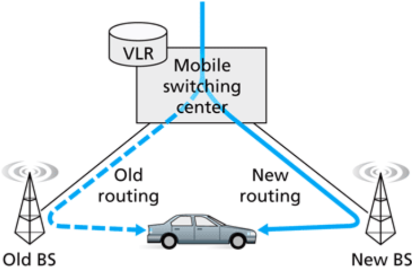
- not possible with today's operating systems
  - TCP sockets use source and destination IP addresses along with ports to identify a connection
  - would need to replace socket API
- TCP performance over wireless may be bad
  - high packet loss over wireless due to bit errors, collisions, handoff
  - TCP interprets loss as congestion, will slow down
- possible solutions
  - reliability at link layer
  - TCP awareness of wireless links – distinguish between congestion and wireless loss, react properly
  - split the connection into two parts – wired and wireless, used in cellular networks

Cellular Call to Mobile User



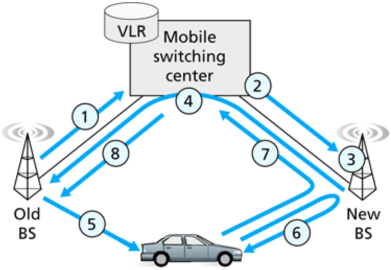
- home network: cellular provider network (e.g. Verizon)
- HLR: home location register - database with your profile (number, services, billing) and location
- VLR: visitor location register - database containing all users currently in network

Cellular Mobility - Same MSC



- goal: route call via new base station with no interruption
- motivation
  - connectivity
  - stronger signal from new BS
  - load balancing
- cell phone measures signal strength of all BS it can hear, reports to current BS
- handoff initiated by current BS

Cellular Handoff Steps



1. old BS informs MSC of handoff, list of 1+ new BS
2. MSC creates circuit to new BS
3. new BS allocates radio channel for phone
4. new BS signals MSC that it is ready
5. old BS tells phone to perform handoff
6. phone activates new channel
7. phone signals MSC that handoff is complete
8. MSC releases circuit to old BS

Cellular Mobility - Different MSC