Mobility Management

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Lecture № 8

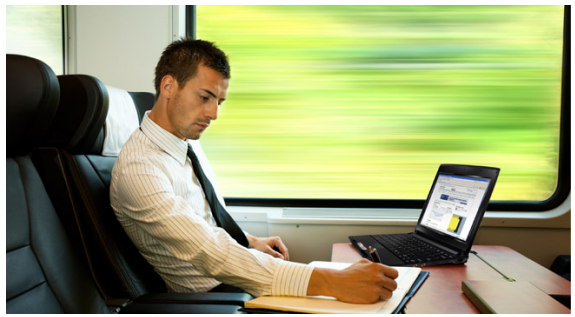
Outline

Introduction

- **Forms of mobility**:
- **Terminal mobility** – the ability for a user terminal to continue to access the network when the terminal moves
- **User mobility** – the ability for a user to continue to access network services under the same user identity when the user moves
  - It also includes the ability for a user to access network services from different terminals under the same user identity
- **Service mobility** – the ability for a user to access the same services regardless of where the user is
- In some cases, a terminal/user may be considered by a network to have 'moved' even if the terminal/user has not changed its physical position
  - E.g., due to switching from GSM to Wi-Fi or vice versa

Introduction (cont'd)

- **Discrete vs. continuous mobility**:
- **Discrete terminal mobility** – the ability for a terminal to move to a new location, connect to the network, and then continue to access the network
  - Aka **portability**
- **Continuous terminal mobility** – the ability for a terminal to remain connected to the network continuously while the terminal is on the move
  - I.e., without user-noticeable interruptions of network access



Introduction (cont'd)

- **Mobility management requirements**:
  - Support all forms of mobility
  - Support mobility for all types of applications
  - Support mobility across heterogeneous radio systems to allow users to move seamlessly across different radio systems
  - Support session (service) continuity
  - Global roaming
- **Roaming** – the ability for a user to move into and use different operators' networks

Introduction (cont'd)

- **Components of mobility management**:
- **Location management** – a process that enables the network to determine a mobile's current location
  - I.e., the mobile's current network attachment point
- **Packet delivery to mobile destinations** – a process that enables to deliver packets to a mobile terminal using location information
- **Handover and roaming** – a process in which a mobile terminal changes its network attachment point
  - I.e., moves into and uses either other cells or different networks
- **Network access control** – a process used by a network provider to determine whether a user is permitted to use a network and/or a specific service provided by the network

Location Management

- **Components of location management**:
- **Location update** – a process whereby mobiles notify the network of their locations
- **Location discovery** – a process for the network to determine a mobile's precise current location
  - Aka **terminal paging** or **paging**

- **Location** – refers to where a mobile is (or can be) attached to the network
  - It does not necessarily indicate the mobile's geographical position

Location Update

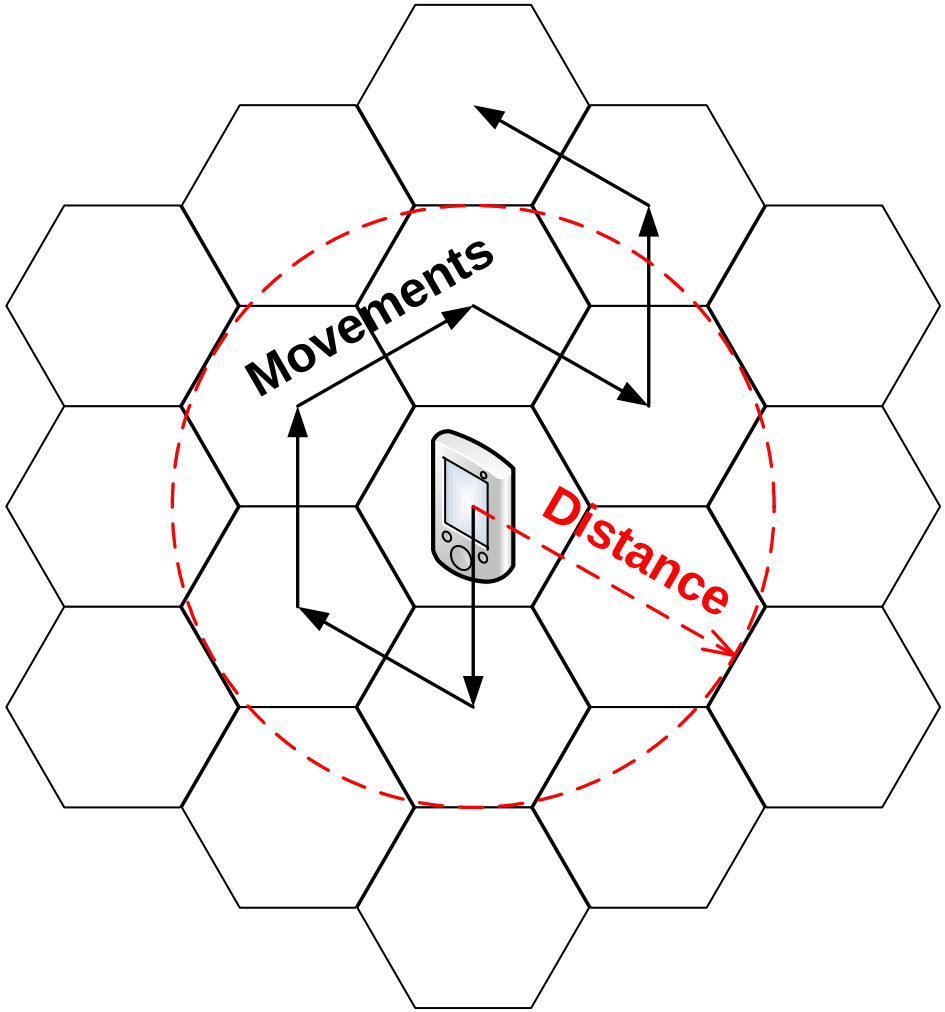
- When a mobile should perform location updates?
- **Straightforward** – every time the mobile changes its network attachment points
  - When mobiles change their network attachment points frequently, this strategy could lead to heavy location update traffic
  - It could also waste limited radio bandwidth and scarce power resources on the mobiles
- To save resources on the mobile and in the wireless network:
  1. Group network attachment points into **location areas**
  2. Do not perform location updates when a mobile remains inside the same location area
  3. When the mobile and the network have no traffic to send to each other, only keep track of which location area each mobile is likely in

Location Update (cont'd)

- **Location update strategies**:
- **Time-based** – periodically at a constant interval (aka **the update interval**)
  - Often used as a backup to other location update strategies
- **Movement-based** – whenever a mobile traverses a predefined number of location areas (aka **the movement threshold**)
  - Most wireless networks (e.g., GSM) use it with the movement threshold set to 1
  - I.e., a mobile updates its location every time it moves into a new location area
- **Distance-based** – whenever a mobile has traveled a predefined distance threshold from the location area in which it performed its last location update

Location Update (cont'd)

- Movement-based vs. distance-based location update strategies



Location Update (cont'd)

- **Parameter-based** – whenever the value of any preselected parameter changes
- **Implicit** – a mobile does not send any message explicitly for the purpose of location update; instead, the network derives its location when it receives other data from the mobile
- **Probabilistic** – a mobile performs location update based on a probability distribution function
  - E.g., the new update time interval after each update may be dynamically adjusted based on the PDF of the call arrival times
  - A probabilistic version of time-based, movement-based, or distance-based location update strategies may be created

- **Movement-based (threshold = 1) and time-based are the most commonly used strategies**

Location Discovery

- Location discovery (paging) is needed when the network does not maintain mobiles' precise locations all the time
- Typically, a network performs paging by sending 1 or multiple paging messages to a paging area where the mobile is likely to be located currently
- **Paging message** – used to inform the mobile terminal that the network has traffic to deliver to the mobile
- **Paging area** – a set of network attachment points
  - Paging areas do not have to be identical to location area

Location Discovery (cont'd)

- Upon receiving a paging message, a mobile needs to update its precise current location with the network
  - It may also need to establish the necessary connectivity with the network for carrying user traffic
- Paging should be done within a reasonable time constraint
  - If paging takes too long, the call setup latency could become intolerable to end users
  - E.g., call attempts may be dropped as a result

Location Discovery (cont'd)

- **Static vs. dynamic paging areas**:
- **Static paging area** – does not change unless reconfigured by the network operator manually or via a network management system
  - Existing wireless networks typically use fixed paging areas
- **Dynamic paging area** – proposed to reduce location update and paging signaling overhead in response to changing network dynamics
  - E.g., distribution of mobile users and/or mobility patterns
  - Supporting dynamic paging areas requires a much more complex signaling protocol

Location Discovery (cont'd)

- **Paging strategies**:
- **Blanket paging** – a paging message is broadcast simultaneously to all radio cells inside the paging area where the mobile is located
  - Deployed in most of today's wireless networks
- **Benefits** of blanket paging:
  - Simplicity and low paging latency
- **Shortcomings** of blanket paging:
  - Broadcasting paging messages to a large number of radio cells could consume a significant amount of scarce resources, including radio bandwidth and power on all the mobiles in the paging area

Location Discovery (cont'd)

- **Sequential paging**
  1. A large paging area is divided into small paging sub-areas (e.g., radio cells)
  2. Paging messages are first sent to a subset of the paging sub-areas where the network believes the mobile is most likely to be located
  3. If the mobile is not in this sub-area, subsequent paging messages will be sent to another paging sub-area
  4. This process continues until either the mobile is found or the entire paging area is searched
- **Benefits** of sequential paging:
  - Efficient resource utilization
- **Shortcomings** of sequential paging:
  - Complexity and high paging latency

Location Discovery (cont'd)

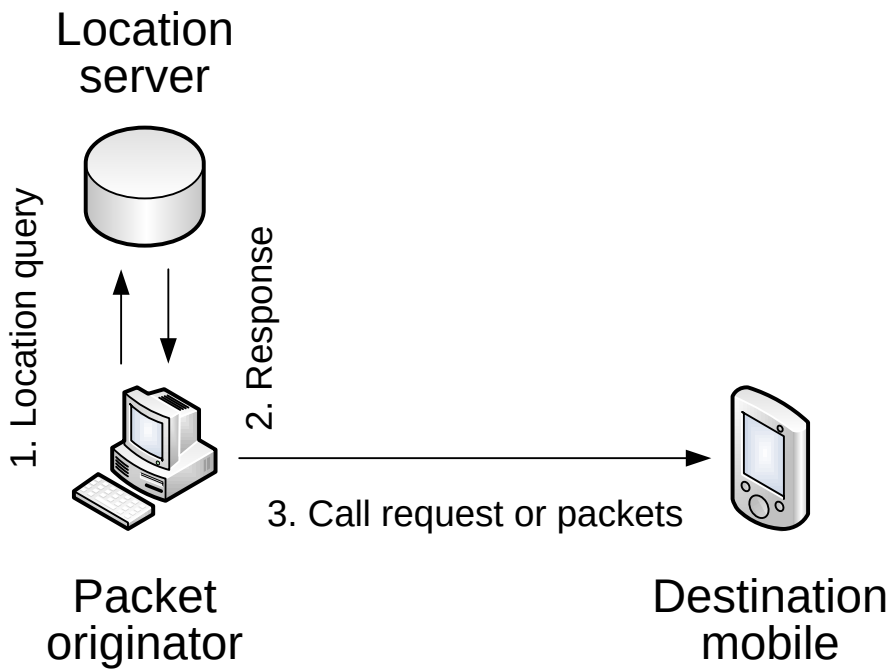
- A key issue in the design of location update and paging protocols is how to achieve a proper **tradeoff** between:
  - Overhead (e.g., network resources consumed)
  - Performance (e.g., paging latency)
  - Complexity
- E.g., performance vs. overhead:
  - Frequent location updates $\Rightarrow$ low paging latency and high location update overhead
  - Infrequent location updates $\Rightarrow$ high paging latency and low location update overhead

Packet Delivery

- **Packet delivery to mobile destinations** – a process whereby a packet originator and the network use location information to deliver packets to a mobile destination
  - Aka **routing** to mobile destinations
  - **Packet originators** may be fixed or mobile terminals, network nodes, or applications
- **Packet delivery strategies**:
  - Direct delivery
  - Indirect (relayed) delivery

Packet Delivery (cont'd)

- **Direct delivery**:
  - A packet originator first obtains the destination mobile's current location from a **location server**
  - Then, it sends packets directly to the current location of the destination mobile

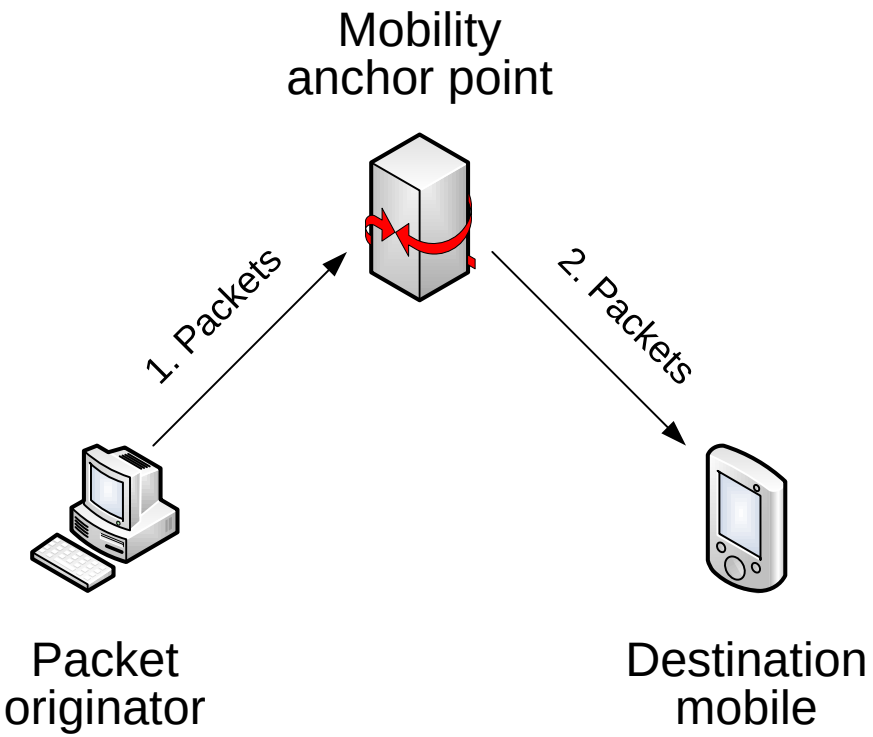


Packet Delivery (cont'd)

- **Benefits** of direct delivery:
  - Ability to route packets along the most direct paths to their destinations
- **Shortcomings** of direct delivery:
  - It requires a packet originator to determine whether the destination of a packet is a mobile or fixed host in order to decide whether a location query should be performed (performing location query for every destination could incur heavy overheads)
  - It requires every packet originator to implement protocols for querying location servers
  - Packet originators need to be able to discover the IP addresses of the location servers

Packet Delivery (cont'd)

- **Relayed delivery**:
  - A packet will be sent first to a **mobility anchor point**, which then relays the packet toward its final destination
  - The packet originator may not necessarily need to be aware of the existence of any mobility anchor point, nor the fact that it is sending call requests or packets to a mobility anchor point

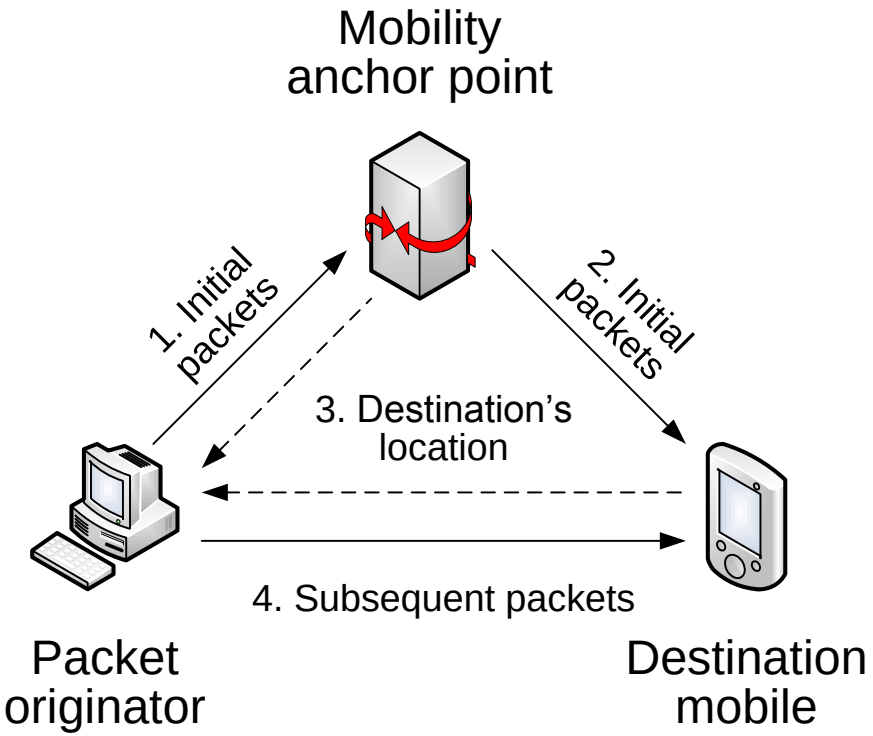


Packet Delivery (cont'd)

- **Benefits** of relayed delivery:
  - It does not require changes to the packet originators; instead, mobility anchor points are responsible for determining the mobiles' locations and relaying packets to these mobiles
- **Shortcomings** of relayed delivery:
  - **Triangle routing problem** – packets must be routed first to the mobility anchor point and then to the final destination, even when a much more efficient route exists between the originator and the mobile
  - Mobility anchor points could become performance bottlenecks
- **Mobile IPv4 (MIPv4), Mobile IPv6 (MIPv6), and mobility management in 3GPP and 3GPP2 networks all use relayed delivery as their basic packet delivery strategy**

Packet Delivery (cont'd)

- Relayed delivery and direct delivery can be combined to take advantages of the strengths of both strategies and to overcome each other's weaknesses
  - E.g., combined relayed and direct delivery has been used in SIP and in the route optimization extensions to MIPv4



Packet Delivery (cont'd)

- Integrated relayed and direct delivery:
  1. Initially, a packet originator does not have to know the destination's current location
  2. Packets addressed to the destination will be routed first toward a mobility anchor point
  3. Upon receiving the packets, the mobility anchor point relays them to the mobile's current location
  4. The mobility anchor point or the destination can then inform the packet originator of the destination's current location
  5. Then, the packet originator can address the packets directly to the mobile's current location

Handover

- **Handover** (aka **handoff**) – a process whereby a mobile changes from one network attachment point to another within the same network
  - E.g., a mobile can change its radio channels from one base station to another or from one frequency band to another on the same base station
- Handovers in IP-based wireless networks may occur at different protocol layers:
  - **Physical layer** – a mobile changes its network attachment point at the physical layer (e.g., radio channel)
  - **Link layer** – a mobile changes its logical link layer over which it exchanges packets with the network (e.g., access point)
  - **Network layer** – a mobile changes its IP address or moves to a different IP access router (e.g., IP subnet)

Handover (cont'd)

- A handover at one layer does not necessarily result in a handover at another layer
  - Mobility at different layers can be managed by different protocols and independently of other layers
- Handovers at each layer may occur in different scopes, e.g.:
  - **Intra-subnet** – a mobile remains on the same IP subnet after it changes its IP address or moves from one base station to another
  - **Inter-subnet** – a mobile moves into a new IP subnet and changes its IP address as a result of the handover
  - **Inter-router** – a mobile moves to a new IP access router as a result of the handover
- Different capabilities may be required to support different handover scopes

Handover (cont'd)

- **Hard vs. soft handover**:
- **Hard handover** – a mobile can receive user data from only one base station at any time
  - Used in TDMA and FDMA systems
- **Soft handover** – a mobile receives copies of the same user data from 2 or more base stations simultaneously
  - The mobile uses signal processing techniques to determine the most likely correct value of the data from its multiple copies
  - Used by the CDMA and WCDMA standards

Handover (cont'd)

- **2 types of hard handover**:
- **Make-before-Break** – a mobile sets up its network connectivity via the new network attachment before it tears down the network connectivity via the old network attachment
- **Break-before-Make** – a mobile tears down its network connectivity via the old network attachment point and then establishes its network connectivity via the new network attachment point

Handover (cont'd)

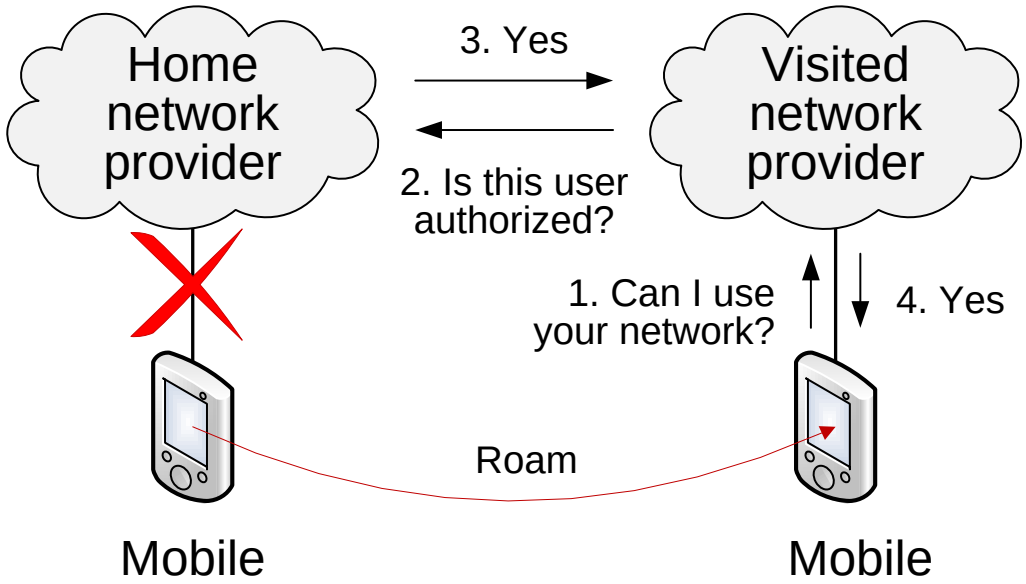
- **Capabilities needed for soft handover**:
- **Data distribution**
  - Separate copies of the same data need to be sent via multiple base stations to the same mobile
- **Data selection**
  - Multiple copies of the same data originated from a mobile will also be sent to the network via different base stations
  - The network should be able to select one copy of the data to send to the destination
- **Data content synchronization**
  - Pieces of data arriving from multiple base stations to a mobile at the same time should be copies of the same data in order for the mobile to combine these copies into a correct single copy

Roaming

- **Roaming** – a process whereby a user moves into a visited domain
- **Home domain** – a user's home domain is the domain where the mobile maintains a service subscription account
  - A user's account contains information regarding the subscriber's identity, billing address, service profile, etc.
  - The service profile describes which network services are subscribed by the user, including which networks the user is allowed to use
  - The home domain uses this information to determine how to provide services to a mobile and how to charge for the services used by the mobile
- **Visited domain** – a domain with which the user does not have an account
  - Aka **foreign domain**

Roaming (cont'd)

- **Extra capabilities needed for roaming**:
  - Network access control for visiting mobiles
  - **Roaming agreement** between the mobile's home domain and visited domains
  - Session continuity while a user crosses domain boundaries



Roaming (cont'd)

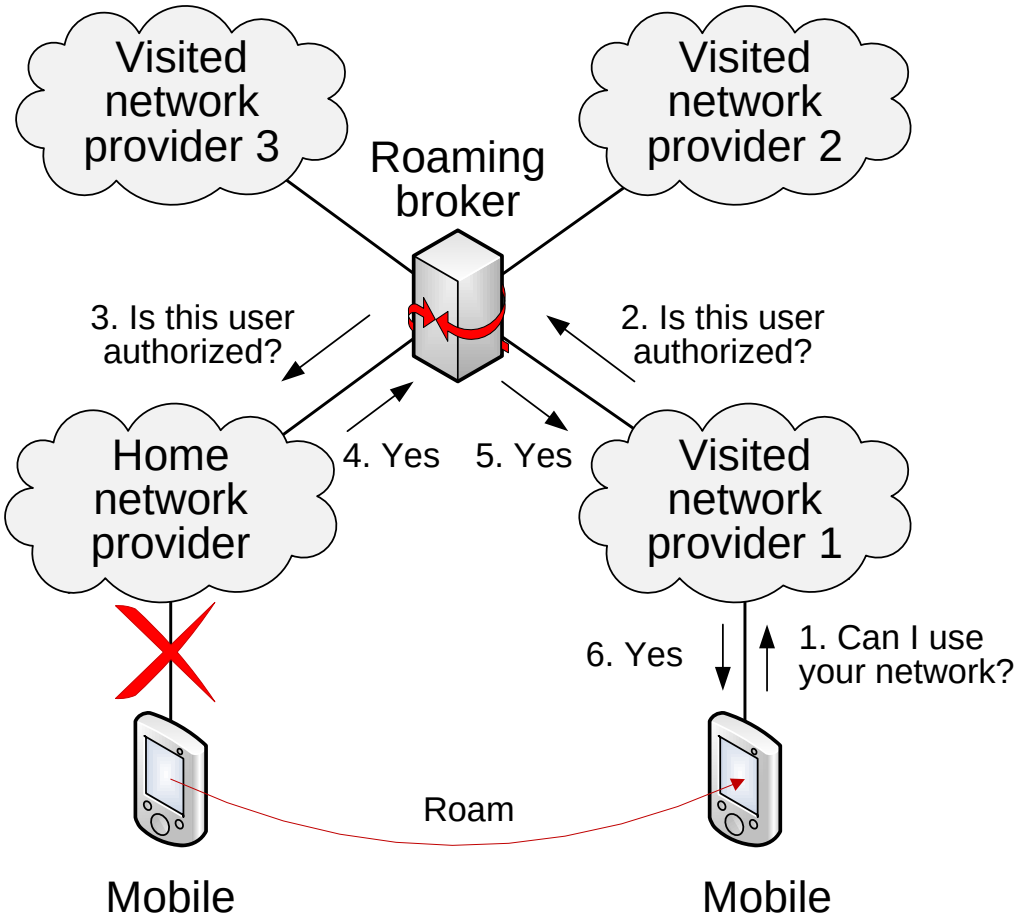
- Roaming:
  1. When a user tries to gain access to a visited domain, the visited domain asks the user's home domain to authenticate the user and to confirm how to charge for the user's use of the visited domain
  2. Upon successful authentication and authorization by the user's home domain, the home domain replies to the request from the visited domain
  3. The home domain may also send information regarding the user's service profile to the visited domain to help the visited domain to determine how to provide services to the user

Roaming (cont'd)

- It is difficult for a network provider to establish a roaming agreement with every other network provider
- Use **a roaming broker** instead:
  1. Each network provider only needs to establish a roaming agreement with the roaming broker
  2. When a user roams into a new visited network, this visited network will ask the roaming broker to authenticate and authorize the user
  3. The roaming broker can relay the authentication and authorization requests received from a network provider to the mobile's home network and then relay the responses back to the mobile's current visited network
- Alternatively, a user could have a single service subscription account with the roaming broker and the roaming broker will then ensure that the user can roam into any network connected to the roaming broker

Roaming (cont'd)

- Roaming broker



Network Access Control

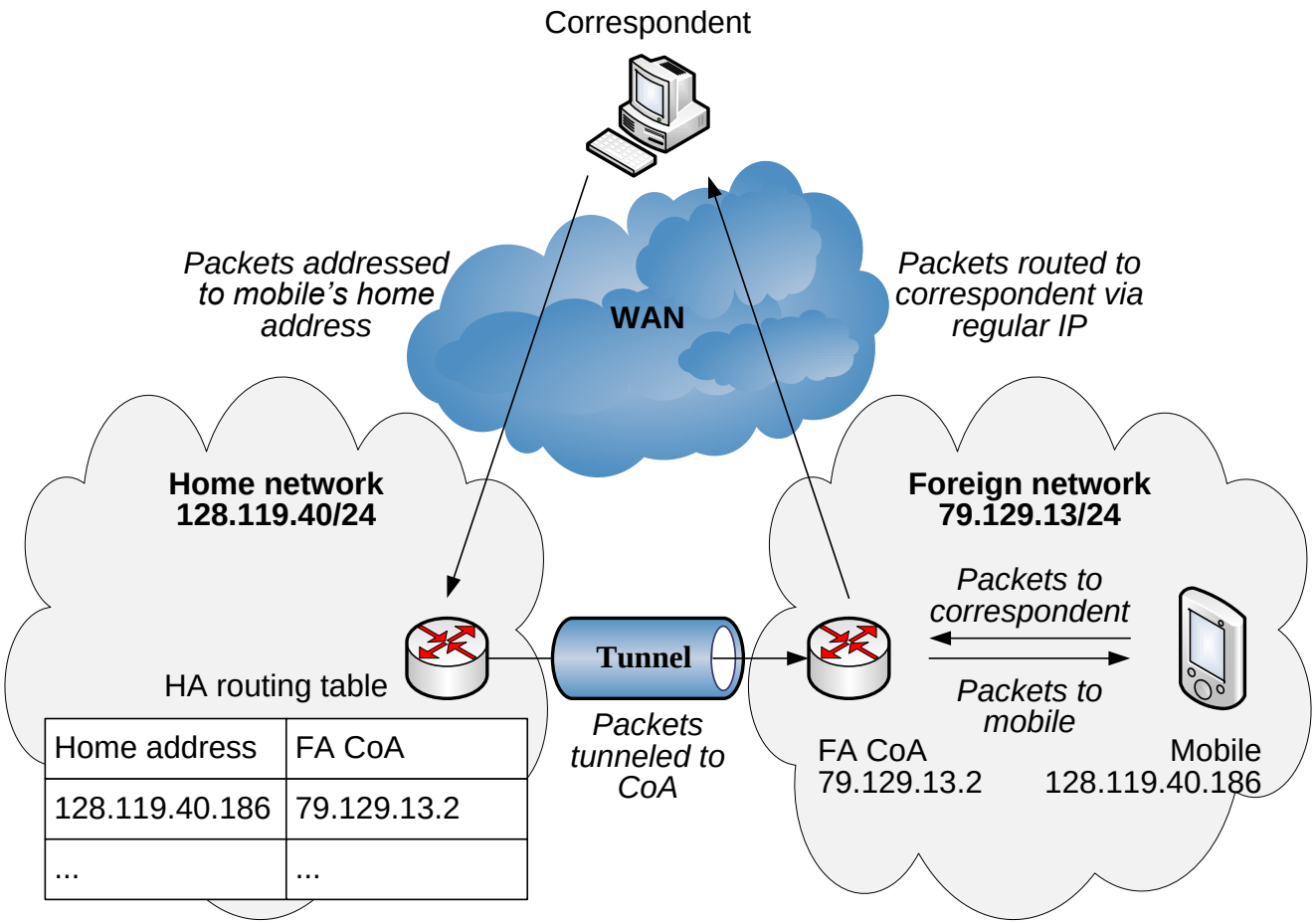
- **Components of network access control**:
  - Aka **AAA**
- **Authentication** – to verify the identity of user
- **Authorization** – to determine whether a user should be permitted to use a network or a network service
- **Accounting** – to collect information on the resources used by a user

Mobile IP

- With regular IP, when a mobile terminal moves to a visited network, the mobile will have to use an IP address from the IP address space of the visited network
- **Mobile IP** – allows a mobile terminal to maintain a **permanent** home address and to receive packets addressed to its home address regardless of its current location
  - RFC 5944 'IP Mobility Support for IPv4, Revised', 2010 (aka **MIPv4**)
  - RFC 6275 'Mobility Support in IPv6', 2011 (aka **MIPv6**)

Mobile IP (cont'd)

- Packet flows between a correspondent host and a mobile
  - The mobile uses a foreign agent Care-of Address (FA CoA)



Mobile IP (cont'd)

- Each mobile has a home network
  - I.e., the network whose network address prefix matches that of the mobile terminal's home address
- Packets addressed to a mobile's home address will be routed by the regular IP routing protocol to the mobile's home network
- When a mobile is inside its home network, it receives and sends packets as a regular host without using Mobile IP
- When a mobile is in a foreign network, a router on the mobile's home network will act as a home agent (HA) for the mobile
  - The home agent will maintain up-to-date location information for the mobile, intercept packets addressed to the mobile's home address, and tunnel these packets to the mobile's current location

Mobile IP (cont'd)

- A mobile's location in a foreign network is identified by a temporary **Care-of Address (CoA)** assigned to the mobile by the foreign network
- A mobile uses its CoA to receive IP packets in the foreign network
- Each time the mobile obtains a new CoA, it will register the new CoA with its home agent
- Each foreign network may have a foreign agent (FA) which:
  - Provides CoAs and other necessary configuration information
  - De-tunnels packets arriving from visiting mobile's home agent and then delivers the packets to the visiting mobile
  - Acts as the IP default router for packets sent by visiting mobiles

Mobile IP (cont'd)

- The Mobile IP standard consists of:
  - **Agent discovery** – protocols used by a home or foreign agent to advertise its services to mobile nodes, and protocols for mobile nodes to solicit the services of a foreign or home agent
  - **Registration with the home agent** – protocols used by the mobile node and/or foreign agent to register and deregister CoAs with a mobile node's home agent
  - **Packet delivery** – the manner in which packets are forwarded to mobile nodes by a home agent, including rules for handling error conditions, etc.

- Book 'IP-Based Next-Generation Wireless Networks: Systems, Architectures, and Protocols' by Jyh-Cheng Chen and Tao Zhang