MODULE 4: WIRELESS AND MOBILE NETWORKS

MODULE 4: WIRELESS AND MOBILE NETWORKS

4.1 Cellular Internet Access

4.1.1 An Overview of Cellular Network Architecture

• Cellular technology can be classified into following generations:

1) First Generation (1G)

- 1G systems were analog FDMA systems designed exclusively for voice-only communication.

2) Second Generation (2G)

- 2G systems were also designed for voice (GSM → Global System for Mobile communication).
- Later, the 2G was extended to support data (i.e., Internet) service.
- GSM was the major system evolved in the second generation:

3) Third Generation (3G)

- 3G systems were also designed for voice and data.
- More emphasis was given on data capabilities and higher-speed radio access links.

4.1.1.1 Cellular Network Architecture, 2G: Voice Connections to the Telephone Network

- The region covered by cellular-network is divided into no. of geographic coverage-areas called cells.
- Each cell contains a BTS (Base Transceiver Station) (Figure 4.1).
- BTS is responsible for delivering the signals to/from the mobile-stations in the cell.
- The coverage-area of a cell depends on following factors:
    1) The transmitting power of the BTS.
    2) The transmitting power of the user devices.
    3) Obstructing buildings in the cell.
    4) The height of base-station antennas.
- The 2G systems use combined FDM/TDM for the air-interface.
- In combined FDM/TDM systems,
    1) The channel is divided into a number of frequency sub-bands.
    2) Within each sub-band, time is partitioned into frames and slots.

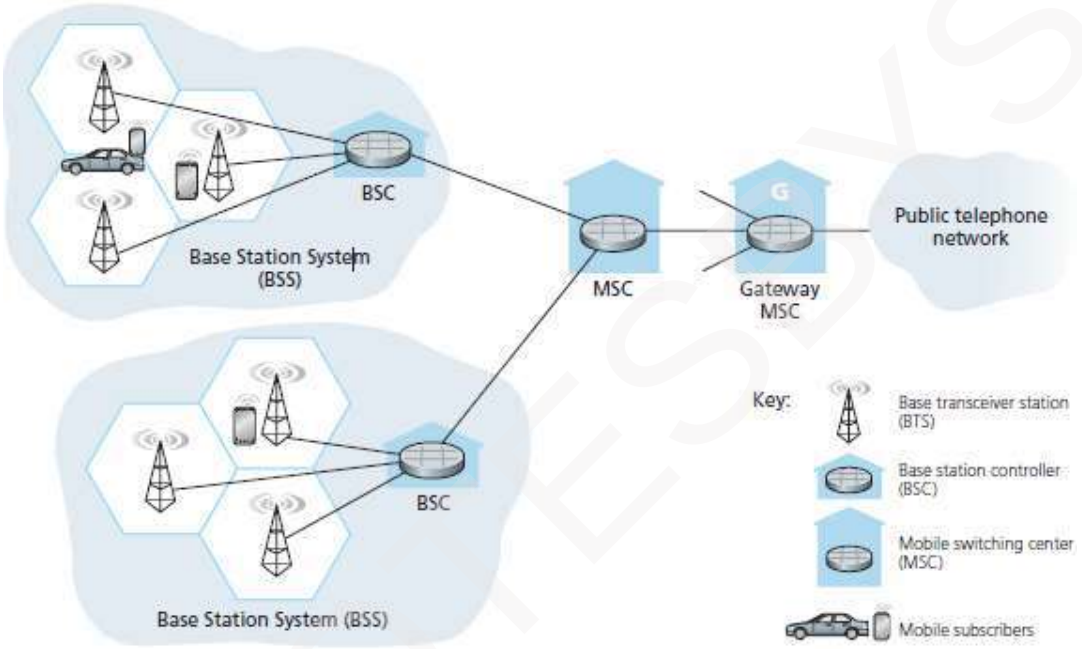

Figure 4.1: Components of the GSM 2G cellular network architecture

- The GSM network contains many BSCs (Base Station Controllers).
- Main responsibilities of the BSC:
    1) Providing service to many BTSs.
    2) Allocating radio-channels to mobile-users.
    3) Performing paging.
    4) Performing handoff of mobile-users.
- BSS (Base Station System) contains the BSC and its controlled BTSs.
- A MSC (Mobile Switching Center) contains upto 5 BSCs. This results in approx 200K subscribers/MSC.
- Main responsibilities of the MSC:
    1) User authorization & accounting
    2) Call establishment & teardown and
    3) Handoff.
- A cellular-provider's network will have a number of special MSCs known as gateway MSCs.
- Gateway MSCs are used to connect the provider's cellular-network to the public telephone-network.

4.1.2 3G Cellular Data Networks: Extending the Internet to Cellular Subscribers

4.1.2.1 3G Core Network

- 3G system architecture is shown in Figure 4.2.
- Main responsibilities of the core-network:
    1) Connects radio access-networks (RANs) to the public Internet.
    2) Interoperates with components of the existing voice-network.

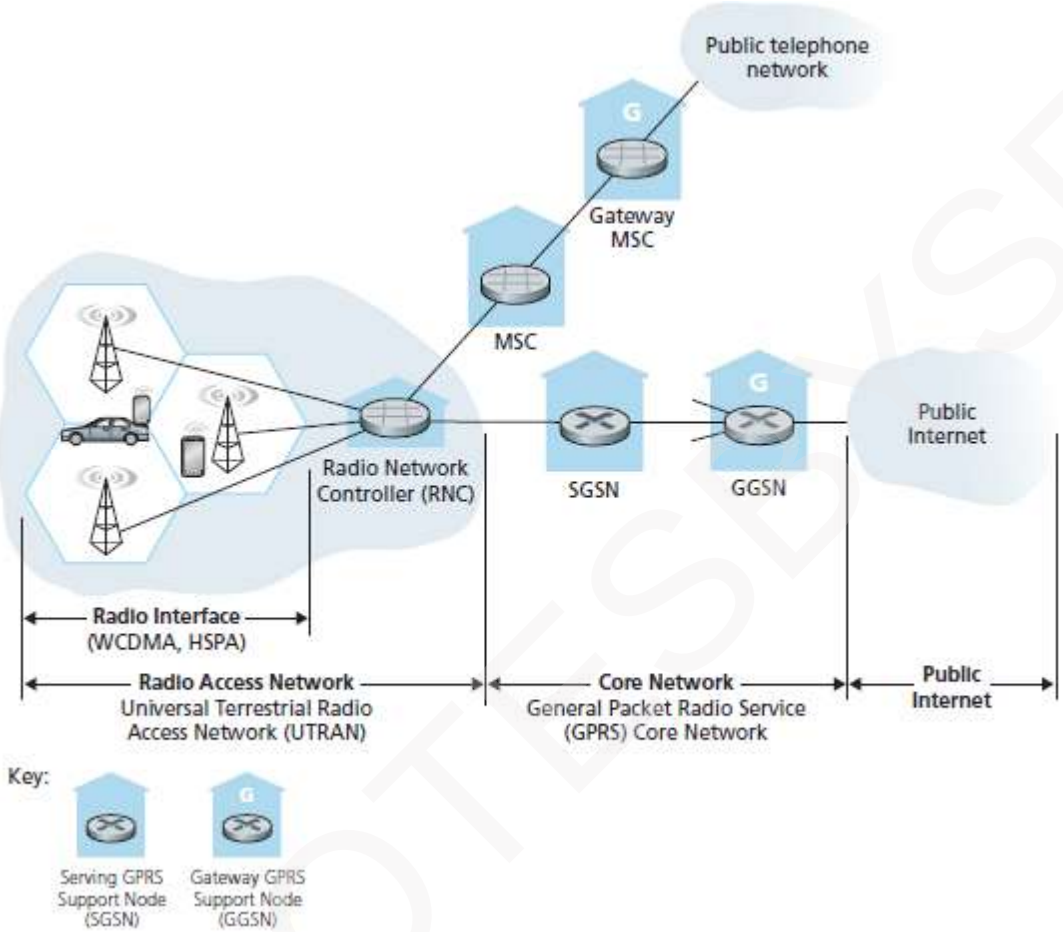

Figure 4.2: 3G system architecture

- The idea of 3G designers:
    "Leave the existing voice-network untouched;
        Add additional data functionality in parallel to the existing voice-network."
- Two types of nodes in the core-network:
    1) Serving GPRS Support Node (SGSN) and
    2) Gateway GPRS Support Node (GGSN).

1) SGSN

- An SGSN is responsible for delivering data to/from the mobile-nodes in the RAN.
- Main responsibilities of the SGSN:
    1) Interacting with the MSC of voice-network.
    2) Providing user authorization and handoff.
    3) Maintaining location information about active mobile-nodes.
    4) Performing data forwarding between a GGSN & mobile-nodes in the RAN.

2) GGSN

- A GGSN acts as a gateway.
- The GGSN is used to connect multiple SGSNs into the larger Internet.
- To the outside world, the GGSN looks like any other router.
- The mobility of the nodes within the GGSN's network is hidden from the outside world.

4.1.2.2 3G Radio Access Network: The Wireless Edge

- The RAN is the wireless first-hop network that the 3G user sees.
- The RNC (Radio Network Controller) typically controls several cell BTSs
- Each cell's wireless-link operates between the mobile-nodes and a BTS.
- The RNC connects to both the circuit-switched voice-network and the packet-switched Internet.
- UMTS (Universal Mobile Telecommunications Service) is a widely deployed 3G technology.
- UMTS uses CDMA technique known as DS-WCDMA within TDMA slots.
- TDMA slots, in turn, are available on multiple frequencies.
- The data-service associated with the WCDMA specification is known as HSP.

(HSP → High Speed Packet access DS-WCDMA→ Direct Sequence Wideband CDMA)

4.1.3 On to 4G: LTE

- The 4G systems have 2 main improvements over 3G systems:
  1) Evolved Packet Core (EPC) and
  2) LTE Radio Access-network.

1) EPC

- It is an "all-IP" network i.e. both voice & data will be carried in IP datagrams.
- Main responsibilities of the EPC:
  1) Combines the circuit-switched voice-network and the packet-switched data-network.
  2) Manages network-resources to provide high QoS.
  3) Allows multiple types of access-networks (such as 2G/3G) to attach to the core-n/w.

2) LTE Radio Access Network

- LTE uses a combination of FDM & TDM on the downstream-channel known as OFDM (Orthogonal Frequency Division Multiplexing).
- Each mobile-node is allocated one or more time-slots in one or more channel-frequencies.
- Figure 4.3 shows an allocation of 8 time-slots over 4 frequencies.
- By allocating more time-slots, a mobile-node is able to achieve higher data-rates.
- Multiple-input, multiple output (MIMO) antennas can be used to increase the data-rate.
- For example:

  In the downstream direction, maximum data-rate = 100 Mbps.
  In the upstream direction, maximum data-rate = 50 Mbps.

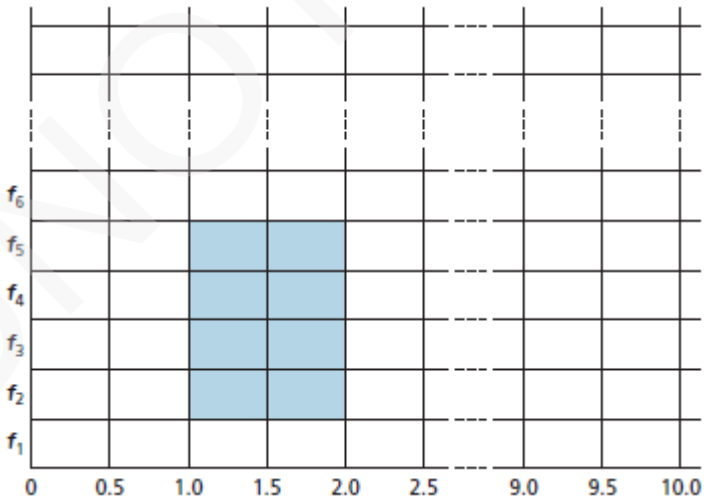

Figure 4.3: Twenty 0.5 ms slots organized into 10 ms frames at each frequency. An eight-slot allocation is shown shaded.

4.2 Mobility Management: Principles

• A mobile-node is one that changes its point of attachment into the network over time.

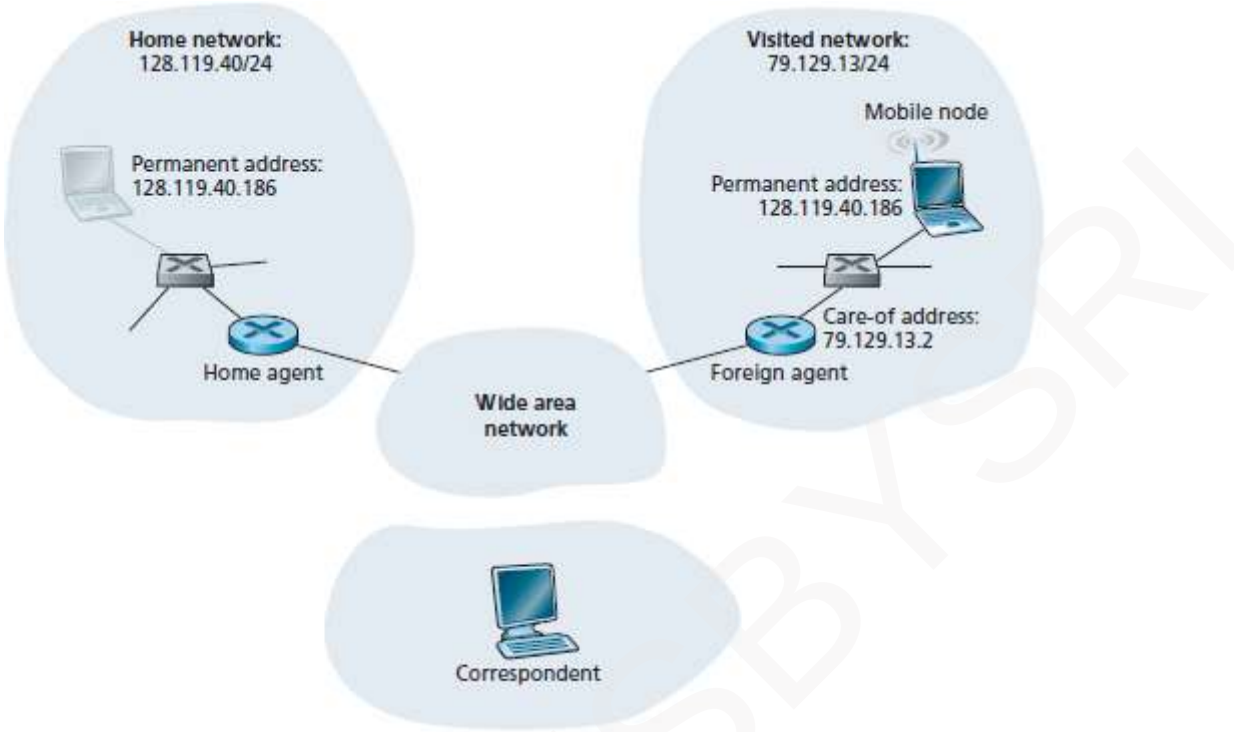

Figure 4.4: Initial elements of a mobile network architecture

• Five elements of mobile-network architecture:

1) Home Network

➢ Home network is a network that is the permanent home of the mobile-node (ex: smartphone)

2) Home Agent

➢ The home-agent is a router within the home-network. (COA → care-of-address)
➢ The home-agent performs the mobility management functions on behalf of the mobile-node.
➢ The home-agent interacts with a foreign-agent to track the mobile-node's COA.

3) Foreign Network

➢ Foreign network is a network to which the mobile-node moves.
➢ The foreign-network is also known as visited-network.

4) Foreign Agent

➢ The foreign-agent is a router within the foreign-network.
➢ The foreign-agent performs the mobility management functions on behalf of the mobile-node.
➢ Two roles of foreign-agent:
    1) Create a care-of-address (COA) for the mobile-node.
    ¤ The network portion of the COA must match with the foreign-network.
    ¤ Two addresses are associated with a mobile-node:
        i) Permanent-address and
        ii) COA (known as a foreign address).
    2) Inform the home-agent that the mobile-node is resident in the foreign-agent's n/w.
    ¤ The foreign-agent has the given COA.

5) Correspondent

➢ The entity wishing to communicate with the mobile-node is known as a correspondent.
➢ Figure 4.4 illustrates these concepts.

4.2.1 Addressing

- When a mobile-node moves from one network to another, the mobile-node must keep its address.
- Thus, user-mobility will be transparent to network-applications.
- When a mobile-node is in a foreign-network, the mobile-node's traffic is routed to foreign-network.
- The foreign-network advertises to the neighbors that it knows a route to mobile-node's permanent-address.
- Then, these neighbors propagate the routing-information throughout the network.
- When the mobile-node moves from one foreign-network to another, the new foreign-network advertises a new route to the mobile-node.
- Disadvantage:

  Scalability: If mobility management is the responsibility of routers, the routers have to maintain forwarding-table entries for potentially millions of mobile-nodes.

4.2.2 Routing to a Mobile Node

• Two approaches are 1) indirect routing and 2) direct routing.

4.2.2.1 Indirect Routing to a Mobile Node

• Four steps are involved. Figure 4.5 illustrates the 4 steps.

Step 1

➢ The correspondent
→ addresses the datagram to the mobile-node's permanent-address and
→ routes the datagram to the mobile-node's home-network.

Step 2

➢ Home-agent encapsulates the correspondent's original datagram within a larger datagram.
➢ This larger datagram is addressed & delivered to the mobile-node's COA.

Step 3

➢ The foreign-agent receives and decapsulates the datagram.
➢ The foreign-agent forwards the original datagram to the mobile-node.

Step 4

➢ The mobile-node directly routes the datagram to the correspondent.
➢ There is no need to route the datagram back through the home-agent.

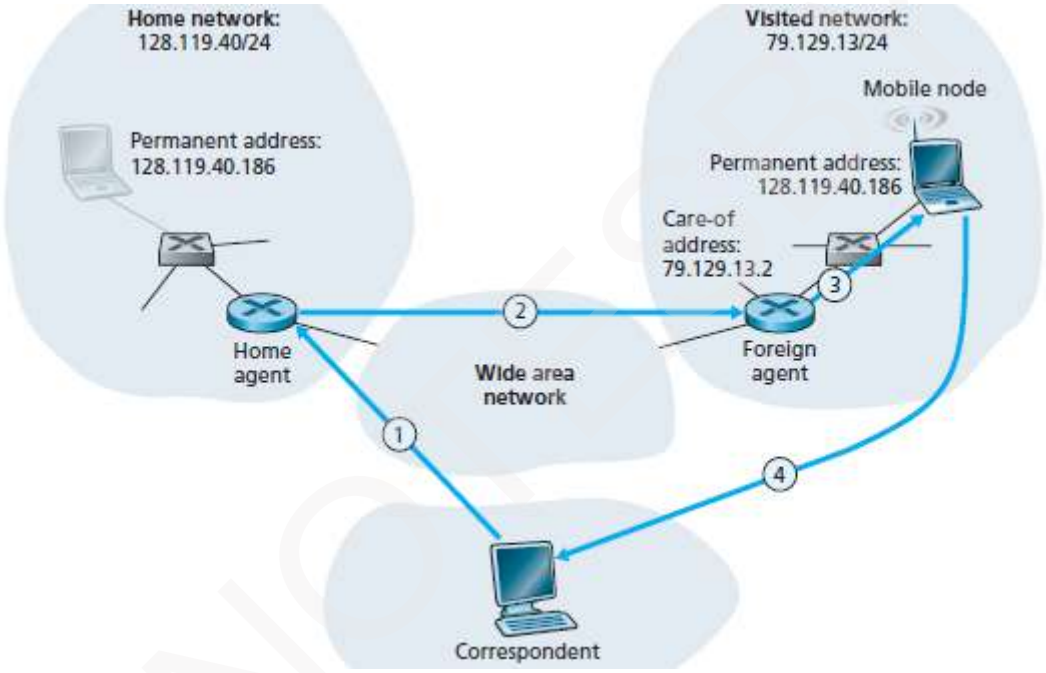

Figure 4.5: Indirect routing to a mobile node

• New functionality required to support mobility:

1) A Mobile-node–to–Foreign-agent Protocol

➢ The mobile-node will register with the foreign-agent when attaching to the foreign-network.
➢ Similarly, a mobile-node will deregister with the foreign-agent leaving the foreign-network.

2) A Foreign-agent–to–Home-agent Registration Protocol

➢ The foreign-agent will register the mobile-node's COA with the home-agent.
➢ A foreign-agent need not explicitly deregister a COA when a mobile-node leaves its network.

3) A Home-agent Datagram Encapsulation Protocol

➢ Encapsulation of correspondent's original datagram within a datagram addressed to the COA.

4) A Foreign-agent Decapsulation Protocol

➢ Extraction of the correspondent's original datagram from the encapsulated-datagram.
➢ Then, the forwarding of the original datagram to the mobile-node.

• Disadvantage of Indirect Routing: Suffers from triangle routing problem: The datagrams addressed to the mobile-node must be routed first to the home-agent and then to the foreign-network, even when an efficient route exists b/w the correspondent and the mobile-node.

• Solution: Use direct routing.

4.2.2.2 Direct Routing to a Mobile Node

- Four steps are involved. Figure 4.6 illustrates the 4 steps.

Steps 1 & 2

- A correspondent-agent in the correspondent's n/w first learns the COA of the mobile-node.
- This can be done by having the correspondent-agent query the home-agent.

Steps 3 & 4

- Then, the correspondent-agent forwards datagrams directly to the mobile-node's COA.

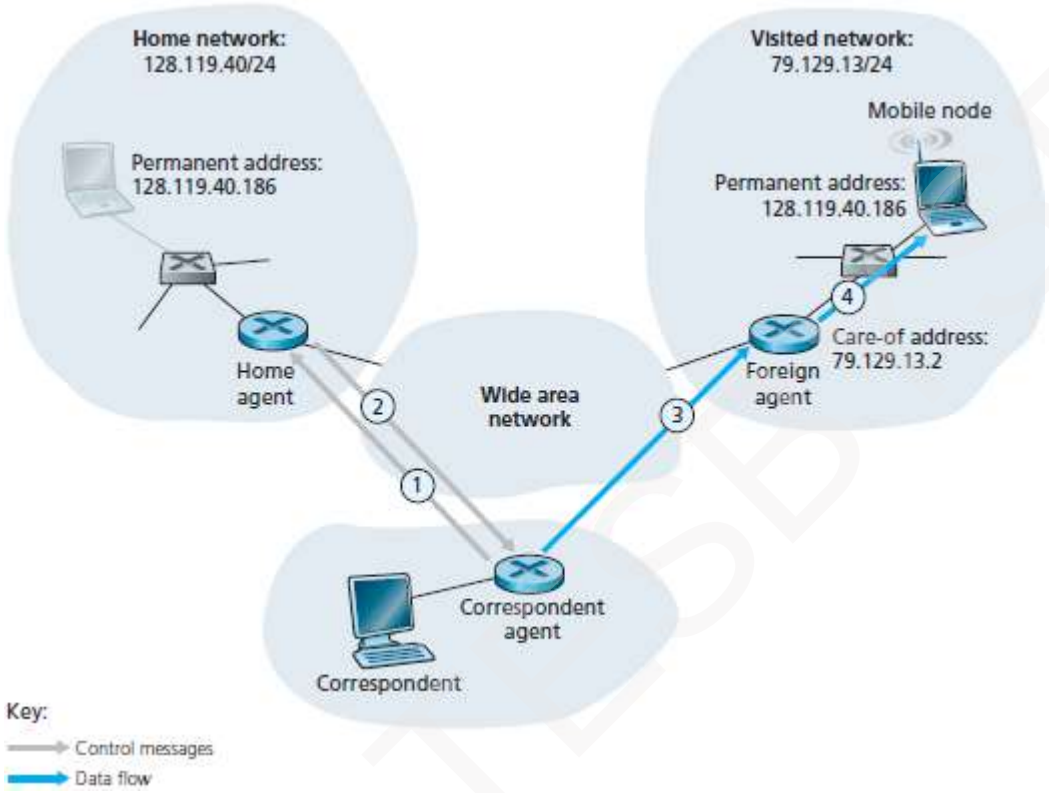

Figure 4.6: Direct routing to a mobile user

4.2.2.2.1 Challenges in Direct Routing

• Two additional challenges:

1) The correspondent-agent needs a mobile location protocol to query the home-agent to obtain the mobile-node's COA (steps 1 & 2 in Figure 4.6).

2) Problem: When the mobile-node moves from one foreign-network to another, how will data be forwarded to the new foreign-network?

Solution: Use anchor foreign-agent.

- An anchor foreign-agent refers to a foreign-agent in the foreign-network where the mobile-node was first found. (step 1 in Figure 4.7).
- When the mobile-node moves to a new foreign-network (step 2), the mobile-node registers with the new foreign-agent (step 3).
- The new foreign-agent provides the anchor foreign-agent with the mobile-node's new COA (step 4).
- When the anchor foreign-agent receives an encapsulated-datagram, the anchor re-encapsulates and forwards the datagram to the mobile-node (step 5).

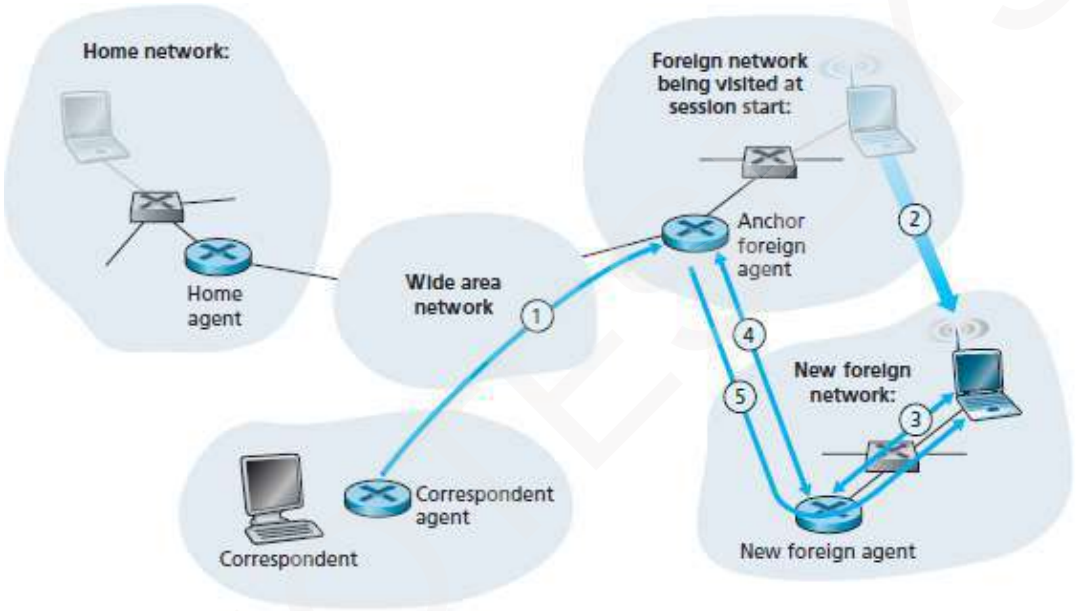

Figure 4.7: Mobile transfer between networks with direct routing

4.3 Mobile IP

- Mobile IP is the extension of IP protocol.
- Mobile IP allows laptops (or smartphones) to be connected to the Internet.
- Services of Mobile IP:
    1) Support for many different modes of operation.
    2) Multiple ways for agents and mobile-nodes to discover each other.
    3) Use of single or multiple COAs.
    4) Multiple forms of encapsulation.
- Three main parts of mobile IP:

    1) Agent Discovery

    ➢ Mobile IP defines the protocols used by a home or foreign-agent to advertise its services to mobile-nodes.

    ➢ It also defines the protocols for mobile-nodes to solicit the services of a foreign or home-agent.

    2) Registration with the Home Agent

    ➢ Mobile IP defines the protocols used by the mobile-node to register COAs with the home-agent.

    3) Indirect Routing of Datagrams

    ➢ Mobile IP defines the manner in which datagrams are forwarded to mobile-nodes by a home-agent.

    ➢ It also defines

    → rules for forwarding datagrams
    → rules for handling error conditions and
    → several forms of encapsulation

4.3.1 Agent Discovery

• A mobile-node arriving to a new network must learn the identity of the corresponding foreign or home-agent. This process is known as agent discovery.
• Two methods to perform agent discovery:
1) Via agent advertisement and
2) Via agent solicitation.

4.3.1.1 Agent Advertisement

• A foreign or home-agent advertises its services using a router discovery protocol.
• The agent periodically broadcasts a router discovery message on all links.
• The router discovery message contains
1) IP address of the agent and
2) A mobility agent advertisement extension.
• Five main fields in the extension:

1) Home Agent (H)
➢ This bit indicates that the agent is a home-agent for the network in which it resides.
2) Foreign Agent (F)
➢ This bit indicates that the agent is a foreign-agent for the network in which it resides.
3) Registration required (R)
➢ This bit indicates that a mobile-user in this network must register with a foreign-agent.
4) M, G Encapsulation
➢ These bits indicate whether an encapsulation other than IP-in-IP encapsulation will be used.
5) Care-of-address (COA) Fields
➢ This field indicates a list of one or more care-of-addresses provided by the foreign-agent.
➢ Figure 4.8 illustrates some of the key fields in the agent advertisement message.

4.3.1.2 Agent Solicitation

• A mobile-node wanting to learn about agents can broadcast an agent solicitation message.
• An agent receiving the solicitation will unicast an agent advertisement directly to the mobile-node.

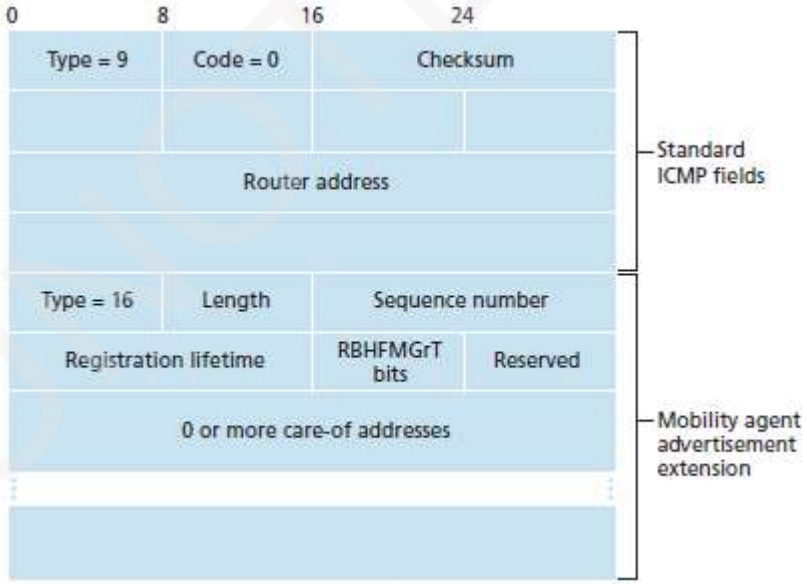

Figure 4.8: ICMP router discovery message with mobility agent advertisement extension

4.3.2 Registration with the Home Agent

• Address must be registered with the home-agent. This can be done in 2 ways:

1) Via the foreign-agent who then registers the COA with the home-agent.
2) By the mobile IP node itself.

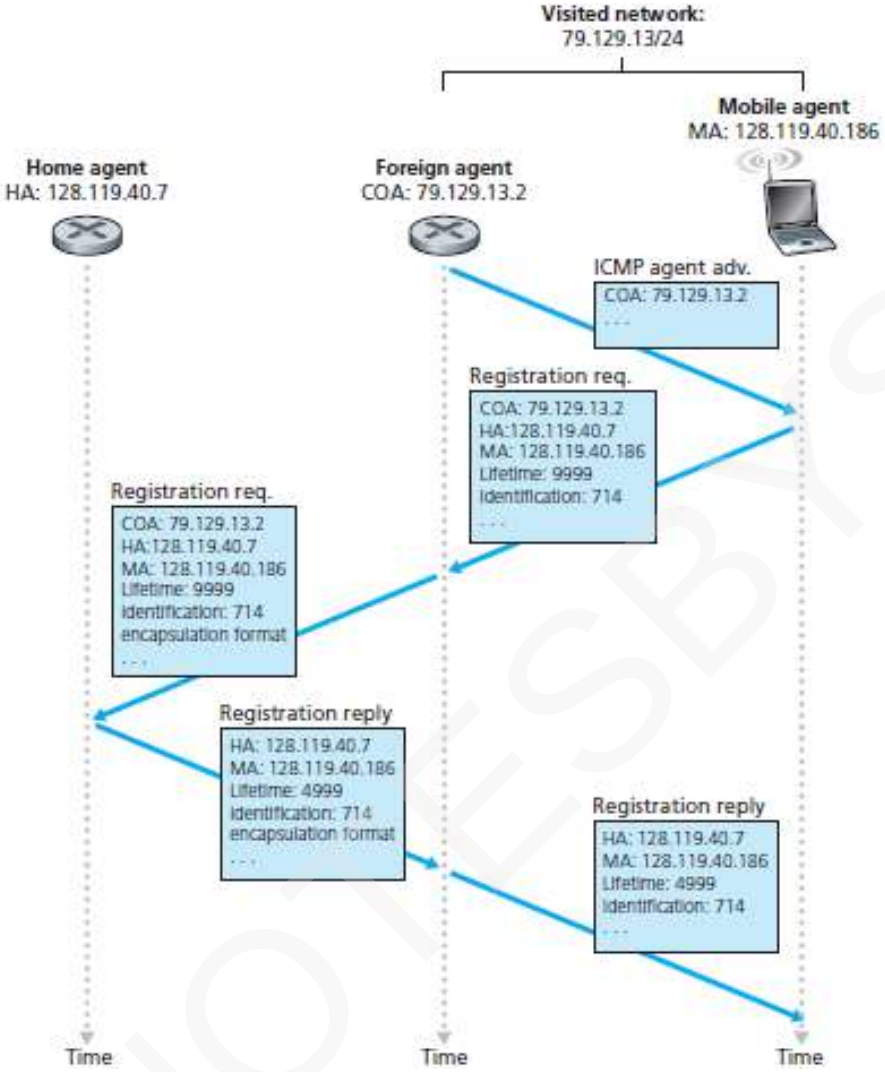

Figure 4.9: Agent advertisement and mobile IP registration

• Four steps are involved. Figure 4.9 illustrates the 4 steps.

1) When a mobile receives a foreign-agent advertisement, the mobile sends a registration-request to the foreign-agent.

- The registration-request contains
  - i) COA advertised by the foreign-agent
  - ii) address of the home-agent (HA)
  - iii) permanent-address of the mobile (MA)
  - iv) registration identification and
  - v) requested lifetime of the registration.
- The requested registration lifetime indicates number of seconds the registration is valid.
- If registration is not renewed within the specified lifetime, the registration will become invalid.

2) When the foreign-agent receives the registration-request, the foreign-agent records the mobile's permanent IP address.

- The foreign-agent then sends a registration-request to the home-agent.

3) When home-agent receives the registration-request, the home-agent checks for correctness.

- The home-agent binds the mobile's permanent IP address with the COA.
- The home-agent sends a registration-reply.

4) The foreign-agent receives and forwards the registration-reply to the mobile-node.

4.4 Managing Mobility in Cellular Networks

- GSM adopts an indirect routing approach.
- The mobile-user's home-network is referred to as home public land mobile-network (home PLMN).
- The home-network is the cellular-provider with which the mobile-user has a subscription.
- Mobile-user's visited-network is referred to as the visited public land mobile-network (visited PLMN).
- The visited PLMN is the network in which the mobile-user is currently residing.
- The responsibilities of the home and visited-networks are quite different:

1) The home-network maintains a database known as the HLR (home location register).
- The HLR contains
  - → permanent phone-number
  - → subscriber profile information.
  - → information about the current locations of the subscribers.
- In home-network, a home MSC is contacted by correspondent when a call is placed to mobile.

2) The visited-network maintains a database known as the VLR (visitor location register).
- The VLR contains an entry for each mobile-user that is currently in the network.
- Thus, VLR entries come and go as mobile-users enter and leave the network.
- A VLR is co-located with MSC that coordinates the setup of a call to & from the visited-n/w.

4.4.1 Routing Calls to a Mobile User

- Three steps are involved. Figure 4.10 illustrates the 3 steps.

1) The correspondent dials the mobile-user's phone-number.
- The call is routed from the correspondent via PSTN to the home MSC in the home-network.

2) The home MSC
- → receives the call and
- → interrogates the HLR to determine the location of the mobile-user.
- The HLR returns the roaming number.
- If HLR doesn't have the roaming number, it returns the address of VLR in the visited-network.
- Then, the home MSC queries the VLR to obtain the roaming number of the mobile-node.

3) The home MSC sets up the call through the network to the MSC in the visited-network.
- The call is completed.

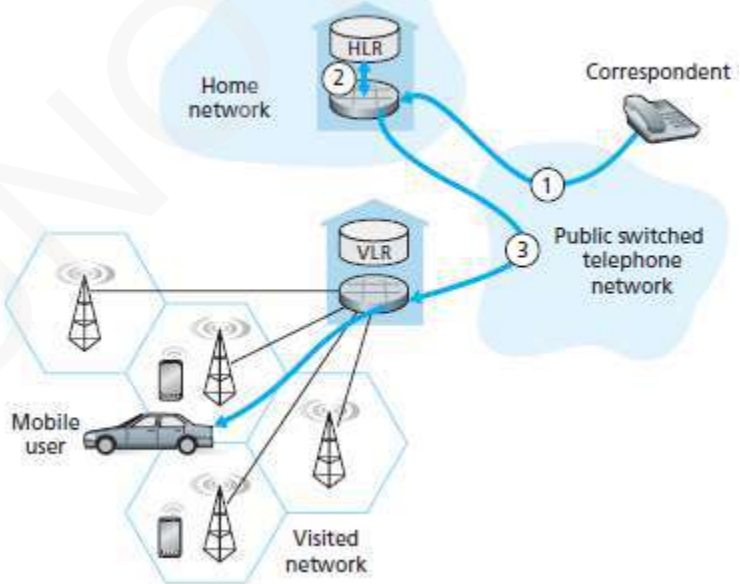

Figure 4.10: Placing a call to a mobile user: indirect routing

4.4.2 Handoffs in GSM

- A handoff occurs when a mobile-station moves from one base-station to another during a call.
- As shown in Figure 4.11,
  1) Before handoff, a call is initially routed to the mobile through old base-station.
  2) After handoff, the call is routed to the mobile through another new base-station.
- Two reasons for handoff**:**
  1) The Call may be Dropped
  - Because the signal between the current base-station and the mobile may have weakened.

  2) To reduce Congestion
  - Because a cell may be overloaded because of handling a large number of calls.
  - This congestion may be reduced by handing off mobiles to less congested cells.

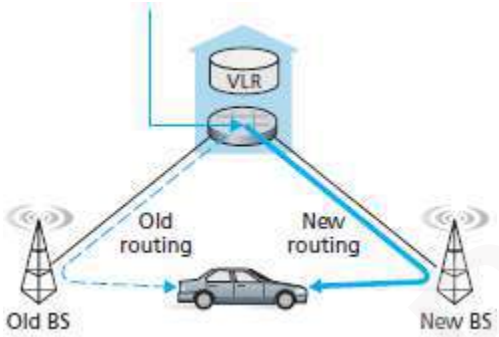

Figure 4.11: Handoff scenario between base stations with a common MSC

- Eight steps are involved. Figure 4.12 illustrates the steps involved when a hand off occurs.
  1) Old base-station (BS) informs both visited MSC & new BS that a handoff is about to happen.
  2) The visited MSC performs following tasks:
     i) Initiates path setup to the new BS.
     ii) Allocates the resources needed to carry the rerouted call.
     iii) Signals the new BS that a handoff is about to occur.
  3) The new BS allocates and activates a radio-channel for the mobile.
  4) The new BS informs both visited MSC and old BS that the new path is set up.
  5) The mobile is informed to perform a handoff.
  6) The mobile & new BS exchange signaling messages to fully activate the new channel.
  7) The mobile sends a handoff complete message to the new BS.
     - This message is then forwarded to the visited MSC.
     - The visited MSC then reroutes the ongoing-call to the mobile via the new BS.
  8) The resources allocated along the path to the old BS are released.

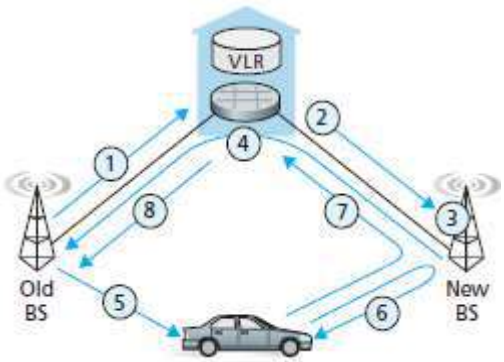

Figure 4.12: A handoff between base stations with a common MSC

4.4.2.1 Problem of Handoffs

- Problem: How inter-MSC handoff occurs?
  - Solution: Use an anchor MSC.
  - This operation is shown in Figure 4.13.
  - The anchor MSC is the MSC visited by the mobile when a call first begins.
  - When a mobile moves from one MSC to another, the ongoing-call is rerouted from the anchor MSC to the new visited MSC.

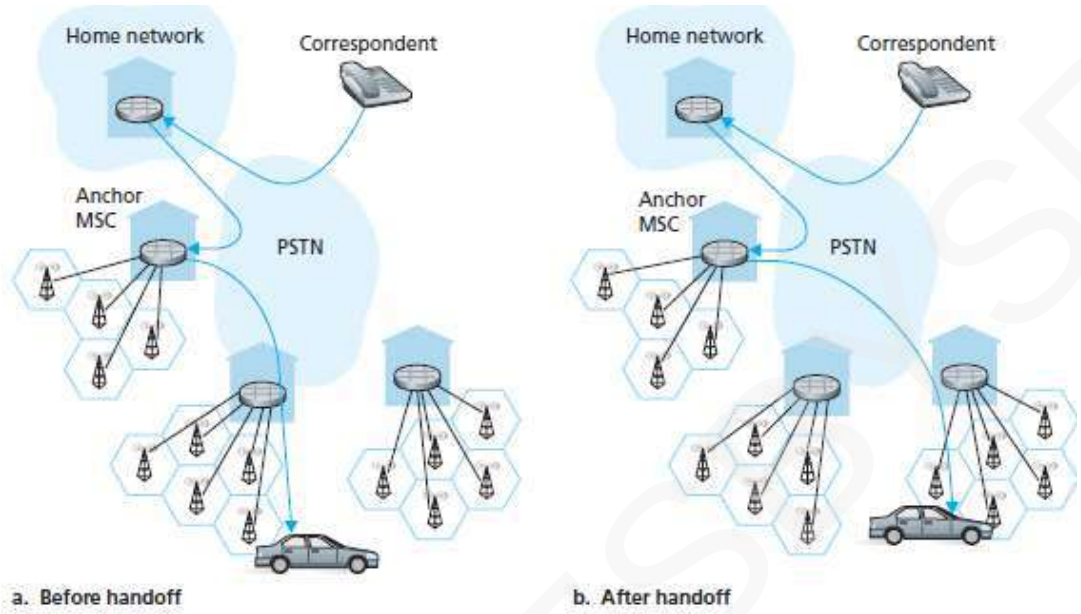

Figure 4.13: Rerouting via the anchor MSC

4.5 Wireless and Mobility: Impact on Higher-Layer Protocols

4.5.1 Commonalities between Mobile IP & GSM

Table 4.1: Commonalities between mobile IP and GSM mobility

GSM element	Comment on GSM element	Mobile IP element
Home system	Network to which the mobile user's permanent phone number belongs.	Home network
Gateway mobile switching center or simply 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 simply 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

4.5.2 TCP Congestion Control Approaches

• Three approaches for dealing with TCP's congestion-control: 1) Local recovery 2) TCP sender awareness of wireless-links and 3) Split-connection approaches

1) Local Recovery

- These protocols recover from bit-errors. For ex: ARQ protocol.

2) TCP Sender Awareness of Wireless Links

- The sender and receiver must be aware of the existence of a wireless-link.
- The sender and receiver must be to distinguish between
  - → congestive losses occurring at the wired-network and
  - → congestive losses occurring at the wireless-network.
- Sender & receiver invoke congestion-control only in response to congestive wired-n/w losses.

3) Split Connection

- The end-to-end connection b/w mobile-user & other end-point are broken into 2 connections:
  1) One connection from the mobile-host to the wireless access-point.
  2) Another connection from the wireless access-point to the other end-point.
- Thus, the end-to-end connection is formed by concatenation of a wireless-part & a wired-part.

MODULE-WISE QUESTIONS

PART 1

1) With a diagram, explain various components of 2G system architecture. (6*)
2) With a diagram, explain various components of 3G system architecture. (8*)
3) With a diagram, explain various components of mobile network architecture. (6*)
4) With a diagram for each, explain indirect & direct routing. (8*)
5) With a diagram, explain the problem & its solution in direct routing. (4)

PART 2

6) Briefly explain mobile IP & its services. (4*)
7) With a diagram, explain the following with respect to mobile IP: (8*)
    i) Agent Discovery
    ii) Registration with the home agent
8) With a diagram, explain how a call is placed to a mobile user. (4*)
9) With a diagram, explain the concept of handoffs. (6*)
10) Compare mobile IP and GSM mobility. (4)
11) Briefly explain TCP congestion control approaches. (4)