# Wireless and Mobile Network Architecture

## Chapter 2: Mobility Management

Prof. **Yuh-Shyan Chen**
Department of Computer Science and Information Engineering
National Taipei University
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## Outline

- Introduction
- Handoff
- Roaming Management
- Roaming Management through SS7
- Summary

## Introduction

- In the PCS system architecture (Fig. 2.1), the mobile service area is covered by a set of BSs which are responsible for relaying the call to/from the MSs
- The BSs are connected to MSCs by land links.
- MSC interfaces the MSs (via BSs) with the PSTN

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## Cont.

- Two types of databases are used for roaming management
  - **Home Location Register (HLR)**
  - **Visitor Location Register (VLR)**
- Examples of the protocols to support mobility management
  - EIA/TIA Interim Standard 41 (IS-41 or ANSI-41)
  - GSM Mobile Application Part (MAP)

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## Fig. 2.1 A common PCS network architecture

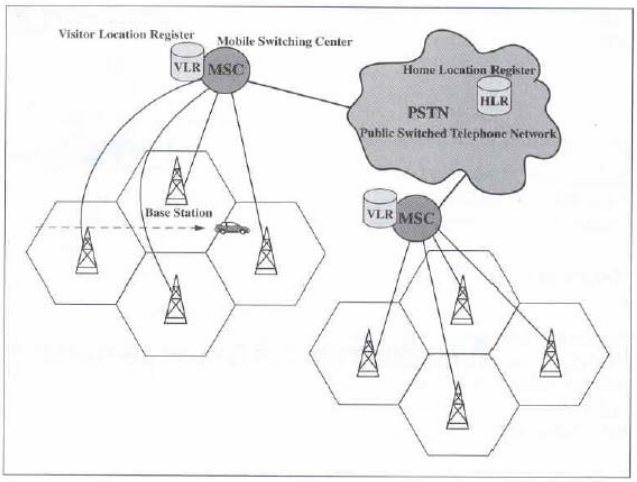


Figure 2.1 A common PCS network architecture.

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## Fig. 2.1 A common PCS network architecture

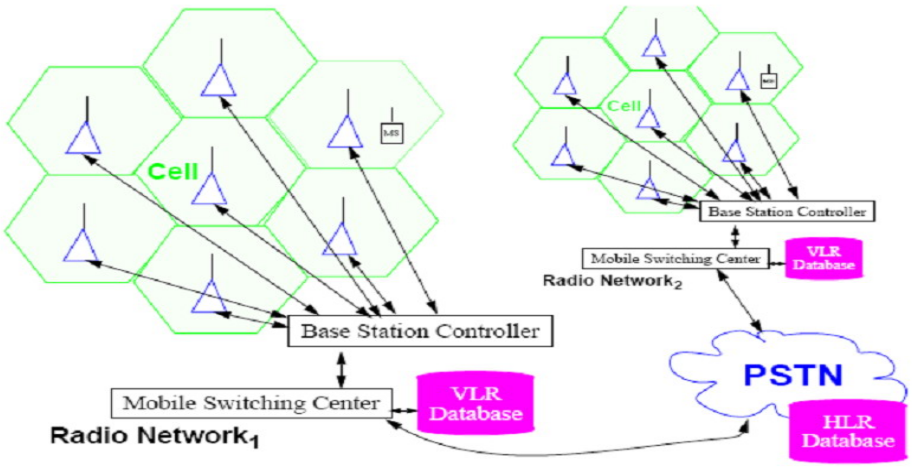


Figure 2.1: PCS network architecture.

## Two Aspects of Mobility in a PCS Network

- Handoff (link transfer, or handover)
  - When a mobile user is engaged in conversion, the MS is connected to a BS via a radio link
  - If the mobile user moves to the coverage area of another BS, the radio link to the old BS is disconnected, and a radio link to the new BS should be established to continue the conversation
- Roaming
  - When a mobile user moves from one PCS system (e.g., the system in Chiayi) to another (e.g., the system in Taipei), the system should be informed of the current location of the user



## Three Strategies for Handoff Detection

- **Mobile-Controlled Handoff (MCHO)**
  - MCHO is used in DECT and PACS
  - The MS continuously monitors the signal of the surrounding BSs,
  - The MS initiates the handoff process when some handoff criteria are met.
- **Network-Controlled Handoff (NCHO)**
  - NCHO is used in CT-2 plus and AMPS
  - The surrounding BSs measure the signal from the MS
  - The network initiates the handoff process when some handoff criteria are met.

## Cont.

- **Mobile-Assisted Handoff (MAHO)**
  - MAHO is used in GSM and IS-95
  - The network asks the MS to measure the signal from the surrounding BSs,
  - The network makes the handoff decision based on reports from the MS



## Inter-BS Handoff

- **The new and old BSs are connected to the same MSC** (Assumed that the need for handoff is detected by MS)
  - The MS ***momentarily suspends conversation*** and initiates the handoff procedure by signaling on an idle channel in the new BS. Then it resumes the conversation on the old BS.
    - Fig. 2.2(a)

# Fig. 2.2 Inter-BS link transfer

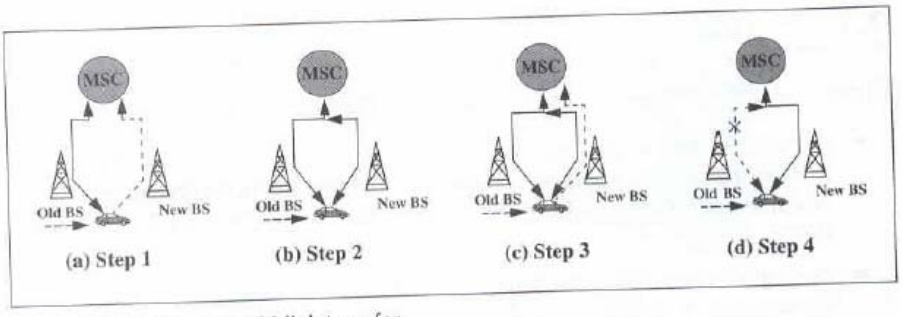


**Figure 2.2** Inter-BS link transfer.



# Cont.

- Upon receipt of the signal, the MSC transfers the encryption information to the selected idle channel of the new BS and ***sets up the new conversation path to the MS through that channel***. The switch bridges the new path with the old path and informs the MS to transfer from the old channel to the new channel.
  - Fig. 2.2(b)

## Cont.

- After the MS has been transferred to the new BS. It ***signals*** the network, and ***resumes conversation*** using the new channel
  - Fig. 2.2(c)
- Upon receipt of the handoff completion signal, the network ***removes the bridge from the path and releases resources*** associated with the old channel.
  - Fig. 2.2(d)



## Cont.

- For NCHO, all handoff signaling messages are exchanged between the MS and the old BS through the failing link. Thus, the whole process must be completed as quickly as possible.
- If the new BS does not have an idle channel, the handoff call may be dropped (forced to terminate).
- Forced termination of an ongoing call is considered less desirable than blocking a new call attempt.

## Channel Assignment Schemes for Handoff Calls

- **Nonprioritized Scheme**
  - The networks handle a handoff in the same manner as a new call attempt
- **Reserved Channel Scheme**
  - Similar to the nonprioritized scheme, except that some channels in each BS are reserved for handoff calls

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## Cont.

- **Queuing Priority Scheme**
  - Based on the fact that adjacent coverage areas of BSs overlap
  - There is a considerable area where a call can be handled by either BS, which is called the handoff area
  - If no new channel is available in the new BS during handoff, the new BS buffers the handoff request in a waiting queue.
  - The MS continues to use the channel with the old BS until either a channel in the new BS becomes available

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## Cont.

- **Subrating Scheme**
  - The new BS creates a new channel for a handoff call by sharing resources with an existing call if no free channel is available.
  - Subrating means an occupied full-rate channel is temporarily divided into two channels at half the original rate.
  - One half-rate channel is to server the exiting call, and the other half-rate channel is to serve the handoff request
  - When occupied channels are released, the subrated channels are immediately switched back to the full rate channels.

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## 2.1.2 Intersystem Handoff

- **Step 1**
  - **MSC A** requests a **MSC B** to perform **handoff measurements** on the call in progress.
  - MSC then selects a **candidate BS**, BS2, and interrogates it for signal quality parameters.
  - MSC B returns the signal quality parameters, along with other relevant information, to MSC A.

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# Fig. 2.3 Intersystem handoff

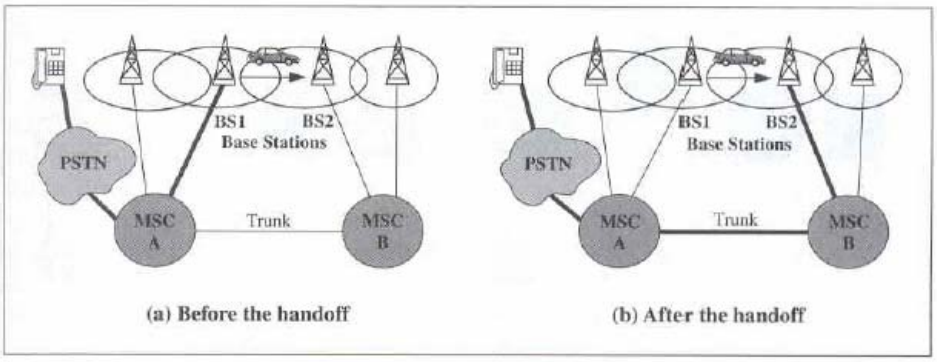


**Figure 2.3** Intersystem handoff.



# Cont.

- **Step 2**
  - MSC A checks if the MS has made too many handoffs recently (e,g,, to avoid that MS is moving within overlapped area) or if intersystem trunks are not available.
  - If so, MSC A exists the procedure
  - Otherwise, MSC A asks MSC B to set up a **voice channels**.

## Cont.

- **Step 3**
  - MSC A sends the MS a handoff order
  - The MS synchronizes to BS 2.
  - After the MS is connected to BS 2, MSC B informs MSC A that the handoff is successful.
- MSC A is referred to as the ***anchor MSC***, and is always in the call path before and after the handoff.

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## Anchor Approach

- If the MS moves back to MSC A again, the connection between MSC A and MSC B is removed.
- If the MS moves to the third MSC C, the MSC B will be in the call path.
- **Path Minimization**
  - When the MS moves to the third MSC, the second MSC may be removed from the call path
  - The link between MSC A and MSC B is disconnected, and MSC C is connected MSC A directly.

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## Fig. 2.4 Handoff forward, handoff backward, and handoff to the third

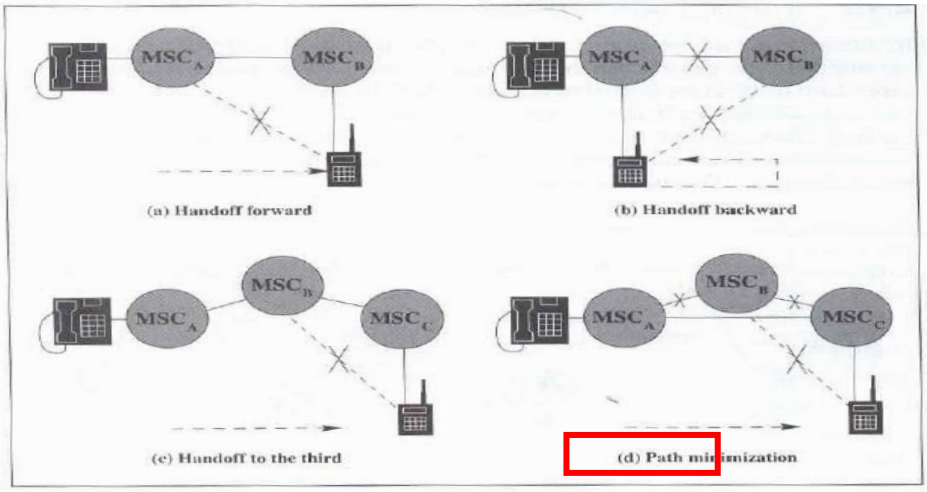


**Figure 2.4** Handoff forward, handoff backward, and handoff to the third.

## 2.2 Roaming Management

- Two basic operations in roaming management are
  - **Registration (or Location Update)**
    - The process whereby an MS informs the system of its current location
  - **Location Tracking**
    - The process during which the system locates the MS (this process is required when the network attempts to deliver a call to the mobile user)

## Cont.

- The roaming management schemes proposed in **IS-41** and **GSM MAP** are two-level strategies
- They use a two-tier system of home and visited databases that are
  - **Home Location Register (HLR).**
  - **Visited Location Register (VLR).**

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## Home Location Register (HLR)

- When a user subscribes to the services of a PCS network, a record is created in the system's database
  - Which is referred as to the home system of the mobile user.
- HLR is a network database that stores and manages all subscriptions of a specified operator.

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## Cont.

- The information contained in HLR includes
  - MS identity
  - Directory number
  - Profile information
  - Current location
  - Validation period



## Visitor Location Register (VLR)

- When the mobile user visits a PCS network other than the home system, a temporary record for the mobile user is created in the **visitor location register (VLR)** of the visited system.
- The VLR temporarily stores subscription information for the visiting subscribers.

## Cont.

- The MSC (corresponding with the VLR) can provide service to the mobile user.
- The VLR is the “other” location register used to retrieve information for handling calls to/from a visiting mobile users.



## MS Registration Process (Fig. 2.5)

- Step 1
  - Suppose that the home system of a mobile user is in Morristown. When the mobile user moves from one visited system (e.g., New York City) to another (e.g., Los Angeles), it must register in the VLR of the new visited system.
- Step 2
  - The new VLR informs the mobile user’s HLR of the person’s current location (the address of the new VLR)
  - The HLR sends an ACK., which includes the MS’s profile, to the new VLR

# Fig. 2.5 MS registration process

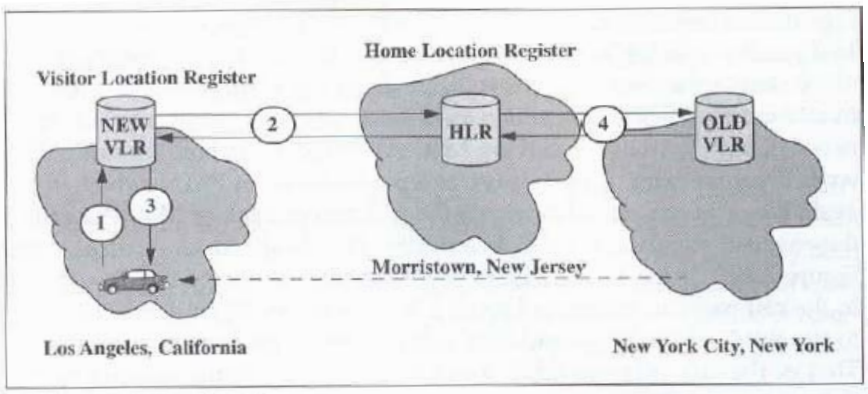


**Figure 2.5** MS registration process.



# Cont.

- Step 3
  - The new VLR informs the MS of the successful registration.
- Step 4
  - After Step 2, the HLR also sends a deregistration message to cancel the obsolete location record of the MS in the old VLR.
  - The old VLR acknowledges the deregistration.

## Call Origination Procedure

- To originate a call, the MS executes the following steps.
  - MS contacts the MSC in the visited PCS network.
  - The call request is forwarded to the VLR for approval.
  - If the call is accepted, the MSC sets up the call to the called party following the standard PSTN call setup procedure.

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## Call Delivery (Call Termination/Location Tracking) (Fig. 2.6)

- **Step 1**
  - **If a wireline phone attempts to call a mobile subscriber**, the call is forwarded to a switch, called the originating switch in the PSTN.
  - The originating switch queries the **HLR** to find the current VLR of the MS.
  - The HLR queries the VLR in the which the MS resides to get a **routable address**.

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## Fig. 2.6 Call delivery procedure

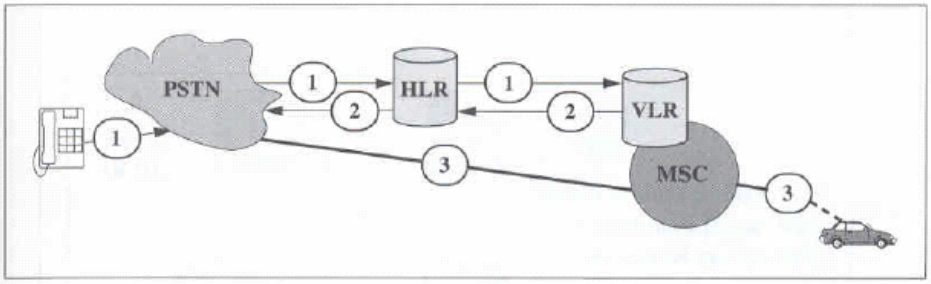


**Figure 2.6** Call delivery procedure.



## Cont.

- Note that, if the originating switch is not capable of querying the HLR (i.e., it is not equipped to support mobility), the call is routed through the PSTN to the subscriber's Gateway MSC, which queries the HLR to determine the current VLR serving the MS.
- **Step 2**
  - The VLR returns the routable address to the originating switch through HLR.
- **Step 3**
  - Based on the routable address, a trunk (voice circuit) is set up from the originating switch to the MS through the visited MSC.

## Roaming Management under SS7

- How is **mobile roaming managed** by the **PSTN** signaling
  - By using **SS7**.
- **Signaling System No. 7** (SS 7) is a *Common Channel Signaling* (**CCS**) system.



## Cont.

- SS7 is developed to satisfy the telephone operating companies' requirement for an improvement to the earlier signaling systems, which is lacked the sophistication required to deliver mush more than **plain old telephone service** (**POTS**).
- Signaling between a PCS network and the PSTN are typically achieved by the SS7 network.

## Common Channel Signaling (CCS)

- CCS is a **out-of-band** signaling network that provides **control** and **management functions** in the telephone network.
- CCS consists of
  - **Supervisory functions**
  - **Addressing**
  - **Call Information Provisioning**



## Cont.

- Functions provided by CCS are
  - To convey messages to initiate and terminate calls
  - To determine the status of some part of the network
  - To control the amount of traffic allowed

## Three Distinct Components of SS7 (Fig. 2.7)

- **Service Switching Point (SSP)**
  - A telephone switch interconnected by SS7 links.
  - The SSPs perform call processing on calls that originate, tandem, or terminate at that nodes.
  - A local SSP in the PSTN can be central or end office (EO).
  - An SSP in a PCS network is called a mobile switching center (MSC).



## Fig. 2.7 Interconnection between a PCS and the PSTN

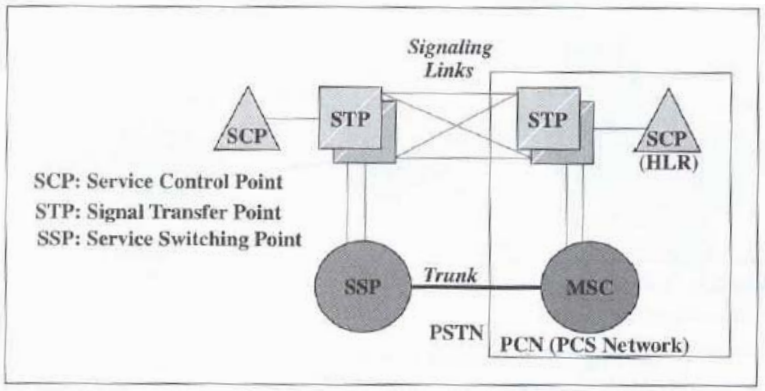


**Figure 2.7** Interconnection between a PCS network and the PSTN.

## Cont.

- **Signal Transfer Point (STP)**
  - A **switch** that reply SS7 message between **network switched** and **databases**
  - Based on the address fields of the SS7 messages, the STPs route the message to the correct out-going signal links.
  - For the reliability requirements, STPs are provisioned in mated pairs.

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## Cont.

- **Service Control Point (SCP)**
  - SCP contains databases for providing enhanced services.
  - An SCP accepts queries from an SSP and returns the requested information to the SSP.
  - In mobile applications, an SCP may contains an HLR or VLR.
- **In SS7 network, the trunks (voice circuits) connects SSPs to carry user data/voice information.**

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## Cont.

- **The signaling links connects SCPs to STPs, and STPs to SSPs.**
- **The SSPs and SCPs are connected indirectly through STPs.**



## Registration through SS7

- **Example: the MS moves from VLR1 to VLR2.**
- **Step 1**
  - The MS enters the area controlled by MSC2.
  - MSC 2 lunches a registration query to its VLR through **STP2**, assuming that VLR2 and MSC2 are not co-located.
- **Step 2**
  - VLR2 sends a registration message to the MS's HLR (HLR4).

## Fig. 2.8 Registration through SS7

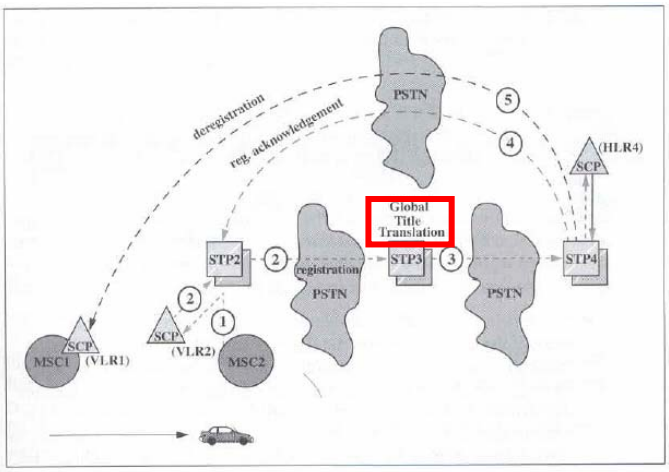


Figure 2.8 Registration through SS7.



## Cont.

- VLR2 may not know the actual address of HLR. Instead, VLR2 sends the message to containing the MS identity, called ***Mobile Identification Number*** (***MIN***), to an STP (STP3) that can translate the MIN into the HLR address.

- **Step 3**
  - The **MIN-to-HLR address translation** is performed at STP3 by a **table-lookup technique** called ***Global Title Translation*** (***GTT***). STP3 the forwards the registration message to HLR.

## Cont.

- **Step 4**
  - After the registration, HLR sends an acknowledgement back to VLR2. Since the address of VLR2 is known, the acknowledgement may be sent to VLR2 using a shortcut, without passing through STP3.
- **Step 5**
  - After Step 3, HLR sends a **deregistration** message to VLR1 to cancel the obsolete record. VLR1 then acknowledges the cancellation.



## Reducing the "Cost" of Deregistration

- **Approach 1: Implicit Deregistration**
  - Obsolete VLR records are deleted until the database is full.
  - If the database if full when an MS arrives, a record is deleted, freeing storage space to accommodate the newly arrived MS.
  - A replacement policy is required to select a record for replacement. (Note that a valid record is replaced, and the information is lost).
- Advantage
  - No deregistration message are sent among the SS7 network elements.

## Cont.

- **Approach 2: Periodic Re-registration.**
  - The MS periodically re-registers to the VLR.
  - If the VLR does not receive the re-registration message within a timeout period, the record is deleted
- Advantage
  - This approach only creates local message traffic between the MSC and the VLR.
  - No SS7 messages are generated if the VLR is co-located with the MSC.



## Reducing the **Registration Traffic** – Pointer Forwarding Scheme

- **Move Operation (registration)**
  - When an MS moves from one VLR to another, a pointer is created from the old VLR to the new VLR.
  - No registration to the HLR is required.
- **Find Operation (call delivery)**
  - When the HLR attempts to locate the MS for call delivery, the pointer chain is traced.
  - After the find operation, the HLR points directly to the destination VLR.

## Fig. 2.9 Pointer forwarding scheme

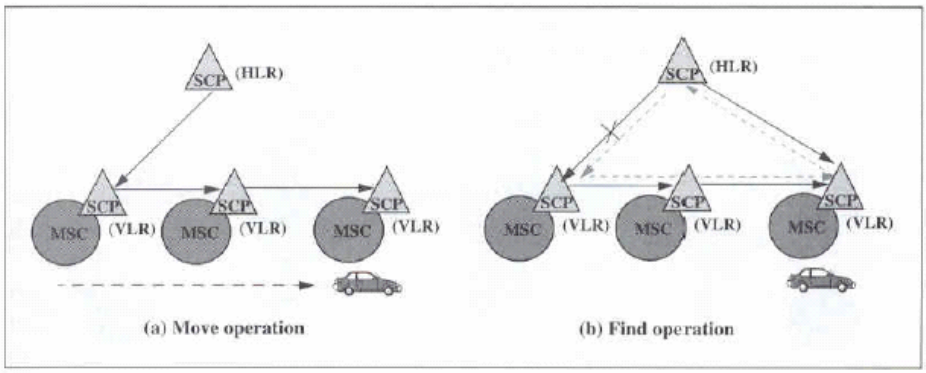


**Figure 2.9** Pointer forwarding scheme.



## **Call Delivery** through SS7

- Similar to the registration process, visited to several STPs, and a GTT maybe required to access the HLR in call delivery
- Several STPs may be visited to obtain the routable address from the VLR.
- To reduce the call delivery traffic, a cache scheme was proposed.

## Fig. 2.10 Call delivery through SS7

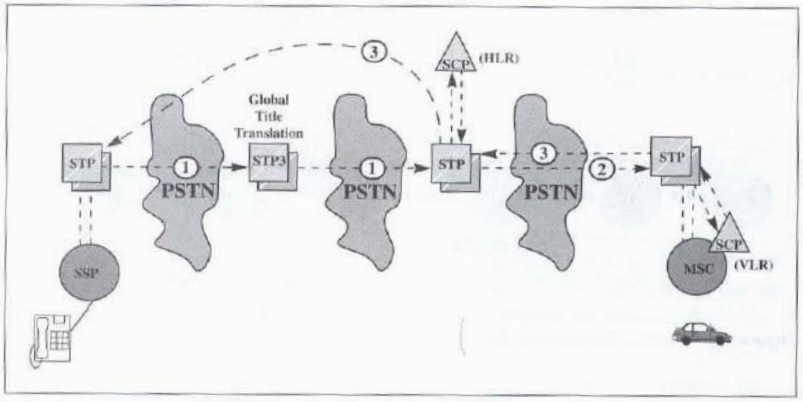


**Figure 2.10** Call delivery through SS7.



## Cache Scheme

- Two possible positions for the cache,
  - **Method 1:** The cache is maintained in the originating **SSP**s.
  - **Method 2:** The cache is maintained in the **STP** that performs GTTs.
- A cache entry consists of two fields:
  - **The MIN of an MS**
  - **The current visited VLR of the MS**
- The cache contains entries for MSs recently accessed from the SSP.

## Fig. 2.11 Cache scheme

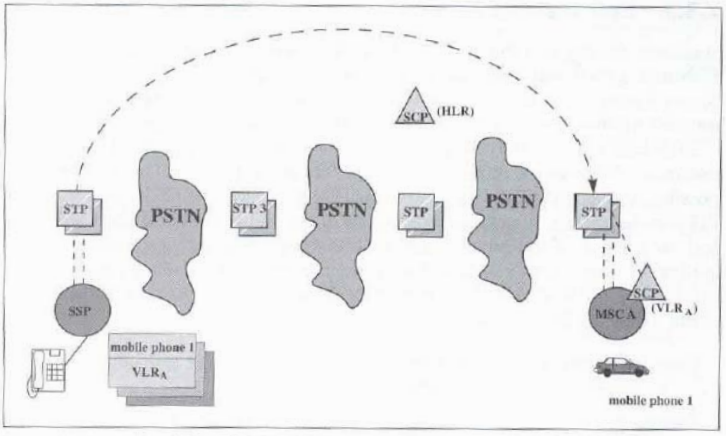


Figure 2.11 Cache scheme.



## Cont.

- When the calling party originates a call to an MS, the SSP first checks if the cache entry for the MS exists. Three possibilities are
  - **Case 1: The cache entry does not exists**
    - The call delivery is processed following the normal procedure.
  - **Case 2: The cache entry exists and is current**
    - The VLR is directly accessed.

## Cont.

- **Case 3: The cache entry exists but is obsolete**
  - Then procedure detects that the cache entry is obsolete if the queried VLR's response is negative. The normal procedure is executed.



## 2.4 Roaming Management for CT2

- In a public environment, CT2 is a one-way calling PCS system
  - A CT2 handset can originate calls, but cannot receive incoming calls.
- To construct two-way calling mechanism into CT2

## 2.4.1 Basic Public CT2 System (One-Way Calling)

**Fig. 2.12 Basic public CT2 system**

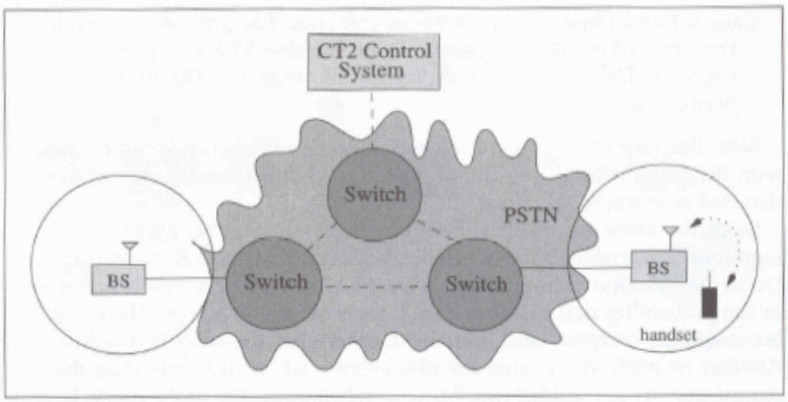


**Figure 2.12** Basic public CT2 system.

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## Fig. 2.13 Meet-at-junction architecture (Two-Way Calling)

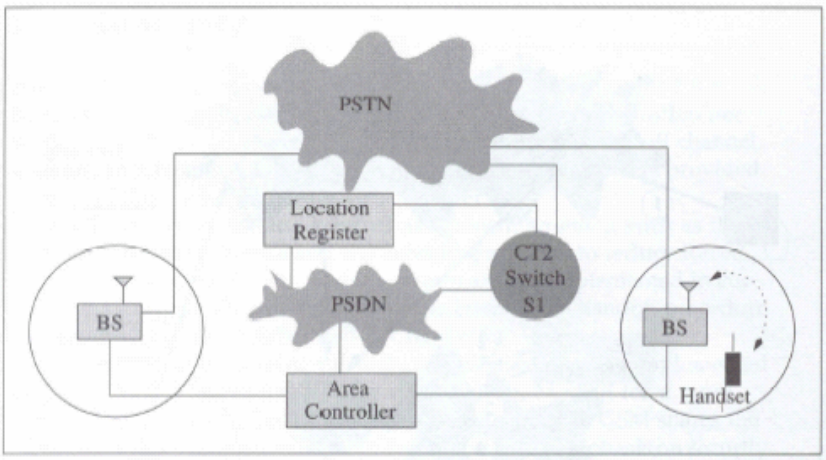


**Figure 2.13** Meet-at-a-junction architecture.

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# Fig. 2.14 CT2 call delivery procedure

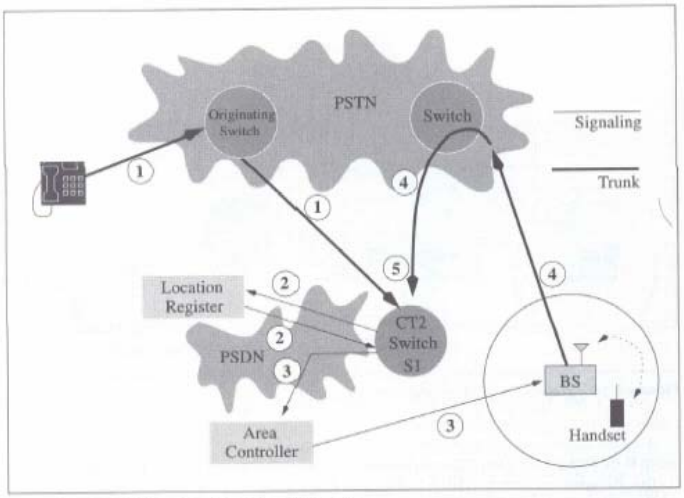


Figure 2.14 CT2 call delivery procedure.



# Call Delivery Procedure

- **Step 1**
  - When the calling party dials the number of a CT2 handset, a voice trunk is set up from the originating switch to the CT2 switch S1.
- **Step 2**
  - S1 queries the location register to identify the area controller of the handset.




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## Cont.

- **Step 3**
  - An alerting message is sent from S1 to the corresponding area controller via the PSDN.
  - The area controller then broadcasts the alerting message to the connected BSs to page the handset.
- **Step 4**
  - If the handset responds, the corresponding base station redials to S1 through PSTN.
- **Step 5.**
  - S1 bridges the two trunks, and the conversation begins.