GSM Mobility Databases

Outline

- Mobility Databases
- Failure Restoration
- VLR Identification Algorithm
- VLR Overflow Control
- Summary

Two Issues of GSM Mobility Databases

- Fault Tolerance
  - If the location database fail, the loss or corruption of location information will seriously degrade the service offered to the subscribers.
- Database Overflow
  - The VLR may overflow if too many users move into the VLR-controlled area in a short period.
  - If the VLR is full when a mobile user arrives, the user fails to register in the database, and thus cannot receive cellular service.
  - This phenomenon is called VLR overflow.

Mobility Databases: Home Location Register (HLR)

- Mobile Station Information. For example,
  - the IMSI (used by the MS to access the network)
  - MSISDN (which is the ISDN number — "Phone Number" of the MS)
- Location Information. For example,
  - the ISDN number (address) of the VLR (where the MS resides)
  - the ISDN number of the MSC (where the MS resides)
- Service Information. For example,
  - service subscription
  - service restrictions
  - supplementary services

Mobility Databases: Visitor Location Register (1/2)

- Mobile Station Information. For example,
  - IMSI
  - MSISDN
  - TMSI
- Location Information. For example,
  - MSC Number
  - Location Area ID (LAI)

Mobility Databases: Visitor Location Register (2/2)

- Service Information.
  - A subset of the service Information stored in HLR
- Note that in the MS-related fields
  - Length TMSI <= 8 digits (TMSI structure defined by the operator)
  - LAI = XXX + XX + XXXXXXXXXXXXXXXX

    (Mobile Country Code) + (Mobile Network Code) + (location access code)

VLR Failure Restoration

- Service Information of a VLR record recovered by
  - The first contact between the VLR and the HLR of the corresponding MS.
- Location Information of a VLR record recovered by
  - First radio contact between the VLR and the MS
- Mobile Station Information of a VLR record recovered by
  - Either by contact with the HLR or the MS

VLR Record Restoration Initiation Event 1 —MS Registration

- The VLR considers the registration as a case of inter-VLR movement.
- Following the normal registration procedure defined in inter-VLR movement.
- In this case, the TMSI sent from the MS to the VLR cannot be recognized, and the MS is asked to send IMSI over the air.

VLR Record Restoration Initiation Event 2 —MS Call Origination

- When the VLR receives the call origination request MAP_SEND_INFO_OUTGOING_CALL from the MSC, the VLR record of the MS is not found.
- The VLR considers the situation as a system error, with the cause “unidentified subscriber”.
- The request is rejected, and the MS is asked to initiate the location registration procedure.

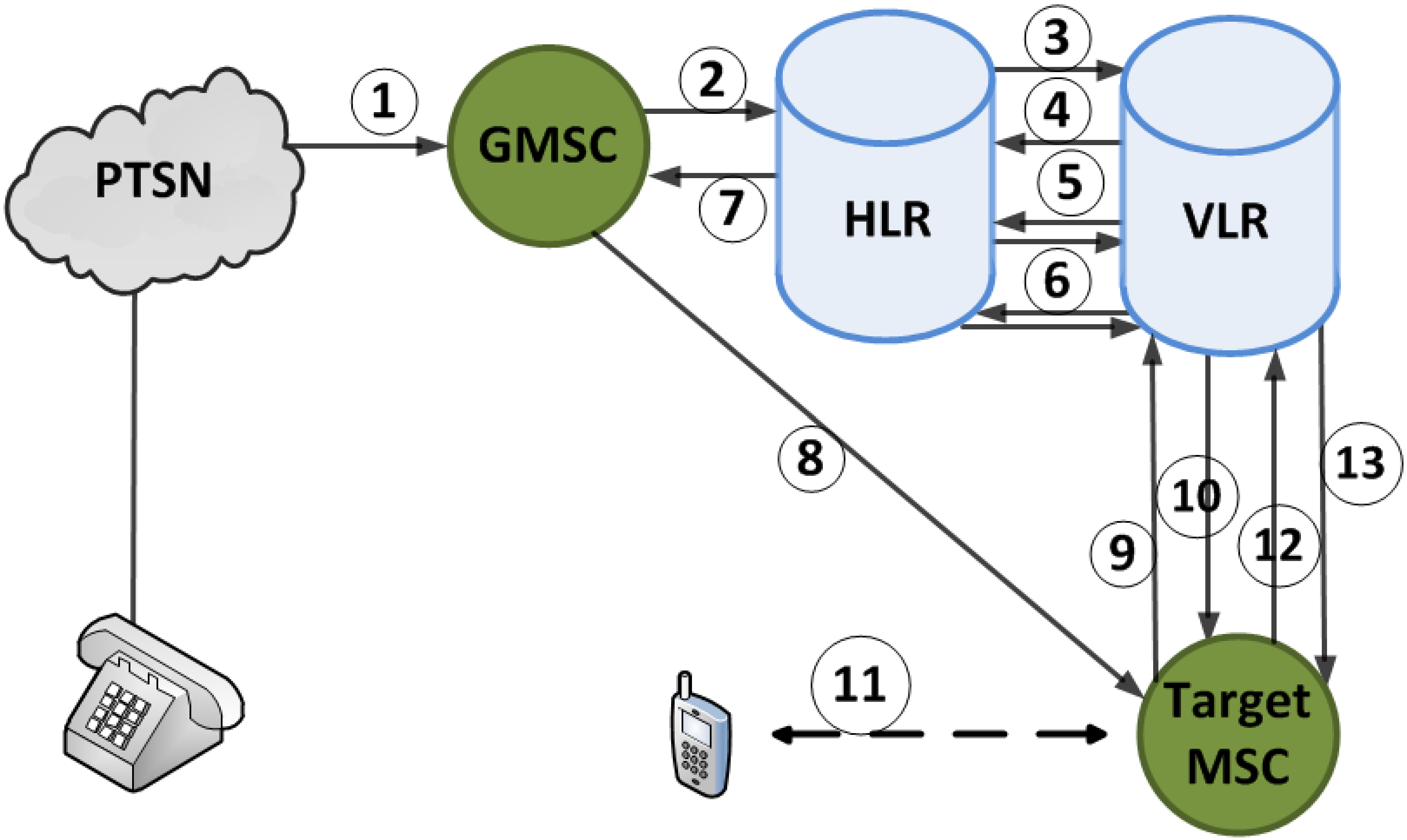
VLR Record Restoration Initiation Event 3 — MS Call Termination (1/8)

- Steps 1-3. Similar to the first three steps of the basic call termination procedure, the VLR is queried to provide the MSRN.
  - Note that since the record has been erased after the failure, the search fails. The VLR creates a VLR record for the MS.
  - Neither the service nor the location info is available.

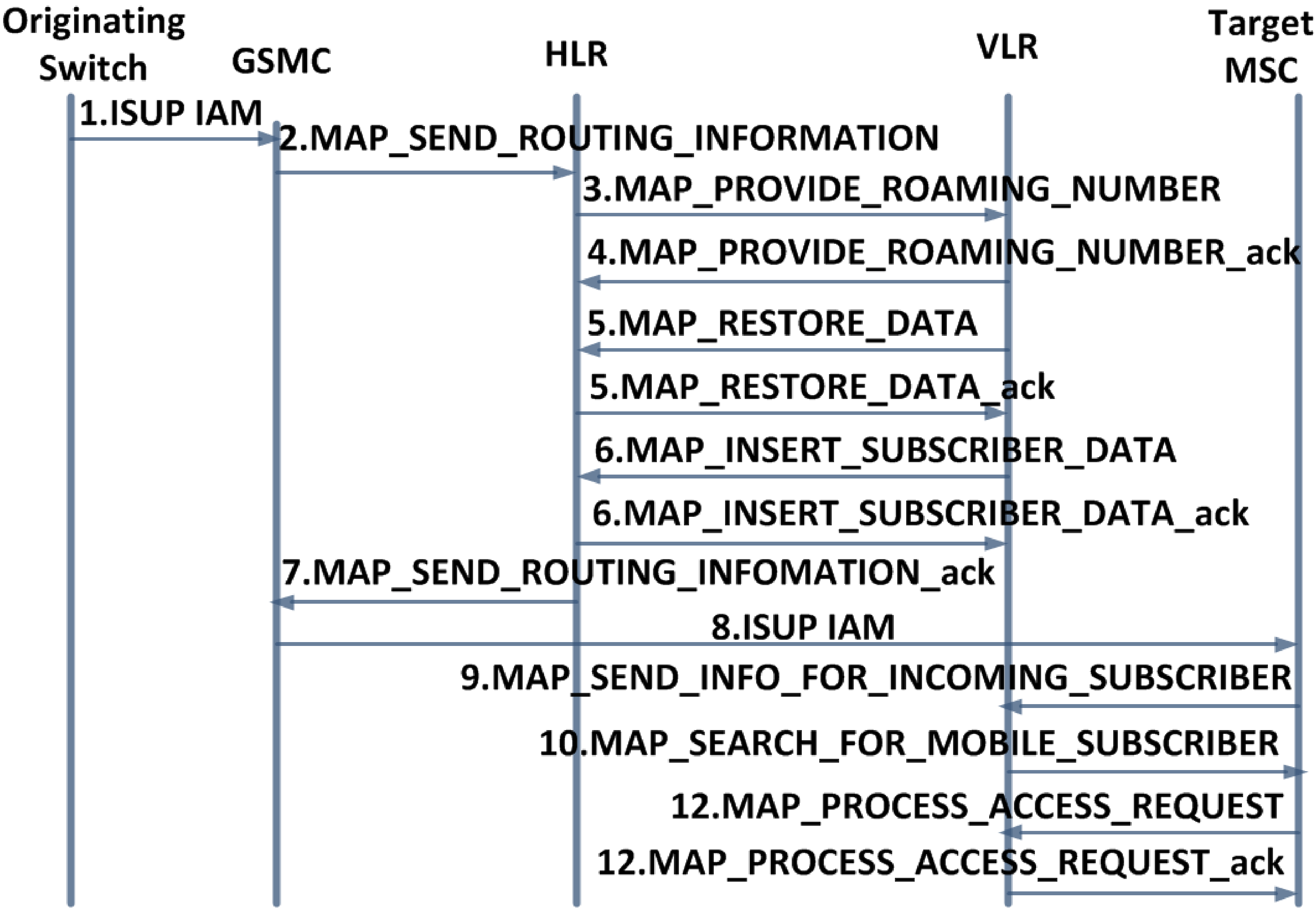
VLR Record Restoration Initiation Event 3 — MS Call Termination (2/8)

- Steps 4 and 7.
  - Since the VLR does not have the routing information, it uses the MSC number provided by MAP_PROVIDE_ROAMING_NUMBER message to create MSRN.
  - The number is sent back to the gateway MSC to setup the call in Step 8.

Call Termination Message (Failure Restoration) (1/2)



Call Termination Message (Failure Restoration) (2/2)



VLR Record Restoration Initiation Event 3 — MS Call Termination (3/8)

- Steps 5 and 6.
  - The VLR recovers the service information of the VLR record by sending a MAP_PROVIDE_ROAMING_NUMBER message to the HLR.
  - The HLR sends the service information to the VLR using the MAP_INSERT_SUBSCRIBER_DATA message.

VLR Record Restoration Initiation Event 3 — MS Call Termination (4/8)

- At this point, the service information of the VLR record has been recovered.
- However, the location information, specifically, the LAI number, still not available. This information will be recovered at Step 11.

- Note that Steps 4 and 5 can be executed in parallel.

VLR Record Restoration Initiation Event 3— MS Call Termination (5/8)

- Step 8. After the gateway MSC receives the MSRN in Step 7, the SS7 ISUP message IAM is sent to the target MSC.

VLR Record Restoration Initiation Event 3 — MS Call Termination (6/8)

- Steps 9-11.
  - The target MSC does not have the LAI info of the MS.
  - In order to proceed to set up the call, the MSC sends the message MAP_SEND_INFO_FOR_INCOMING_CALL to the VLR.
  - Unfortunately, the VLR does not have the LAI info either.
  - Hence the VLR asks the MSC to determine the LA of the MS by sending a MAP_SEARCH_FOR_MOBILE_SUBSCRIBER message.

VLR Record Restoration Initiation Event 3 — MS Call Termination (7/8)

- Steps 12 and 13.
  - The MSC initiates paging of the MS in all LAs.
  - If the paging is successful, the current LA address of the MS is sent back to the VLR by the MAP_PROCESS_ACCESS_REQUEST message.
  - At this point, the location information of the VLR record is recovered.

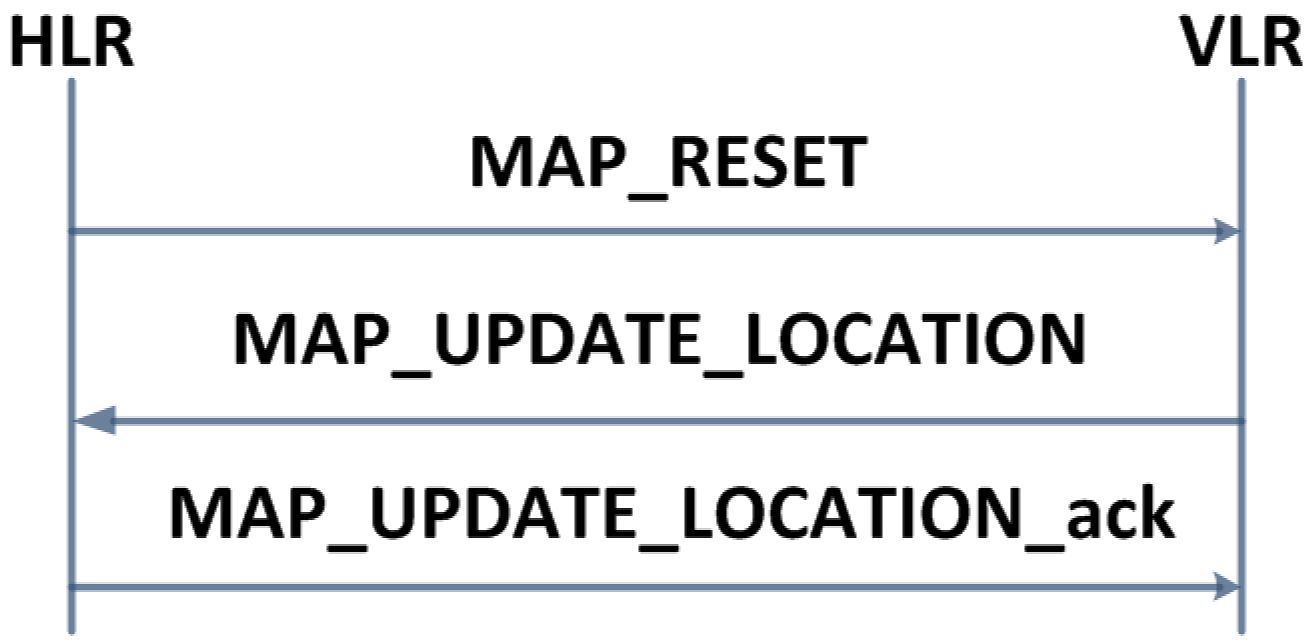
VLR Record Restoration Initiation Event 3 — MS Call Termination (8/8)

- Note that
  - MAP_SEARCH_FOR_MOBILE_SUBSCRIBER is an expensive operation because every BTS connected to the MSC must perform the paging operation.
  - To avoid this “Wide Area Paging”, the GSM system may periodically asks the MSs to re-register.

HLR Failure Restoration

- It is mandatory to save the updates into nonvolatile storage.
- Changes of the service information are saved into the backup storage device immediately after any update.
- The location information is periodically transferred from the HLR into the backup.
- After an HLR failure, the data in the backup are reloaded into the HLR.

HLR Restoration Procedure Message Flow



HLR Restoration Procedure (1/3)

- After an HLR failure, the data in the backup are reloaded into the HLR.
- An Uncovered Period = the time interval after the last backup operation and before the restart of the HLR.
- Data that have been changed in the uncovered period can not be recovered.

HLR Restoration Procedure (2/3)

- Step 1. The HLR sends an SS7 TCAP message MAP_RESET to the VLRs where its MSs are located.
- Step 2. All the VLRs derive all MSs of the HLR. For each MS, they send an SS7 TCAP message, MAP_UPDATE_LOCATION, to the HLR.

HLR Restoration Procedure (3/3)

- The HLR restoration procedure is not robust.
  - An MS may move into a VLR (which does not have any other MSs from the given HLR residing) during the uncovered period.
  - The new location is not known to the HLR at the last check-pointing time.
  - If so, the HLR will not be locate the VLR of the MS during Step 1 of HLR restoration.
- VLR Identification Algorithm is to solve the problem.

Data Structure in VLR Identification Algorithm (VIA) (1/3)

- To simply the description, we assume that every VLR covers exactly one MSC.
- To implement VIA, extra data structures are required.
- In the backup, the extra data structure is a set VLR_List* of VLRs that have been modified during the uncovered period.
- After an HLR failure, the HLR only needs to send the MAP_RESET messages to VLRs listed in VLR_List*.

Data Structure in VLR Identification Algorithm (VIA) (2/3)

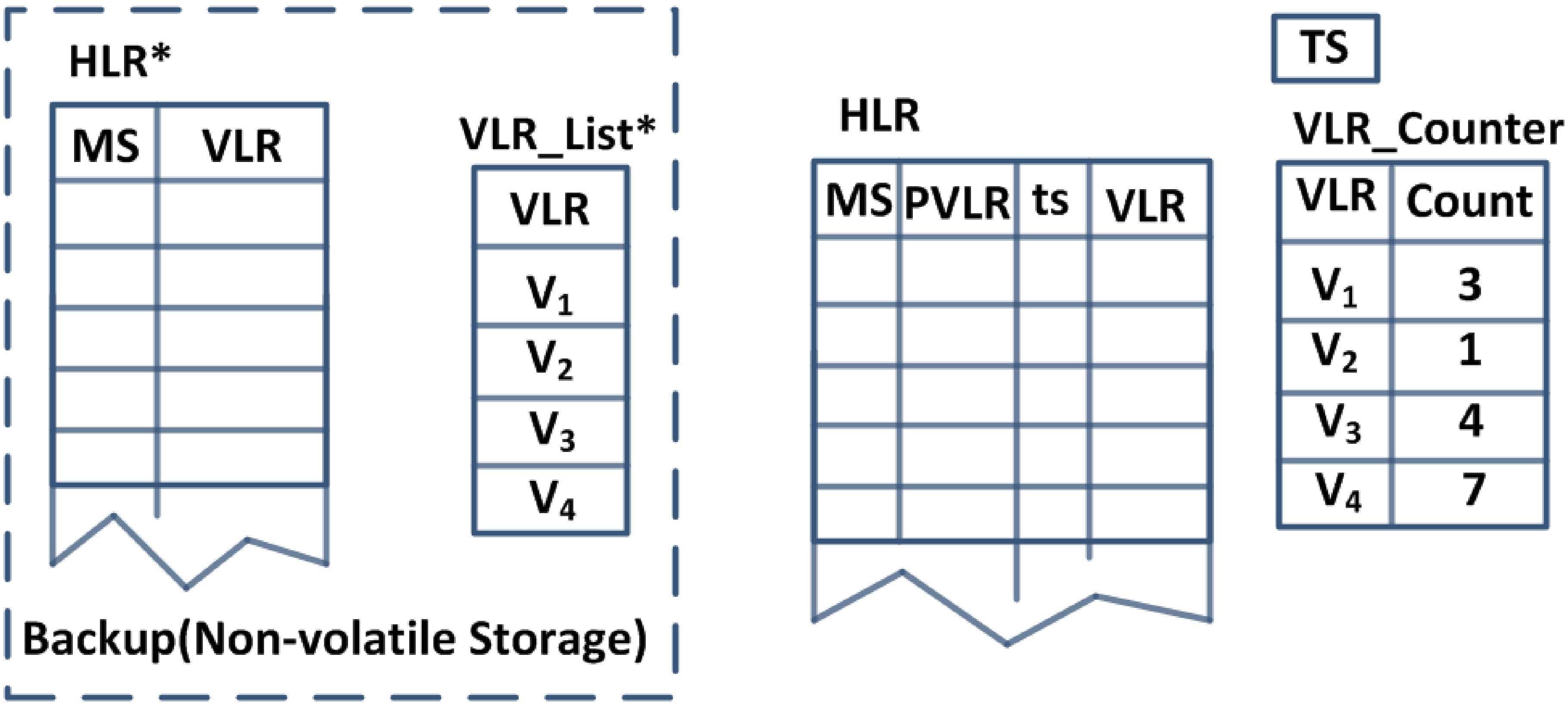
- In HLR, every record includes two extra fields.
  - The ts field = the last time of location update
  - The PVLR field = the address of VLR where the resided at the lat check-pointing time. Thus, for any MS p, we have

$$HLR^*[p].VLR = HLR[p].PVLR$$

Data Structure in VLR Identification Algorithm (VIA) (3/3)

- Two extra data structures are introduced in the HLR.
  - TS = the last check-pointing or backup time
  - VLR_Counter = {(VLR1,Count), (VLR2,Count), …, (VLRn,Count)} where Count represents the "effective number" of MSs entering the VLR VLRn during the uncovered period.
  - An MS is not effective to a VLR if it entered the VLR area then left the area during uncovered period.
  - Note that the VLRs recorded in VLR_Counter are the VLRs in VLR_List*.

VIA Data Structure



VIA Procedure 1: Check-Pointing

- In VIA, information of the HLR is periodically saved into the backup by this procedure.
- Step 1. For every entry p in HLR* do:

  HLR[p]*.VLR <- HLR[p].VLR;
- Step 2. TS <- current time;
- Step 3. For every location entry p in HLR do:

  HLR[p].ts <- TS; HLR[p].PVLR <- HLR[p].VLR;
- Step 4. VLR_Counter <- NULL; VLR_List* <- NULL;

VIA Procedure 2: Registration (1/3)

- Step 1. Update HLR:
  - V_{old} <- HLR[p].VLR;
  - Send message, MAP_CANCEL_LOCATION, to cancel the VLR entry of p at V_{old};
  - HLR[p].VLR <- V_{new};
  - told <- HLR[p].ts;
  - HLR[p].ts <- t;

VIA Procedure 2: Registration (2/3)

- Step 2. Update the V_{new} Count field in VLR_Counter:

```
If (HLR[p].VLR <> HLR[p].PVLR){
    If (VLR_Counter[Vnew] exists){
            VLR_Cpunter[Vnew].Count <- VLR_Counter[Vnew].Count+1;
    }else{
            create VLR_Counter[Vnew] and VLR_List*[Vnew];
            VLR_Counter[Vnew] <- 1;
    }
}
```

VIA Procedure 2: Registration (3/3)

- Step 3. Update the V_{old} counter entry:

```
If (t_old > TS and V_old <> HLR[p].PVLR){
    VLR_Counter[V_old].Count <- VLR_Counter[V_old].Count – 1;
    If (VLR_Counter[V_old].Count = 0){
            Delete VLR_Counter[V_old] and VLR_List*[V_old];
    }
}
```

VIA Procedure 3: Restore

- Step 1. TS <- current time;
- Step 2.

```
for (every location entry p in HLR){
    HLR[p].PLVR = HLR[p].VLR <- HLR[p]*.VLR;
    HLR[p].ts <- TS;
}
```

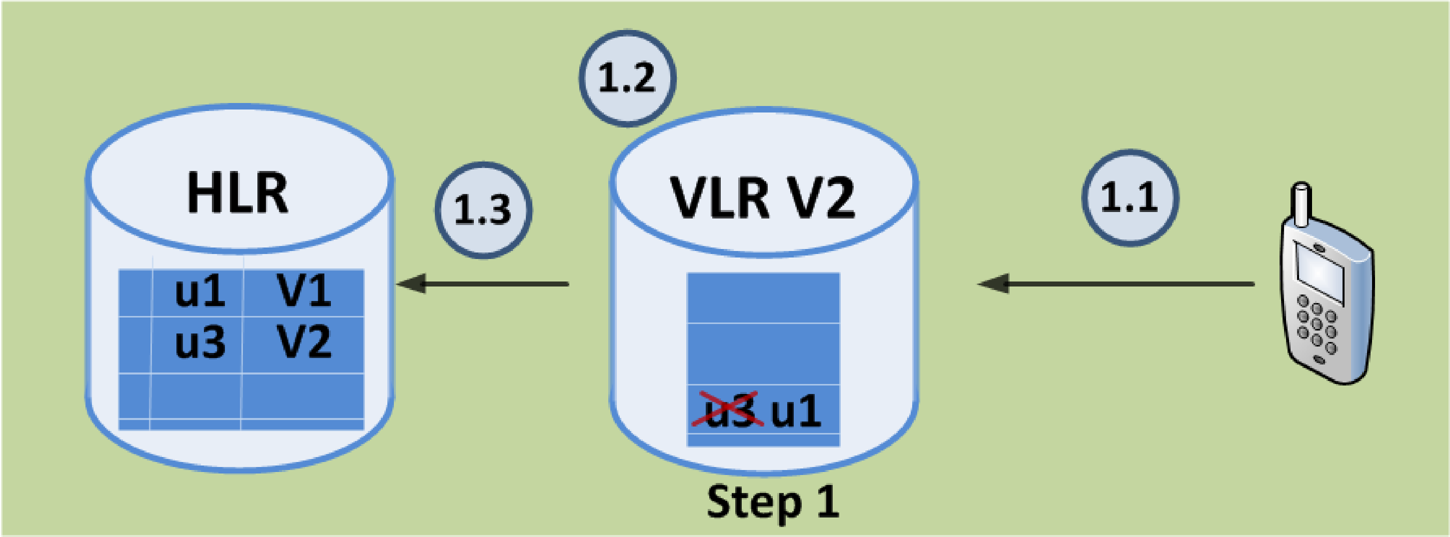
- Step 3.

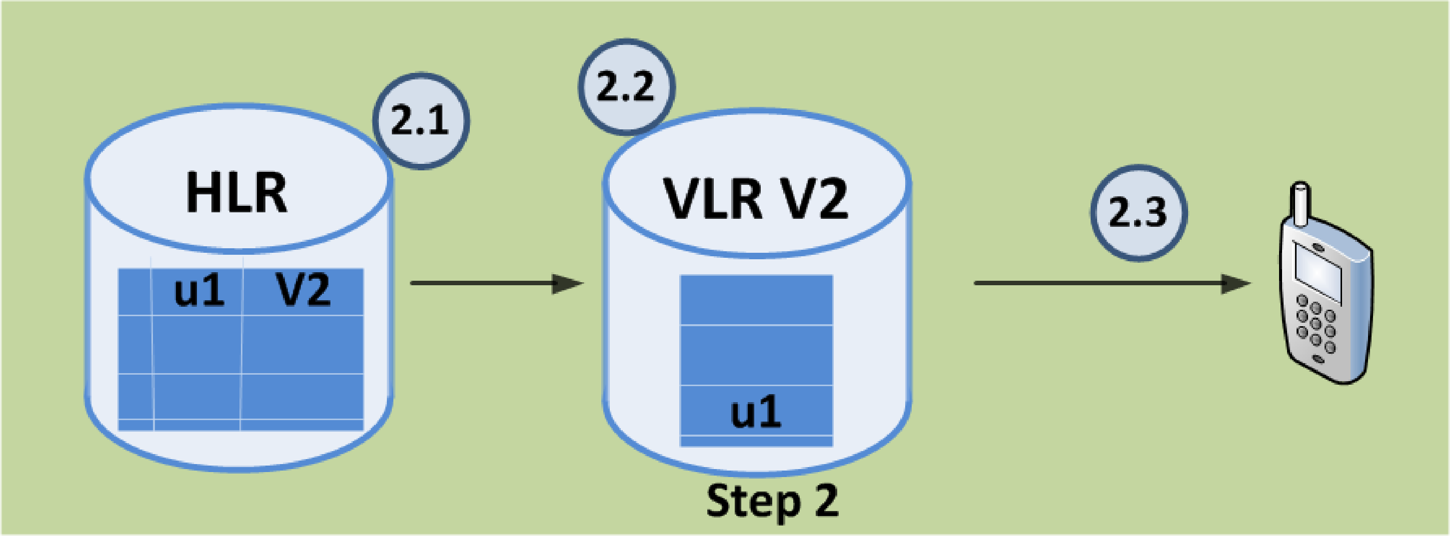
```
for (every VLR entry V in VLR_List*){
    send an SS7 TCAP MAP_RESET message to V;
}
```

VLR Overflow Control

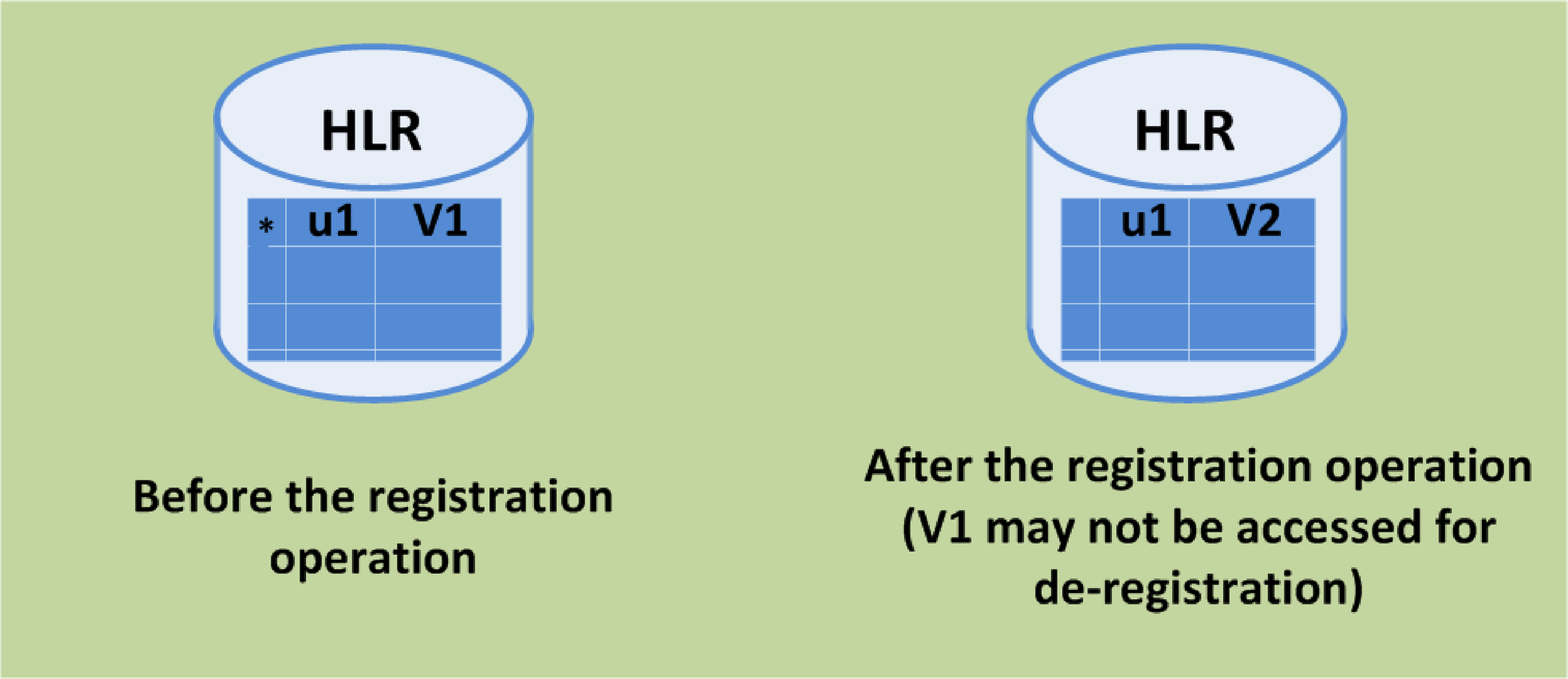
- The number of records in the VLR can change dynamically.
- It is possible that the number of the records in the corresponding VLR may be larger than that of the HLR, and the VLR may overflow if too many mobile users move into the LA in a short period.
- When a VLR is full, the incoming mobile users cannot register using the registration.
- To Solve the problem, overflow control algorithms O-I, O-II, O-III, and O-IV are presented.

Overflow Registration Operation

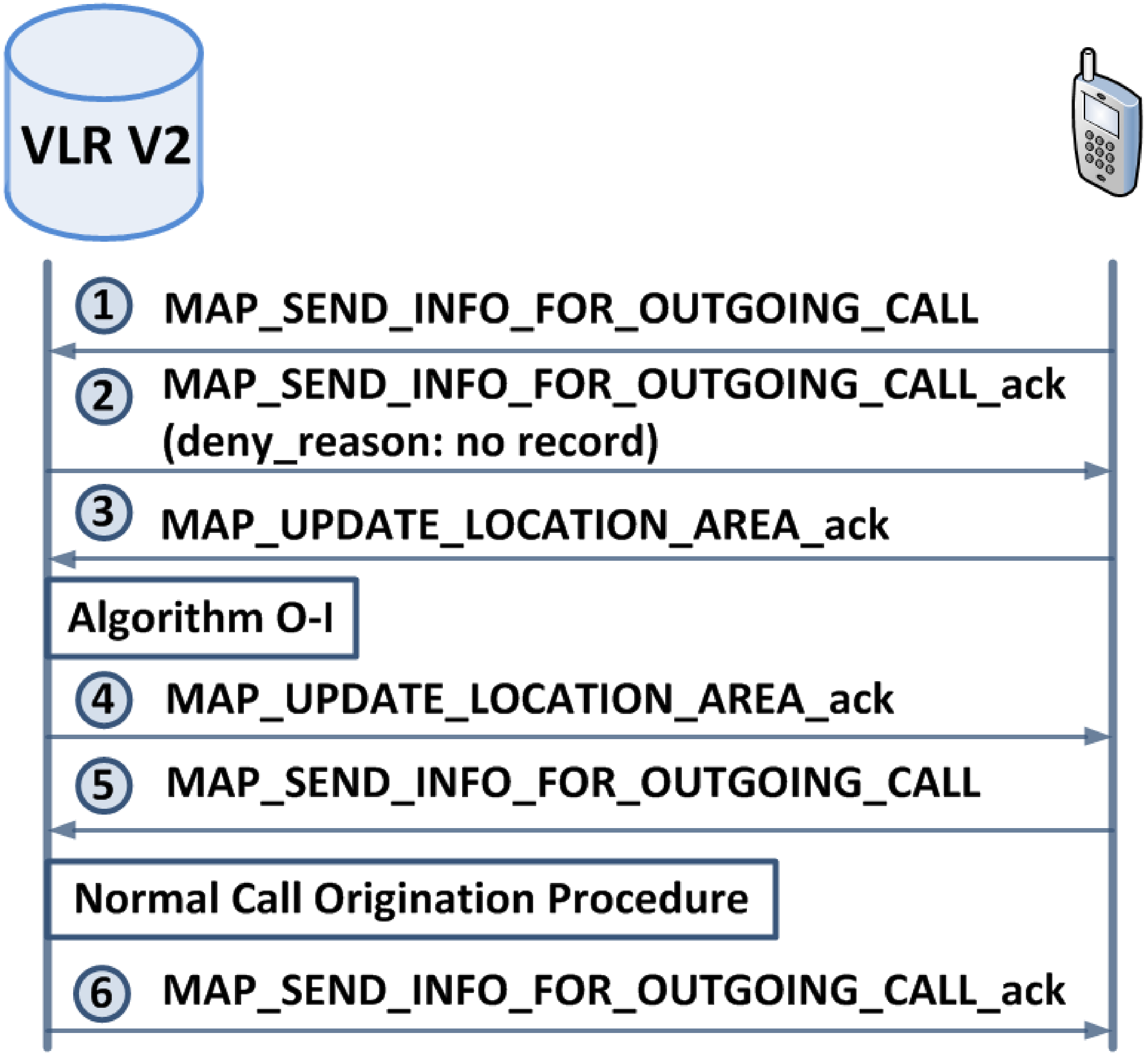




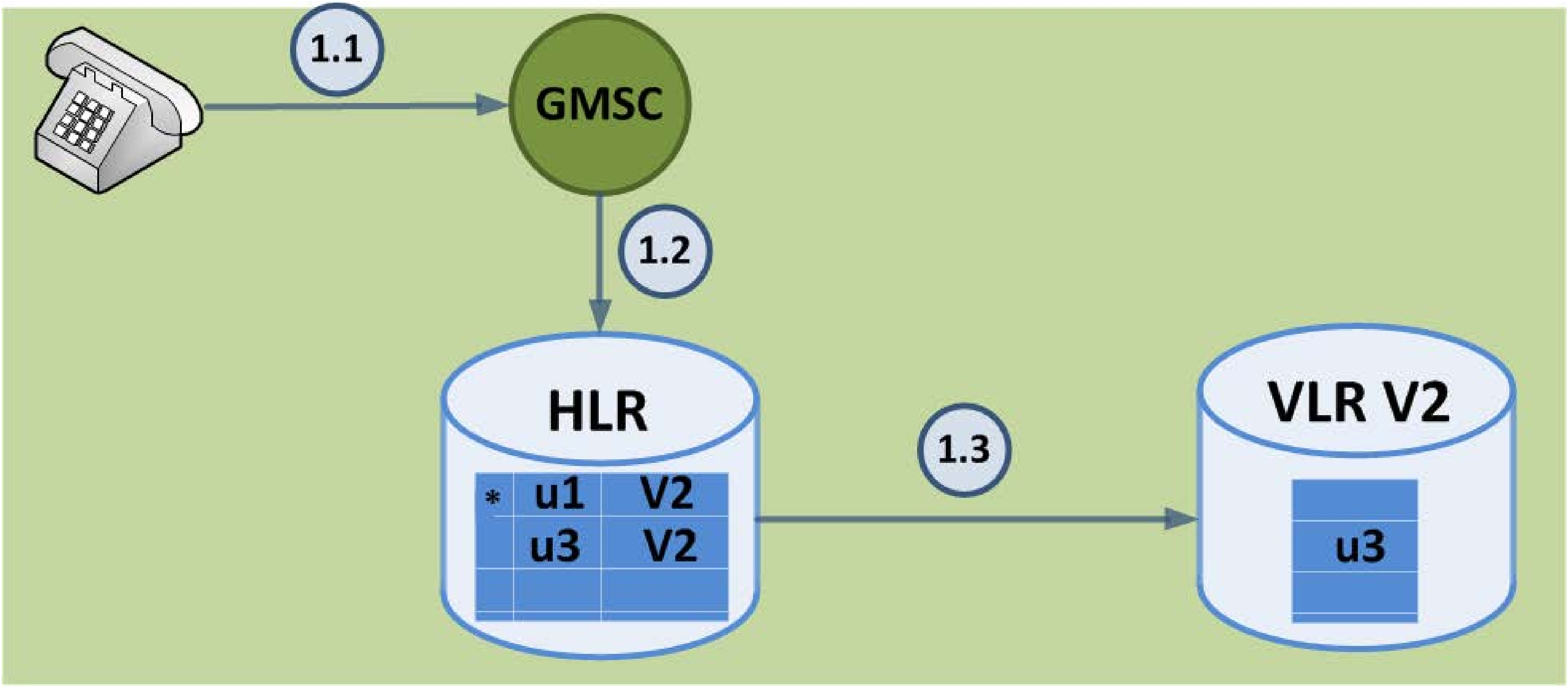
Cancellation Operation with Overflow VLR



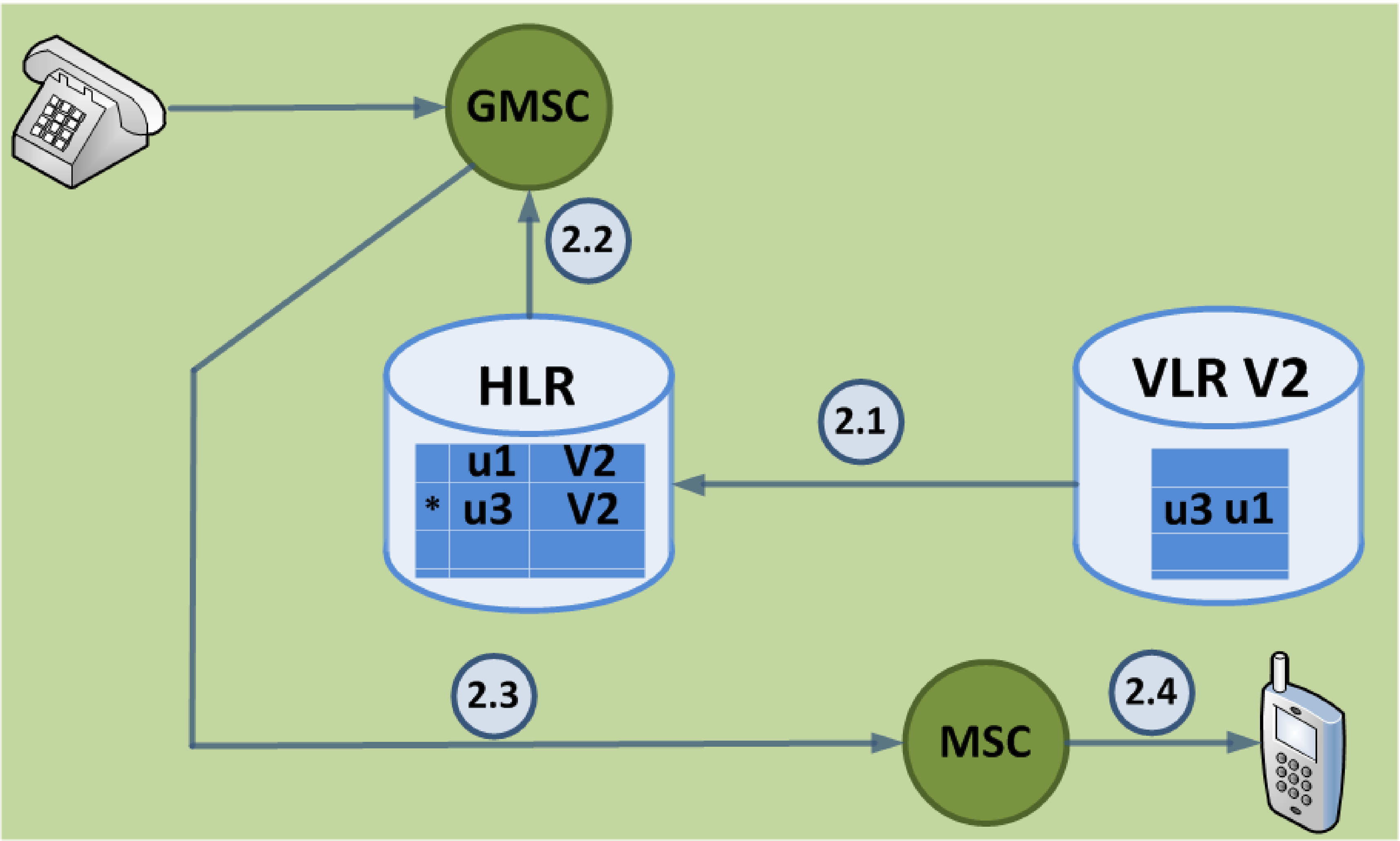
Call Origination with Overflow VLR



Call Termination with Overflow VLR (1/2)



Call Termination with Overflow VLR (2/2)



Summary

- Mobility Databases
- Failure Restoration
- VLR Identification Algorithm
- VLR Overflow Control