GSM UMTS PLMN Selection

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Introduction

The MS normally operates on its home PLMN (HPLMN) or Equivalent Home PLMN (EHPLMN). However a visited PLMN (VPLMN) may be selected, e.g., if the MS loses coverage. There are two modes for PLMN selection:

- *Automatic mode* - This mode utilizes a list of PLMNs in priority order. The highest priority PLMN which is available and allowable is selected.

- *Manual mode* - Here the MS indicates to the user which PLMNs are available. Only when the user makes a manual selection does the MS try to obtain normal service on the VPLMN.

LA & PLMN lists

To prevent repeated attempts to have roaming service on a not allowed LA, when the MS is informed in Location Update Reject message (or corresponding GPRS messages) that 'roaming not allowed in this LA' (cause #13), the LA is added to a list of 'forbidden LAs for roaming' which is stored in the MS. The MS than performs PLMN selection instead of a cell selection.
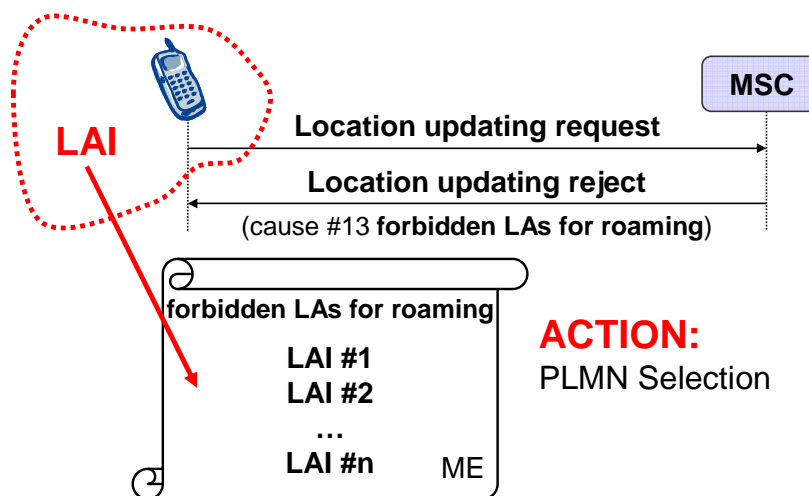

Figure 1 Forbidden LAs for roaming (part 1)

If a 'No Suitable Cells In LA' (cause #15) is received by an MS, that LA is added to the list of 'forbidden LAs for roaming' which is stored in the MS. The MS then searches for a suitable cell in the same PLMN but belonging to an LA which is not in the 'forbidden LAs for roaming' list.
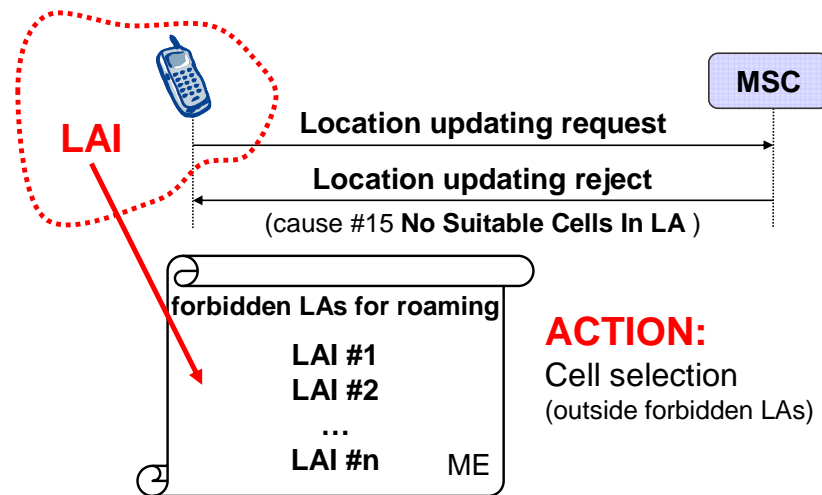
Figure 2 Forbidden LAs for roaming (part 2)

An MS may have a 'regionally restricted service' where it can only obtain service on certain LAs. If such an MS attempts to camp on a cell of an LA for which it does not have service entitlement, when it does an LR request, it will receive an 'LA not allowed' message (cause #12). In this case, the MS stores the forbidden LAI in a list of 'forbidden LAs for regional provision of service', to prevent repeated access attempts on a cell of the forbidden LA and enters the limited service state. This list is deleted when the MS is switched off or the SIM is removed. The MS than performs a cell selection.
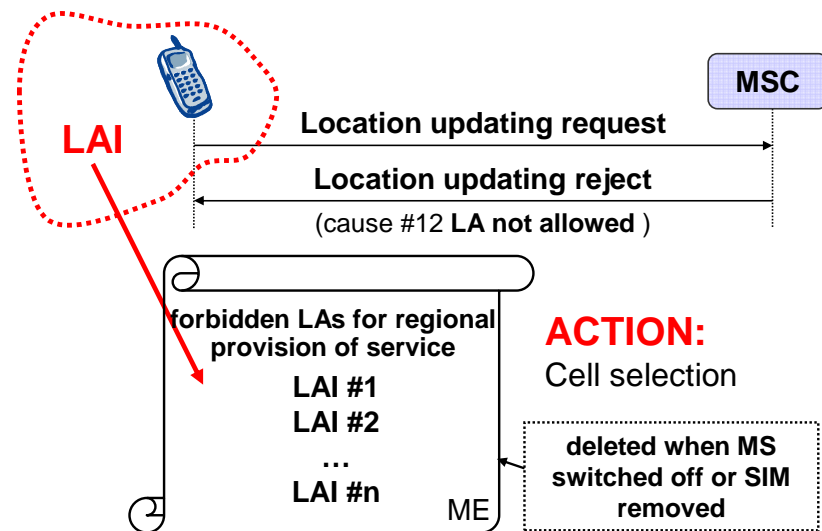

Figure 3 Forbidden LAs for regional provision of service

When the MS is camped on a cell, the LA of which belongs to the list of 'forbidden LAs for regional provision of service', the MS is not allowed to initiate establishment of a CM connection except for an emergency call; it may respond to paging. Also, the MS is not allowed to request GPRS services when camped on a cell of a LA of which belongs to the list of 'forbidden LAs for regional provision of service'.

If a 'PLMN not allowed' (cause #11) is received by an MS in response to an Location Registration request from a VPLMN, that VPLMN is added to a list of 'forbidden PLMNs' in the SIM and thereafter that VPLMN will not be accessed by the MS when in automatic mode. A PLMN is removed from the 'forbidden PLMNs' list if, after a subsequent manual selection of that PLMN, there is a successful LR. This list is retained when the MS is switched off or the SIM is removed. The HPLMN (if the EHPLMN list is not present or is empty) or an EHPLMN (if the EHPLMN list is present) is never stored on the list of 'forbidden PLMNs'.
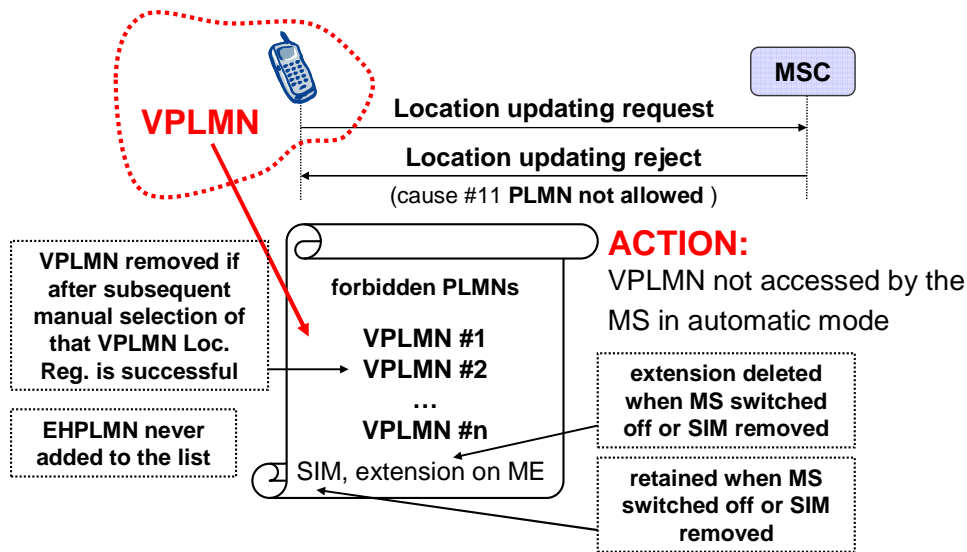

Figure 4 Forbidden PLMN

Optionally the ME may store in its memory an extension of the 'forbidden PLMNs' list. The contents of the extension of the list is deleted when the MS is switched off or the SIM is removed.

A cell may be reserved for Support of Localised Service Area (SoLSA) exclusive access. An MS is only allowed to camp normally on such a cell if it has a Localised Service Area subscription to the cell. Other MS may enter the limited service state.

In a SoLSA exclusive cell the MCC+MNC code is replaced by an unique escape PLMN code, not assigned to any PLMN, in SI3 and SI4. An MS not supporting SoLSA may request for location update to an exclusive access cell. In this case the location attempt is rejected with the cause 'PLMN not allowed' (cause #11) and the escape PLMN code is added to the list of the 'forbidden PLMNs'. An ME not supporting SoLSA may consider a cell with the escape PLMN code to be a part of a PLMN belonging to the list of 'forbidden PLMNs'.
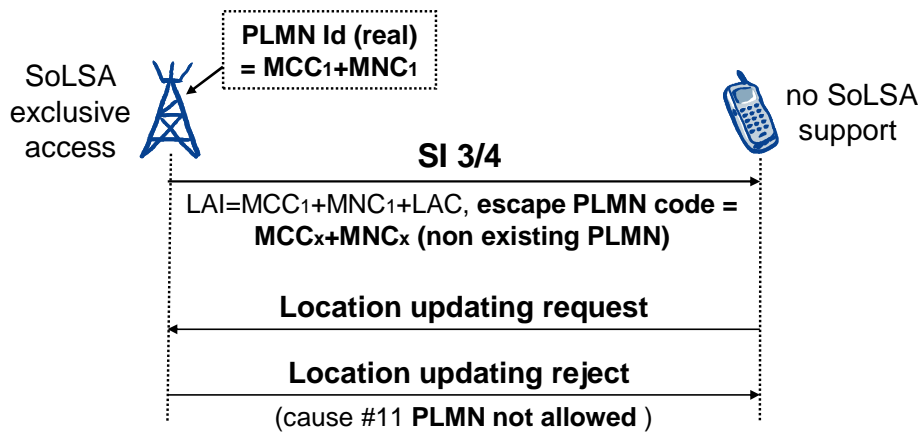
Figure 5 Forbidden PLMN & SoLSA

If a 'GPRS services not allowed in this PLMN' (cause #14) message is received by an MS in response to an GPRS attach, GPRS detach or Routing Area Update Request from a VPLMN, that VPLMN is added to a list of 'forbidden PLMNs for GPRS service' which is stored in the MS and thereafter that VPLMN will not be accessed by the MS for GPRS service when in automatic mode. This list is deleted when the MS is switched off or when the SIM is removed. A PLMN is removed from the list of 'forbidden PLMNs for GPRS service' if, after a subsequent manual selection of that PLMN, there is a successful GPRS attach. The maximum number of possible entries in this list is implementation dependant, but must be at least one entry. The HPLMN (if the EHPLMN list is not present or is empty) or an EHPLMN (if the EHPLMN list is present) is never stored on the list of 'forbidden PLMNs for GPRS service'.
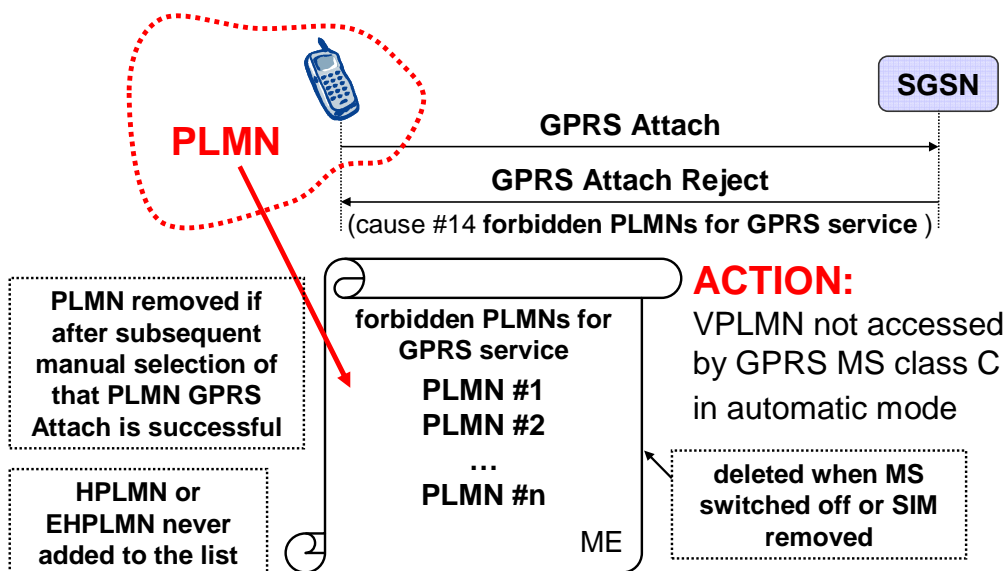

Figure 6 Forbidden PLMN for GPRS service

If the LAI or PLMN identity contained in the Location Updating Accept message is a member of the list of 'forbidden location areas for regional

provision of service', the list of 'forbidden location areas for roaming' or the 'forbidden PLMN list" then such entries are deleted.

The network may also send a list of 'equivalent PLMNs' in the Location Updating Accept message. Each entry of the list contains a PLMN code (MCC+MNC). The MS stores the list, as provided by the network in Location Update Accept, Routing Area Accept or GPRS Attach Accept, except that any PLMN code that is already in the 'forbidden PLMN list' is removed from the 'equivalent PLMNs' list before it is stored by the MS. In addition the MS adds to the stored list the PLMN code of the registered PLMN that sent the list. All PLMNs in the stored list are regarded as equivalent to each other for PLMN selection, cell selection/re-selection and handover. The stored list in the MS is replaced on each occurrence of the Location Updating Accept message. If no list is contained in the message, then the stored list in the MS is deleted. The list is stored in the MS while switched off so that it can be used for PLMN selection after switch on.
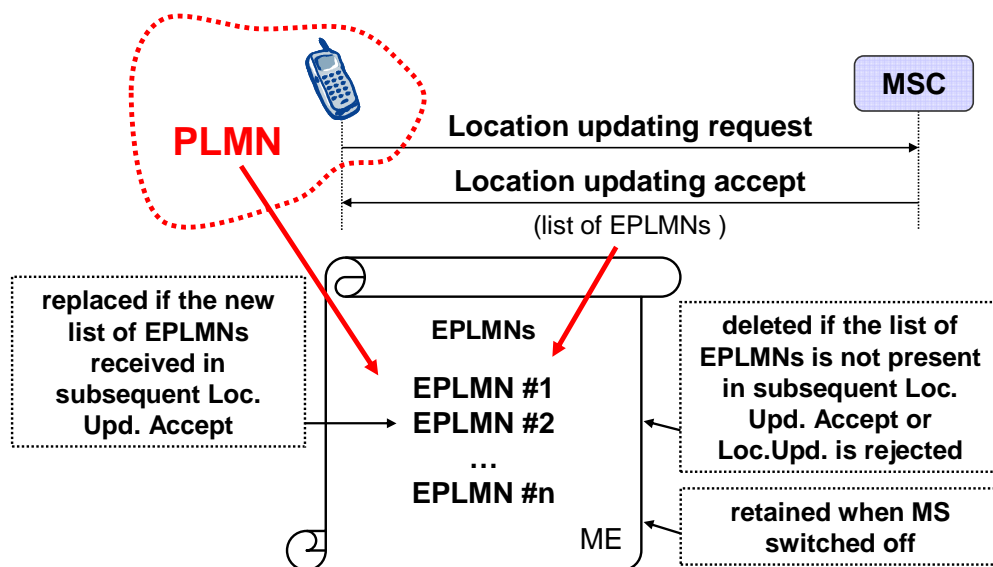
Figure 7 Equivalent PLMNs

If the location updating cannot be accepted the network sends a Locating Updating Reject message to the MS. The MS than deletes the list of 'equivalent PLMNs' for all causes except #12 (Location Area not allowed), #14 (No Suitable Cells In Location Area) and #15 (Network failure).

To allow provision for multiple HPLMN codes, PLMN codes that are present within the Equivalent HPLMN list on the USIM shall replace the HPLMN code derived from the IMSI for PLMN selection purposes. This list is stored on the USIM and is known as the EHPLMN list. The EHPLMN list may also contain the HPLMN code derived from the IMSI. If the HPLMN code derived from the IMSI is not present in the EHPLMN list then it shall be treated as a Visited PLMN for PLMN selection purposes.

EHPLMNs

EHPLMN #1
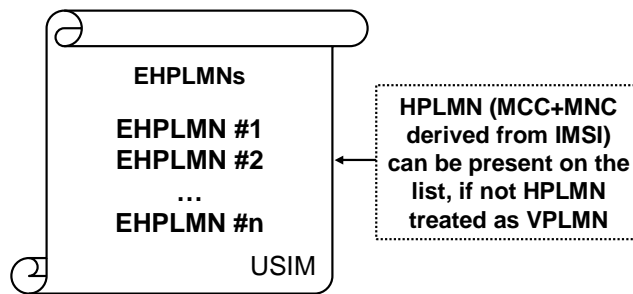**EHPLMN #2**
…
EHPLMN #n

USIM

HPLMN (MCC+MNC derived from IMSI) can be present on the list, if not HPLMN treated as VPLMN

Figure 8 Equivalent HPLMNs

Selection process

The ME utilises all the information stored in the SIM related to the PLMN selection; e.g. 'HPLMN Selector with Access Technology', 'Operator controlled PLMN Selector with Access Technology', 'User Controlled PLMN Selector with Access Technology', 'Forbidden PLMNs', 'Equivalent HPLMN'.

SIM

HPLMN Selector

1st PLMN (highest priority) - 1st PLMN Access Technology Identifier

2nd PLMN - 2nd PLMN Access Technology Identifier

⋮

Nth PLMN (lowest priority) - Nth PLMN Access Technology Identifier

MCC+MNC   UTRAN/GSM/COMPACT

only used by the MS to get the HPLMN access technologies related to the HPLMN code which corresponds to the PLMN code included in the IMSI
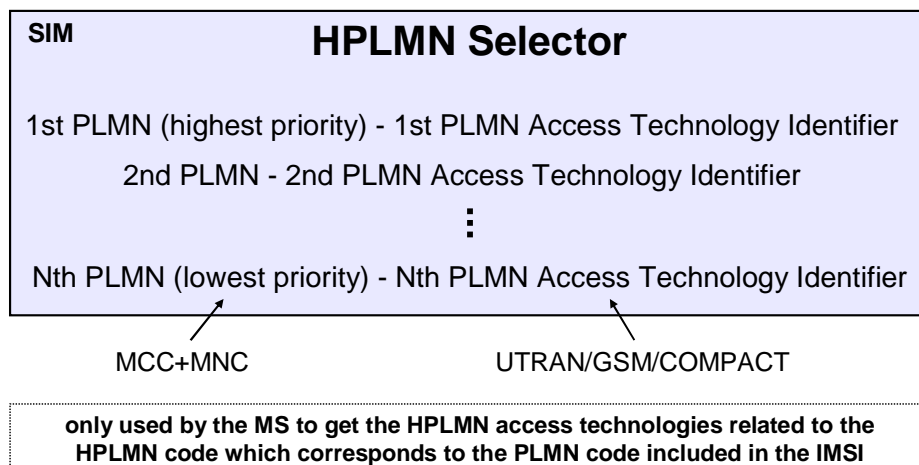
Figure 9 HPLMN Selector with Access Technology

SIM

Operator controlled PLMN Selector

1st PLMN (highest priority) - 1st PLMN Access Technology Identifier

2nd PLMN - 2nd PLMN Access Technology Identifier

⋮

Nth PLMN (lowest priority) - Nth PLMN Access Technology Identifier

MCC+MNC   UTRAN/GSM/COMPACT
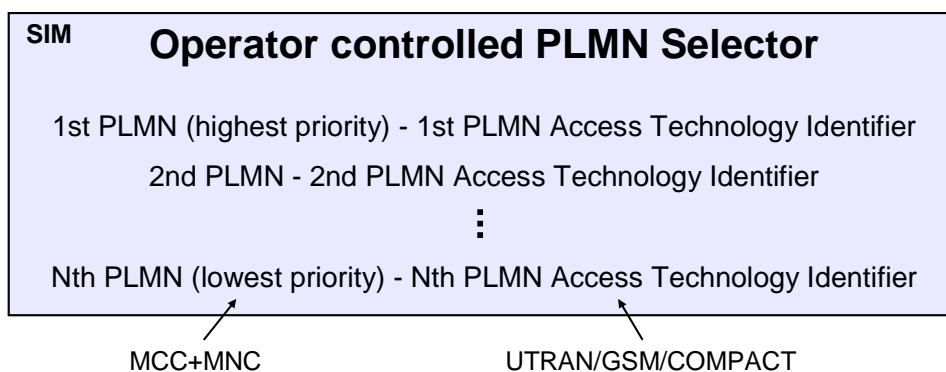
Figure 10 Operator controlled PLMN Selector with Access Technology

SIM

User controlled PLMN Selector

1st PLMN (highest priority) - 1st PLMN Access Technology Identifier

2nd PLMN - 2nd PLMN Access Technology Identifier

⋮

Nth PLMN (lowest priority) - Nth PLMN Access Technology Identifier

MCC+MNC   UTRAN/GSM/COMPACT

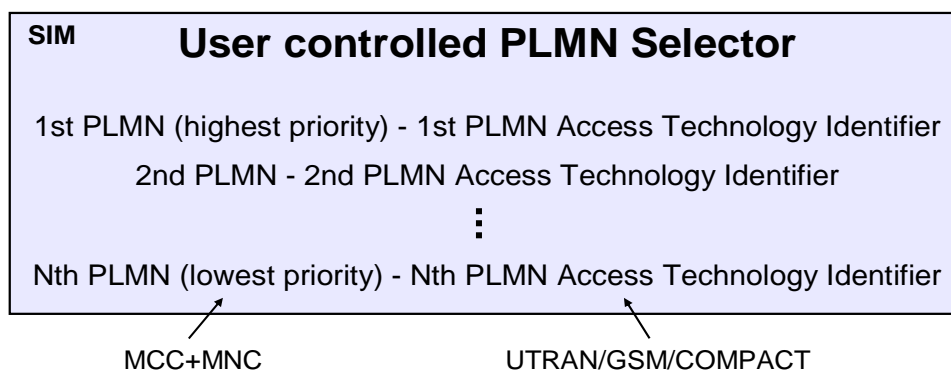*Figure 11 User controlled PLMN Selector with Access Technology*

The 'HPLMN Selector with Access Technology', 'User Controlled PLMN Selector with Access Technology' and 'Operator Controlled PLMN Selector with Access Technology' data files in the SIM include associated access technologies for each PLMN entry. The PLMN/access technology combinations are listed in priority order. If an entry indicates more than one access technology, then no priority is defined for the access technologies within this entry and the priority applied to each access technology within this entry is an implementation issue. If no particular access technology is indicated in an entry, it is assumed that all access technologies supported by the ME apply to the entry. If an entry only indicates access technologies not supported by the ME, the entry is ignored. If an entry indicates at least one access technology supported by the ME, the entry is used in the PLMN selection procedures if the other criteria defined for the specific PLMN selection procedures are fulfilled.

It is possible for the home network operator to identify alternative Network IDs as the HPLMN. If the EHPLMN list is present, and not empty, the entries in the EHPLMN list are used in the network selection procedures. When attempting to select a network the highest priority EHPLMN that is available is selected. If the EHPLMN list is present and is empty or if the EHPLMN list is not present, the HPLMN derived from the IMSI is used for network selection procedures.

The inclusion of the HPLMN derived from the IMSI in the EHPLMN list is allowed. The priority of the HPLMN derived from the IMSI is given by its position in the EHPLMN list.

The 'HPLMN Selector with Access Technology' data file is only used by the MS to get the HPLMN access technologies related to the HPLMN code which corresponds to the PLMN code included in the IMSI if the EHPLMN list is not present or is empty. If the EHPLMN list is present then this data field is applicable to all the entries within the EHPLMN list.

Different GSM frequency bands (e.g. 900, 1800, 1900, 400) are all considered GSM access technology. An MS supporting more than one band should scan all the bands it's supports when scanning for GSM frequencies.

At switch-on or recovery from lack of coverage

At switch on, or following recovery from lack of coverage, the MS selects the registered PLMN or equivalent PLMN (if it is available) using all access technologies that the MS is capable of and if necessary attempts to perform a Location Registration.

As an alternative option to this, if the MS is in automatic network selection mode and it finds coverage of the HPLMN, the MS may register on the HPLMN and not return to the registered PLMN. The operator is able to control by SIM configuration (parameter *Last RPLMN Selection Indication*) whether an MS that supports this option shall perform this alternative behaviour.

If successful registration is achieved, the MS indicates the selected PLMN.

If there is no registered PLMN, or if registration is not possible due to the PLMN being unavailable or registration failure, the MS follows one of the following two procedures depending on its PLMN selection operating mode. At switch on, if the MS provides the optional feature of user preferred PLMN selection operating mode at switch on then this operating mode shall be used.
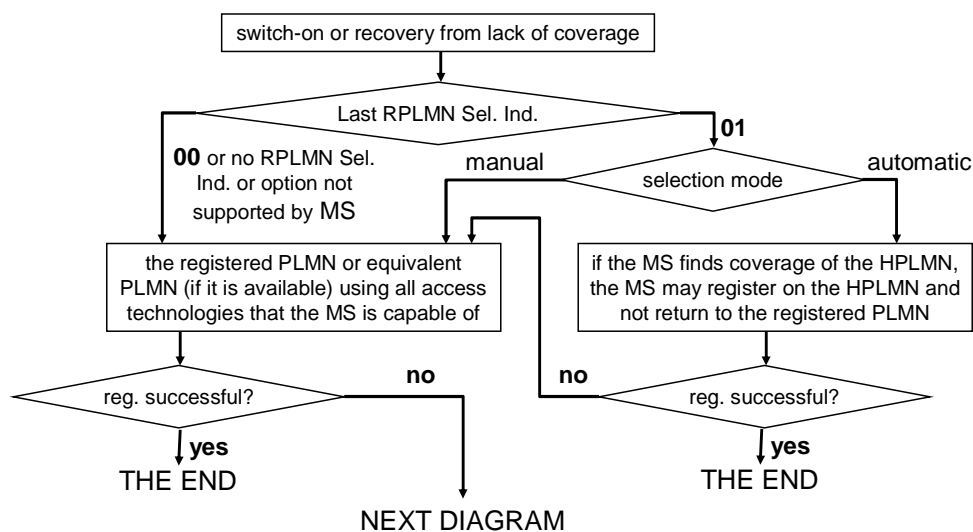

Figure 12 PLMN Selection (part 1)

At switch on, if the MS is in manual mode and neither registered PLMN nor PLMN that is equivalent to it is available but EHPLMN is available, then instead of performing the manual network selection mode procedure the MS may select and attempt registration on the highest priority EHPLMN. If the EHPLMN list is not available or is empty and the HPLMN is available, then the MS may select and attempt registration on the HPLMN. The MS remains in manual mode.

If successful registration is achieved, then the current serving PLMN becomes the registered PLMN and the MS does not store the previous registered PLMN for later use.
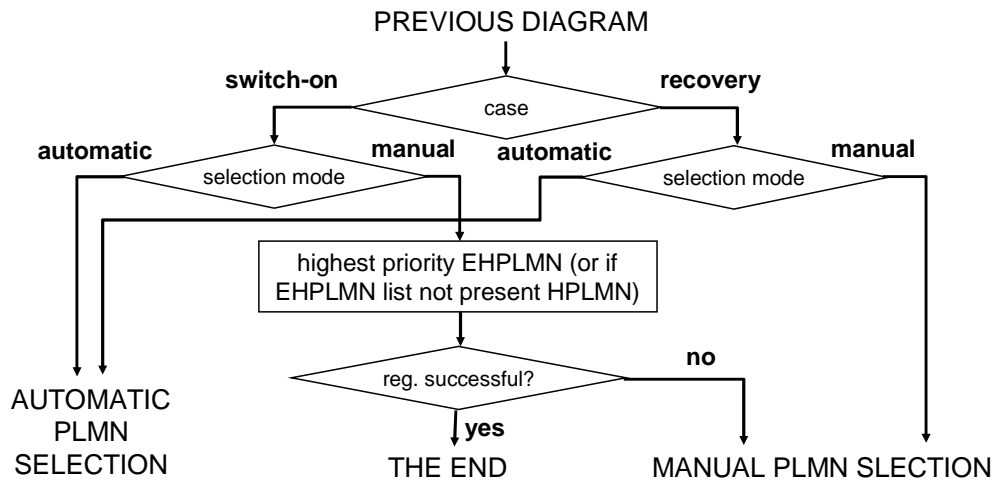

Figure 13 PLMN Selection (part 2)

As an exception, if registration is not possible on recovery from lack of coverage due to the registered PLMN being unavailable, an MS attached to GPRS services may, optionally, continue looking for the registered PLMN for an implementation dependent time. An MS attached to GPRS services should use the above exception only if one or more PDP contexts are currently active.

Automatic Network Selection Mode

The MS selects and attempts registration on other PLMN/access technology combinations, if available and allowable, in the following order:

❶ either the HPLMN (if the EHPLMN list is not present or is empty) or the highest priority EHPLMN that is available (if the EHPLMN list is present);

❷ each PLMN/access technology combination in the 'User Controlled PLMN Selector with Access Technology' data file in the SIM (in priority order);

❸ each PLMN/access technology combination in the 'Operator Controlled PLMN Selector with Access Technology' data file in the SIM (in priority order);

❹ other PLMN/access technology combinations with received high quality signal (GSM – RLA ≥ -85 dBm, UTRAN FDD - CPICH RSCP above -95 dBm) in random order;

❺ other PLMN/access technology combinations in order of decreasing signal quality.

When following the above procedure the following requirements apply:

- In ❷ and ❸, the MS should limit its search for the PLMN to the access technology or access technologies associated with the PLMN in the appropriate PLMN Selector with Access Technology list (User Controlled or Operator Controlled selector list). An MS using a SIM without access technology information storage (i.e. the 'User Controlled PLMN Selector with Access Technology' and the 'Operator Controlled PLMN Selector with Access Technology" data files are not present) shall instead use the 'PLMN Selector' data file, for each PLMN in the 'PLMN Selector' data file, the MS shall search for all access technologies it is capable of and shall assume GSM access technology as the highest priority radio access technology.

- In ❹ and ❺, the MS shall search for all access technologies it is capable of, before deciding which PLMN to select.

- In ❶, the MS shall search for all access technologies it is capable of. No priority is defined for the preferred access technology and the priority is an implementation issue, but "HPLMN Selector with Access Technology" data file on the SIM may be used to optimise the procedure.

- In ❶, an MS using a SIM without access technology information storage (i.e. the "HPLMN Selector with Access Technology" data file is not present) shall search for all access technologies it is capable of and shall assume GSM access technology as the highest priority radio access technology.

- In ❺, the MS shall order the PLMN/access technology combinations in order of decreasing signal quality within each access technology. The order between PLMN/access technology combinations with different access technologies is an MS implementation issue.

If successful registration is achieved, the MS indicates the selected PLMN.

If registration cannot be achieved because no PLMNs are available and allowable, the MS indicates 'no service' to the user, waits until a new PLMN is available and allowable and then repeats the procedure.

If there were one or more PLMNs which were available and allowable, but an LR failure made registration on those PLMNs unsuccessful or an entry in any of the lists 'forbidden LAs for roaming', or 'forbidden LAs for regional provision of service' prevented a registration attempt, the MS selects the first such PLMN again and enters a limited service state.

Manual Network Selection Mode

The MS indicates whether there are any PLMNs, which are available using all supported access technologies. This includes PLMNs in the 'forbidden PLMNs' list and PLMNs which only offer services not supported by the MS.

If displayed, PLMNs meeting the criteria above are presented in the following order:

❶ either the HPLMN (if the EHPLMN list is not present or is empty) or, if one or more of the EHPLMNs are available then based on an optional Equivalent HPLMN Presentation Indication on the SIM either only the availability of the highest priority EHPLMN is to be presented to the user or all available EHPLMNs are presented to the user in priority order. If the data field is not present on the SIM, then only the availability of the highest priority EHPLMN is presented;

❷ PLMN/access technology combinations contained in the " User Controlled PLMN Selector with Access Technology " data file in the SIM (in priority order);

❸ PLMN/access technology combinations contained in the "Operator Controlled PLMN Selector with Access Technology" data file in the SIM (in priority order);

❹ other PLMN/access technology combinations with received high quality signal in random order;

❺ other PLMN/access technology combinations in order of decreasing signal quality.

In ❷ and ❸, an MS using a SIM without access technology information storage (i.e. the 'User Controlled PLMN Selector with Access Technology' and the 'Operator Controlled PLMN Selector with Access Technology' data files are not present) shall instead present the PLMNs contained in the 'PLMN Selector' data file in the SIM (in priority order).

In ❺, the MS orders the PLMN/access technology combinations in order of decreasing signal quality within each access technology. The order between PLMN/access technology combinations with different access technologies is an MS implementation issue.

The HPLMN may provide on the SIM additional information on the available PLMNs. If this information is provided then the MS shall indicate it to the user. This information, provided as free text may include:

- preferred partner,

- roaming agreement status,

- supported services.

Furthermore, the MS may indicate whether the available PLMNs are present on the EHPLMN list, the Forbidden list, the User Controlled PLMN List or the Operator Controlled PLMN List. The MS may also indicate that the PLMN is not present on any of these lists.

The user may select his desired PLMN and the MS then initiates registration on this PLMN using the access technology chosen by the user for that PLMN or using the highest priority available access technology for that PLMN, if the associated access technologies have a priority order. (This may take place at any time during the presentation of PLMNs). For such a registration, the MS ignores the contents of the 'forbidden LAs for roaming', 'forbidden LAs for

regional provision of service', 'forbidden PLMNs for GPRS service' and 'forbidden PLMNs' lists.

It is an MS implementation option whether to indicate access technologies to the user. If the MS does display access technologies, then the access technology used should be the access technology chosen by the user for that PLMN. If the MS does not display access technologies, then the access technology chosen for a particular PLMN should be the highest priority available access technology for that PLMN, if the associated access technologies have a priority order.

Once the UE has registered on a PLMN selected by the user, the UE shall not automatically register on a different PLMN unless:

❶ the new PLMN is declared as an equivalent PLMN by the registered PLMN; or

❷ the user selects automatic mode.

If the user does not select a PLMN, the selected PLMN is the one that was selected before the PLMN selection procedure started. If no such PLMN was selected or that PLMN is no longer available, then the MS attempts to camp on any acceptable cell and enter the limited service state.

User reselection

At any time the user may request the MS to initiate reselection and registration onto an available PLMN, according to the following procedures, dependent upon the operating mode.

Automatic Network Selection Mode

The MS selects and attempts registration on PLMNs, if available and allowable, in all of its bands of operation in accordance with the following order:

❶ the HPLMN (if the EHPLMN list is not present or is empty) or the highest priority EHPLMN that is available (if the EHPLMN list is present);

❷ PLMN/access technology combinations contained in the "User Controlled PLMN Selector with Access Technology" data file in the SIM (in priority order) excluding the previously selected PLMN/access technology combination;

❸ PLMN/access technology combinations contained in the "Operator Controlled PLMN Selector with Access Technology" data file in the SIM (in priority order) excluding the previously selected PLMN/access technology combination;

❹ other PLMN/access technology combinations with the received high quality signal in random order excluding the previously selected PLMN/access technology combination;

❺ other PLMN/access technology combinations, excluding the previously selected PLMN/access technology combination in order of decreasing signal quality or, alternatively, the previously selected PLMN/access technology combination may be chosen ignoring its signal quality;

❻ The previously selected PLMN/access technology combination.

The previously selected PLMN/access technology combination is the PLMN/access technology combination which the MS has selected prior to the start of the user reselection procedure.

If the previously selected PLMN is chosen, and registration has not been attempted on any other PLMNs, then the MS is already registered on the PLMN, and so registration is not necessary.

The equivalent PLMNs list is not applied to the user reselection in Automatic Network Selection Mode.

Manual Network Selection Mode

The normal Manual Network Selection Mode Procedure is followed.

In VPLMN

If the MS is in a VPLMN, the MS periodically attempts to obtain service on its HPLMN (if the EHPLMN list is not present or is empty) or one of its EHPLMNs (if the EHPLMN list is present) or a higher priority PLMN/access technology combinations listed in 'User Controlled PLMN Selector' or 'Operator Controlled PLMN Selector' by scanning in accordance with the requirements that are applicable to steps ❶, ❷ and ❸ in the Automatic Network Selection Mode. The MS limits its attempts to access higher priority PLMN/access technology combinations to PLMN/access technology combinations of the same country as the current serving VPLMN.

In the case that the mobile has a stored 'Equivalent PLMNs' list the mobile only selects a PLMN if it is of a higher priority than those of the same country as the current serving PLMN which are stored in the 'Equivalent PLMNs' list.

For this purpose, a value T minutes may be stored in the SIM (Higher Priority PLMN search period), T is either in the range 6 minutes to 8 hours in 6 minute steps or it indicates that no periodic attempts shall be made. If no value is stored in the SIM, a default value of 60 minutes is used.

The attempts to access the HPLMN or an EHPLMN or higher priority PLMN shall be as specified below:

- The periodic attempts shall only be performed in automatic mode when the MS is roaming;

- After switch on a period of at least 2 minutes and at most T minutes shall elapse before the first attempt is made;

- The MS shall make the following attempts if the MS is on the VPLMN at time T after the last attempt;

- Periodic attempts shall only be performed by the MS while in idle mode;

- If the HPLMN (if the EHPLMN list is not present or is empty) or a EHPLMN (if the list is present) or a higher priority PLMN is not found, the MS shall remain on the VPLMN.

- Only the priority levels of Equivalent PLMNs of the same country as the current serving VPLMN, shall be taken into account to compare with the priority level of a selected PLMN.

- If the PLMN of the highest priority PLMN/access technology combination available is the current VPLMN, or one of the PLMNs in the 'Equivalent PLMNs' list, the MS shall remain on the current PLMN/access technology combination.

Abnormal cases

If there is no SIM in the MS, if there is an authentication failure, or if the MS receives an 'IMSI unknown in HLR' (cause #2), 'illegal ME' (cause #6) or 'illegal MS' (cause #3) response to an LR request, then effectively there is no selected PLMN ('No SIM' state). In these cases, the states of the cell selection process are such that no PLMN selection information is used. No further attempts at registration on any PLMN are made until the MS is switched off and on again, or a SIM is inserted.

When in Automatic Network Selection mode and the MS is in the 'not updated' state with one or more suitable cells to camp on; then after the maximum allowed unsuccessful LR requests the MS may continue (or start if it is not running) the user reselection procedure.

Roaming not allowed in this LA

If in either PLMN selection mode the LR response 'Roaming not allowed in this LA' (cause #13) is received, the PLMN Automatic or Manual Mode Selection Procedure are followed, depending on whether the MS is in automatic or manual mode.

Acronyms and Abbreviations

CM   Connection Management
CPICH   Common Pilot Channel
EHPLMN   Equivalent Home PLMN
FDD   Frequency Division Duplex
GPRS   General Packet Radio Service
GSM   Global System for Mobile Communication
HPLMN   Home PLMN
IMSI   International Mobile Subscriber Identity
LA   Location Area
LAI   Location Area Identity
MCC   Mobile Country Code
ME   Mobile Equipment
MNC   Mobile Network Code
MS   Mobile Station
MSC   Mobile Services Switching Centre
PLMN   Public Land Mobile Network
RSCP   Received Signal Code Power
SGSN   Serving GPRS Support Node
SIM   Subscriber Identity Module
SoLSA   Support of Localised Service Area
UMTS   Universal Mobile Telecommunication System
USIM   UMTS Subscriber Identity Module
UTRAN   UMTS Terrestrial Radio Access network
VPLMN   Visited PLMN

References

This section contains the locations of various specifications, document references and useful information where you can learn more about this subject.

[1]   3GPP TS 23.122 Non-Access-Stratum (NAS) functions related to Mobile Station (MS) in idle mode

[2]   3GPP TS 25.304 User Equipment (UE) procedures in idle mode and procedures for cell reselection in connected mode

[3]   3GPP TS 31.102 Characteristics of the Universal Subscriber Identity Module (USIM) application

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