Chapter-6A(E1-E2:CM)
Roaming

ROAMING

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This report gives information about how international and national roaming is performed in the radio network once a roaming agreement between two operators has been settled. Strategies on how to influence (improve) roaming performance are presented. Important geographical areas are pointed out together with recommendations for parameter settings and coverage. A recommended checklist for the operator is presented. Some open issues are mentioned that could be investigated further.

Introduction

The information here has been taken from GSM Specification 02.11, 03:22 and 05.08. The information has been slightly modified in order to be easier to understand. There are two operating modes for PLMN (Public Land Mobile Network) selection available in the MS, automatic and manual.

Registration on a PLMN

In both automatic and manual modes, the concept of *registration* on a PLMN is used. An MS (Mobile Station) successfully *registers* on a PLMN if:
a) The MS has found a suitable cell of the PLMN to camp on; and
b) a LU (Location Update) request from the MS has been accepted in the LA (Location Area) of the cell on which the MS is camped.
When the PLMN has been successfully *registered* in the MS, the PLMN identity is stored on the SIM card.

Registration process at switch-on/recovery from lack of coverage

At switch on, the MS selects and attempts to perform a LU on the *registered* PLMN (if it exists). On recovery from lack of coverage , the MS selects the *registered* PLMN (if it exists) and, if necessary, attempts to perform a LU. If successful *registration* is achieved, the MS indicates the selected PLMN. If there is no *registered* PLMN in the SIM card or if *registration* is not possible (due to the PLMN being unavailable or *registration* failure) the MS follows the procedure below:
The MS first scans the whole GSM frequency band that the MS is capable of scanning and makes *registration* attempts. This means that:

♦ A single band 900 MS must investigate at least the 30 strongest RF channels in GSM 900 that were discovered during the scan.

♦ A dual band 900/1800 MS must investigate at least the 30 strongest RF channels in GSM 900 plus the 40 strongest RF channels for GSM 1800 that were discovered during the scan.

If the investigated frequency is a BCCH, the MS will try to decode the PLMN identity. It is only when all the investigated frequencies have been analysed that a list of available

PLMN is created. What is done with this list depends on the MS operating mode, automatic or manual:

Automatic Network Selection Mode Procedure

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

I. HPLMN (if not previously selected);
II. Each PLMN in the "PLMN Selector" data field in the SIM (in priority order);
III. Other PLMNs with received signal level above -85 dBm in random order;
IV. All other PLMNs in order of decreasing signal strength.

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. It will then wait until a new PLMN is available and allowable and then repeat the procedure. In case one or more PLMNs were available and allowable, but an LU failure made *registration* on those PLMNs unsuccessful or an entry in a forbidden LAI list prevented a *registration* attempt, the MS selects the first such PLMN again and enters a limited service state. An MS goes into lack of coverage when the C1 criterion of the cell the MS is camping on falls below zero for a period of time equal to or greater than 5 seconds. If during this time no better cell can be found, the MS experiences of coverage. Manual Network Selection Mode Procedure ,the MS indicates whether there are any PLMNs, in all of its bands of operation, which are available. Also “Forbidden PLMNs" are indicated. Any PLMN shall only be presented once.

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

I. HPLMN;
II. PLMNs contained in the "PLMN Selector" data field in the SIM (in priority order);
III. Other PLMNs with received signal level above -85 dBm in random order;
IV. All other PLMNs in order of decreasing signal strength.

The user may select his desired PLMN and the MS then initiates *registration* on this PLMN. (This may take place at any time during the presentation of PLMNs).

For such a *registratio*n, the MS shall ignore the contents of the forbidden LAI and PLMN lists. Hence, the user may initiate *registration* on all indicated PLMNs.

If the user does not select a PLMN, the selected PLMN shall be 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 shall attempt 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:

I. HPLMN;

II. PLMNs contained in the "PLMN Selector" data field in the SIM (in priority order) excluding the previously selected PLMN;
III. Other PLMNs with the received signal level above -85 dBm in random order excluding the previously selected PLMN;
IV. Any other PLMNs, excluding the previously selected PLMN in order of decreasing signal strength or, alternatively, the previously selected PLMN may be chosen ignoring its signal strength;
V. The previously selected PLMN.
The previously selected PLMN is the PLMN that the MS has selected prior to the start of the user reselection procedure Manual Network Selection Mode

Roaming in VPLMN of home country (National Roaming)

With the liberalisation in the Telecom industry, there was a need to specify a new type of roaming to be used between operators in the same country. “National Roaming” was then specified for phase 2 mobiles. A requirement to look for home PLMN when visiting another PLMN in the same country was added to the GSM standard. In case of national roaming, the MS shall periodically attempt to obtain service on its HPLMN. For this purpose, value “EF HPLMN ” minutes may be stored in the SIM by the service provider. EF HPLMN 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 30 minutes is used. Only the service provider is allowed to set the EF HPLMN -value. The attempts to access the HPLMN shall be as specified below:
a) The periodic attempts shall only be performed in automatic mode when the MS is roaming in its home country;
b) After switch on, a period of at least 2 minutes and at most EF HPLMN minutes shall elapse before the first attempt is made;
c) The MS shall make an attempt if the MS is on the VPLMN at time EF HPLMN after the last attempt;
d) The MS shall only perform periodic attempts while in idle mode;
e) If the HPLMN is not found, the MS shall remain on the VPLMN.
Note that it is not possible to define National Roaming with a foreign operator (with another MCC). This leads unfortunately to undesired behavior at borders between countries. Once an MS has registered in a PLMN of a foreign operator it must first loose coverage from that PLMN before attempting to register in its HPLMN.

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" or "illegal MS" response to an LU 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 4 unsuccessful LU requests the MS may continue (or start if it is not running)

Roaming not allowed in this LA

If in either PLMN selection mode the LU response "Roaming not allowed in this LA" is received: the PLMN Automatic or Manual Mode Selection, depending on whether the MS is in automatic or manual mode. (This requirement applies to all MSs.) Strategies (to obtain and keep the roaming traffic)
The GSM specifications have been written to distribute roaming traffic as even as possible among the available operators. Thus, in theory, if three operators are sharing the roaming traffic, they get one third of the traffic each. This is however only true if they have exactly the same network with the same parameter settings. This section will discuss what can be done in the network in order to capture and keep as much roaming traffic as possible.

Assumption

Most MSs are set to run in Automatic Mode. Only advanced users bother to select the network manually. This indicates that the strategy of capturing roaming traffic should be adapted to the Automatic Mode selection process rather than to the Manual one.

Random selection

.Thus, the random function is mobile specific, which means that it is up to the MS manufacturer to have a good randomizer. Ericsson is using a standardised randomiser in their MSs, supplied by IAR systems (www.iar.com). It is possible that other MS manufacturers use less good randomisers giving priority to networks with high signal strength or certain frequency range.

How to capture the international roaming traffic

Given that a roaming agreement with the roaming MS is existing, the main rule is to capture the traffic as early as possible when the roaming MS enters the country of the own network. Statistically it also helps to have as high signal strength as possible Thus, in general the cell should be placed where the roaming user switches on his/her MS and the output power of the cell should be maximised. At the border (entrance area) Cells should be set up on all major entrances to the country such as highways, trains and boat connections. Not only sufficient coverage is needed, high signal strength levels are also important at the actual border and in a zone stretching from the border into the own country along the path the MS is travelling. This could for example be along a road or a railway track. The intention is to capture both the users that make a temporary stop at the border (and maybe switch on their phones as they entry the country) plus the users that just travel across the border. The later are thus captured when they leave the coverage from the foreign PLMN network. This usually happens inside the own country a certain distance away from the border.

At international airports

Here it is important to have indoor cells. If it is possible to set up antennas in the gates/corridors leading out to the aircraft, this could be a good solution since this is where most users switch their MSs on and off. Also outdoor coverage on the tarmac is important since some users switch on/off their phones in the aircraft.

At train stations

People may also enter the country by train. Train lines should be covered at the border in the same way., but all MSs are not active (in Idle or Dedicated Mode) while onboard the train. Instead, the users switch on their MSs when they reach the final destination (the train station) in order to call a friend or a taxi. The coverage on the station platform and in the station building should therefore be as good as possible. Also the outdoor coverage close to the train station is important.

Other coverage aspects

Good coverage within the country also captures roaming MSs. It is particularly important that the own network has coverage where the competitor networks does not, for example tunnels (car and train), underground passages and car parks, restaurants and hotels. Roaming MSs that leave a competitor network in the mentioned areas will thus change networks if there is another network available.

How to keep the international roaming traffic

Registration

It is important that the roaming traffic that gets connected to the network also gets *registered.* This is important since when a roaming MS looses coverage, it first tries to re-connect to the *registered* network. If this fails, other networks are selected accordingly. An investigation of the registration success rate is recommended. There is unfortunately no counter for registration. Coverage aspects In order to keep the roaming traffic in the network , it is essential to have coverage everywhere where the competitor networks have coverage. If this is not the case, roaming traffic will, in case of lack of coverage, chose another network to camp on. Example:In an underground car park, a roaming MS loses coverage. A competitor network has built an indoor cell in the garage. The MS will then try to re-connect to the *registered* network, but since there is no coverage, it will instead connect to the competitor PLMN. Hence, indoor coverage in cities is very important in this sense.

National roaming

National roaming is allowed and activated on a LA basis. Only the service provider can influence the periodic timer HPLMN . This means that the operator allowing the roaming in its network can not influence (prevent or delay) how often the MSs should try to go back to its HPLMN.

Parameter settings

Parameter *not* influencing roaming performance

It must be stressed that roaming is done while the mobile is in idle mode. Hence, all radio network features that only affect active mode behaviour can not give influence on the roaming performance. This includes:

- Locating
- HCS – Hierarchical Cell Structure
- MS and BTS power control
- CLS - Cell Load Sharing
- OL / UL subcell structure

The next section describes the parameters of the feature Idle mode behaviour. Idle mode behaviour parameters For MSs:

- ACCMIN *(minimum received signal level for network access)*

The setting of ACCMIN is important. In order to make the MSs camp as long as possible on the network, ACCMIN should be set as low as possible. This corresponds to –110 dBm.

- CCHPWR *(maximum MS output power for network access)*

The setting of CCHPWR also has an effect on this issue since the cell selection quantity (the *C1* criterion) is calculated according to the following:

C1 = (received signal level – ACCMIN) – max(CCHPWR – P, 0),

C1 is satisfied if *C1* > 0

The condition states that the MS must measure the DL higher than ACCMIN, and that the MS must be able to transmit enough power in the UL (P ≥ CCHPWR, P in the formula corresponds to the maximum output power of the MS according to its class). If the UL is weaker than the DL, playing with the CCHPWR setting could make some MS classes stay longer on the network in low signal strength areas. However, these mobiles would not be able to keep a connection since the UL is too weak.

- Idle mode BA list *(BCCH allocation list for cell re-selection)*

After a cell has been successfully selected, the MS will start the cell reselection task. The MS continuously monitors all neighbouring BCCH carriers, as indicated by the idle mode BA list. It is important that this BA list is as complete as possible. If some ARFCNs are missing, the MS may end up in a state where it has to scan the whole operating band, even if the signal strength from that PLMN is still sufficient. After scanning the whole band it *could* happen that the MS ends up in another PLMN. One of the reasons could be that the PLMN to which the MS was registered is not among the strongest RF channels (even if it exists and is above ACCMIN). The recommendation is to have an idle mode BA list as complete as possible. Examples on how to allocate the BA frequencies is presented below:

⇒ Take all BCCH frequencies in both GSM900 and GSM1800. This solution is very easy but will certainly generate a BA list that will be too long.

⇒ Take every frequency in the active mode BA list. This corresponds to the neighbours of the cell. Now add the BCCH frequencies of the co-sited neighbours to these cells.

⇒ Take the BCCHs of the neighbouring cells and add the neighbours of the neighbouring cells. Restrict the length of this list with, for example, a criteria based on distance. For phase 2 MSs only:

♦ CBQ *(control of cell priority)*

The parameter CBQ should be set to HIGH to reduce cell reselection times. If the MS encounters cells with CBQ set to LOW it will have to check the whole BA list for another cell with CBQ set to high that could have priority. This is time consuming.

♦ CRO *(Cell reselection offset)*

This gives a kind of "bonus" to the signal strength of the cell and therefore the MSs will camp longer on it. This has no particular influence on roaming if the idle mode BA list is adapted to the size of the cell in idle mode. It is not possible to use CRO to try to go below ACCMIN.

♦ PT and TO *(Penalty Time and Temporary Offset for fast moving MSs)*

Parameter TO should only be used in areas where fast moving mobiles move through small sized cells, i.e. micro cells. Otherwise the recommendation is to set TO = 0. In combination with TO = 0, PT could be set to any value between 0 – 30. Note, the value PT = 31 is reserved to change the sign of CRO. The value PT = 31 is only recommended to be used in special conditions where a negative CRO value is wanted, hence when the cell is supposed to be down prioritised. This is definitely not the case in for example border areas.

PLMN selector on SIM card

When looking at the PLMN selection process it seems that the data contained in the SIM is an important factor. A better understanding of the "PLMN selector field" of the SIM card is needed in order to investigate its impact on roaming performance. What happens in the SIM is not considered as being a part of the GSM radio network. Therefore this has not been investigated further here. An idea in order to increase the amount of international roaming users could be to get foreign operators to put the identity of "your own network" in the PLMN selector field of their SIM cards. Note that the ranking of "your network" in this list must be higher than the ranking of the competitor networks in your own country (only if also present).

Multiband aspects

The PLMN selection and registration process is the same on GSM900 and GSM1800 cells. The type of cell is of no importance, only the coverage difference (path-loss) could have an influence. It is also important that the Idle mode BA list is as complete as possible, especially in the border regions. Conclusions and recommendations The registration process has been explained. The radio related parameters that can have an influence on roaming have been listed. Coverage aspects and SIM related issues have been discussed. In order to improve the roaming performance the following checklist should be studied:

♦ Check if possible radio related agreements (ACCMIN settings, antenna directions, frequency allocation, output power etc.) with neighbouring PLMN networks (from neighbouring countries) are being respected. In some cases this also involves PLMNs from the own country.

♦ Check the coverage in the border areas and the important places pointed. Close to the border it is important to have a good signal strength where the signal strength of foreign networks falls below their ACCMIN.

♦ Look for coverage holes within the own country where roamers could be lost (tunnels, in underground car parks, indoor locations, etc.).

♦ Check the setting of the Idle mode behaviour parameters

♦ Make Idle mode BA lists complete in border areas and areas with bad coverage.

♦ Make agreements with foreign operators to put the identity of "your network" in the PLMN selector fields of their SIM cards.

This study focuses on the radio part of the GSM network. Other parts of the GSM system have an influence on the roaming performance and should be studied further:

♦ It is important that the MSs get *registere*d. What are the elements that can influence the registration process? Is it possible to measure the registration success rate? What could be the reasons for having a registration failure?

♦ The behaviour of the different type of mobiles can vary a lot and this could have an influence on the roaming behaviour. Whether this should be investigated or not is a trade off between the possible gain and the cost of the time consuming work.

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