BG96 Network Searching Scheme Introduction

LTE Module Series

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About the Document

History

Revision	Date	Author	Description
1.0	2017-10-18	Walker HAN	Initial
1.1	2018-01-10	Hyman DING	Updated the description of Chapter 1.1
1.2	2018-05-07	Elvis SUN/ Hyman DING	1. Added the description of processes that may affect network registration speed (Chapter 4). 2. Added solutions for speeding up network searching. 3. Added typical problems and corresponding analyses.

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1 Introduction

This document introduces the supported RATs (Radio Access Technologies) and frequency bands of BG96 module, and also describes its network searching scheme through illustrating related AT commands and network searching/registration procedure.

Also, the document describes some problems observed in the process of searching the network, and gives corresponding cause analysis.

2 Supported RAT(s) and Band(s)

Quectel BG96 module supports three RATs: LTE Cat M1, LTE Cat NB1 and EGPRS.

- The default RATs are LTE Cat M1 and EGPRS. And the searching sequence is: LTE Cat M1 → EGPRS.
- If the three RATs need to be supported synchronously or other RAT combinations are needed, then please configure through AT commands. The details of AT commands are provided in ***Chapter 5***.

The following table lists the supported frequency bands of BG96.

Table 1: Frequency Bands of BG96 Module

RAT	Frequency Band
LTE Cat M1	LTE-FDD: B1/B2/B3/B4/B5/B8/B12/B13/B18/B19/B20/B26/B28 LTE-TDD: B39
LTE Cat NB1	LTE-FDD: B1/B2/B3/B4/B5/B8/B12/B13/B18/B19/B20/B26/B28
EGPRS	GSM850, EGSM900, DCS1800, PCS1900

3 Network Searching/Registration Procedure

The network searching/registration procedure of BG96 is illustrated below:

1. **UE initialization**

   Including (U)SIM card recognition and reading of NV related to network searching.

2. **PLMN/RAT selection**

   - Set the RAT searching sequence and the RAT(s) allowed to be searched according to network searching related NV and related (U)SIM EF files.
   - PLMN selection include automatic and manual modes.

3. **(E)ARFCN scan**

   - LTE EARFCN scan includes system scan and band scan steps.
   - EGPRS ARFCN scan mainly refers to power scan.

4. **Acquisition**

   Refer to cell recognition and downlink synchronization.

5. **System information analyze**

   Refer to system information reading.

6. **Cell selection**

   If the acquired band satisfies the signal strength requirement of UE, then go to the next step (cell camping) directly, otherwise continue band scan.

7. **Cell camping**

   Cell camping is started after successful cell selection.

8. **Attach request/location update request**

   After cell camped, the UE will send the attach request/location update request.

9. **Random access**

UE performs uplink synchronization (random access) after sending attach request/location update request.

10. RRC connection request

11. Network sends attach accept/location update accept

4 Processes Affect Registration Speed

RAT/PLMN selection and EARFCN scan are procedures that affect registration speed, and the following provides details on the two procedures.

4.1. PLMN/RAT Selection

This chapter describes the steps involved in PLMN/RAT selection procedure. The following figure illustrates the overall process of PLMN/RAT selection under automatic network operation mode. As shown below, the PLMN/RAT selection process is determined by not only the module setting but also some files in the (U)SIM card. By default, the (U)SIM card has a higher priority.

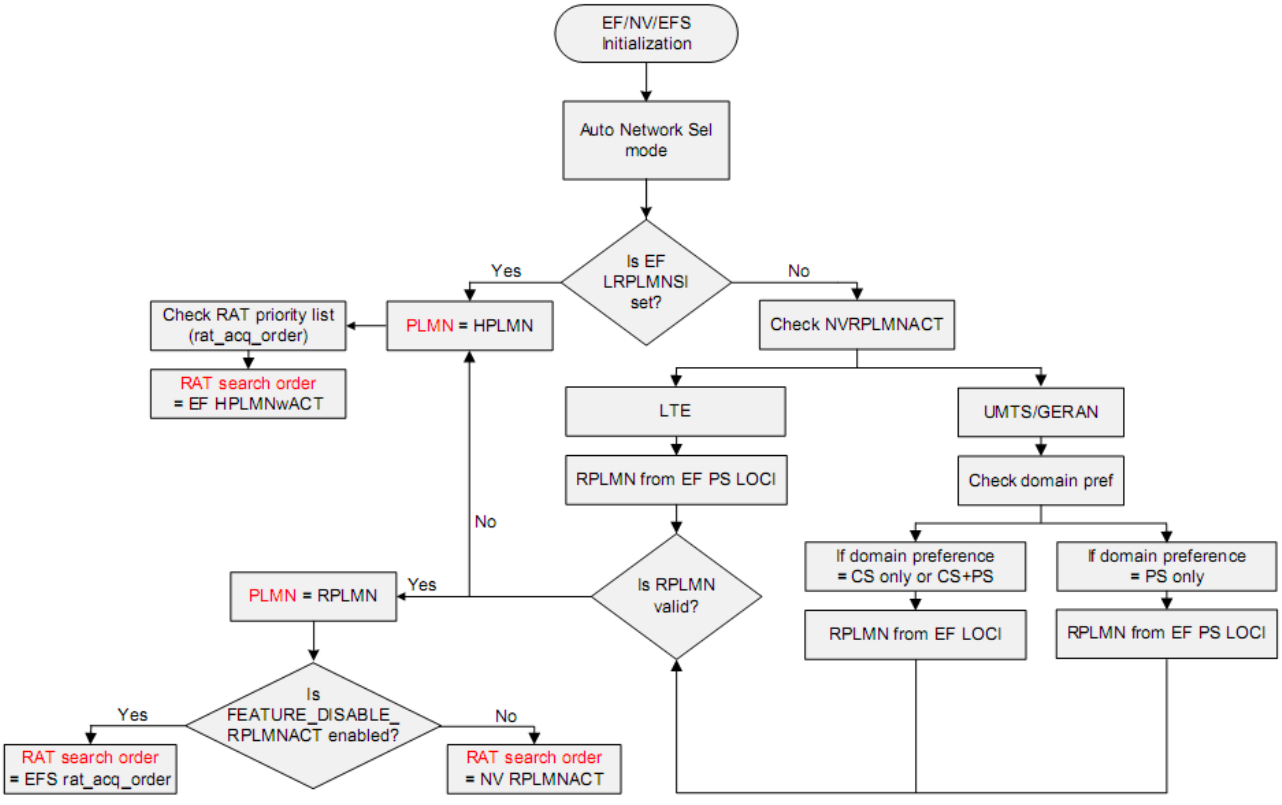


Figure 1: PLMN/RAT Selection Procedure

4.2. EARFCN Scan (Frequency Scan)

This chapter describes the effect of EARFCN scan process on the speed of network registration.

LTE EARFCN scan includes RAT scan and band scan steps. When the module shuts down, it will store the current network registration information (e.g. EARFCN, PCI and so on). When the module powers on next time for network registration, UE will try to acquire the stored network information. This process is called **system scan**. This procedure will speed up network registration process. If the network information acquisition failed in RAT scan, UE will attempt to scan all supported bands. This process is called **band scan**.

According to statistics, the scan for all bands under EGPRS and LTE Cat M1 takes about tens of seconds. But under LTE Cat NB1, due to the characteristics of LTE Cat NB1 network (especially the weak signal feature), it will take a longer period of time for frequency scan. The following table shows the test result of one of our tests, which displays the frequency scan time required in each band.

Table 2: Network Searching Time under LTE Cat NB1 with Different SNR in Each Band

Band	Band Width	Searching Time with SNR 0 (Unit: s)	Searching Time with SNR 1 (Unit: s)	Searching Time with SNR 2 (Unit: s)
B1	60M	25	139	313
B2	60M	26	132	310
B3	75M	32	164	386
B4	45M	20	104	229
B5	25M	11	69	132
B8	35M	15	77	185
B12	17M	7	38	90
B13	10M	4	21	49
B18	15M	7	36	78
B19	15M	6	39	77
B20	40M	13	67	157
B25	65M	15	86	183
B28	45M	20	104	238

As BG96 supports 13 LTE Cat NB1 bands, we recommend that customers only enable the bands used by the service operator.

Table 3: LTE Cat M1/NB1 Band Deployment Conditions over the World (For Reference Only)

Band	DL Freq. (MHz)	Applicability as per 3GPP TS36.1.0.1	U.S.	China	The Middle East	Japan	Korea	Europe	Australia
B1	2100	Cat M1/NB1		■		■			
B2	1900	Cat M1/NB1	■						
B3	1800	Cat M1/NB1		■	■		■	■	■
B4	1700	Cat M1	■						
B5	850	Cat M1/NB1		■			■		
B8	900	Cat M1/NB1		■	■	■		■	
B12/B17	700	Cat M1/NB1	■						
B13	700	Cat M1/NB1	■						
B18	800	Cat M1/NB1				■			
B19	800	Cat M1/NB1				■			
B20	800	Cat M1/NB1						■	
B26	850	Cat M1/NB1		■					
B28	700	Cat M1/NB1			■				■
B39	1900	Cat M1		■					

5 Network Searching Related AT Commands

In order to optimize network searching/registration time, related AT commands can be used to set the RAT searching sequence, RAT(s) to be searched, network category to be searched under LTE RAT, and preferred bands to be searched.

5.1. AT+QCFG="nwscanseq" Configure RAT Searching Sequence

The command specifies the searching sequence of RATs. If **<effect>** is omitted, the configuration will take effect immediately.

AT+QCFG="nwscanseq" Configure RAT Searching Sequence	
Write Command **AT+QCFG="nwscanseq"[,<scanseq>[,<effect>]]**	Response If **<scanseq>** and **<effect>** are both omitted, return the current configuration: **+QCFG: "nwscanseq",<scanseq>** **OK** If **<scanseq>** and **<effect>** are not omitted, configure the RAT searching sequence: **OK** If there is an error related to ME functionality, response: **+CME ERROR: <err>** If there is any other error, response: **ERROR**
Maximum Response Time	300ms

Parameter

<scanseq>	Number format. RAT searching sequence.

	(e.g.: 020301 stands for LTE Cat M1 → LTE Cat NB1 → GSM) 00 Automatic (LTE Cat M1 → LTE Cat NB1 → GSM) 01 GSM 02 LTE Cat M1 03 LTE Cat NB1
<effect>	Number format. When to take effect. 0 Take effect after UE reboots 1 Take effect immediately

5.2. AT+QCFG="nwscanmode" Configure RAT(s) to be Searched

The command specifies the RAT(s) allowed to be searched. If **<effect>** is omitted, the configuration will take effect immediately.

AT+QCFG="nwscanmode" Configure RAT(s) to be Searched	
Write Command **AT+QCFG="nwscanmode"[,<scanmode>[,<effect>]]**	Response If **<scanmode>** and **<effect>** are both omitted, return the current configuration: **+QCFG: "nwscanmode",<scanmode>** **OK** If **<scanmode>** and **<effect>** are not omitted, configure the RAT(s) to be searched: **OK** If there is an error related to ME functionality: **+CME ERROR: <err>** If there is any other error, response, **ERROR**
Maximum Response Time	300ms

Parameter

<scanmode>	Number format. RAT(s) to be searched. 0 Automatic 1 GSM only 3 LTE only
<effect>	Number format. When to take effect. 0 Take effect after UE reboots

	1	Take effect immediately

5.3. AT+QCFG="iotopmode" Configure Network Category to be Searched under LTE RAT

The command specifies the network category to be searched under LTE RAT. If **<effect>** is omitted, the configuration will take effect immediately.

AT+QCFG="iotopmode" Configure Network Category to be Searched under LTE RAT	
Write Command **AT+QCFG="iotopmode",[<mode>[,<effect>]]**	Response If **<mode>** and **<effect>** are both omitted, return the current configuration: **+QCFG: "iotopmode",<mode>** **OK** If **<mode>** and **<effect>** are not omitted, configure the network category to be searched under LTE RAT: **OK** If there is an error related to ME functionality: **+CME ERROR: <err>** If there is any other error, response: **ERROR**
Maximum Response Time	300ms

Parameter

<mode>	Number format. Network category to be searched under LTE RAT.	
	0	LTE Cat M1
	1	LTE Cat NB1
	2	LTE Cat M1 and LTE Cat NB1
<effect>	Number format. When to take effect.	
	0	Take effect after UE reboots
	1	Take effect immediately

5.4. AT+QCFG="band" Band Configuration

The command specifies the frequency bands allowed to be searched of UE. If **<effect>** is omitted, the configuration will take effect immediately.

AT+QCFG="band" Band Configuration	
Write Command **AT+QCFG="band"[,<gsmbandval>,<catm1bandval>,<catnb1bandval>[,<effect>]]**	Response If all configuration parameters and **<effect>** are omitted (that is, only execute **AT+QCFG="band"**), return current configuration: **+QCFG: "band",<gsmbandval>,<catm1bandval>,<catnb1bandval>** **OK** If configuration parameters are all entered, configure the frequency bands allowed to be searched: **OK** If there is an error related to ME functionality : **+CME ERROR: <err>** If there is any other error, response: **ERROR**
Maximum Response Time	300ms

Parameter

<gsmbandval>	A hexadecimal value that specifies the GSM frequency band. If it is set to 0, it means not to change GSM frequency band. (eg.: a=2(GSM1800)+ 8(GSM1900)) 00000000 No change 00000001 GSM 900MHz 00000002 GSM 1800MHz 00000004 GSM 850MHz 00000008 GSM 1900MHz 0000000F Any frequency band
<catm1bandval>	A hexadecimal value that specifies the LTE Cat M1 frequency band. If it is set to 0 or 0x40000000, it means not to change the frequency band. (eg.: 0x15=0x1(LTE B1)+0x4(LTE B3)+0x10(LTE B5)) 0x1 (CM_BAND_PREF_LTE_EUTRAN_BAND1) LTE B1 0x2 (CM_BAND_PREF_LTE_EUTRAN_BAND2) LTE B2 0x4 (CM_BAND_PREF_LTE_EUTRAN_BAND3) LTE B3

	0x8 (CM_BAND_PREF_LTE_EUTRAN_BAND4)	LTE B4
	0x10 (CM_BAND_PREF_LTE_EUTRAN_BAND5)	LTE B5
	0x80 (CM_BAND_PREF_LTE_EUTRAN_BAND8)	LTE B8
	0x800(CM_BAND_PREF_LTE_EUTRAN_BAND12)	LTE B12
	0x1000 (CM_BAND_PREF_LTE_EUTRAN_BAND13)	LTE B13
	0x20000 (CM_BAND_PREF_LTE_EUTRAN_BAND18)	LTE B18
	0x40000(CM_BAND_PREF_LTE_EUTRAN_BAND19)	LTE B19
	0x80000 (CM_BAND_PREF_LTE_EUTRAN_BAND20)	LTE B20
	0x2000000 (CM_BAND_PREF_LTE_EUTRAN_BAND26)	LTE B26
	0x8000000(CM_BAND_PREF_LTE_EUTRAN_BAND28)	LTE B28
	0x4000000000(CM_BAND_PREF_LTE_EUTRAN_BAND39)	LTE B39
	0x400A0E189F (CM_BAND_PREF_ANY)	Any frequency band
<catnb1bandval>	A hexadecimal value that specifies the LTE Cat NB1 frequency band. If it is set to 0 or 0x40000000, it means not to change the frequency band.	
	0x1 (CM_BAND_PREF_LTE_EUTRAN_BAND1)	LTE B1
	0x2 (CM_BAND_PREF_LTE_EUTRAN_BAND2)	LTE B2
	0x4 (CM_BAND_PREF_LTE_EUTRAN_BAND3)	LTE B3
	0x8 (CM_BAND_PREF_LTE_EUTRAN_BAND4)	LTE B4
	0x10 (CM_BAND_PREF_LTE_EUTRAN_BAND5)	LTE B5
	0x80 (CM_BAND_PREF_LTE_EUTRAN_BAND8)	LTE B8
	0x800(CM_BAND_PREF_LTE_EUTRAN_BAND12)	LTE B12
	0x1000 (CM_BAND_PREF_LTE_EUTRAN_BAND13)	LTE B13
	0x20000 (CM_BAND_PREF_LTE_EUTRAN_BAND18)	LTE B18
	0x40000(CM_BAND_PREF_LTE_EUTRAN_BAND19)	LTE B19
	0x80000 (CM_BAND_PREF_LTE_EUTRAN_BAND20)	LTE B20
	0x2000000 (CM_BAND_PREF_LTE_EUTRAN_BAND26)	LTE B26
	0x8000000(CM_BAND_PREF_LTE_EUTRAN_BAND28)	LTE B28
	0xA0E189F (CM_BAND_PREF_ANY)	Any frequency band
<effect>	Number format. When to take effect.	
	0	Take effect after UE reboots
	1	Take effect immediately

6 Solutions to Speed up Network Searching

6.1. Overview of LTE Cat NB1 Network Searching Time

As per 3GPP specifications, LTE Cat NB1 is expected to be deployed in much lower coverage area. Expected Minimum Coupling Loss for Cat NB1 is 164dB whereas for Cat M1 it is only around 155dB. This pushes device to accommodate more SNR range to detect a possible Cat NB1 cell deployment. And LTE Cat M1 has a bandwidth of 1.4MHz, whereas Cat NB1 has a 200KHz bandwidth. This means Cat NB1 has much more candidates to scan and detect in a given LTE deployed area, which leads to Cat NB1 searching time is a lot longer than Cat M1.

BG96 module divides the search process into three stages according to LTE Cat NB1 signal characteristics:

- Frequency scan level 0 (SNR 0): Scan only cells that are restricted to SNR 0. This takes only few milliseconds each raster.
- Frequency scan level 1 (SNR 1): Scan only cells that are restricted to SNR -9dB. This takes few 100msec for each raster.
- Frequency scan level 2 (SNR 2): Scan only cells that are restricted to SNR -12dB. This takes few 400-500msec each raster.

According to test results in ***Table 2***, it is shown that a long time has been used to search LTE Cat NB1 network, and the details are listed below. This, coupled with BG96's 13 FDD bands, makes the total network searching time very long.

- Under SNR 0, the module will only take tens of seconds to search the network.
- Under SNR 1, it takes five to six times the time under SNR 0.
- Under SNR 2, it takes ten to fifteen times of the time under SNR 0.

In order to avoid the long network searching time, it is recommended that the customers use either of the following solutions to optimize the network searching scheme of BG96.

6.2. Solutions to Speed up Network Searching

6.2.1. Disable LTE Cat NB1 and Only Enable Required RAT(s)

Network searching can be speed up by disabling LTE Cat NB1 and only enabling the required RAT(s).

Table 4: Solutions to Speed up Network Searching (Disable LTE Cat NB1)

Solutions		Related AT Commands
Disable LTE Cat NB1		Default configuration
Enable Required RAT(s)	Enable EGPRS only	AT+QCFG="nwscanmode",1
	Enable LTE Cat M1 only	AT+QCFG="iotopmode",0 AT+QCFG="nwscanmode",3
	Enable LTE Cat M1 and EGPRS both	AT+QCFG="iotopmode",0 AT+QCFG="nwscanmode",0

6.2.2. Enable Only LTE Cat NB1 Bands Supported by Current Operator

When LTE Cat NB1 is necessary, it is recommended to enable only the bands supported by the current service operator.

Table 5: Solutions to Speed up Network Searching (LTE Cat NB1 Enabled)

Regions	Solutions	Related AT Commands
U.S	● Enable the 3 RATs at the same time. ● Set B2, B4, B12 and B13 as the bands to be searched.	AT+QCFG="band",F,180A,180A AT+QCFG="iotopmode",2 AT+QCFG="nwscanseq",020301 AT+QCFG="nwscanmode",0 AT+QCFG="nwscanmode",3 *(set only when EGPRS is not needed)*
Europe	● Enable the 3 RATs at the same time. ● Set B3, B8 and B20 as the bands to be searched.	AT+QCFG="band",F,80084,80084 AT+QCFG="iotopmode",2 AT+QCFG="nwscanseq",020301 AT+QCFG="nwscanmode",0 AT+QCFG="nwscanmode",3 *(set only when EGPRS is not needed)*
Korea	● Enable the 3 RATs at the same time. ● Set B3 and B5 as the bands	AT+QCFG="band",F,14,14 AT+QCFG="iotopmode",2 AT+QCFG="nwscanseq",020301

	to be searched.	AT+QCFG="nwscanmode",0 AT+QCFG="nwscanmode",3 *(set only when EGPRS is not needed)*
Australia	• Enable the 3 RATs at the same time. • Set B3 and B28 as the bands to be searched.	AT+QCFG=”band”,F,8000004,8000004 AT+QCFG=”iotopmode”,2 AT+QCFG=”nwscanseq”,020301 AT+QCFG="nwscanmode",0 AT+QCFG="nwscanmode",3 *(set only when EGPRS is not needed)*
The Middle East	• Enable the 3 RATs at the same time. • Set B3, B5 and B28 as the bands to be searched.	AT+QCFG="band",F,8000084,8000084 AT+QCFG="iotopmode",2 AT+QCFG="nwscanseq",020301 AT+QCFG="nwscanmode",0 AT+QCFG="nwscanmode",3 *(set only when EGPRS is not needed)*
Japan	• Enable the 3 RATs at the same time. • Set B1, B8, B18 and B19 as the bands to be searched.	AT+QCFG="band”,F,60081,60081 AT+QCFG="iotopmode",2 AT+QCFG="nwscanseq",020301 AT+QCFG="nwscanmode",0 AT+QCFG="nwscanmode",3 *(set only when EGPRS is not needed)*
China	• Enable the 3 RATs at the same time. • Set B1, B3, B5, B8, B26 and B39 (B39 for LTE Cat M1 only) as the bands to be searched.	AT+QCFG="band”,F,4002000095,2000095 AT+QCFG="iotopmode",2 AT+QCFG=”nwscanseq",020301 AT+QCFG="nwscanmode",0 AT+QCFG="nwscanmode",3 *(set only when EGPRS is not needed)*

7 Typical Problems and Cause Analysis

This chapter describes some typical customer problems and corresponding cause analysis.

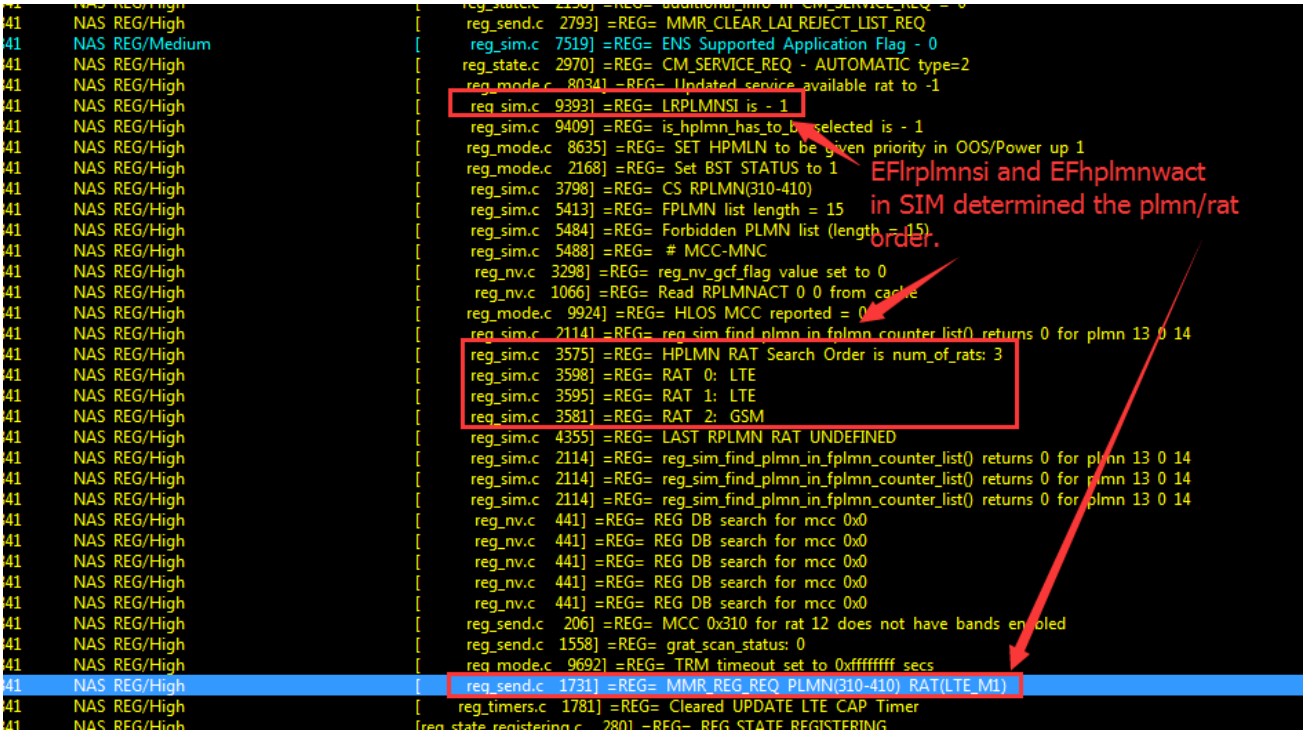
7.1. Network Searching Sequence Determined by (U)SIM Card Files

Problem Description:

The RAT searching sequence does not comply with the setting of AT+QCFG="nwscanseq".

Cause Analysis:

The sequence is determined by some files in (U)SIM card, as illustrated in the example below



7.2. Network Searching Sequence Determined by RPLMN/RPLMNACT Stored in Module

Problem Description:

The RAT searching sequence does not comply with the setting of AT+QCFG="nwscanseq".

Cause Analysis:

In the example as shown below, $EF_{LRPLMNSI}$ (0x6FDC, this file is optional in 3GPP protocol) is not existed in the (U)SIM card. The module thus searches RPLMN/RPLMNACT stored inside.