BG95&BG77

Network Searching Scheme Introduction

LPWA Module Series

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About the Document

Revision History

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1 Introduction

This document mainly introduces the supported RATs and frequency bands of Quectel BG95 and BG77 modules, and also describes the network searching scheme by illustrating related AT commands and network searching/registration procedure.

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

2 Supported RATs and Bands

2.1. Supported RATs and Bands of BG95

Quectel BG95 series module supports three RATs: eMTC, NB-IoT and EGPRS.

- Default RATs: eMTC and EGPRS
- Default searching sequence: eMTC → EGPRS
- If the three RATs need to be supported synchronously or other searching sequences 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 BG95 series modules.

Table 1: Frequency Bands of BG95 Series Modules

RAT	Frequency Band
eMTC	B1/B2/B3/B4/B5/B8/B12/B13/B14/B18/B19/B20/B25/B26/B27/B28/B31/B66//B72/B73/B85
NB-IoT	B1/B2/B3/B4/B5/B8/B12/B13/B18/B19/B20/B25/B26/B28/B31/B66/B71/B72/B73/B85
EGPRS	GSM850, EGSM900, DCS1800, PCS1900

NOTE

Quectel BG95 series module includes multiple versions with different RATs and frequency bands. For specific differences, please refer to *Quectel_BG95_LPWA_Specification*.

2.2. Supported RATs and Bands of BG77

Quectel BG77 module supports two RATs: eMTC and NB-IoT.

- Default RAT to be searched: eMTC
- If the two RATs need to be supported synchronously or other searching sequences 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 BG77.

Table 2: Frequency Bands of BG95&BG77 Modules

RAT	Frequency Band
eMTC	B1/B2/B3/B4/B5/B8/B12/B13/B14/B18/B19/B20/B25/B26/B27/B28/B66/B85*
NB-IoT	B1/B2/B3/B4/B5/B8/B12/B13/B18/B19/B20/B25/B26/B28/B66/B71/B85*

NOTE

"*" means under development.

3 Network Searching/Registration Processes

The network searching/registration processes of BG95/BG77 are illustrated below:

1. **UE initialization**

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

2. **RAT/PLMM selection**

   - Set the RAT searching sequence and the RAT(s) allowed to be searched according to network searching related NVM and related (U)SIM EF files.
   - PLMN selection can be performed in either automatic or manual modes.

3. **(E)ARFCN scan (frequency scan)**

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

4. **Cell searching**

   Cell searching refers to cell recognition and downlink synchronization.

5. **System information analysis**

   This step is mainly to read and analyze MIB and SIB information. For detailed definition of system information, please refer to *3GPP TS 36.331 [5.2]*.

   - MIB information includes the number of antennas, downlink bandwidth, cell ID and registered frequency point.
   - SIB information includes PLMN, cell ID, etc.

6. **Cell selection**

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

7. **Cell camping**

   Cell camping is started after successful cell selection.

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

   After the cell is 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 an attach accept/location updating accept**

4 Processes Influencing Network Registration Speed

During network searching/registration, RAT/PLMN selection and LTE EARFCN scan are the processes that will affect network registration speed, and the following provides details about the two processes.

4.1. RAT/PLMN Selection

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

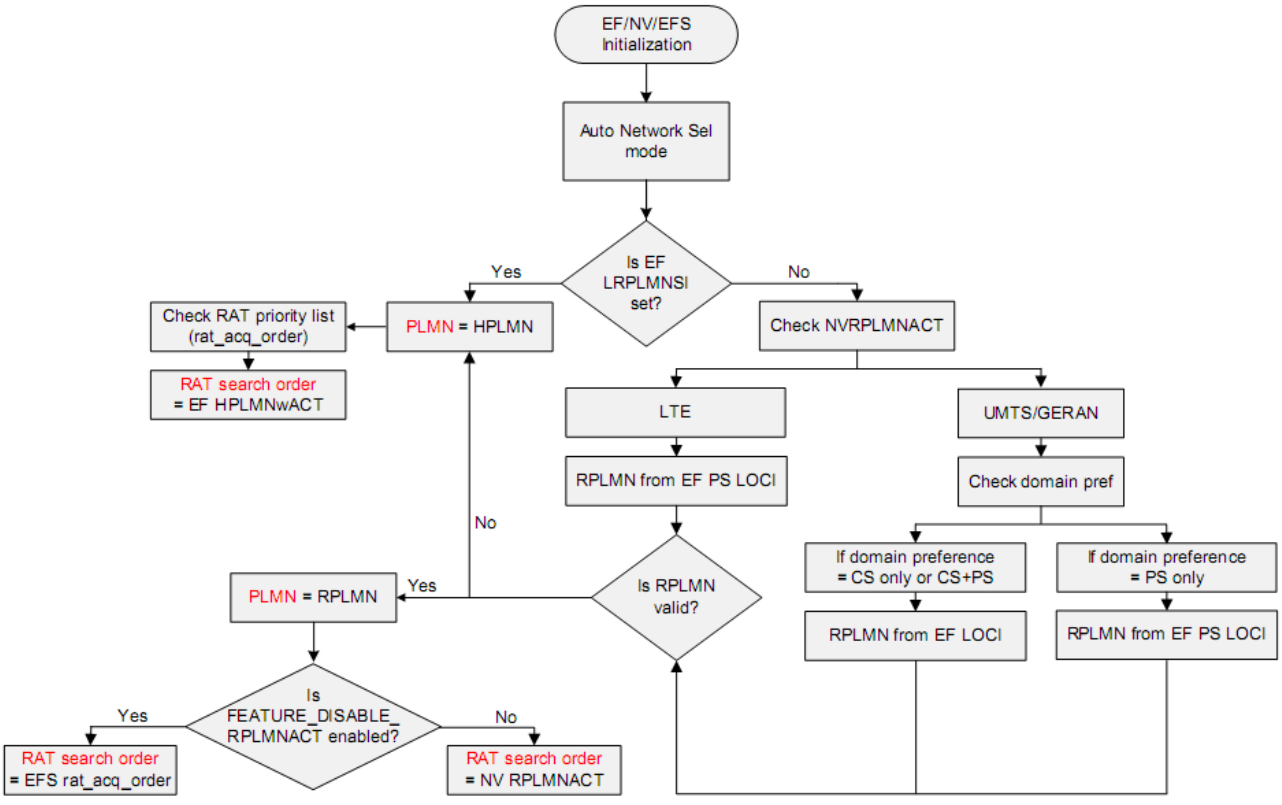


Figure 1: RAT/PLMN Selection Procedure

4.2. LTE EARFCN Scan (Frequency Scan)

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

LTE EARFCN scan includes system scan and band scan. 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 procedure is called system scan. This procedure will speed up network registration process. If the network information acquisition failed in system scan, UE will attempt to scan all supported bands, and this is band scan.

According to statistics, the scan for all bands under eMTC and EGPRS takes about tens of seconds. But under NB-IoT, due to the characteristics of NB-IoT network (especially the weak signal feature), it will take a longer period of time for frequency scan. The following table shows the test results of some of the NB-IoT bands, which displays the frequency scan time required in each band.

Table 3: Network Searching Time under NB-IoT with Different SNR in Each Band

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

As BG95 and BG77 modules support dozens of bands under NB-IoT, it is recommended to enable only the bands supported by the service operator.

Table 4: eMTC/NB-IoT 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	eMTC/NB-IoT		■		■			
B2	1900	eMTC/NB-IoT	■						
B3	1800	eMTC/NB-IoT		■	■		■	■	■
B4	1700	eMTC	■						
B5	850	eMTC/NB-IoT		■			■		
B8	900	eMTC/NB-IoT		■	■	■		■	
B12	700	eMTC/NB-IoT	■						
B13	700	eMTC/NB-IoT	■						
B18	800	eMTC/NB-IoT				■			
B19	800	eMTC/NB-IoT				■			
B20	800	eMTC/NB-IoT						■	
B26	850	eMTC/NB-IoT		■					
B28	700	eMTC/NB-IoT			■				■

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.

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** As long as **<scanseq>** is present, configure the RAT searching sequence: **OK** If there is an error related to ME functionality: **+CME ERROR: <err>** If there is any other error: **ERROR**
Maximum Response Time	300ms

Parameter

<scanseq>	Number format. RAT searching sequence. (e.g.: 020301 stands for eMTC → NB-IoT → GSM)

	00	Automatic (eMTC → NB-IoT → GSM)
	01	GSM (For BG95-M3/-M5 only)
	02	eMTC
	03	NB-IoT
<effect>	Number format. When to take effect. The default value will be used if it is omitted.	
	0	Take effect after UE reboots
	1	Take effect immediately

NOTES

1. This command is invalid on BG95-M1 and BG95-N1.
2. GSM RAT (**<scanseq>**=02) is valid on BG95-M3/-M5 only.
3. NB-IoT is disabled by default.

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

The command specifies the RAT(s) allowed to be searched.

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** As long as **<scanmode>** is present, 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: **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. The default value will be used if it is omitted. 0 Take effect after UE reboots 1 Take effect immediately

NOTE

This command is valid on BG95-M3/-M5 only.

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

The command specifies the network category to be searched under LTE RAT.

AT+QCFG="iotopmode"	**Configure Network Category 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** As long as **<mode>** is present, 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: **ERROR**
Maximum Response Time	300ms

Parameter

<mode>	Number format. Network category to be searched under LTE RAT. 0 eMTC 1 NB-IoT 2 eMTC and NB-IoT
<effect>	Number format. When to take effect. The default value will be used if it is omitted. 0 Take effect after UE reboots 1 Take effect immediately

NOTE

This command is invalid on BG95-M1 and BG95-N1.

5.4. AT+QCFG="band" Configure Band

The command specifies the frequency bands allowed to be searched of UE.

AT+QCFG="band" Configure Band	
Write Command **AT+QCFG="band"[,<gsmbandval>,<emtcbandval>,<nbiotbandval>[,<effect>]]**	Response If all configuration parameters are omitted, return the current configuration: **+QCFG: "band",<gsmbandval>,<emtcbandval>,<nbiotbandval>** **OK** As long as **<gsmbandval>**, **<emtcbandval>** and **<nbiotbandval>** are 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 900 MHz 00000002 GSM 1800 MHz 00000004 GSM 850 MHz 00000008 GSM 1900 MHz 0000000F Any frequency band
<emtcbandval>	A hexadecimal value that specifies the eMTC frequency band. If it is set to 0, 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 0x2000 (CM_BAND_PREF_LTE_EUTRAN_BAND14) LTE B14 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 0x1000000 (CM_BAND_PREF_LTE_EUTRAN_BAND25) LTE B25 0x2000000 (CM_BAND_PREF_LTE_EUTRAN_BAND26) LTE B26 0x4000000 (CM_BAND_PREF_LTE_EUTRAN_BAND27) LTE B27 0x8000000 (CM_BAND_PREF_LTE_EUTRAN_BAND28) LTE B28 0x40000000 (CM_BAND_PREF_LTE_EUTRAN_BAND31) LTE B31 0x20000000000000000(CM_BAND_PREF_LTE_EUTRAN_BAND66) LTE B66 0x800000000000000000 (CM_BAND_PREF_LTE_EUTRAN_BAND72) LTE B72 0x1000000000000000000 (CM_BAND_PREF_LTE_EUTRAN_BAND73) LTE B73 0x10000000000000000000 (CM_BAND_PREF_LTE_EUTRAN_BAND85) LTEB85 0x4001C2000000000F0E389F (CM_BAND_PREF_ANY) Any frequency band
<nbiotbandval>	A hexadecimal value that specifies the NB-IoT frequency band. If it is set to 0, 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
	0x1000000 (CM_BAND_PREF_LTE_EUTRAN_BAND25)	LTE B25
	0x2000000 (CM_BAND_PREF_LTE_EUTRAN_BAND26)	LTE B26
	0x8000000 (CM_BAND_PREF_LTE_EUTRAN_BAND28)	LTE B28
	0x40000000 (CM_BAND_PREF_LTE_EUTRAN_BAND31)	LTE B31
	0x20000000000000000 (CM_BAND_PREF_LTE_EUTRAN_BAND66)	LTE B66
	0x400000000000000000 (CM_BAND_PREF_LTE_EUTRAN_BAND71)	LTE B71
	0x800000000000000000 (CM_BAND_PREF_LTE_EUTRAN_BAND72)	LTE B72
	0x1000000000000000000 (CM_BAND_PREF_LTE_EUTRAN_BAND73)	LTE B73
	0x10000000000000000000 (CM_BAND_PREF_LTE_EUTRAN_BAND85)	LTE B85
	0x4001C2000000004E0E189F (CM_BAND_PREF_ANY)	Any frequency band
<effect>	Number format. When to take effect. The default value will be used if it is omitted.	
	0 Take effect after UE reboots	
	1 Take effect immediately	

NOTES

1. **<gsmbandval>** is valid on BG95-M3/-M5 only.
2. **<emtcCbandval>** is invalid on BG95-N1.
3. **<nbiotbandval>** is invalid on BG95-M1.

6 Solutions to Speed up Network Searching

6.1. Overview of NB-IoT Network Searching Time

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

BG95 and BG77 modules divide the search process into three levels according to NB-IoT signal characteristics:

- Frequency scan level 0 (SNR level 0): SNR value > 0 dB. This takes only few milliseconds for each raster.
- Frequency scan level 1 (SNR level 1): SNR value ranges from 0 to -9 dB. This takes about 100 msec for each raster.
- Frequency scan level 2 (SNR level 2): typical SNR value is about -12 dB. This takes about 400 to 500 msec for each raster.

According to the test results in ***Table 2***, it is shown that a long period of time has been used to search NB-IoT network, and the details are listed below. This, coupled with the dozens of bands supported by the modules, makes the total network searching time very long.

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

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

6.2. Solutions to Speed up Network Searching

6.2.1. Disable NB-IoT and Enable Required RAT(s)

Network searching can be sped up by disabling NB-IoT and only enabling the required RAT(s).

Table 5: Solutions to Speed up Network Searching (Disable NB-IoT)

Solutions		Related AT Commands
Disable NB-IoT		Default configuration
Enable Required RAT(s)	Enable EGPRS only	AT+QCFG="nwscanmode",1
	Enable eMTC only	AT+QCFG="iotopmode",0 AT+QCFG="nwscanmode",3
	Enable eMTC and EGPRS both	AT+QCFG="iotopmode",0 AT+QCFG="nwscanmode",0

6.2.2. Enable NB-IoT Bands Supported by Current Operator Only

When NB-IoT is necessary, it is recommended to enable only the bands supported by the current service operator.

Table 6: Solutions to Speed up Network Searching (Enable NB-IoT Bands Supported)

Regions	Solutions	Related AT Commands
U.S	Enable the three RATs synchronously. 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 three RATs synchronously. 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 three RATs synchronously. Set B3 and B5 as the bands to be searched.	AT+QCFG="band",F,14,14 AT+QCFG="iotopmode",2 AT+QCFG="nwscanseq",020301 AT+QCFG="nwscanmode",0

		AT+QCFG="nwscanmode",3 (set only when EGPRS is not needed)
Australia	Enable the three RATs synchronously. 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 three RATs synchronously. 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 three RATs synchronously. 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 three RATs synchronously. Set B1, B3, B5, B8 and B26 as the bands to be searched.	AT+QCFG="band",F,2000095,2000095 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 problems and corresponding cause analysis.

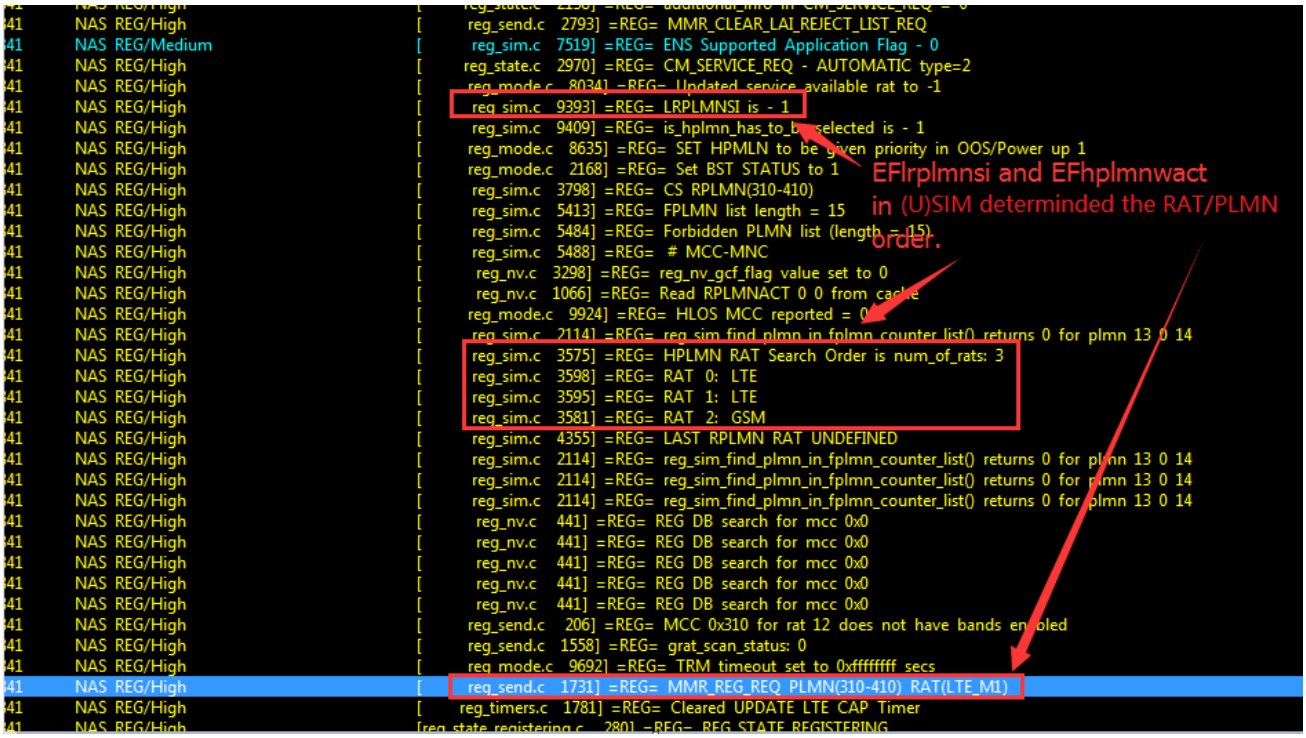
7.1. Network Searching Sequence Determined by (U)SIM Card Files

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



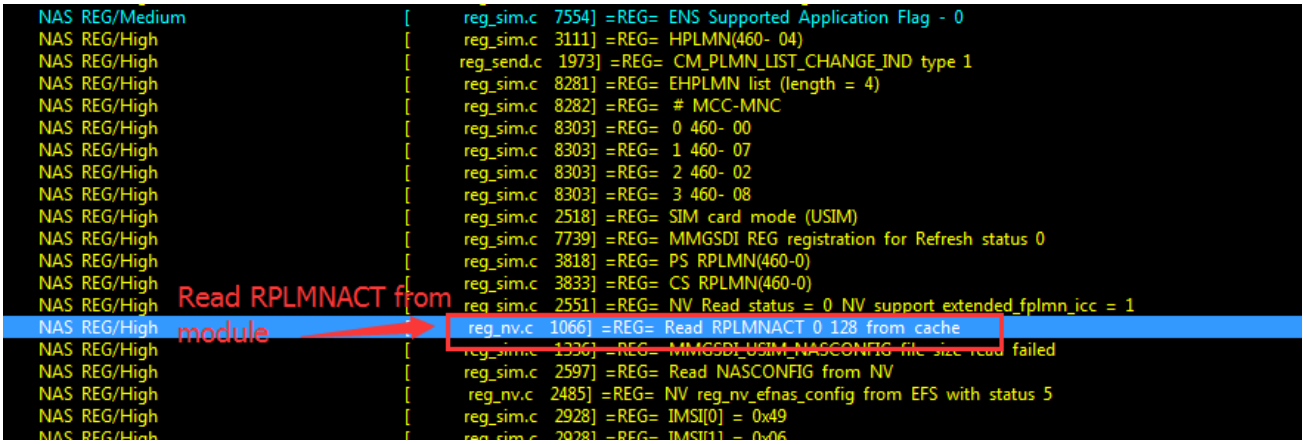
7.2. Network Searching Sequence Determined by RPLMN/RPLMNACT Stored in Modules

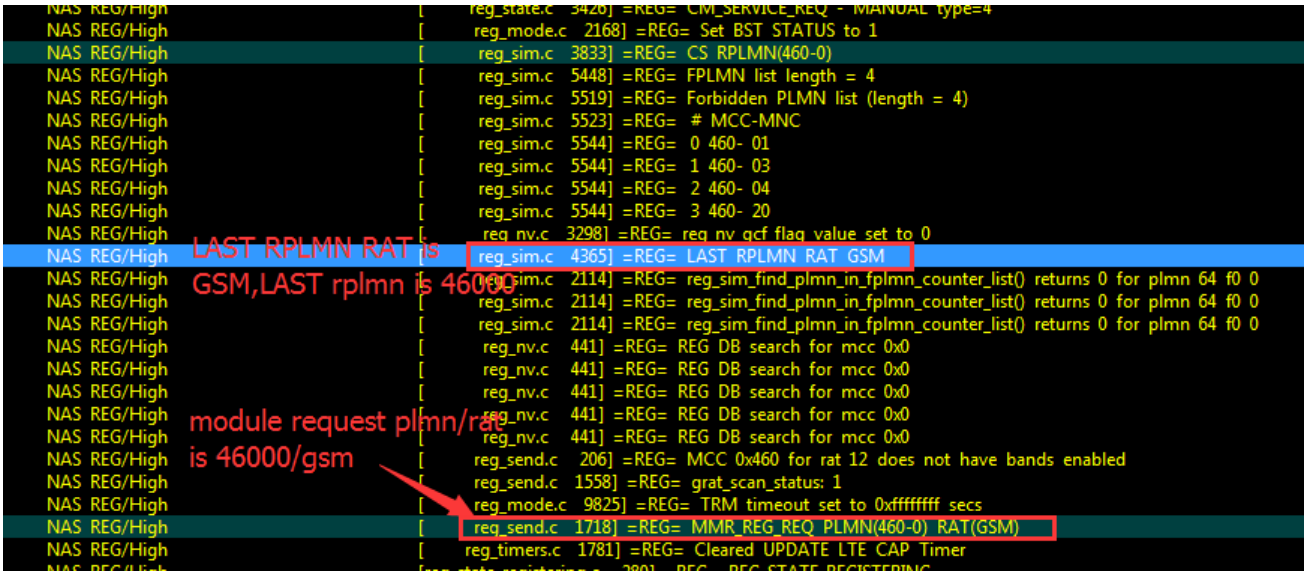
Problem Description:

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.





8 Appendix A References

Table 7: Terms and Abbreviations

Abbreviation	Description
3GPP	3rd Generation Partnership Project
ARFCN	Absolute Radio Frequency Channel Number
EARFCN	E-UTRA Absolute Radio Frequency Channel Number
EGPRS	Enhanced General Packet Radio Service
EF	Elementary File
eMTC	Enhanced Machine Type Communication
GSM	Global System for Mobile Communications
LTE	Long Term Evolution
MIB	Master Information Block
NB-IoT	Narrow Band Internet of Things
NVM	Non-Volatile Memory
PCI	Peripheral Component Interconnect
PLMN	Public Land Mobile Network
RAT	Radio Access Technology
RRC	Radio Resource Control
SIB	System Information Block
SNR	Signal Noise Ratio
(U)SIM	(Universal) Subscriber Identity Module
UE	User Equipment