

BC66 Network Searching Scheme Introduction

NB-IoT Module Series

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About the Document

History

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1 Introduction

This document introduces the supported bands of BC66 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.

1.1. Supported Bands

Quectel BC66 supports the following bands:

B1, B2, B3, B4, B5, B8, B12, B13, B17, B18, B19, B20, B25, B26*, B28, B66

NOTE

“*” means under development.

2 Network Searching/Registration Procedure

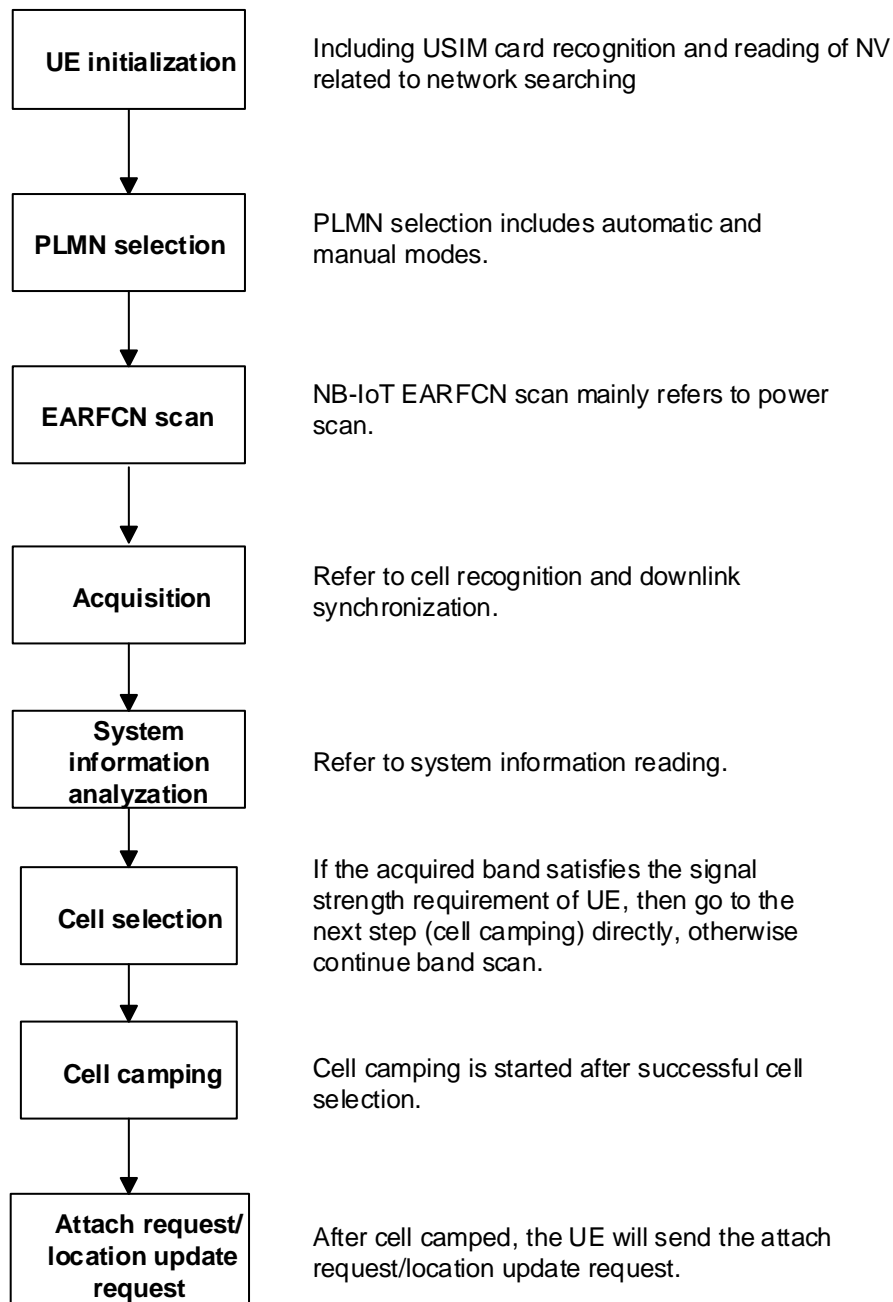


Figure 1: Overall Network Searching Process

3 Processes Affect Registration Speed

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

3.1. PLMN Selection

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

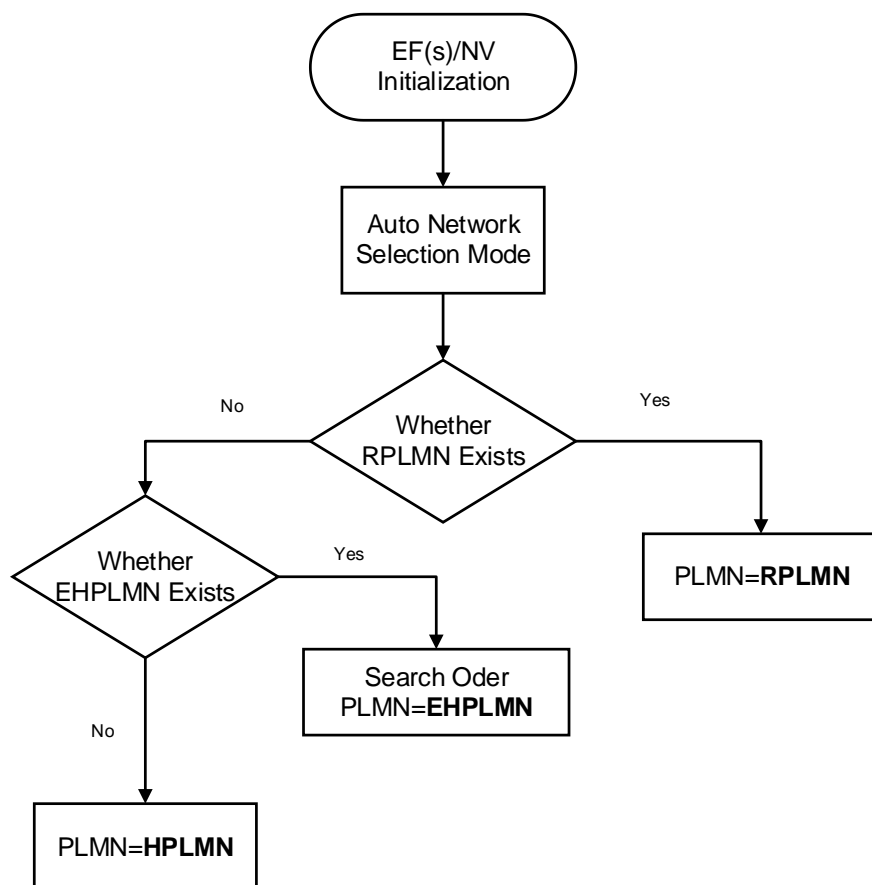


Figure 2: PLMN Selection Procedure

3.2. EARFCN Scan (Frequency Scan)

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

When the PLMN is selected, the module begins to scan all supported bands under NB-IoT network to find a suitable cell to camp on for communication with the network. UE will optimize this process according to the data recorded in the inserted USIM card and NVRAM to accelerate the speed of network access. The overall search process is as follows:

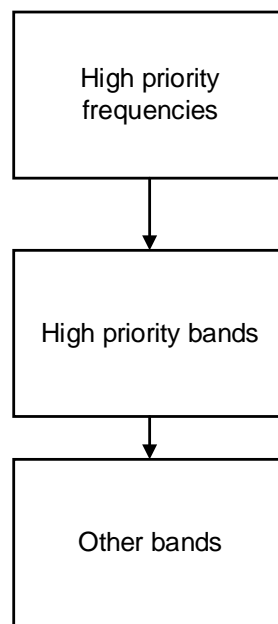


Figure 3: Frequency Scanning Process

The high-priority frequencies include the previously registered frequencies or prior frequencies according to the EHPLMN/HPLMN of the inserted USIM card and the frequencies which are recorded in the search process.

Please be noted that in the scanning process, if an appropriate frequency is scanned and the access criteria is met, UE will initiate an attach procedure and will not continue to search for other frequencies or bands.

BC66 supports multiple bands under LTE Cat NB1, so it may spend a few minutes on searching a suitable cell during full-band search. Due to the bandwidth of NB-Clot is 200KHz, it may take a longer period of time for frequency scan, especially in weak signal conditions. The following table shows our test results, which displays the frequency scan time required for each band, and the unit of time is second.

Table 1: Network Searching Time under LTE Cat NB1 with Different CEL in Each Band

Band	F _{DL_low} (MHz)	N _{Offs-DL}	Range of N _{DL}	F _{UL_low} (MHz)	N _{Offs-UL}	Range of N _{UL}	Band Width	Time in CE 0	Time in CE 1	Time in CE 2
1	2110	0	0 - 599	1920	18000	18000 - 18599	60M	36	180	432
2	1930	600	600 - 1199	1850	18600	18600 - 19199	60M	36	180	432
3	1805	1200	1200 - 1949	1710	19200	19200 - 19949	75M	45	225	540
4	2110	1950	1950 - 2399	1710	19950	19950 - 20399	45M	27	135	324
5	869	2400	2400 - 2649	824	20400	20400 - 20649	25M	15	75	180
8	925	3450	3450 - 3799	880	21450	21450 - 21799	35M	21	105	252
12	729	5010	5010 - 5179	699	23010	23010 - 23179	17M	10.2	51	122.4
13	746	5180	5180 - 5279	777	23180	23180 - 23279	10M	6	30	72
17	734	5730	5730 - 5849	704	23730	23730 - 23849	12M	7.2	36	86.4
18	860	5850	5850 - 5999	815	23850	23850 - 23999	15M	9	45	108
19	875	6000	6000 - 6149	830	24000	24000 - 24149	15M	9	45	108
20	791	6150	6150 - 6449	832	24150	24150 - 24449	30M	18	90	216
25	1930	8040	8040 - 8689	1850	26040	26040 - 26689	65M	39	195	468
26	859	8690	8690 - 9039	814	26690	26690 - 27039	35M	21	105	252
28	758	9210	9210 - 9659	703	27210	27210 - 27659	45M	27	135	324
66	2110	66436	66436 - 67335	1710	131972	131972 - 132671	90M	54	270	648

NOTES

1. F_{DL_low}: The lowest frequency of the downlink operating band
2. F_{UL_low}: The lowest frequency of the uplink operating band
3. N_{Offs-DL}: Offset used for calculating downlink EARFCN
4. N_{Offs-UL}: Offset used for calculating uplink EARFCN

5. N_{DL}: Downlink EARFCN
6. N_{UL}: Uplink EARFCN

As BC66 supports sixteen LTE Cat NB1 bands, we recommend that customers only enable the bands used by the service operator.

Table 2: LTE Cat NB1 Band Deployment Conditions over the World

Band	U.S.	China	The Middle East	Japan	Korea	Europe	Australia
1		■		■			
2	■						
3		■	■		■	■	■
4	■						
5		■			■		
8		■	■	■		■	
12	■						
13	■						
17							
18				■			
19				■			
20		■				■	
25							
26							
28			■				■
66	■						

4 Network Searching Related AT Commands

In order to optimize network searching/registration time, related AT commands can be used to set the preferred bands or preferred frequency to be searched.

4.1. AT+QBAND Get and Set Mobile Operation Band

The command is used to get the currently locked band or set the bands to be locked. Please refer to *Quectel_BC66_AT_Commands_Manual* for possible **<err>** values.

AT+QBAND Get and Set Mobile Operation Band	
Test Command AT+QBAND=?	Response +QBAND: (range of <band number>s)[,(list of supported <band>s)] OK
Read Command AT+QBAND?	Response +QBAND: <Setting Band> OK If there is any error, response: ERROR or +CME ERROR: <err>
Write Command AT+QBAND=<band number>[,<band>[,<band>[,...]]]	Response OK If there is any error, response: ERROR or +CME ERROR: <err>
Maximum Response Time	300ms

Parameter

<band number>	Integer value indicating the number of bands that can be locked 0 No band to be locked 1-16 Number of bands to be locked
<band>	Integer value indicating NB-IoT band(s) that can be locked Valid values: 1, 2, 3, 4, 5, 8, 12, 13, 17, 18, 19, 20, 25, 26*, 28, 66
<Setting Band>	Integer value indicating the band(s) being locked Valid values: 1, 2, 3, 4, 5, 8, 12, 13, 17, 18, 19, 20, 25, 26*, 28, 66

NOTE

"*" means under development.

Example

```

AT+QBAND=?           //Query the list of bands that can be locked
+QBAND: (0-16),(1,2,3,4,5,8,12,13,17,18,19,20,25,26,28,66)

OK
AT+QBAND=1,5         //Set the band to be locked

OK
AT+QBAND?            //Query the band being locked
+QBAND: 5

OK

```

4.2. AT+QLOCKF Lock NB-IoT Frequency

This command is used to lock UE to specific frequency and optionally Cell ID. Please refer to *Quectel_BC66_AT_Commands_Manual* for possible <err> values.

AT+QLOCKF Lock NB-IoT Frequency

Test Command AT+QLOCKF=?	Response OK
Read command AT+QLOCKF?	Response OK
Write Command AT+QLOCKF=<mode>[,<earfcn>,<ear	Response OK

fcn_offset>[,<pci>]	<p>If there is any error, response:</p> <p>ERROR</p> <p>or</p> <p>+CME ERROR: <err></p>
Maximum Response Time	300ms

Parameter

<mode>	<p>Integer value indicating activate/remove lock</p> <p>0 Remove lock</p> <p>1 Activate lock</p>
<earfcn>	<p>Integer value indicating requested EARFCN on which to lock. Range: 0-262143.</p> <p>Value 0 indicates to remove any lock for EARFCN and Cell.</p>
<earfcn_offset>	<p>Integer value indicating requested EARFCN offset</p> <p>0 Offset of -2</p> <p>1 Offset of -1</p> <p>2 Offset of -0.5</p> <p>3 Offset of 0</p> <p>4 Offset of 1</p>
<pci>	<p>Integer value indicating the physical cell ID. Range: 0-503.</p>

Example

```
AT+QLOCKF=1,2175,2 //Lock the frequency
OK
```

4.3. AT+QCSEARFCN Clear NB-IoT Stored EARFCN List

This command is used to clear stored EARFCN list for the UE. Please refer to *Quectel_BC66_AT_Commands_Manual* for possible **<err>** values.

AT+QCSEARFCN Clear NB-IoT Stored EARFCN List	
<p>Execution Command</p> <p>AT+QCSEARFCN</p>	<p>Response</p> <p>+QCSEARFCN: <status></p> <p>OK</p> <p>If there is any error, response:</p> <p>ERROR</p>

	or +CME ERROR: <err>
Maximum Response Time	300ms

Parameter

<status>	Integer value indicating the EARFCN has been cleared
0	Successful
2	Failure
3	No stored EARFCN found

Example

AT+QCSEARFCN

+QCSEARFCN: 0

OK

5 Solutions to Speed up Network Searching

5.1. 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. The Expected Maximum Coupling Loss for Cat NB1 is 164dB, which means the device needs to accommodate more RSRP range to detect a possible Cat NB1 cell deployment. LTE Cat NB1 has a bandwidth of 200KHz, which means the UE has more candidates to scan and detect in a given deployed area compared to the UE in LTE networks.

If the preferred frequencies or the preferred bands exist, UE will search these preferred frequencies or the preferred bands first. If it cannot find a suitable cell in the selected PLMN, it will try to search another suitable cell for at most two times with different thresholds in all other bands which are supported in the selected PLMN. And if it still cannot find a suitable cell to camp on, it will search cells in another new PLMN.

5.2. Solutions to Speed up Network Searching

It is recommended to enable only the bands supported by the current service operator.

For example, the module may be configured to enable only B2/B4/B12/B13/B66 in the U.S. with **AT+QBAND=5,2,4,12,13,66**. According to the table below, the module can be set to enable different bands in different areas. And further, the module may be configured to enable only the bands supported by the USIM card inserted.

Table 3: Solutions to Speed up Network Searching

Operator	AT Command	Description
T-Mobile	AT+QBAND=4,2,4,12,66	To enable B2/B4/B12/B66 only
SoftBank	AT+QBAND=4,1,8,18,19	To enable B1/B8/B18/B19 only

Vodafone	AT+QBAND=3,3,8,20	To enable B3/B8/B20 only
LGU+	AT+QBAND=1,5	To enable B5 only
RJIO	AT+QBAND=2,3,5	To enable B3/B5 only
Thailand's Operator	AT+QBAND=1,8	To enable B8 only

NOTE

The above configurations may vary with the changes of corresponding operator's network deployments.

6 Typical Problems and Cause Analysis

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

6.1. Network Registration Failure

Problem Description:

The module is always in cell searching status, and cannot register on the network.

Cause Analysis:

- 1) The band locked does not match with the band supported by the network operator of the USIM card inserted. The USIM card is provided by mobile network operator CMCC which supports LTE B8 while the band locked is B5 (as shown in the log below), so it cannot find a suitable cell to camp on. If there is no LTE Cat NB1 network signal available, the module will also fail in network registration and no logs are available.

```

10 | AlsReadPlmnSelCnf
10 | AlsReadPlmnSelReq
10 | MmrEhplmnListReq
10 | ErrcUpdateReq
10 | ApexMmNetworkStateInd
10 | CirmDataInd
10 | CimuxAtDataReq
10 | CimuxAtDataCnf
10 | MmrPlmnListReq
10 | ErrcUpdateReq
10 | ErrcPlmnListReq
10 | ErrcDebugStateChangeInd
10 | NphyCellSearchReq
10 | AlsReadPlmnSelCnf

id
body.nphyCellSearchReq.searchType
body.nphyCellSearchReq.searchScope
body.nphyCellSearchReq.bandNum
body.nphyCellSearchReq.band[0].band
body.nphyCellSearchReq.band[0].priority
body.nphyCellSearchReq.isAppIpmnSearch
body.nphyCellSearchReq.startBandFreqIncluded
body.nphyCellSearchReq.startBand
body.nphyCellSearchReq.startFreq
body.nphyCellSearchReq.carrierNum
body.nphyCellSearchReq.cellNum

= SIG_NPHY_CELL_SEARCH_REQ 0x00031803 ;
= NPHY_SEARCH_TYPE_BAND_LIST 0x00 ;
= NPHY_BAND_SEARCH_SCOPE_ALL 0x00 ;
= 0x01 1 ;
= 0x0005 5 ;
= NPHY_BAND_PRIORITY_LOW 0x01 ;
= 0x00 0 ;
= 0x00 0 ;
= 0x0000 0 ;
= 0x00000000 0 ;
= 0x00 0 ;
= 0x00 0 ;

```

B5 is locked

- 2) If there is a signal from another operator, the module may try to camp on the cell which supports the band, while the attach request will be rejected with the cause as shown below.

```

000864 | 2018-12-12 15:58:49.604 | 000:00:24.800 | LTE_BCCH_SCH | Sib1 | EARFCN = 2504, PCI = 280
000868 | 2018-12-12 15:58:49.950 | 000:00:24.850 | LTE_BCCH_BCH | Sib1 | EARFCN = 2506, PCI = 33
000870 | 2018-12-12 15:58:49.952 | 000:00:24.850 | LTE_BCCH_SCH | Sib1 | EARFCN = 2506, PCI = 33
000874 | 2018-12-12 15:58:50.316 | 000:00:25.210 | LTE_BCCH_BCH | Sib1 | EARFCN = 2508, PCI = 62
000876 | 2018-12-12 15:58:50.318 | 000:00:25.210 | LTE_BCCH_SCH | Sib1 | EARFCN = 2508, PCI = 62
000894 | 2018-12-12 15:59:05.333 | 000:00:40.230 | LTE_BCCH_BCH | Sib1 | EARFCN = 2508, PCI = 281
000896 | 2018-12-12 15:59:05.337 | 000:00:40.230 | LTE_BCCH_SCH | Sib1 | EARFCN = 2508, PCI = 281
000900 | 2018-12-12 15:59:06.381 | 000:00:41.240 | LTE_BCCH_SCH | Sib1 | EARFCN = 2508, PCI = 281
000917 | 2018-12-12 15:59:06.507 | 000:00:41.260 | UL | LEN:50 | Attach request
000923 | 2018-12-12 15:59:06.513 | 000:00:41.270 | LTE_UL_CCH | SRB0 | Rrc_connection_request_r13
000941 | 2018-12-12 15:59:06.923 | 000:00:41.810 | LTE_DL_CCH | SRB0 | Rrc_connection_setup_r13
000948 | 2018-12-12 15:59:06.937 | 000:00:41.820 | LTE_UL_CCH | SRB1bis | Rrc_connection_setup_complete_r13
000963 | 2018-12-12 15:59:07.105 | 000:00:41.940 | LTE_DL_CCH | SRB1bis | Dl_information_transfer_r13
000966 | 2018-12-12 15:59:07.107 | 000:00:41.940 | LTE_DL_CCH | SRB1bis | Rrc_connection_release_r13
000970 | 2018-12-12 15:59:07.112 | 000:00:41.940 | DL | LEN:3 | Attach reject
000998 | 2018-12-12 15:59:07.237 | 000:00:42.020 | LTE_BCCH_BCH | Sib1 | EARFCN = 2508, PCI = 281

```

Contents of NAS message: 07440E
DLT: 147, Payload: nas-eps_plain (Non-Access-Stratum (NAS) PDU)
Non-Access-Stratum (NAS) PDU
0000 = Security header type: Plain NAS message, not secured
... 0111 = Protocol discriminator: EPS mobility management m
NAS EPS Mobility Management Message Type: Attach reject (0x14)
EMM cause
Cause: EPS services not allowed in this PLMN (14)

6.2. Ultra-long Time for Network Registration Initiation

Problem Description:

The module requires a long period of time (approx. 10 minutes) for initiating network registration.

108717	001175	2018-12-14 10:06:05.547	000:00:27.760	LTE_DL_DCH	SRB1bis	Rrc_connection_release_r13	
111903	003823	2018-12-14 10:09:11.572	000:03:00.580	LTE_BCCH_SCH	Sib1	EARFCN = 3736, PCI = 47	
112357	004376	2018-12-14 10:09:43.977	000:03:32.990	LTE_BCCH_SCH	Mib	EARFCN = 1452, PCI = 39	
112359	004378	2018-12-14 10:09:43.985	000:03:32.990	LTE_BCCH_SCH	Sib1	EARFCN = 1452, PCI = 39	
112382	004406	2018-12-14 10:09:44.805	000:03:33.650	LTE_BCCH_SCH	Sib1	EARFCN = 1454, PCI = 281	
116964	009926	2018-12-14 10:15:13.365	000:09:02.050	LTE_BCCH_SCH	Sib1	EARFCN = 2506, PCI = 193	
117623	010716	2018-12-14 10:15:59.147	000:09:48.140	LTE_BCCH_SCH	Mib	EARFCN = 1454, PCI = 117	
117625	010718	2018-12-14 10:15:59.156	000:09:48.140	LTE_BCCH_SCH	Sib1	EARFCN = 1454, PCI = 117	
117980	011134	2018-12-14 10:16:20.518	000:10:09.310	LTE_BCCH_SCH	Sibx	EARFCN = 1454, PCI = 117	
117995	011150	2018-12-14 10:16:21.775	000:10:09.350	UL	LEN:86	Attach request	
118009	011167	2018-12-14 10:16:22.088	000:10:09.470	LTE_BCCH_SCH	Mib	EARFCN = 1454, PCI = 117	
118016	011175	2018-12-14 10:16:22.202	000:10:09.470	LTE_UL_CCH	SRB0	Rrc connection request r13	

```

{
  plmn-identity-r13
  {
    mcc
    {
      4,
      6,
      0
    },
    mnc
    {
      0
    }
  }
}, ...

```

Cause Analysis:

The module initiates network registration approx. 10 minutes after its power-up. Through checking the log, it is found that the EHPLMN in the USIM is 46001. However, the EHPLMN deployed by the current network operator China Unicom is not 46001, which makes the module failed in initiating network registration after it searches B3 and B8 as well as all other bands it supported. In the process, the EHPLMNs of the cells with PCIs of 47/39/281/193 are all not belong to 46001, so the module will not initial the attach procedure. Then it selected another EHPLMN 46006 for cell searching, and finally found a suitable cell with EARFCN of 1454.

4	00:00:02.860	MmrEhplmnListReq		body.errcPlmnListReq.requestedPlmn.mcc	= 0x0460	1120 ;
4	00:00:02.860	ErrcUpdateReq		body.errcPlmnListReq.requestedPlmn.mnc	= 0x0001	1 ;
6	00:00:02.860	ApexMmNetworkStateInd		.requestedPlmn.is_three_digit_mnc	= FALSE	0x00 0 ;
3	00:00:02.860	CirmDataInd		.requestedPlmn.accessTechnology	= 0x4000	16384 ;
3	00:00:02.870	CimuxAtDataReq		body.errcPlmnListReq.carrier_num	= 0x00	0 ;
4	00:00:02.870	MmrPlmnListReq		body.errcPlmnListReq.search_type_present	= 0x01	1 ;
4	00:00:02.870	ErrcUpdateReq		body.errcPlmnListReq.search_type	= EUTRA_SEARCH_TYPE_DEEP	0x01 ;
5	00:00:02.870	ErrcPlmnListReq		body.errcPlmnListReq.band_num	= 0x02	2 ;
7	00:00:02.870	ErrcDebugStateChangeInd		body.errcPlmnListReq.band[0]	= 0x0008	8 ;
5	00:00:02.870	NphyCellSearchReq		body.errcPlmnListReq.band[1]	= 0x0003	3 ;
				body.errcPlmnListReq.lockPresent	= 0x00	0 ;
				body.errcPlmnListReq.lock	= Not_Present	

Summary:

- 1) China Unicom network signal is too weak, so it takes a longer time for signal decoding.
- 2) The EHPLMN setting in the USIM card of China Unicom is incorrect, making the module cannot initiate network registration during the first-time cell searching.

7 Appendix A References

Table 4: Related Document

SN	Document Name	Remark
[1]	Quectel_BC66_AT_Commands_Manual	BC66 AT commands manual

Table 5: Terms and Abbreviations

Abbreviation	Description
CEL	Coverage Enhancement Level
CMCC	China Mobile Communications Corporation
EARFCN	Evolved-UTRA Absolute Radio Frequency Channel Number
EF(s)	Elementary File(s)
EHPLMN	Equivalent Home PLMN
HPLMN	Home PLMN
LTE	Long Term Evolution
NB-CIoT	Narrowband Cellular Internet of Things
NB-IoT	Narrowband Internet of Things
NV	Non-volatile (Memory)
NVRAM	Non-volatile Random-access Memory
PLMN	Public Land Mobile Network
RPLMN	Registered PLMN
UE	User Equipment
USIM	Universal Subscriber Identity Module