

# HAC-LBee

## 2.4G Low Power Consumption Wireless Data Transmission Module (ZigBee Protocol)

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### User Manual



SHENZHEN HAC TELECOM TECHNOLOGY CO., LTD

**Add:** Fl.6, Building 2, Jiuxiangling New Industry Park, No.4227,  
Xilihu Road, Nanshan, Shenzhen, China.

**Tel :** +86-755-23981078

**Fax :** +86-755-23981007

**Email :** [webmaster@rf-module-china.com](mailto:webmaster@rf-module-china.com)

**Web :** <http://www.rf-module-china.com>

➤ High Performance

- ✧ 20dbm, 3.5Km (LOS, light of sight)

➤ Low Power Consumption

- ✧ Transmitting current: 150mA @ 20dBm
- ✧ Receiving current: 30mA @ 20dBm
- ✧ Sleep current: 3μA @ 20dBm

➤ MESH Network

- ✧ Self-organizing, Self-routing, Self-healing
- ✧ Point-to-point and Point-to-multipoint Transmission

➤ Simply To Use

- ✧ AT, API AT, Remote API AT command
- ✧ Transparent mode, API mode

➤ Standards

- ✧ Zigbee 2007 PRO

➤ High Reliability

- ✧ DSSS O-QPSK modulation
- ✧ CSMA-CA Automatic Backoff Mechanism
- ✧ Re-transmission and Response Mechanism

➤ High Security

- ✧ AES Encryption for Network Layer
- ✧ AES Encryption for Application Layer

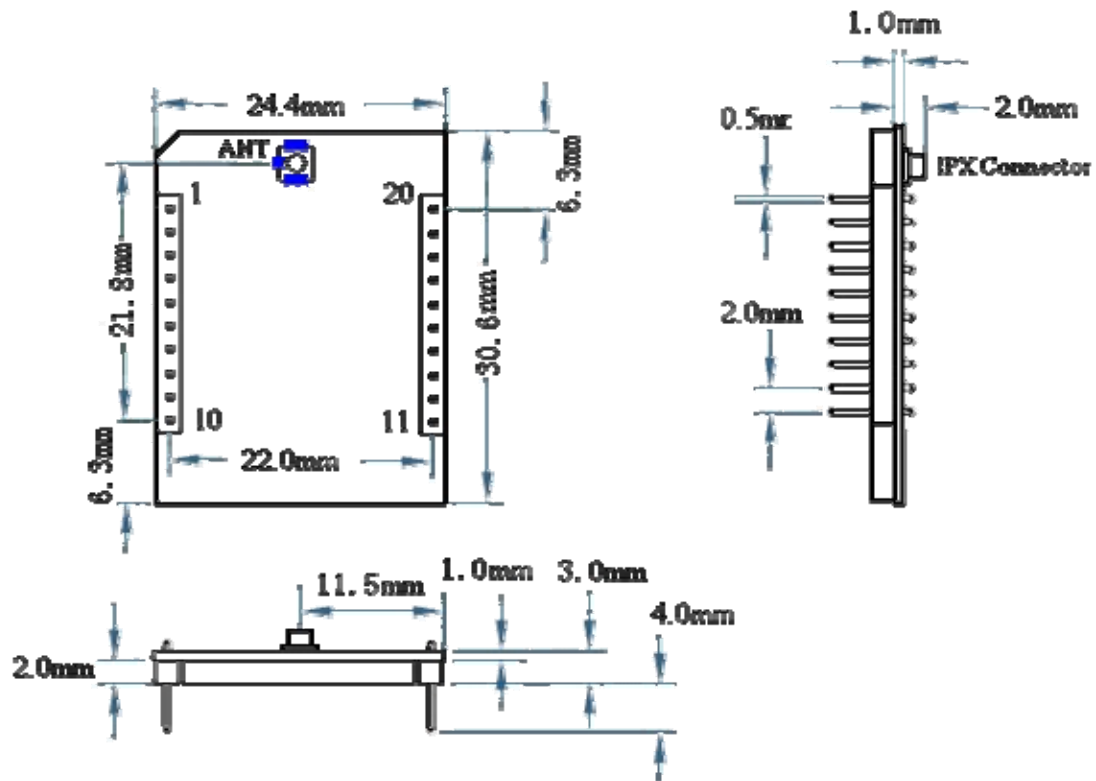
# Catalog

<b>I. HAC-LBEE MODULE.....</b>	<b>5</b>
1 THE SIZE AND PIN ORDER OF LBEE MODULE.....	5
2 PIN DEFINITION.....	5
3 TECHNICAL PARAMETERS.....	6
<b>II. HAC-LBEE MODULE OPERATION .....</b>	<b>7</b>
1 UART PORT INSTRUCTION.....	7
2 COMMUNICATION PROTOCOL .....	7
2.1 <i>Transparent Mode</i> .....	7
2.2 <i>API Mode</i> .....	7
3 AT COMMAND MODE .....	7
3.1 <i>Enter AT Command Mode</i> .....	8
3.2 <i>Send AT Command</i> .....	8
3.3 <i>AT Command Response</i> .....	8
3.4 <i>Exit AT Command Mode</i> .....	8
<b>III. API OPERATION.....</b>	<b>9</b>
1 API FRAME FORMAT .....	9
2. API FRAME .....	9
2.1. <i>Local AT Command Frame</i> .....	9
2.2. <i>Response Frame for Local AT Command</i> .....	10
2.3. <i>Request Frame for Remote AT Command</i> .....	11
2.4. <i>Response Frame for Remote AT Command</i> .....	12
<b>IV. AT COMMAND .....</b>	<b>14</b>
1 ADDRESS COMMAND.....	14
2 NETWORK COMMAND .....	14
3 RF PARAMETER COMMAND.....	16
4 SERIAL PORT PARAMETER COMMAND .....	16
5 I/O PARAMETER COMMAND .....	17
6 DIAGNOSTICS PARAMETER COMMAND.....	17
7 AT COMMAND PARAMETER .....	18
8 SLEEP COMMAND .....	18
9 EXECUTE COMMAND.....	19
<b>V. LBEE ZIGBEE NETWORK.....</b>	<b>20</b>
1 COORDINATOR.....	20
2 ROUTER.....	20
3 ENDDVICE.....	21
3.1 <i>The Relationship between Father node and Child node</i> .....	21
3.2 <i>Child Node Capability</i> .....	21
4 WORKING PROCESS FOR CHILD NODE.....	22
5 WORKING PROCESS FOR FATHER NODE.....	22

ANNEX .....	23
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## I. HAC-LBee Module

### 1 The Size and Pin Order of LBee Module



Pin Order: From PIN1 to PIN20, Anticlockwise.

### 2 Pin Definition

Pin No.	Definition	Default State	Function instruction
1	VCC		Power supply
2	TXD	Output	UART data output
3	RXD	Input	UART data input
4	DIO1	Input/output	GPIO1, RS485 Enable
5	RESET	Input	Low level reset
6	DIO2	Input/output	GPIO2
7	DIO3	Input/output	GPIO3
8	DIO4/DD	Input/output	GPIO4/Programming data
9	DIO5/DC	Input/output	GPIO5/Programming

			Clock/Sleep function enable
10	GND		Ground
11	DIO6	Input/output	GPIO6
12	DIO7	Input/output	GPIO7
13	DIO8	Input/output	GPIO8
14	DIO9	Input/output	GPIO9
15	DIO10	Input/output	GPIO10
16	DIO11	Input/output	GPIO11
17	DIO12 / ADC3	Input/output	GPIO12 / Analog Input 3
18	DIO13 / ADC2	Input/output	GPIO13 / Analog Input 2
19	DIO14 / ADC1	Input/output	GPIO14 / Analog Input 1
20	DIO15 / ADC0	Input/output	GPIO15 / Analog Input 0

### 3 Technical Parameters

Name	HAC-LBee Parameter			Unit
	Minimum	Typical Value	Maximum	
Electric Performance （25℃）				
Power Supply	3.0	3.3	3.6	V
Interface Level	-0.3		VCC+0.3≤3.6 V	V
Transmitting Current	140	150	160	mA
Receiving Current	29	30	31	mA
Sleeping Current		3		μA
Wireless Performance （25℃）				
Working Frequency	2.405		2.485	GHz
Transmitting Power	19.0	19.5	20.2	dBm
Receiving Sensitivity		-107		dBm
RF Data Rate		250		Kbps
General Performance				
Interface baud rate	1200	9600	115200	bps
Working Temperature	-40		80	℃
Distance (LOS)		3500		m

## **II. HAC-LBee Module Operation**

### **1 UART Port Instruction**

LBee module is controlled through the UART port. Please refer to the pin definition for more information.

In the actual operation, users need to pay attention to that, the external controller should have the same setting (including the baud rate, parity and stop bit) as the UART port of LBee module. The default baud rate is 38400bps, users can use 'DB' command to set it. The default parity is no parity, users can use 'NB' command to set it.

### **2 Communication Protocol**

LBee module support transparent mode and API mode.

#### **2.1 Transparent Mode**

Under the transparent mode, LBee module will not deal with the data from UART port, i.e. it transmits any data from the UART\_RX port to the air and output the receiving air data from the UART\_TX port.

The transparent mode can be set by AT command, set 'AP = 0' and exit the AT command mode, i.e. it will enter the transparent mode. Please pay attention to that, when it is in the API mode, the 'AP = 1'.

#### **2.2 API Mode**

When LBee module works under the API mode, its UART port should send or receive the data according to the definite frame format. The API mode also can be set by AT command, set 'AP = 1' and exit the AT command mode, it will enter the API mode. Under this mode, users can interchange some parameters of network layer.

Under API mode, users can add the destination address and data load info into the sending data frame, in this way, there is no need to use command to set these parameters. In the same way, the receiving data frame includes the state info, source address and data load info, which is more convenient for dealing with.

### **3 AT Command Mode**

Under some cases, users have to use the AT command for operation, for example, convert the

transparent mode into the API mode. AT command can be used to read or set the parameters of LBee module. Under the AT command mode, the receiving characters from the UART\_RX port of LBee module is interpreted as commands.

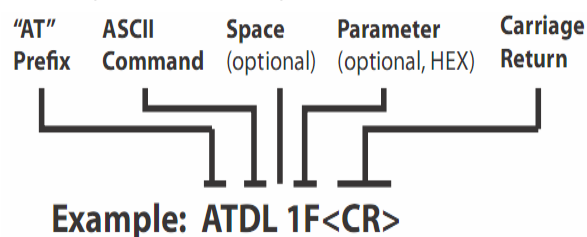
The AT command operating steps are shown as follow:

### 3.1 Enter AT Command Mode

Input 3-character command sequence '+++', LBee module will enter the AT command mode. When inputting, please pay attention to the '+' interval. Once LBee module enters the AT command mode, it will active a timeout timer, if there is no effective AT command input within the timeout, it will exit the AT command mode automatically. So when inputting every effective AT command, the timer will re-start for calculating.

### 3.2 Send AT Command

AT command is sent according to the following format.



If the AT command does not include the parameter, it is used to read the parameter value of this command. If the AT command includes the parameter, it is used to set the parameter value of this command. In the above example, it means that set the 'DL' value as '0x1F'. **Note: the parameter is in hex format.**

**Note:** when changing the parameter, to keep using the changed parameter after reset, users should use the 'ATWR' command to write the changed parameter into Flash to avoid value lost caused by power off.

### 3.3 AT Command Response

When LBee module receives the AT command, it will analyze and execute the command. If the command has been executed successfully, it will output 'OK' through UART\_TX port. Under the following situations, it will output 'ERROR', i.e. a. The parameter setting range is wrong. b. The reading command goes with parameter value. c. The command is not executed correctly.

### 3.4 Exit AT Command Mode

Users can use the following ways to exit AT command mode:

- A. Send ATCN command
- B. There is no effective AT command within the set time.

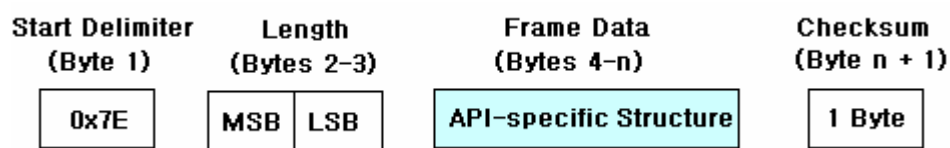


### III. API Operation

API mode is sending or receiving data according to the data frame. The API mode will point out how to interchange the command, command response and state info through UART port of LBee module.

#### 1 API Frame Format

When 'AP = 1' and exit the AT command mode, LBee module will enter the API mode. The API frame format is shown as follow:



0x7E: Start Delimiter, the head of frame

Length: 2 bytes, the length of frame data, excluding 0x7E, itself and parity byte.

Frame Data: Different types' frames have different formats. It is listed in the following.

Checksum: Excluding 0x7E and length, add all bytes of Frame Data, keep only the lowest 8 bits of the result and subtract from 0xFF, then you will get the checksum. When verifying, excluding 0x7E and length, add all bytes keeping only the lowest 8 bits of the result, then plus the checksum. If the sum is equal 0xFF, and the checksum is correct.

**Note:** In the above field, if there are multi bytes, please send by big-endian format.

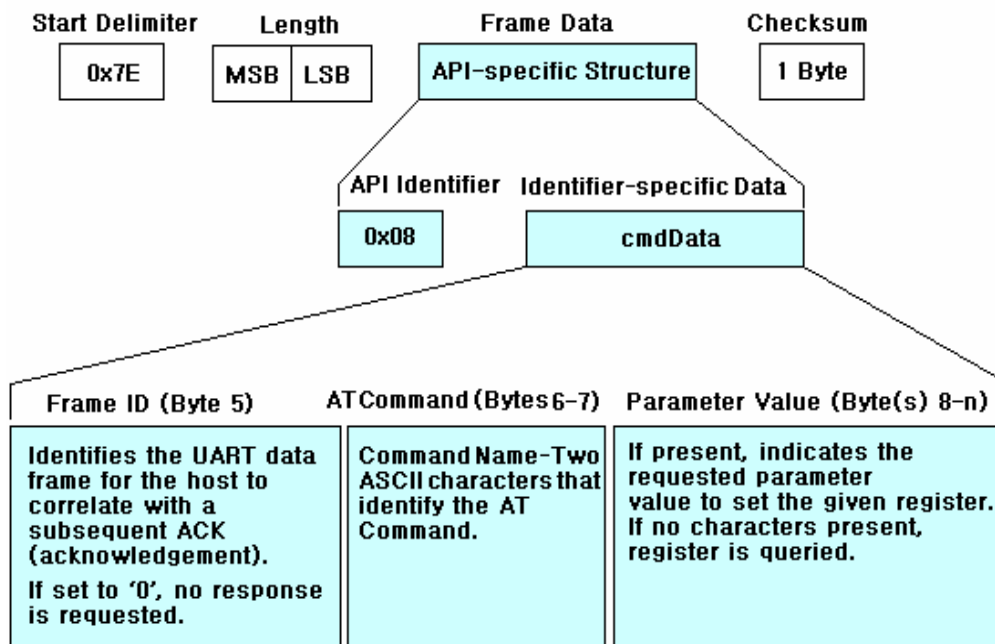
Every frame should start from 0x7E, so LBee module will discard the data before 0x7E and will not deal with them. If the receiving data frame is not correct, for example the byte length is wrong or the parity is wrong, LBee module will not deal with them neither.

#### 2. API Frame

Different frame types have different frame structures. The detailed instruction for various frame structure are shown as follow:

##### 2.1. Local AT Command Frame

This API frame's function is same as the AT command under the AT command mode, it is used to set or check the parameters of local module. Users can use this API frame to set AT command. The API frame structure is shown as follow:



Start Delimiter: 0x7E

Length: Excluding the start delimiter, itself and parity

Frame type: 0x08

Frame ID: When there are many frames, the frame ID can be used to identify the frame. If the frame ID is '0', the LBee module will not respond.

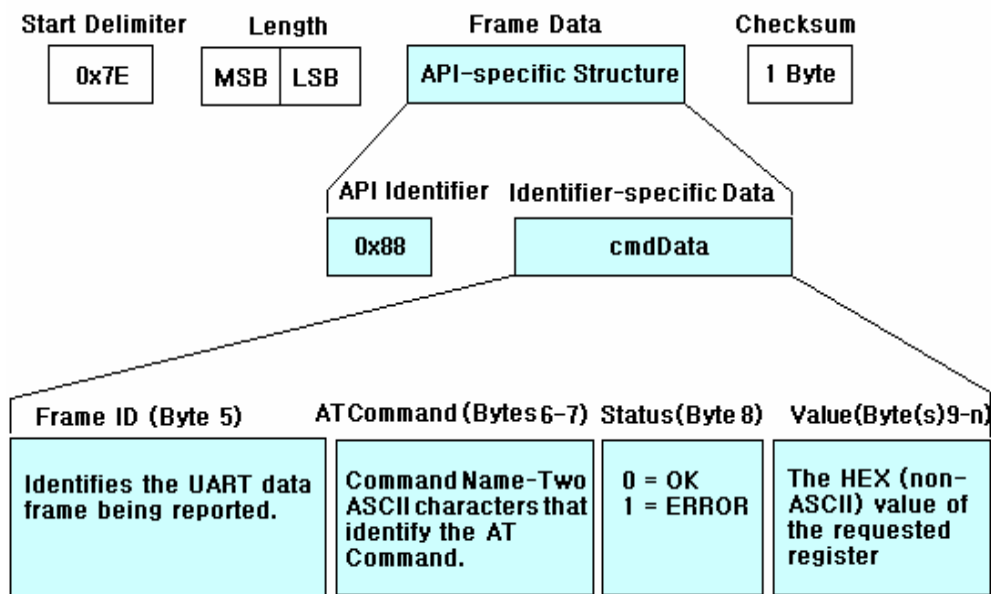
AT Command: Currently, all AT commands are only 2 characters, for example 'DL', 'ID' etc. It is the ASCII value of the AT command letter.

Parameter Value: If AT command goes with parameter, it means to set the parameter, if going without parameter, and it means to read the parameter.

Checksum: Excluding 0x7E and length, add all bytes of Frame Data, keep only the lowest 8 bits of the result and subtract from 0xFF, then you will get the checksum.

## 2.2. Response Frame for Local AT Command

When inputting correct AT command frame, LBee module will output the response frame for AT command. Some commands output multi-frame, such as ND command. The API frame structure is shown as follow:



Start Delimiter: 0x7E

Length: Excluding the start delimiter, itself and parity

Frame type: 0x88

Frame ID: This ID is the one in the AT command frame. If the frame ID is '0', the LBe module will not respond.

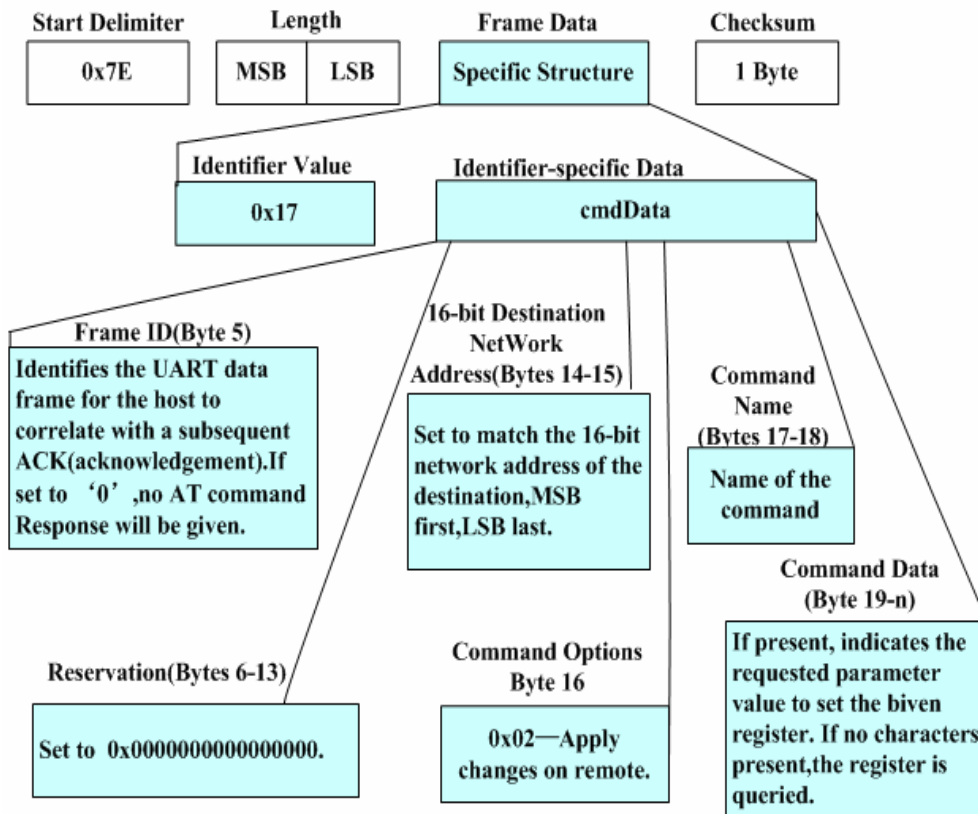
AT Command: Currently, all AT commands are only 2 characters, for example 'DL', 'ID' etc. It is the ASCII value of the AT command letter.

Parameter Value: If the AT command is check command, it goes with parameter. If it is set command, it goes without parameter.

Checksum: Excluding 0x7E and length, add all bytes of Frame Data, keep only the lowest 8 bits of the result and subtract from 0xFF, then you will get the checksum.

### 2.3. Request Frame for Remote AT Command

Comparing with AT command frame, the request frame for remote AT command is used to check or set the parameters of remote module, not the local module. Its frame structure is shown as follow:



Start Delimiter: 0x7E

Length: Excluding the start delimiter, itself and parity

Frame type: 0x17

Frame ID: When there are many frames, the frame ID can be used to identify the frame. If the frame ID is '0', the LBee module will not respond.

64-bit Destination Address: The MAC address of the destination device, it is 64 bits. If it is '0x000000000000FFFF', it is the broadcasting address, i.e. broadcast data.

16-bit Destination Address: The network address of the destination device, it is 16 bits. If it is '0xFFFF', it is the broadcasting address, i.e. broadcast data.

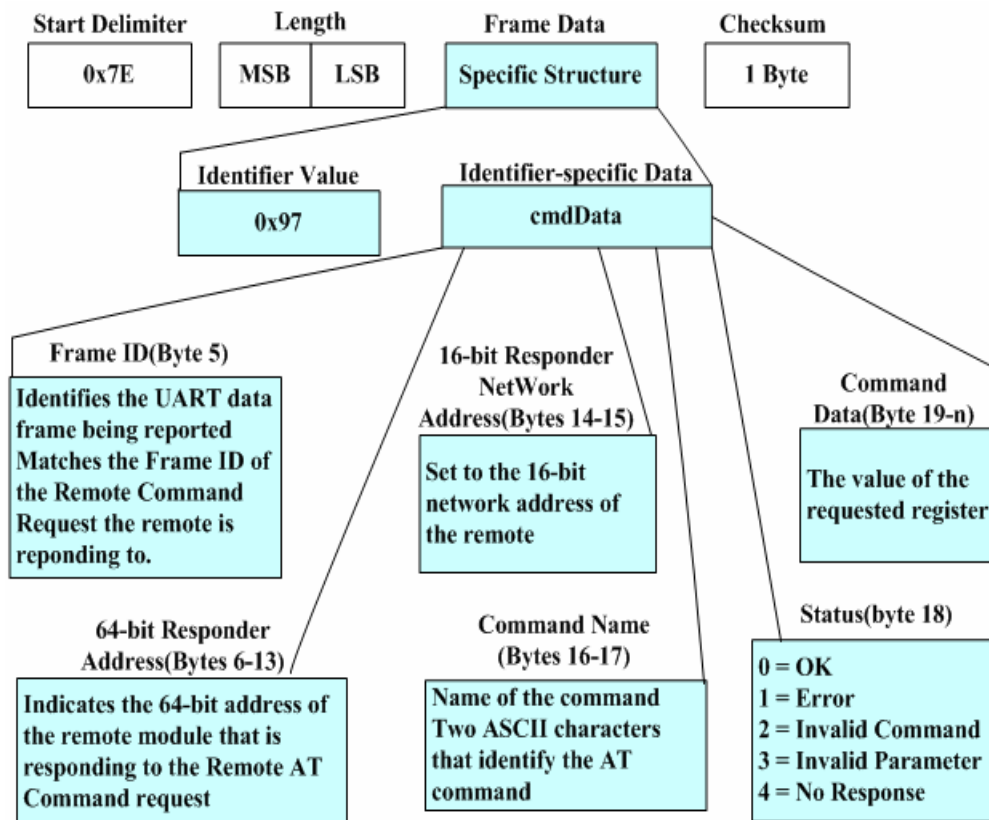
AT Command: Currently, all AT commands are only 2 characters, for example 'DL', 'ID' etc. It is the ASCII value of the AT command letter.

Parameter Value: If AT command goes with parameter, it means to set the parameter, if going without parameter, and it means to read the parameter.

Checksum: Excluding 0x7E and length, add all bytes of Frame Data, keep only the lowest 8 bits of the result and subtract from 0xFF, then you will get the checksum.

## 2.4. Response Frame for Remote AT Command

When LBee module receives the response data of remote AT command from the air, it will output the data from UART port according to the response frame format for remote AT command. The frame format is shown as follow:



Start Delimiter: 0x7E

Length: Excluding the start delimiter, itself and parity

Frame type: 0x97

Frame ID: This ID is the serial number for the request frame of remote AT command, it can identify the response for which request.

64-bit Source Address: The 64-bit MAC address for source address

16-bit Destination Address: The 16-bit network address for source address

AT Command: Currently, all AT commands are only 2 characters, for example 'DL', 'ID' etc. It is the ASCII value of the AT command letter.

Parameter Value: If the AT command is check command, it goes with parameter. If it is set command, it goes without parameter.

Checksum: Excluding 0x7E and length, add all bytes of Frame Data, keep only the lowest 8 bits of the result and subtract from 0xFF, then you will get the checksum.

## IV. AT Command

### 1 Address Command

AT Command	Command Description	Parameter Range	Default Value
MY	Read the 16-bit network address of module, '0xFFFF' means the module has not entered the network.	0-0xFFFFE <b>(Read Only)</b>	0xFFFFE
MP	Read the 16-bit network address of father node, '0xFFFF' means this node doesn't have father node.	0-0xFFFFE <b>(Read Only)</b>	0xFFFFE
NH	Feedback the next Router node address that the current node should pass to the specified node. The parameter is an effective 16-bit destination address.	0-0xFFFF	
SH	Read the high 32-bit of the 64-bit MAC address	0-0xFFFFFFFF <b>(Read Only)</b>	Fixed value
SL	Read the low 32-bit of the 64-bit MAC address	0-0xFFFFFFFF <b>(Read Only)</b>	Fixed value
NI	Node identifier, it is a character string, it should be printable ASCII character. The max length should not more than 20 characters.	no more than 20 characters	0x20

### 2 Network Command

AT Command	Command Description	Parameter Range	Default Value
CH	Read the working channel. Using the channel No. defined by 802.15.4. '0' means the module has not enter the network.	0, 0x0B-0x19. <b>(Read Only)</b>	

CE	Set the module type, set the device as Coordinator or Router (Note: EndDevice can not be set).	0 - Coordinator 1 - Router	1
ID	PAN ID, it is 16 bits. If it is '0xFFFF', the Coordinator will select a ID randomly, Router and EndDevice will enter the network with any PAN ID that can be entered.	0-0xFFFF	29AC
PI	The gained 16-bit PAN ID, this value is the module PAN ID distributed in the network.	0-0xFFFF <b>(Read Only)</b>	
NT	Node inquiry time, when execute the ND command, the NT value will be broadcasted together. After other nodes receive the broadcasting data, they will delay in a random time (< NT) and send the response to avoid network congestion.	0x20-0xFF (×100ms)	0x3C
NO	Network search option, when execute the NDcommand, whether display the local node info or not.	0 – Not display 1 - Display	1
RL	Inquiry the Router info  Parameter format:  1. No parameter, inquiry all the Router info saved in the local node.  2. ATRL srcAddr-dstAddr  Inquiry the routing way for sending message from srcAddr to dstAddr		
NL	Inquiry the neighbour's table, return the neighbour node info of the current node	No parameter	
SC	Set the working channel. When Coordinator	1-0xFFFF	0x0001

	<p>builds the network or Router (EndDevice) enters the network, they only search these channels.</p> <p>This value uses the bit definition for selection, i.e. if one bit is '1', and the corresponding channel is chosen.</p> <p>0 (0x0B)    1 (0x0C)    2 (0x0D)</p> <p>3 (0x0E)    4 (0x0F)    5 (0x10)</p> <p>6 (0x11)    7 (0x12)    8 (0x13)</p> <p>9 (0x14)    10 (0x15)    11 (0x16)</p> <p>12 (0x17)    13 (0x18)    14 (0x19)</p> <p>15 (0x1A)</p>		
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### 3 RF Parameter Command

AT Command	Command Description	Parameter Range	Default Value
PL	Transmitting Power Level	0=12 dBm 1=14 dBm 2=16 dBm 3=18dBm 4=20 dBm	4

### 4 Serial Port Parameter Command

AT Command	Command Description	Parameter Range	Default Value
AP	API enable, set whether use API mode or not.	0 – API disable 1-API enable	0
BD	UART port baud rate setting	0-1200bps 1-2400	5



		2-4800 3-9600 4-19200 5-38400 6-57600 7-115200	
NB	Parity bit setting of UART port	0 – no parity 1 – even parity 2 – odd parity	0

## 5 I/O Parameter Command

AT Command	Command Description	Parameter Range
PT	Collect/set the DIO2 (6 <sup>th</sup> pin) state	None – Digital input 0 - Digital output, low level 1 - Digital output, high level
S1	Collect voltage value, 20 <sup>th</sup> pin	
S2	Collect voltage value, 19 <sup>th</sup> pin	
S3	Collect voltage value, 18 <sup>th</sup> pin	
S4	Collect voltage value, 17 <sup>th</sup> pin	

## 6 Diagnostics Parameter Command

AT Command	Command Description	Parameter Range
VR/SV	Firmware version	<b>Read Only</b>
VL	Read the detailed version info of module	ASCII character string. Only can be read by local AT command. <b>Read Only</b>

HV	Read the hardware version	<b>Read Only</b>
FV	Read the protocol stack version	<b>Read Only</b>
AI	Read the network state	0 – in the network 1 – not in the network <b>Read Only</b>

## 7 AT Command Parameter

AT Command	Command Description	Parameter Range	Default Value
CN	Exit AT command mode. When execute this command, the module will exit AT command mode immediately.	---	---

## 8 Sleep Command

AT Command	Command Description	Parameter Range	Default Value
SN	The times for EndDevice scans the network. The default state: doesn't scan the network and stay in the sleep state all the time.	0-9	0
SS	The sleep period before EndDevice enters the network. Before entering the network, if EndDevice still doesn't enter the network after scan 'SN' times network, it will enter the sleep state. 'SS' is used to define the time for sleep.	0x01-0xFFFF (× 1ms)	0xFFFE
SM	Sleep mode, this value for Coordinator and Router should be '0' , EndDevice is '1' .	0 – Disable Sleep 1- Periodic sleep, but it can be waken up	

		forcibly through pin.	
SP	Sleep period, it defined the sleep time for of EndDevice. For the father node, this value defines how long does it save the information for its child node.	0x01-0xFFFF (× 10ms)	0x012C
ST	After receiving the data, EndDevice will enter into sleep after ‘ST’ time. After receiving the air data, EndDevice will start a timer, if there is no data within ‘ST’ time, it will enter into sleep.	1-0xFFFE (× 1ms)	0x32 (5s)

## 9 Execute Command

AT Command	Command Description	Parameter Range	Default Value
WR	Save the parameter value into Flash to keep the value even after power off.	---	---
RE	Restore to default value	---	---
FR	Firmware restart. After receive this command, the module will execute firmware restart after 2s.	---	---
RN	Network reset	0- Don’ t reset 1- Reset without any cases 2- If the network layer parameters have been changed, reset the network. Otherwise do	0

		not reset the network.	
ND	Search all nodes in the network. After execute this command, the module will broadcast the data frame for finding network node and output the responses of all nodes from UART port.	---	---

## V. LBee Zigbee Network

The Physical layer and MAC layer of Zigbee are based on the IEEE802.15.4. The Zigbee Alliance defines the Network Layer and Application layer based on the IEEE802.15.4. LBee module can be compatible with all these layers completely. In the LBee Zigbee network, there are three kinds of modules, i.e. Coordinator, Router and EndDevice. Please refer to the following info about these module types.

### 1 Coordinator

The Coordinator is responsible for choosing a channel and a PAN ID to build the network. And it is the only device to build the network, so every network should have a Coordinator. After the Coordinator builds the network, it allows new devices for entering network, route data package and communication with other device types.

The Coordinator selects the channel by scanning different channels. When Coordinator scans one channel and finds that channel level is larger than a certain value, it will consider as that this channel has been occupied by other networks, give up this channel and continue to scan until it finds the unoccupied channel. Users can use SC command to set the Coordinator work on a definite channel.

After the Coordinator finishes channel and network scanning, it will select a usable channel and PAN ID to build the network. Users can use ATMY command to check whether the network is built or not. When the command response is '0x0000', it means the network is already built. Users also can use ID command to appoint 16-bit PAN ID for Coordinator.

### 2 Router

Before entering the network, the Router needs to find and enter the network. After entering the network, Router can help other modules to enter the network, route data package and communication with other nodes.

The Router finds the network by using network scanning, it is almost same as the way of Coordinator. When Router sends out a beacon request frame on a definite channel, the Coordinators or Routers in the nearby network will reply a beacon response. The beacon response includes the network PAN ID and the info whether it allows other modules for entering. Router selects a suitable network for entering. The selection condition is that the PAN ID is same as ID command (when ID = 0xFFFF, it doesn't need to meet this condition), and the network should allow other modules for entering. If this channel can not meet these conditions, it will select next channel for network scanning.

Users can set the SC command value to make that the Router only scans on some channels. Users also can set ID value to appoint the Router only enters the network with appointed PAN ID. After Router enters the network, it will get a 16-bit network address for network communication, which can be read by MY command.

### **3 EndDevice**

Same as Router, before entering the network, EndDevice needs to find and enter the network. After it enters the network, it can communicate with other nodes. Because it is powered by battery, it has strict limits for power consumption, so it can not route data package and allow other nodes for entering.

The networking scanning of EndDevice is similar to Router. The standards for judging whether a node is allowed for entering are shown as follow:

- (1) If its ID command is not '0', and the PAN ID should be same as the ID value.
- (2) Whether this node allows other nodes for entering or not.
- (3) Whether this node can contain the child node or not.

After EndDevice enters the network, it will get a 16-bit network address for network communication from its father node, which can be read by MY command. Users can use AI command to check whether the EndDevice enters the network successfully or not. If the return value for AI command is '0', it means that the EndDevice enters the network successfully.

Note: Because EndDevice has strict limits for power consumption, so the default setting is 'Do not scan network'. Users can use SN command to set the times for network scanning.

#### **3.1 The Relationship between Father node and Child node**

The power saving of EndDevice is achieved by the periodical sleep. When there are some coming data packages, the EndDevice is still in sleep state, its father node who help it enter the network will save the data packages until it wakes up and forward to it after waking up. This is the relationship between father node and child node.

#### **3.2 Child Node Capability**

Router and Coordinator have a child node table, it is used to maintain its child nodes. The size of the table determines its ability to accommodate child nodes. If there is still space for child nodes, Router (or Coordinator) will allow other child nodes for entering.

## EndDevice

The working principle and operation of EndDevice is the most complicated. It is described separately here.

When EndDevice enters the network, the node who help it to enter the network is called its father node.

For power saving purpose, EndDevice sleeps periodically. During the sleep period, it can not receive data, its father node helps to save the coming data, wait and send to it after waken up. About the working process for child node and father node, please refer to the following points for more info.

## 4 Working Process for Child Node

EndDevice sleeps periodically. When EndDevice wakes up, it will send the request frame to its father node. After the father node receives the request, it will check whether it has saved the data for the child node or not, then it will reply a response frame to tell the child node whether it has data. If the child node receives the father node's response and finds that there is no data, it will enter into sleep state. When waking up again, it will send the request frame again to its father node. The sleep period can be set by SP command.

If the child node receives the father node's response and finds that there is data, it will prepare to receive data and will not enter sleep state. After receiving every data package, it will start a Timer and ask its father node whether there is data for it timely until the Timer is overtime, i.e. reach the time set by ST command, it will enter sleep.

If EndDevice wants to send data to other nodes in the network, it only could send the data to its father node first, then execute routing query and finding destination address etc, after that send out the data, report the sending state to it finally.

When EndDevice is in the sleep state, users can use 9<sup>th</sup> pin to force it wake up.

## 5 Working Process for Father Node

If father node receives the data from child node, it will help to save the data, wait the child node wake up, then send a request frame to child node, after that send the data to child node.

If the child node doesn't request data from father node within the required time, father node will delete the data. The required time is called SP, it can be set by SP command. Usually, every node's SP value in the same network should be the same.

## **Annex**

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

### **FCC Radiation Exposure Statement**

The modular can be installed or integrated in mobile or fix devices only. This modular cannot be installed in any portable device, for example, USB dongle like transmitters is forbidden.

This modular complies with FCC RF radiation exposure limits set forth for an uncontrolled environment. This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter. This modular must be installed and operated with a minimum distance of 20 cm between the radiator and user body.

If the FCC identification number is not visible when the module is installed inside another device, then the outside of the device into which the module is installed must also display a label referring to the enclosed module. This exterior label can use wording such as the following: "Contains Transmitter Module FCC ID: WMUHAC-LBEE

When the module is installed inside another device, the user manual of this device must contain below warning statements;

1. This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:
  - (1) This device may not cause harmful interference.
  - (2) This device must accept any interference received, including interference that may cause undesired operation.
2. Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.