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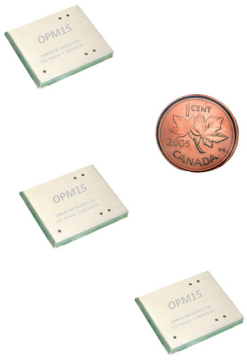

Section 1: Purpose

This document describes the Application Programming Interface (API – Version 3.2.0) for OMESH's OPM15 mesh serial modules. The document includes an overview of the interaction between the Host and OPM15 (the Module) as well as a list of API functions.

Section 2: Interface and Definitions

All communications between the Module and the Host are through a two/four line serial interface. **Always wait for the response from the Module after writing a command to it; and take further actions immediately after having received a successful response.** If the Module does not give a relevant response to a command within 5ms time, the Host shall resend the command until it gets either a successful or a failure response. If the Host needs to write bytes to the Module after a command response, the Host should do so within 0.5 second time; otherwise the command will time-out at the Module.

By default, the baud-rate of the Module serial interface is 9,600, with no parity or flow control. It is recommended to configure the baud-rate to 230,400 or higher in data communications by using the command in Section 3.34. When there is a RS232-TTL on board that converts the UART serial to RS232 DB9 port, the operation could result in board voltage fluctuation and slightly affect radio performance.

The set of defined commands and events are listed in below:

```
#define COMMAND_RESET          0x00
#define COMMAND_SLEEP          0x01
#define COMMAND_CONFIG         0x0B
#define COMMAND_GETSTATE       0x02
#define COMMAND_BROADCAST      0x03
#define COMMAND_UNICAST        0x04
#define COMMAND_SETADDR        0x05
#define COMMAND_GETADDR        0x06
#define COMMAND_READCALI       0x07
```

```
#define COMMAND_SETPOWER          0x08
#define COMMAND_READRX            0x09
#define COMMAND_READSTA           0x0D
#define COMMAND_RESETSTA          0x0E
#define COMMAND_CLEARAD           0x0F
#define COMMAND_SETPASSCODE       0x10
#define COMMAND_SETRETRYLIM       0x11
#define COMMAND_GETVERSION        0x12
#define COMMAND_GETPASSCODE       0x13
#define COMMAND_SETMESHADDR       0x14
#define COMMAND_GETMESHADDR       0x15
#define COMMAND_SETMACADDR        0x16
#define COMMAND_GETMACADDR        0x17
#define COMMAND_GETDEVICEID       0x18
#define COMMAND_RADIOTEST         0x1A
#define COMMAND_STOPTEST          0x1B
#define COMMAND_READPOWER         0x1C
#define COMMAND_GETRETRYLIM       0x1D
#define COMMAND_POWERSAVEON       0x1E
#define COMMAND_POWERSAVEOFF      0x1F
#define COMMAND_QUERY             0x20
#define COMMAND_QUERYCONF         0x21
#define COMMAND_SETINTLEV         0x22
#define COMMAND_READINTLEV        0x23
#define COMMAND_SETBAUD           0x24
#define COMMAND_READCONF          0x25
#define COMMAND_SETROUTELIM       0x26
#define COMMAND_GETROUTELIM       0x27
#define COMMAND_MBROADCAST        0x28
#define COMMAND_CALIBRATE         0x29
#define COMMAND_READQUERYCONF     0x2A
#define RSP_SUCCESS               0x80
#define RSP_FAIL                  0x00
#define EVENT_RESET               0x0A
#define EVENT_WAKEUP              0x0C
```

Section 3: Commands and Events

3.1 Command RESET

Write COMMAND_RESET (0x00) to the serial interface of the Module. The Module will return a RSP_SUCCESS | COMMAND_RESET (0x80). The command always has a successful response.

On receiving the RSP_SUCCESS | COMMAND_RESET (0x80), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB, and then the Module will reset itself after about 1.6ms. Reset will cause configurable parameters of the module to revert to their default settings, including those specified in Sections 3.3, 3.7, 3.10, 3.16, 3.31, 3.32, 3.34, and 3.36.

3.2 Command SLEEP

Write COMMAND_SLEEP (0x01) to the serial interface of the Module. If the Module is in IDLE (0x01) state, the command will be successful; and the Module will return a RSP_SUCCESS | COMMAND_SLEEP (0x81). Otherwise, the Module will return RSP_FAIL | COMMAND_SLEEP (0x01).

On receiving the RSP_SUCCESS | COMMAND_SLEEP (0x81), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB, followed by another unsigned word (3 bytes little Endian) to specify the time (in 32KHz) that the Module should sleep. The Module will enter low-power sleep mode on receiving the time information. The time should be set to be longer than 2ms (or 64 – 0x40 0x00 0x00).

3.3 Command CONFIG

Write COMMAND_CONFIG (0x0B) to the serial interface of the Module. The Module will always return a RSP_SUCCESS | COMMAND_CONFIG (0x8B). This command does not have a failure response.

On receiving the RSP_SUCCESS | COMMAND_CONFIG (0x8B), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB, followed by one configuration byte:

RESERVED (bits 7-6) 00	RT/CT (bit 5)	STATE (bit 4)	ADDRESS (bit 3)	BACKOFF (bit 2)	CHANNEL (bits 1-0)

RT/CT (1 bit): 0- Disable RT/CT lines of the serial port; 1- Enable RT/CT lines of the serial port. (Note: RT/CT is only used in OPM15-E series radios).

Default Configuration on Reset: 0.

STATE (1 bit): 0 – State lines configuration 1; 1- State lines configuration 2.

Default Configuration on Reset: 0.

State lines configuration 1:

- STATE_A (STA1): 1- Power on, and Calibration Completed; 0- Sleep;
- STATE_B (STA2): 1- Join to Receive; 0 - IDLE;

- STATE_C (STA3): 1- Initiate to Transmit; 0 - IDLE;

State lines configuration 2:

- STATE_A (STA1): 1- Power on, and Calibration Completed; 0- Sleep;
- STATE_B (STA2): 1- Packets in Receiving Buffer; 0 – Receiving Buffer Free;
- STATE_C (STA3): 1- Packets full in Transmitting Buffer; 0 – Available in Transmitting Buffer;

Performance Tips: the configuration 2 of state-lines can be used for the timing of read/write packets from serial; the configuration 1 can be used for prototyping and monitoring the behaviors of the radio with LEDs.

ADDRESS (1 bit):

1 – The module will backup the current address when setting up a new address; the old address will still be valid only in receiving packets destined to it.

0 – The module will not backup the current address when setting up a new address.

Default Configuration on Reset: 0.

BACKOFF (1 bit):

1 – The module will use a larger back-off window to avoid collision. (Set in dense networks with high traffic volume)

0 – The module will use a smaller back-off window to improve throughput.

Default Configuration on Reset: 0.

Performance Tips: if there are more than two traffic flows with high bandwidth requirement, it is recommended to use the larger window (set BACKOFF=1); otherwise using BACKOFF=0 can provide slightly better performance.

CHANNEL (2 bits):

00 – Three channel operation;

01 – Single channel operation on Channel 1;

10 – Single channel operation on Channel 2;

11 – Single channel operation on Channel 3;

Default Configuration on Reset: 00.

3.4 Command GETSTATE

Write COMMAND_GETSTATE (0x02) to the serial interface of the Module. On receiving the command, the Module will return its current state | RSP_SUCCESS. The command does not have a failure response. State IDLE is denoted by 0x01 for normal operation; and State TEST (Section 3.24) is denoted by 0x11 for a special radio test mode.

3.5 Command BROADCAST

Write COMMAND_BROADCAST (0x03) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_BROADCAST | RSP_SUCCESS (0x83) if there is available TX buffer space in the Module and the network address is valid. Otherwise the Module will return COMMAND_BROADCAST | RSP_FAIL (0x03).

On receiving the COMMAND_BROADCAST | RSP_SUCCESS (0x83), the Host must write the packet for broadcasting to the Module serial interface.

BYTE 0: Length of Transferring N (N must be: > 0 and < 122)

BYTE 1: Broadcast Sequence Number

BYTE 2 –N: Payload of Broadcasting Packet

Broadcast packets do not have an ACK mechanism in the protocol, therefore successful packet delivery is not guaranteed at the wireless link level.

3.6 Command UNICAST

Write COMMAND_UNICAST (0x04) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_UNICAST | RSP_SUCCESS (0x84) if there is available TX buffer space in the Module and the network address is valid. Otherwise the Module will return COMMAND_UNICAST | RSP_FAIL (0x04).

On receiving the COMMAND_UNICAST | RSP_SUCCESS (0x84), the Host must write the packet for unicasting to the Module serial interface.

BYTE 0: Length of Transferring N (N must be: > 2 and < 116)

BYTE 1-3: Address of the Unicast Destination

BYTE 4: Unicast Sequence Number

BYTE 5 –N: Payload of Unicasting Packet

Unicast packets have an ACK mechanism in the protocol, therefore successful packet delivery is guaranteed at the wireless link level subject to a maximum retry limit (Section 3.16).

Performance Tips:

1. *In either broadcasting or unicasting, packet Sequence Number can be used by application/network for packet fragmentation. We recommend at least one byte sequence number (as suggested in Section 3.5, 3.6 and 3.11). If the customer application requires very large networks (e.g. larger than 50 hops), we recommend to use two-byte sequence number which simply takes the first byte of the packet payload as the second byte of sequence number in Section 3.5, 3.6 and 3.11.*
2. *The Module has a TX buffer of 2 packets for all the transmitting packets: including both source packets (from the local Host) and relay packets (from remote Hosts and received by RF).The Host can send a transmitting packet to the Module, if and only if there is at least one packet TX buffer available. And a Module would participate in relaying if and only if there is at least one packet TX buffer available.*

3.7 Command SETADDRESS

Write COMMAND_SETADDRESS (0x05) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_SETADDRESS | RSP_SUCCESS (0x85) if the system state is IDLE (0x01); otherwise the Module will return COMMAND_SETADDRESS | RSP_FAIL (0x05).

On receiving the COMMAND_SETADDRESS | RSP_SUCCESS (0x85), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB, followed by a 3-byte network address setting.

The Host is responsible for configuring the network address of the Module: the first byte contains a Network ID (the first 2 bit) and a Node ID (the last 6 bit). The second and third bytes (0-255) are loosely representing the X and Y grid coordinates of the node respectively (except for "0xFF (255)" which has a special definition as to be described later). Any valid network address must have a non-zero first byte. **A Module must have a valid network address in order to send or receive packets. And no two nodes in a network shall have identical network address.**

The default address setting on reset is the mesh address saved in the device flash memory (Section 3.19, 3.20); however calling the COMMAND_SETADDRESS (to change the network address) does not change the saved mesh address in the device flash memory.

A network address with the second and third bytes as "0xFF (255)" cannot be relaying unicast packets, nor be the destination of any "multi-hop (larger than 1 hop)" unicast packets (i.e., no unicast packets with such destination address can be relayed). No unicast packets can be relayed by a relay node with different Network ID than the respective destination node.

The network address can either be pre-configured or be dynamically configured from the node's network neighborhood information. Under the same Network ID, the Manhattan distance between two nodes within a single-hop range should be configured about between 0 and 6, depending on the mapping of mutual RSSI. The RSSI values can be read from the receiving packets as specified in 3.11, or COMMAND_QUERY as specified in 3.30; the typical RSSI range is -25 to 25. The higher the RSSI, the smaller the mutual Manhattan distance should be.

The Manhanttan distance between two nodes 1 and 2 is defined by |X1-X2|+ |Y1-Y2|, where X1, Y1 are the last two bytes of node 1 network address, and X2, Y2 are the last two bytes of node 2 network address. Unicast packets can be transmitted from a transmitter node (pervious-hop relay or source node) to a candidate relay node, if any one of the following conditions can be met:

1) Transmitter node address has a different Network ID than destination node address; relay node address has the same Network ID as destination node address.
2) Transmitter, relay, and destination nodes have their network address under the same Network ID. The Manhanttan distance between transmitter and destination nodes is greater than the Manhanttan distance between relay and destination nodes.

For example, with a linear deployment of 8 nodes, it could be convenient to configure the network addresses as (in ASCII character) "1,1,1", "1,1,3", "1,1,5", "1,1,7", "1,1,9", "1,1,B", "1,1,D", "1,1,F".

Performance Tips: for getting better throughput performance over multiple wireless hops, every node would need to see (in single-hop range) at least two or more relay nodes in the forwarding area. Since the radios are half-duplex, this setup can avoid a direct loss of 50% throughput. The higher the node density, the higher the performance of OPM15 networks can be.

3.8 Command GETADDRESS

Write COMMAND_GETADDRESS (0x06) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_GETADDRESS | RSP_SUCCESS (0x86). The command does not have a failure response.

After the response byte, the Module will write a 3-byte network address setting to the Host.

3.9 Command READCALI

Write COMMAND_READCALI (0x07) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_READCALI | RSP_SUCCESS (0x87). The command does not have a failure response.

After the response byte, the Module will write the calibration data to the Host. The command is for testing only. The calibration data is renewed when the radio is reset.

BYTE 0: Noise Floor in dBm

BYTE 1-16: RSSI in dBm on data radio when the second radio is transmitting on {5,3,1,-1,-2,-3,-4,-6,-8,-10,-12,-14,-16,-18,-20,-22} dBm

3.10 Command SETPOWER

Write COMMAND_SETPOWER (0x08) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_SETPOWER | RSP_SUCCESS (0x88). The command does not have a failure response.

On receiving the COMMAND_SETPOWER | RSP_SUCCESS (0x88), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB, follow by 1-byte power setting. The power byte must be between 0 and 8, which denotes the following output power levels: {5, 3, 2, 1, 0, -2, -4, -7, -18} dBm.

The default value on reset is 0 (or 5dBm).

3.11 Command READRX

Write COMMAND_READRX (0x09) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_READRX | RSP_SUCCESS (0x89) if there is a valid packet in the RX buffer of the Module. Otherwise, the Module will return COMMAND_READRX | RSP_FAIL (0x09).

After the successful response byte, the Module will write one packet to the Host. Below is the format of the broadcast and unicast packet respectively.

BRAODCAST PACKET (Also see Section 3.5):

BYTE 0: Length of the packet N

BYTE 1: Control byte

Protocol reserved – bits 7-4	TYPE – bits 2-0

TYPE: 0x00 for Broadcast Packet;

BYTE 2-4: Source address

BYTE 5: Sequence ID

BYTE 6-N-2: Broadcast Payload Data

BYTE N-1: RSSI

BYTE N: Bit 7 is CRC check result (should always be 1- Success)

UNICAST PACKET (Also see Section 3.6):

BYTE 0: Length of the packet N

BYTE 1: Control byte

Protocol reserved – bits 7-4	TYPE – bits 2-0

TYPE: 0x02 for Unicast Packet;

BYTE 2-4: Own address

BYTE 5-7: Transmitter address

BYTE 8-10: Source address

BYTE 11-13: Destination address

BYTE 14: Sequence ID

BYTE 15-N-2: Unicast Payload

BYTE N-1: RSSI

BYTE N: Bit 7 is CRC check result (should always be 1- Success)

MULTIHOP BRAODCAST PACKET (Also see Section 3.38):

BYTE 0: Length of the packet N

BYTE 1: Control byte

Protocol reserved – bits 7-4	TYPE – bits 2-0

TYPE: 0x03 for Multi-hop Broadcast Packet;

BYTE 2-4: Source address

BYTE 5-6: Broadcast address range (lower byte first)

BYTE 7: Sequence ID

BYTE 8-N-2: Broadcast Payload Data

BYTE N-1: RSSI

BYTE N: Bit 7 is CRC check result (should always be 1- Success)

Performance Tips:

1. *For some applications (such as location networks), the radio signal strength of received packets may be required. This can be read from the RSSI byte of the packet frame. RSSI is a signed byte with typical range from -25 (0xE7) to 25 (0x19). Each value represents (RSSI-76) in dBm power: for example, RSSI=0 represents -76dBm; RSSI=-25 represents -101dBm; RSSI=25 represents -51dBm.*

2. *The Module has a RX buffer of 4 packets. All received packets, including broadcast packets and unicast packets with destination to local network address, are stored in the RX buffer until they are read out by the Host. Once the RX buffer is full, the Module will stop receiving any new packets. In bi-directional communications, it can be important to keep the RX buffer from full so that communications will not be blocked. Therefore the READRX command shall be sent to poll the Module about every 20ms; or the READRX command shall be sent according to the state-line configuration which indicates packet availability in the RX buffer as specified in Section 3.3.*

3.12 Command READSTA

Write COMMAND_READSTA (0x0D) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_READSTA | RSP_SUCCESS (0x8D). The command does not have a failure response.

On success response, the Module further writes the following bytes to the Host:

Word 1 (2 Bytes Low - High): Packet_Transmit_Try: Number of Packet Transmission Tries;

Word 2: (2 Bytes Low - High): Packet_Transmitted: Number of Packets Successfully Transmitted;

Word 3: (2 Bytes Low - High): Packet_Receive_Try: Number of Packet Receiving Tries;

Word 4: (2 Bytes Low - High): Packet_Received: Number of Packets Successfully Received;

Word 5: (2 Bytes Low - High): Packet_Dropped: Number of Packets Dropped.

Word 6: (2 Bytes Low -High): Packet_Relayed: Number of Packets Successfully Received as a Relay Packet.

3.13 Command RESETSTA

Write COMMAND_RESETSTA (0x0E) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_RESETSTA | RSP_SUCCESS (0x8E). The command does not have a failure response.

On receiving the COMMAND_RESETSTA | RSP_SUCCESS (0x8E), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB. Then the module status-record bytes (as described in Section 3.12) will be cleared to all zeros.

3.14 Command CLEARAD

Write COMMAND_CLEARAD (0x0F) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_CLEARAD | RSP_SUCCESS (0x8F) if successful (i.e., when a stored old network address is valid). Otherwise, the failure return is COMMAND_CLEARAD | RSP_FAIL (0x0F).

On receiving the COMMAND_CLEARAD | RSP_SUCCESS (0x8F), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB. Then the stored old network address will be cleared, i.e., when the ADDRESS bit in the configuration byte is set to be 1 (see Section 3.3).

3.15 Command SETPASSCODE

Write COMMAND_SETPASSCODE (0x10) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_SETPASSCODE | RSP_SUCCESS (0x90). The command does not have a failure response.

On receiving the COMMAND_SETPASSCODE | RSP_SUCCESS (0x90), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB, followed by a 16-byte (128 bits) pass code. Modules with different pass codes cannot communicate to each other at the link level. This provides protection of products from different vendors and networks based on the OPM15 module.

The written pass code is saved in flash memory of the Module, and is preserved on reset or power-down. The manufacturer default value of the pass code is all zeros.

3.16 Command SETRETRYLIM

Write COMMAND_SETRETRYLIM (0x11) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_SETRETRYLIM | RSP_SUCCESS (0x91). The command does not have a failure response.

On receiving the COMMAND_SETRETRYLIM | RSP_SUCCESS (0x91), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB, followed by a one-byte maximum retry limit (0-255) for unicasting. Maximum retry limit number 0 indicates that uni-casting packet will not be re-sent if the first attempt fails. A maximum retry limit of 255 (0xFF) indicates infinite retries and guarantees zero packet loss.

The default value on reset is 80.

3.17 Command GETVERSION

Write COMMAND_GETVERSION (0x12) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_GETVERSION | RSP_SUCCESS (0x92). The command does not have a failure response.

After the response byte, the Module will write a 3-byte API version ID setting to the Host. The current version ID is [0x03, 0x02, 0x00].

3.18 Command GETPASSCODE

Write COMMAND_GETPASSCODE (0x13) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_GETPASSCODE | RSP_SUCCESS (0x93). The command does not have a failure response.

After the response byte, the Module will write the 16-byte pass code setting to the Host.

3.19 Command SETMESHADDR

Write COMMAND_ SETMESHADDR (0x14) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_SETMESHADDR | RSP_SUCCESS (0x94). The command does not have a failure response.

On receiving the COMMAND_SETMESHADDR | RSP_SUCCESS (0x94), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB, followed by a 3-byte mesh address. The written mesh address is saved in flash memory of the Module, and is preserved on reset or power-down. The manufacturer default value of mesh address is of all zeros.

The network address (Section 3.7, 3.8) takes the saved mesh address in the device flash memory on reset. Note that this command however does not affect the current network address.

3.20 Command GETMESHADDR

Write COMMAND_GETMESHADDR (0x15) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_GETMESHADDR | RSP_SUCCESS (0x95). The command does not have a failure response.

After the response byte, the Module will write the 3-byte mesh address in the device flash memory to the Host.

3.21 Command SETMACADDR

Write COMMAND_SETMACADDR (0x16) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_SETMACADDR | RSP_SUCCESS (0x96). The command does not have a failure response.

On receiving the COMMAND_SETMACADDR | RSP_SUCCESS (0x96), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB, followed by a 6-byte MAC address. The written MAC address is saved in flash memory of the Module, and is preserved on reset or power-down. The manufacturer default value of the MAC address is of all zeros.

3.22 Command GETMACADDR

Write COMMAND_GETMACADDR (0x17) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_GETMACADDR | RSP_SUCCESS (0x97). The command does not have a failure response.

After the response byte, the Module will write the 6-byte MAC address to the Host.

3.23 Command GETDEVICEID

Write COMMAND_GETDEVICEID (0x18) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_GETDEVICEID | RSP_SUCCESS (0x98). The command does not have a failure response.

After the response byte, the Module will write a 6-byte unique device ID to the Host. The device ID is globally unique, and is set up by the manufacturer.

3.24 Command RADIOTEST

Write COMMAND_RADIOTEST (0x1A) to the serial interface of the Module. If the Module is in IDLE (0x01) or (existing) TEST (0x11) state, the command will be successful; and the Module will return a RSP_SUCCESS | COMMAND_RADIOTEST (0x9A). Otherwise, the Module will return RSP_FAIL | COMMAND_RADIOTEST (0x1A).

On receiving the RSP_SUCCESS | COMMAND_RADIOTEST (0x9A), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB, followed by additional three bytes in sequence:

- The LSB of the first byte indicates which transceiver (either secondary ANT2 –'0' or primary ANT1 – '1') will be transmitting for radio testing. The MSB of the first byte indicates whether to transmit ('1') or receive ('0'). If it is configured to transmit, the next bit (i.e., the first bit next to MSB) indicates whether to transmit unmodulated ('0') or modulated ('1') signal.
- The second byte indicates the testing tone frequency ranged from 2405MHz to 2480MHz, where 0x05 denotes 2405MHz and 0x50 denotes 2480MHz. Any other setting out of the range between 0x05 and 0x50 will be taken as 2405MHz in default.
- The third byte indicates the transmitting power: The power byte must be between 0 and 8, which denotes the following output power levels: {5, 3, 2, 1, 0, -2, -4, -7, -18} dBm for the secondary transceiver; and {5, 3, 1, -2, -4, -6, -10, -14, -18} dBm for the primary transceiver. Any other setting will be taken as 5dBm in default. In receiving mode configuration, this byte is ignored by the Module, however, the Host must write the byte.

Once COMMAND_RADIOTEST is successfully executed, the Module enters into a special TEST state (0x11) where no other commands will be taken except for COMMAND_RADIOTEST, COMMAND_STOPTEST (Section 3.25), COMMAND_RESET (Section 3.1) and COMMAND_GETSTATE (Section 3.4). COMMAND_RADIOTEST can be called for multiple times to adjust frequency and power, and/or to put both transceivers in transmitting test frequency tones.

Performance Tips: the special TEST mode is triggered by COMMAND_RADIOTEST which can be used for the processes of antenna measurements and design.

3.25 Command STOPTEST

Write COMMAND_STOPTEST (0x1B) to the serial interface of the Module. If the Module is in TEST (0x11) state, the command will be successful; and the Module will return a RSP_SUCCESS | COMMAND_STOPTEST (0x9B). Otherwise, the Module will return RSP_FAIL | COMMAND_STOPTEST (0x1B).

On receiving the RSP_SUCCESS | COMMAND_STOPTEST (0x9B), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB. Once the command is successfully executed, the Module will be put back to IDLE (0x01) state for normal operations.

3.26 Command READPOWER

Write COMMAND_READPOWER (0x1C) to the serial interface of the Module. On receiving the command, the Module will return its power setting (0-8) | RSP_SUCCESS. The command does not have a failure response. The definition of power setting was in Section 3.10.

3.27 Command GETRETRYLIM

Write COMMAND_GETRETRYLIM (0x1D) to the serial interface of the Module. On receiving the command, the Module will return its unicast retry limit setting (0-255). The command does not have a failure response. The definition of retry-limit setting was in Section 3.16.

3.28 Command POWERSAVEON

Write COMMAND_POWERSAVEON (0x1E) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_POWERSAVEON | RSP_SUCCESS (0x9E) if successful (i.e., when the power-save mode is off). Otherwise, the failure return is COMMAND_ POWERSAVEON | RSP_FAIL (0x1E).

On receiving the COMMAND_POWESAVEON | RSP_SUCCESS (0x9E), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB. Then the Module will enter a power-save mode which saves about 50% energy in idle listening. The mode however can bring negative impacts on performance in high traffics. In default, the power-save mode is off.

3.29 Command POWERSAVEOFF

Write COMMAND_POWERSAVEOFF (0x1F) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_POWERSAVEOFF | RSP_SUCCESS (0x9F) if successful (i.e., when the power-save mode is on). Otherwise, the failure return is COMMAND_ POWERSAVEOFF | RSP_FAIL (0x1F).

On receiving the COMMAND_POWESAVEOFF | RSP_SUCCESS (0x9F), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB. Then the Module will quit the power-save mode. In default, the power-save mode is off.

3.30 Command QUERY

Write COMMAND_QUERY (0x20) to the serial interface of the Module. On receiving the command, if there are query responses saved in the Module, the Module will return COMMAND_QUERY | RSP_SUCCESS (0xA0). Otherwise, the failure return is COMMAND_ QUERY | RSP_FAIL (0x20).

On sending the COMMAND_QUERY | RSP_SUCCESS (0xA0) response, the Module will further write a block of query response data from a neighboring Module to the Host without broadcasting a query packet to its neighbors. The data takes the following format:

BYTE 0: Length of the response data N, N shall be a multiple of 3

BYTE 1 to 3: Source address of a neighboring Module

BYTE 4: the first RSSI (typical range -25 to 25), in the unit of (RSSI-76) dBm

BYTE 5 to 6: the sequence ID of the preceding RSSI record (lower byte first)

BYTE N-2: the last RSSI (typical range -25 to 25), in the unit of (RSSI-76) dBm

BYTE N-1 to N: the sequence ID of the preceding RSSI record (lower byte first)

On sending the COMMAND_QUERY | RSP_FAIL (0x20) response, the Module will broadcast a query packet to its neighborhood, where neighboring Modules will respond to the Module query response data in accordance with the configuration described in Section 3.31.

3.31 Command QUERYCONF

Write COMMAND_QUERYCONF (0x21) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_QUERYCONF | RSP_SUCCESS (0xA1). The command does not have a failure response.

On receiving the COMMAND_QUERYCONF | RSP_SUCCESS (0XA1), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB. The Host shall then write two-byte configuration to the Module:

BYTE 0: Enable (0x01) or Disable (0x00) collecting and sending query response data when receiving query broadcasts;

Default Configuration on Reset: Disabled (0x00).

BYTE 1: The number of RSSI records to collect per unique source address before sending a query response data back to the same source address (one RSSI record corresponds to the RSSI data and a 16bit sequence ID of a received query broadcast from an unique source address;

Minimum Configuration Number (0x01): 1;

Maximum Configuration Number (0x10): 16;

Default Configuration Number on Reset (0x0A): 10.

By Command QUERYCONF, an OPM15 radio can maximally save and respond the RSSI records from 32 distinctive nodes (as differentiated by network address) at the same time.

3.32 Command SETINTLEV

Write COMMAND_SETINTLEV (0x22) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_SETINTLEV | RSP_SUCCESS (0xA2). The command does not have a failure response.

On receiving the COMMAND_SETINTLEV | RSP_SUCCESS (0xA2), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB, followed by 1-byte interference setting. The interference byte must be between 0 (0x00) and 15 (0x0F). The Module can be much more robust to external interference (e.g., WLAN and other external wireless) with a larger interference byte. Increasing the interference byte by 1 can also decrease wireless link budget by 1 dB.

The value of the interference byte is also automatically calibrated and configured by calibration (Section 3.39), reset (Section 3.1), and power-on actions.

3.33 Command READINTLEV

Write COMMAND_READINTLEV (0x23) to the serial interface of the Module. On receiving the command, the Module will return its interference byte (0x00-0x0F) | RSP_SUCCESS. The command does not have a failure response. The definition of the interference byte was in Section 3.32.

3.34 Command SETBAUD

Write COMMAND_SETBAUD (0x24) to the serial interface of the Module. On receiving the command the Module will return COMMAND_SETBAUD | RSP_SUCCESS (0xA4). The command does not have a failure response.

On receiving the COMMAND_SETBAUD | RSP_SUCCESS (0xA4), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB, follow by 1-byte serial baud rate setting.

Byte Setting	Baud Rate (bps)
0x00	9,600
0x01	14,400
0x02	28,800
0x03	57,600
0x04	115,200
0x05	230,400
0x06	460,800
0x07	921,600

Others	9,600

The default value of the interference byte on reset is 0x00 (or 9600bps). It is recommended to configure it to 230,400 or above in data communications, so that the serial speed will not become a bottleneck.

3.35 Command READCONF

Write COMMAND_READCONF (0x25) to the serial interface of the Module. On receiving the command, the Module will return its Configuration Byte | RSP_SUCCESS. The command does not have a failure response. The definition of the configuration byte was in Section 3.3.

3.36 Command SETROUTELIM

Write COMMAND_SETROUTELIM (0x26) to the serial interface of the Module. On receiving the command the Module will return COMMAND_SETROUTELIM | RSP_SUCCESS (0xA6). The command does not have a failure response.

On receiving the COMMAND_SETROUTELIM | RSP_SUCCESS (0xA6), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB, followed by 4-byte route limit setting.

BYTE 0: the Center_X of destination address

BYTE 1: the Center_Y of destination address

BYTE 2: the Delta_X of destination address

BYTE 3: the Delta_Y of destination address

The Module will only relay Unicast packet with destination address under the limitation of either one of the two conditions (in addition to the rules specified in Section 3.7):

1) The second byte of destination address is in the range (inclusive) from Center_X–Delta_X to Center_X+Delta_X.
2) The third byte of destination address is in the range (inclusive) from Center_Y–DeltaY to Centre_Y+Delta_Y.

The default values on reset are all 128 (0x80) for Center_X, Center_Y, Delta_X, and Delta_Y. This includes all possible destination addresses.

3.37 Command GETROUTELIM

Write COMMAND_GETROUTELIM (0x27) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_GETROUTELIM | RSP_SUCCESS (0xA7). The command does not have a failure response.

After the response byte, the Module will write the 4-byte limitation setting (see Section 3.36) to the Host.

3.38 Command MBROADCAST

Write COMMAND_MBROADCAST (0x28) to the serial interface of the Module. On receiving the command, the Module will return COMMAND_BROADCAST | RSP_SUCCESS (0x83) if there is available TX buffer space in the Module and the network address is valid. Otherwise the Module will return COMMAND_BROADCAST | RSP_FAIL (0x03).

On receiving the COMMAND_BROADCAST | RSP_SUCCESS (0x83), the Host must write the packet for multi-hop broadcasting to the Module serial interface.

BYTE 0: Length of Transferring N (N must be: > 2 and < 122)

BYTE 1-2: Multi-hop Broadcasting Range (Lower byte first)

BYTE 3: Broadcast Sequence Number

BYTE 4 –N: Payload of Multi-hop Broadcasting Packet

The Multi-hop Broadcasting Range is a 16 bit unsigned word. On receiving a multi-hop broadcast packet, the Module will automatically re-broadcast the same packet if all the following conditions are met:

1) The source network address and local (own) network address have the same Network ID (see Section 3.7).
2) The Manhattan distance (see Section 3.7) from the source address to local (own) address is less than or equal to the Multi-hop Broadcasting Range.
3) Any packet from the same source address and with the same sequence number was not received in the last 10 packets from the source address.

If a packet from the same source address and with the same sequence number was received (in the last 10 packets from the source address), the new packet will be neglected by the Module. Therefore, it is important for the Host to assign every multi-hop broadcasting packet a Broadcast Sequence Number that changes for every consecutive packet.

3.39 Command CALIBRATE

Write COMMAND_CALIBRATE (0x29) to the serial interface of the Module. If the Module is in IDLE (0x01) state, the command will be successful; and the Module will return a RSP_SUCCESS | COMMAND_CALIBRATE (0xa9). Otherwise, the Module will return RSP_FAIL | COMMAND_CALIBRATE (0x29).

On receiving the RSP_SUCCESS | COMMAND_CALIBRATE (0xa9), the Host must write to the Module a special combination of 4 bytes in sequence 0xFD 0xDE 0xED 0xAB.

The Module will then perform calibration which typically takes 3-10 seconds. The state line STA1 (Section 3.3) is turned zero during the calibration process. The calibration measures ambient noise and antenna configuration to set parameters that are important to radio operation. For example, the calibration data (Section 3.9) and the interference byte (Section 3.32) are refreshed after calibration.

3.40 Command READQUERYCONF

Write COMMAND_READQUERYCONF (0x2A) to the serial interface of the Module. On receiving the command, if the query response (Section 3.31) is enabled, the Module will return the byte: RSSI Record Number per Response (Section 3.31) | RSP_SUCCESS | 0xC0. If the query response is disabled, the Module will return the byte: RSSI Record Number per Response (Section 3.31) | RSP_SUCCESS. The command does not have a failure response.

3.41 Event Reset

The Module writes EVENT_RESET (0x0A) to the Host on resetting after initial calibration.

3.42 Event Wakeup

The Module writes EVENT_WAKEUP (0x0C) to the Host when recovering from sleeping.

Section 4: Quick Start

A quick start of the module after reset (or power on) in steps:

- Wait for EVENT_RESET;
- Use Command SETADDRESS (Section 3.7) to set up the network address of the module;
- Use Command BROADCAST (Section 3.5) or Command UNICAST (Section 3.6) on the transmitter radio to send packets;
- Use Command READRX (Section 3.11) to read received packets on the receiver radio.

Section 5: Release Notes

The release of OPM15 API 3.2.0 is compatible with OPM15 API 3.1.0, except for the following changes:

- Command_SETINTLEV in Section 3.32 was revised to allow for automatic configurations.
- Command_READRX in Section 3.11 was revised to allow for multi-hop broadcast packets.
- Command_SETROUTELIM was added in Section 3.36.
- Command_GETROUTELIM was added in Section 3.37.
- Command_MBROADCAST was added in Section 3.38.
- Command_CALIBRATE was added in Section 3.39.
- Command_READQUERYCONF was added in Section 3.40.

The release OPM15 API 3.1.0 is compatible with OPM15 API 3.0.1, except for the following changes:

- The default baud rate of the module serial interface is changed to 9600.
- Command CONFIG in Section 3.3 was revised to remove baud rate configuration.
- Command READSTA in Section 3.12 was revised to add another information word about the number of relayed packets.
- Command SETBAUD was added in Section 3.34 for the baud rate configuration of the module serial interface.
- Command READCONF was added in Section 3.35 to read the configuration byte defined in Section 3.3.

The release OPM15 API 3.0.1 is compatible with OPM15 API 3.0.0, except for the following changes:

- Command SETINTLEV was added in Section 3.32 to increase the Module robustness to external interference in special environments.
- Command READINTLEV was added in Section 3.33.

The release OPM15 API 3.0.0 is compatible with OPM15 API 2.1.0, except for the following changes:

- Command QUERY was added in Section 3.30.
- Command QUERYCONF was added in Section 3.31.
- Command RADIOTEST was updated in Section 3.24 to include receiving mode testing.

The current release OPM15 API 2.1.0 is compatible with OPM15 API 2.0.8, except for the following changes:

- Command POWERSAVEON was added in Section 3.28.
- Command POWERSAVEOFF was added in Section 3.29.
- Command RADIOTEST was updated in Section 3.24 to add the capability of transmitting continuously modulated signal.
- The channel frequency points are adjusted to better accommodate world-wide regulations in 2.4GHz band.

The release OPM15 API 2.0.8 is compatible with OPM15 API 2.0.2, except for the following changes:

- Command GETPASSCODE was added in Section 3.18.
- Command SETMESHADDR was added in Section 3.19.
- Command GETMESHADDR was added in Section 3.20.
- Command SETMACADDR was added in Section 3.21.
- Command GETMACADDR was added in Section 3.22.
- Command GETDEVICEID was added in Section 3.23.
- Command RADIOTEST was added in Section 3.24.
- Command STOPTEST was added in Section 3.25.
- Command READPOWER was added in Section 3.26.
- Command GETRETRYLIM was added in Section 3.27.
- Change of network address (Section 3.7) default on reset from [0,0,0] to the saved mesh address in flash (Section 3.19, 3.20).
- Pass code (Section 3.15) is preserved on reset or power-down.
- A special 4-byte code (0xFD 0xDE 0xED 0xAB) is required for setting commands including: Command RESET (Section 3.1), SLEEP (Section 3.2), CONFIG (Section 3.3), SETADDRESS (Section 3.7), SETPOWER (Section 3.10), RESETSTA (Section 3.13), CLEARAD (Section 3.14), SETPASSCODE (Section 3.15), SETRETRYLIM (Section 3.16), SETMESHADDR (Section 3.19), SETMACADDR (Section 3.21), RADIOTEST (Section 3.24), and STOPTEST (Section 3.25).

The release OPM15 API 2.0.2 is compatible with OPM15 API 1.2.2, except for the following changes:

- Command SETPASSCODE in Section 3.15: the pass code is 128 bits (16 bytes) now in 2.0.2 instead of 32 bits (4 bytes) in 1.2.2; it gives much better protection customer data/network at link level;
- The channel frequency points are adjusted to better accommodate world-wide regulations in 2.4GHz band;
- Command GETVERSION was added in Section 3.17.

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