SmartMesh IP Mote User Guide

Advance Information

This document contains advance information of a product in development. All specifications are subject to change without notice. Consult LTC factory before using.

Table of Contents

1 About This Guide

1.1 Related Documents

The following documents are available for the SmartMesh-enabled network:

- SmartMesh IP Quick Start Guide
- SmartMesh IP Network User Guide
- SmartMesh IP Manager User Guide
- SmartMesh IP Manager CLI Guide
- SmartMesh IP Manager API Guide
- SmartMesh IP Mote User Guide
- SmartMesh IP Mote API Guide
- SmartMesh IP Mote CLI Guide

1.2 Conventions Used

The following conventions are used in this document:

`Computer type` indicates information that you enter, such as specifying a URL.

Bold type indicates buttons, fields, and menu commands.

Italic type is used to introduce a new term

Tips provide useful information about the product.

Informational text provides additional information for background and context

Notes provide more detailed information about concepts.

Warning! Warnings advise you about actions that may cause loss of data, physical harm to the hardware or your person.

```
code blocks display examples of code or API
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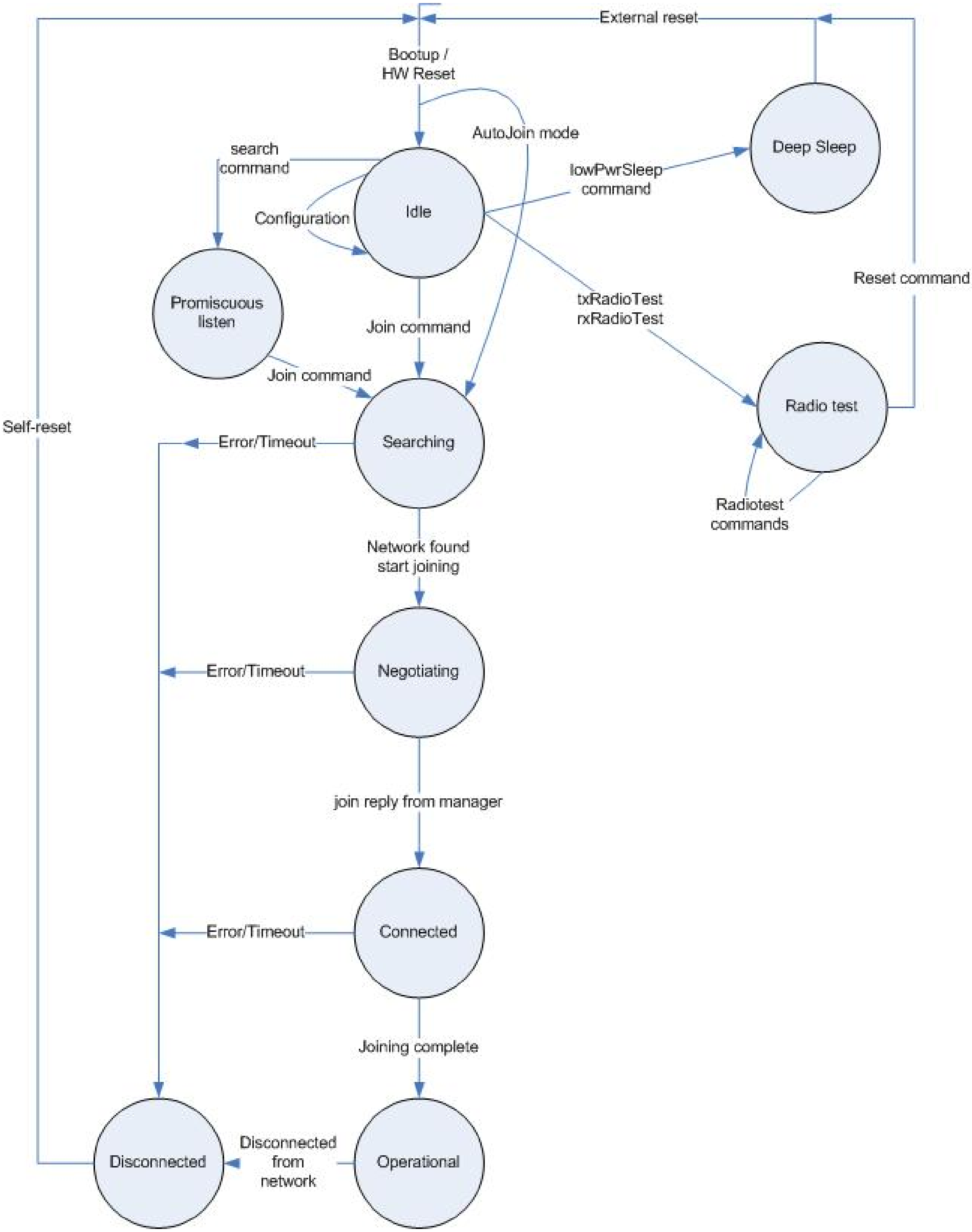
1.3 Revision History

Revision	Date	Description
1	07/17/2012	Initial release

2 Mote State Machine

The following state machine describes the general behavior of a mote during operation:



The mote states are as follows:

- **Idle -** While in this state, the mote accepts configuration commands. This state is skipped if the mote is configured to auto-join.
- **Deep Sleep** - The mote enters Deep Sleep when it receives the *lowPowerSleep* command from the attached serial processor. In this state, the device can no longer respond to serial commands and must be reset to resume normal operation. For power consumption information, refer to the mote product datasheet.
- **Promiscuous Listen** - A special search state, invoked by the *search* command, where the mote listens for advertisements from any network ID, and reports heard advertisements. The mote will not attempt to join any network, and will proceed to the **Searching** state when given the join command.
- **Searching** (unsynchronized search) **-** The mote is searching for the network that matches its network id. It keeps its radio receiver on with a configurable join duty cycle.
- **Synchronized Search (not shown) -** Short period at the end of searching. The device has heard an advertisement and has synchronized to the network. It keeps its radio receiver on at the configured join duty cycle, listening for additional potential neighbors.
- **Negotiating -** The device started joining the network
- **Connected -** The device heard join reply from the manager and is being configured by it.
- **Operational** - The device finished network joining and is ready to send data.
- **Disconnected** - The device is disconnected from the network.
- **Radio Test -** In this state the device is executing Radio Test commands. It must be reset to return to normal operation.

3 Joining

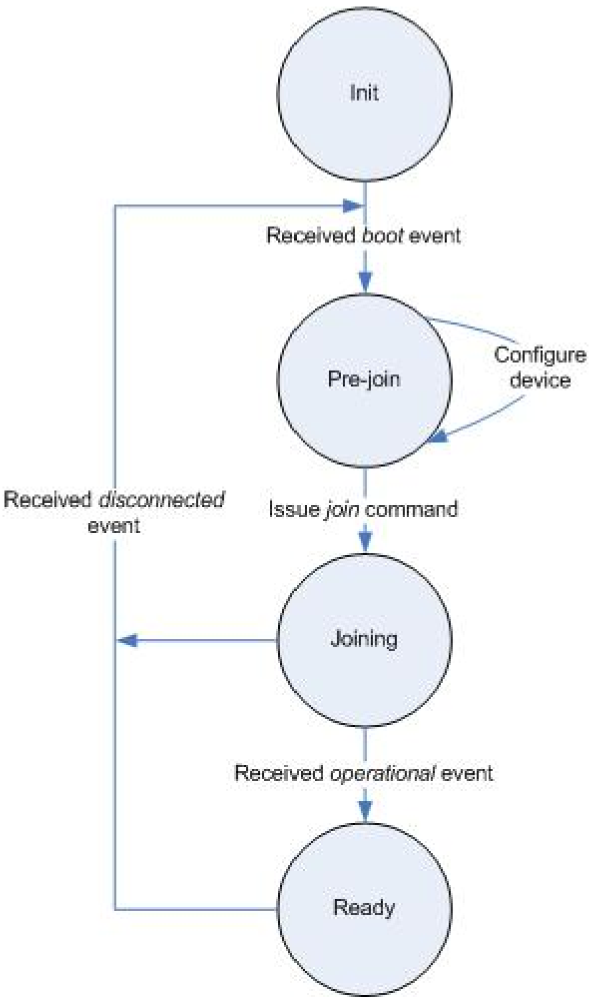
3.1 Manual Join

To join the network, the device must be configured with the following parameters that bind the device to the network.

- *networkId*
- *joinKey*

These parameters are persistent and may be set once during commissioning. In addition, other parameters such as *joinDutyCycle*, *routingMode*, *powerSourceInfo* all affect joining behavior and can be optionally set.

The client application should use the following state machine to join the network:



In this diagram, the following states are assumed:

- **Init** - in this state the application is booting up and initializing. The mote may be held in hardware reset until the app is ready to communicate with it.
- **Pre-join -** Once the mote boots up (as indicated by the *boot* event), the application may be proceed to configure it by making a number of *setParam* API calls. At the end of this state, the application may issue a *join* command.
- **Joining -** In this state the mote is joining the network. Successful join will eventually be reported via the *Operational* event notification. A failed join will be reported via the *joinFail* event notification.
- **Ready** - In this state the device is completed joining and is part of the network. The application may proceed to request bandwidth and communicate wirelessly.

3.2 Auto join

The mote may be configured to automatically search for and start joining its network after reboot. This setting is controlled via persistent *autoJoin* parameter. In this case, no explicit *join* command is required. Note that all parameters, such as network id, power source, etc. must be pre-configured.

> If the device is configured to auto join, radio test functionality cannot be exercised.

3.3 Joining adjacent network

In some cases the network id may not be known in advance. To find out which networks are in the proximity of the device, one can use the *search* API command. This command puts the device into promiscuous listen mode. In this mode, all received advertisements are reported via *advReceived* notification. After the correct network id has been established, the user may set it via *setParam<networkId>*, and follow up with a *join* command.

The following is the summary of the steps to follow after the mote boots up:

1. Put the mote into promiscuous listen state (*search* command)
2. Process *advReceived* notifications
3. Configure network id (*setParam<networkId>*)
4. Start joining (*join* command)

4 Services

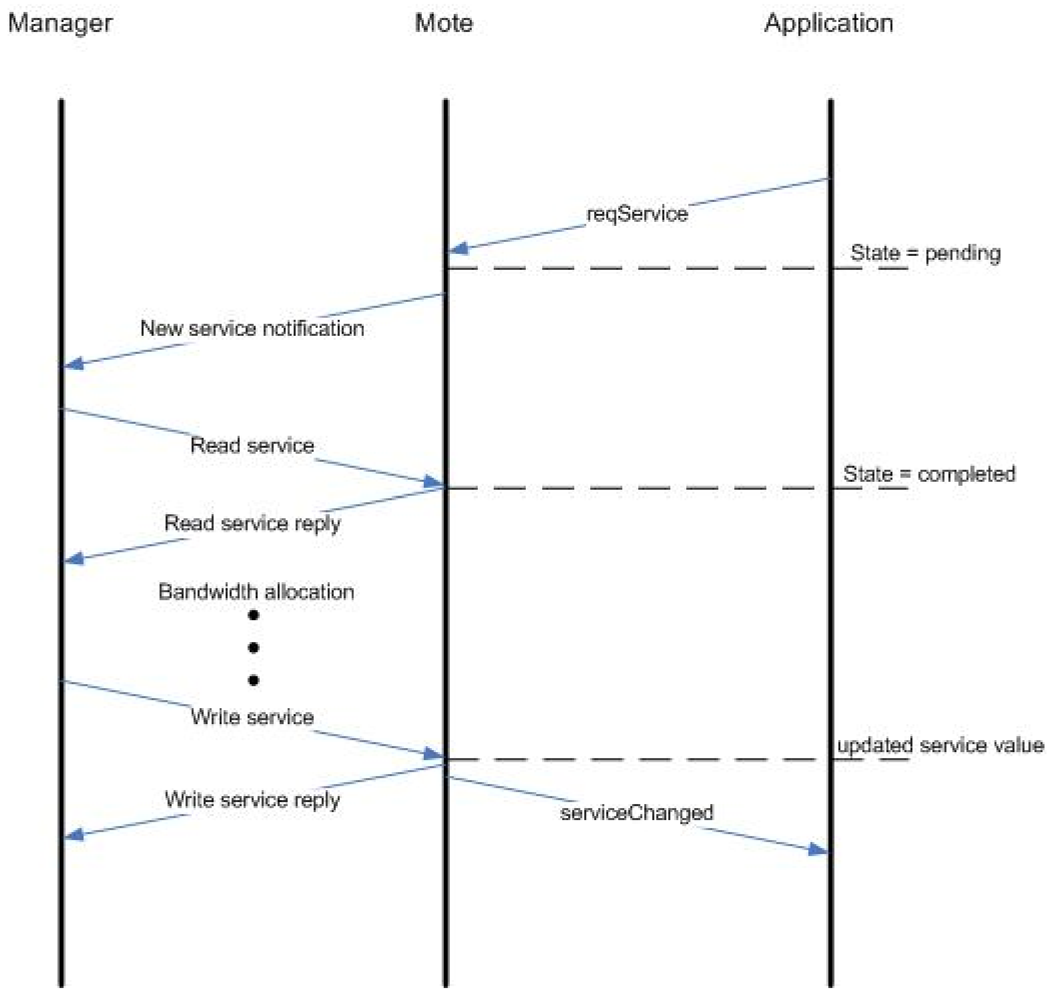
4.1 Requesting bandwidth

Once a mote is in the network and has reached Operational state, it can begin to send data packets. Initially all motes will receive a proscribed amount of upstream bandwidth (the global *base bandwidth)* to the manager - if this is not sufficient for mote's publishing rates, the application may request additional network bandwidth to a destination – this is called asking for a *service*. To find out the allocation to a destination, the application may use *getServiceInfo* API. Note that a mote will receive base bandwidth for communication with the manager even without explicitly asking for it.

A service is identified by its in-mesh destination and includes aggregate bandwidth needed by the mote. Only one service is allowed per destination, so an application that generates packets at different rates must request a single service equal to the total aggregate period. Currently the only in-mesh destination that motes can send traffic to is the manager (mesh address 0xFFFE).

When the application uses *requestService* API, the mote sends a notification to the manager about a pending service request. At this time the service state returned via API will be *pending*. Once the manager responds to the service request from the mote, the service state will change to *completed*. After getting the service request from the mote the manager stores most recent value requested and will notify the mote any time the bandwidth allocation changes – the app will receive a *serviceChanged* notification. Note that such notification may come at any point and any number of times if the network conditions change. The application may change its service requirements at any time using another *requestService* – the manager will always treat the last request as the most up-to-date.

The following transaction diagram demonstrates what is occurring between the application, mote and the manager during service request:



4.2 Back-off mechanism

The application can begin sending data immediately via the *sendTo* API after requesting a service, however it is required to back off, such that at any point it will only publish at a level that the network can tolerate. If multiple variables are being published to the same destination, the app should aggregate the total services required and make a single request.

The following back off algorithm is recommended:

- If RC_NO_RESOURCES is received, double the interval between packets. If held off again, then it goes to 3x, then 4x, ..., 255x.
- If packet transmission has been held off and is now succeeding, the interval decreases along the same pattern, 5x, 4x, ..., 1x, as the queue continues to have space.

5 Communication

5.1 Sockets

A socket is an endpoint of communication flow between a mote and another IP device. Mote sockets are loosely based on the Berkeley sockets standard. In order to communicate, the application must open a socket and bind it to a port. An application that terminates multiple ports may open multiple sockets.

Here's a normal sequence of using a socket:

1. Call *openSocket*
2. Call *bindSocket*
3. Use *sendTo* and/or process *receive* notifications. Repeated calls to *sendTo* can be made on the open socket.
4. Once done with the socket, call *closeSocket*

Currently SmartMesh IP only supports UDP sockets.

5.2 UDP Port Assignment

UDP ports in the range of 0xF0B0-0xF0BF are most efficiently compressed inside the mesh, and should be used whenever possible to maximize useable payload.

On the mote, the following port assignment is used:

Port	Description
0xF0B0	Management traffic between manager and mote
0xF0B1	Reserved (used by OTAP)
0xF0B2-0xF0B7	Reserved
0xF0B8-0xF0BF	Available for application

On the manager, the following port assignment is used:

Port	Description
0xF0B0	Management traffic between manager and mote
0xF0B1	Reserved (used by OTAP)

0xF0B2	Reserved
0xF0B3-0xF0B7	Reserved
0xF0B8-0xF0BF	Available for application

Other ports may be used at a penalty of 3 bytes of payload.

5.3 Sending and Receiving Data

Once a socket is created, the application may send data to any IPv6 device using the sendTo API, including the manager. The manager's IPv6 address is FF02::02. If a packet is sent to the manager, it will be turned into a Data notification on manager's Serial API. A packet sent to any other IPv6 address will be turned into an IP Data Notification on the manager's Serial API.

Wireless data that the application sends is highly reliable (typically better than 99.9%), but end-to-end delivery is not guaranteed with UDP. If the application cannot tolerate any lost packets then application layer reliable messaging must be provided by the customer's application.

The application may only receive packets on ports for which sockets are open and bound to a particular port number. Once this is done, the mote will forward all packets received on that port the application using the receive notification.

6 Events and Alarms

The mote API includes events and alarms that allow an application to have better visibility of mote states and conditions. An alarm is an ongoing condition, such as an error in non-volatile memory or a low buffer condition. To read current alarms, the application can use getParameter<moteStatus> API.

By contrast, an event is defined as a discrete occurrence in mote or network operation. Examples of events include a mote startup event, or a change in alarm condition. The application can control which events it is subscribed to by using setParam<eventMask> API call.

7 Factory Default Settings

The mote ships with the following factory defaults:

Parameter	Default value
Network Id	1229
Transmit Power	+8 dBm
Join Key (16 bytes, Hex)	44 55 53 54 4E 45 54 57 4F 52 4B 53 52 4F 43 4B
OTAP Lockout	0 (permitted)
Routing Mode	0 (enabled)
Join Duty Cycle	64 (25%)
maxStCurrent	0xFFFF (no limit)
minLifetime	0 (no limit)
currentLimit	0 (none)
Auto Join	off

8 Power Considerations

8.1 Power Source Information

For full description, refer to the documentation of setParam<pwrSrcInfo> API.

Of the parameters described in the *pwrSrcInfo* documentation, only maxStCurrent is used to make decisions by the SmartMesh IP manager. In assigning links, the manager will assume that each RX and TX link receives a maximum-length packet. Additional links are assigned to the mote only until maxStCurrent is met. Note that there is a minimum number of links required for operation in the network and that setting a maxStCurrent below this threshold will result in the mote getting the minimum link configuration, effectively ignoring maxStCurrent. This threshold varies depending on the downstream frame multiplier and the randomly chosen base frame size, but is ~30 uA.

This single parameter also has an impact on backbone activity. For an upstream backbone, only "powered" motes with no current restriction, i.e motes with maxStCurrent=0xFFFF, are eligible to have upstream RX links in the backbone frame. Having powered motes is the only way to construct a multi-hop upstream backbone. For a bi-directional backbone, all motes have a RX link every two slots as all motes need to participate in listening on the backbone. This will happen regardless the power setting.

The other power parameters are not currently used by the manager but products should be designed to fill them in properly so that they work with future implementations. The minLifetime parameter will be used as a complement to maxStCurrent, and the manager will obey whichever limit is more strict. For example, if minLifetime results in a mote being able to have 10 links/s but maxStCurrent sets the limit at 12 links/s, then the 10 links/s value will be used. This parameter is most useful in networks wherein devices have different types of batteries. Additionally, we provide three sets of temporary current limits. The first set consists of currentLimit_0, dischargePeriod_0, and rechargePeriod_0. The intent here is to have currentLimit_0 be higher than maxStCurrent. For example, a device that scavenges power may be able to source 40 uA of current throughout its lifetime but an on-board capacitor may be available to provide 100 uA of current for 1 minute at a time after which it needs 10 minutes to recharge. In this case, we would set currentLimit_0 = 100, dischargePeriod_0 = 60 and rechargePeriod_0 = 600. By having three different such sets, a very general power profile can be described for each mote that allows for the enabling of different types of temporary services and bandwidth.

8.2 Routing Mode

Independent of the power setting, each mote is given a routing mode that may be changed via setParam<routingMode> API.

Setting mode=non-routing disables routing, meaning the *non-routing* mote will not be assigned children. This affords some real energy savings for the mote as it is not given advertisement links or a discovery RX link. These changes take effect even if the mote is set to maxStCurrent=0xFFFF. Note that setting all motes to non-routing forces the network into a 1-hop star topology with the AP as the only parent.

Setting mote=routing enables routing (default), meaning the mote could be assigned children. The mote will send advertisements and listen on discovery RX links for packets from other motes. It is not guaranteed that a mote with routing enabled will receive children as not all motes need children for an optimal network. A routing-enabled mote that happens to not have children is still called a *leaf*. A network where all motes are routing-enabled will have at least one leaf.

8.3 Join duty cycle

The joinDutyCycle parameter allows the microprocessor to control the join duty cycle - the ratio of active listen time to doze time (a low-power radio state) during the period when the mote is searching for the network. The default duty cycle enables the mote to join the network at a reasonable rate without using excessive battery power. If you desire a faster join time at the risk of higher power consumption, use the setParameter<joinDutyCycle> command to increase the join duty cycle up to 100%. Note that the setParameter<joinDutyCycle> command is not persistent and affects only the next join. For power consumption information, refer to the mote product datasheet. This command may be issued multiple times during the joining process. This command is only effective when the mote is in the IDLE and SEARCHING states.