ZigBeeNet™ Software 1.0

Application Note

Battery Lifetime Estimation

Summary

This Application Note describes how to evaluate battery life for devices based on MeshNetics ZigBit hardware platform.

Intended audience

This document is intended for system designers and hardware developers evaluating power consumption and battery requirements of MeshNetics ZigBee modules.

Related documents:

[1] ZigBit™ OEM Modules. Product Datasheet. MeshNetics Doc. M-251~01

ZigBee Networking Overview

ZigBee networks differentiate among three device (or node) roles. Not surprisingly, power consumption requirements depend on the device type, i.e. the fundamental restrictions imposed by the ZigBee specification, and the way the device is powered in a particular application, i.e. battery or mains-powered. For the purposes of this application note, we omit discussion of energy-harvesting strategies.

There are three types of devices in a ZigBee network:

- **Coordinator.** This is the "core" node of the entire ZigBee network, responsible for starting the network and managing it to a certain extent. The coordinator is typically mains-powered, because it generates and receives lots of radio traffic and must remain always on to maintain ongoing operation of the entire network.

- **Router.** These nodes are responsible for relaying data across multiple hops of the network, extending coverage and network flexibility. Since they also use the radio chip actively, routers are mains-powered in most scenarios.

- **End device**. This is the "workhorse" of the network, performing data collection, etc. at regular intervals and/or on demand. These nodes can be (and, in most cases, are) battery-powered and spend most of the time in "sleep" mode, waking up either by timer or from external event (interrupt) to receive data from external source (sensor, etc.) and send it to the collecting node (router or coordinator). Control messages directed to a sleeping end device can be queued up at the nearest router and received during the time interval when the device is awake. Typical scenario for end device is as follows:

a) Node is in power-saving mode (sleeps) until a wake-up event is triggered or external interrupt is received.

b) Node goes to full power, optionally re-establishes the connection to the network if it has been lost during sleep, receives the data and then sends it to the parent node over radio (if the network is still available).

c) Node shuts down the radio circuitry and goes back to power-saving mode.

d) Repeat (a)-(c).

Duty Cycle

The typical stages in the operation of an end device determine what is commonly known as a duty cycle. Duty cycle is the fraction of time during which a component, device, or system is operated, i.e. it is computed by dividing the time spent in (b) state by the time spent in (a) and (b) states. ZigBee specification sets the maximum sleep time to 4 hours for all end devices. Minimum on-time is bounded below by the turnaround trip time, i.e. the time needed for an end device to send a packet to the nearest router and wait for an acknowledgment.

Battery Lifetime Estimation

The formulas used below do not account for several important parameters, e.g. battery self-discharge and internal leakage, that affect real power consumption and related battery lifetime. Thus the formula should be used solely as a rough guide in estimating appropriate battery capacity in the target application. Also, the formula computes battery lifetime based solely on the power consumed by a ZigBit module [1]. In actual application, the power consumed by the ZigBit itself is often dwarfed by the connected peripherals, thus any design must account total power consumed by all components in sleep and active states.

The following calculation shows how to compute battery lifetime for a given battery capacity and duty cycle.

Assume:

Battery capacity: **W** = 2000mAh.

Because of voltage requirements as per datasheet, actual design may require more than one battery connected in series. For example, the minimum allowed voltage of 1.8V will require at least two AA-sized batteries of 1.25V each. As the batteries drain, their voltage decreases, thus one battery of 1.8V will last less than two batteries of 1.25V each.

Estimation period (just an arbitrary example): $\mathbf{T_{period}}$ = 3.6 sec.

Power consumption in active mode (ZigBit module only, without external circuitry or peripherals, as per documentation, see [1]): $\mathbf{I_{awake}}$ = 19mA.

Power consumption in sleep mode (ZigBit module only, without external circuitry): $\mathbf{I_{sleep}}$ = 0.006mA

Defines*:*

Total battery lifetime: $\mathbf{T_{work}}$ (seconds).

Time spent in active mode: $\mathbf{T_{awake}}$ (seconds).

Sleep interval: $\mathbf{T_{sleep}}$ (seconds).

$\mathbf{T_{work}}$ is calculated as follows:

$\mathbf{T_{work}} = \mathbf{W} / \mathbf{I_{av}},$
where $\mathbf{I_{av}}$ is the time-averaged power consumption:

$\mathbf{I_{av}} = (\mathbf{I_{sleep}} \cdot \mathbf{T_{sleep}} + \mathbf{I_{awake}} \cdot \mathbf{T_{awake}}) / \mathbf{T_{period}}$
and
$\mathbf{T_{sleep}} = \mathbf{T_{period}} - \mathbf{T_{awake}}$

Here you may see that the most important factor is $\mathbf{T_{awake}}$ (length of active cycle, when the power consumption is maximum). $\mathbf{T_{sleep}}$ is subject to much smaller relative changes; in fact, it is almost constant in most cases. To illustrate this, let us calculate the working time for two values of $\mathbf{T_{awake}}$: 20ms and 200ms.

For $\mathbf{T_{awake}}$ = 200ms:

$\mathbf{T_{awake}}$, sec	$\mathbf{T_{sleep}}$, sec	$\mathbf{I_{av}}$, mA	$\mathbf{T_{work}}$
0.2	3.4	1.061	***1884 hours (78 days)***

For $\mathbf{T_{awake}}$ = 20ms:

$\mathbf{T_{awake}}$, sec	$\mathbf{T_{sleep}}$, sec	$\mathbf{I_{av}}$, mA	$\mathbf{T_{work}}$
0.02	3.58	0.121	***16521 hour (688 days)***

Conclusion

The above formula can be used by system designers and hardware developers to estimate battery capacity requirements and expected battery lifetime for ZigBit-based nodes in a ZigBee network. The calculation provides rough design guidelines that should be refined considering battery technology, connected peripherals, and required duty cycles for each particular application.