Application Report
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ZigBee Power Calculator Understanding Measurement Setup and Results

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ABSTRACT

This purpose of this application report is to provide information to understand the configuration and results that can be obtained using the ZigBee power consumption calculator.

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1 Introduction

This document provides a resource guide pointing to the relevant collateral necessary to understand the theory of operation and bench setup settings used to measure the power consumption of a ZigBee® end device using Z-Stack™ software.

2 Test Setup Overview

To understand the hardware setup used for the power consumption measurements, see the *Measurement Setup* section in [1] for measurements on the SimpleLink™ CC2530 Micro Controller Unit (MCU). For measurements on the SimpleLink CC2538 Wireless MCU, see [2].

Z-Stack Sample Switch and Z-Stack Sample Light are the applications used to extract power consumption measurements implemented as ZigBee end device and coordinator, respectively. The Z-Stack software stack and applications are configured with the same options and settings provided in the power calculator tool for different user defined knobs (such as network layer security, number of application layer payload bytes for transmitted and received data, application acknowledgment service) to calculate the power consumption for various system configurations. To understand how to configure Z-Stack for various configuration settings available in the power consumption calculator tool, see the *Z-Stack Developers Guide*, *Z-Stack API* document, and *Z-Stack Application* level tuning documents. These documents, along with other useful collateral, are present within the “/Documents” folder in your Z-Stack installation folder. The measurement procedure used for power consumption measurements is described in the *Measurements* and *Application to a Practical Use Case* sections [1] for CC2530 and [2] for CC2538. The application reports also show and describe the voltage vs time plot to understand power consumption for each message transaction between the coordinator and the end device in detail.

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In the test setup, the end device associates to the network with the coordinator as the parent. In addition to periodic polling messages and maintaining low power mode when there is no operation to be executed for the purpose of simplifying measurements, it was assumed that only the end device would transmit application messages to the coordinator parent and receive response messages from the coordinator for those messages. The response message is typically an application layer acknowledgment of the processing of the command. When doing the measurements, the Zigbee Cluster Library (ZCL) layer default response was the response message from the coordinator to the end device. The number of times the end device sends an application message to the coordinator is a configurable value that depends on the type of the application and can be configured in the “Usage Model” tab of the ZigBee Power Consumption Calculator. For each application message transmitted by the end device a sequence of message transfer activity starts, which depends on the condition whether or not the APS layer acknowledgment is enabled or disabled. If APS acknowledgment is disabled, the message sequence is as described in the *Application to a Practical Use Case* section of [1] and [2], also described in Section 2.1. The power calculation method explained in the *Estimation for Usage Scenario* section of [1] and [2] can be used to compute the final consumption in this case. Whereas, if the APS layer acknowledgment is additionally enabled after each message that the end device sends, it would receive two messages as in response: the APS acknowledgment message and the response message to the transmitted command. This is shown in Section 2.2. For final power measurements (when APS acknowledgment is enabled) as explained in the *Estimation for Usage Scenario* section of [1] and [2], the power consumption due to operation of receiving APS ACK would need to be added in the calculations for accurate measurements.

2.1 Case 1

Figure 1 shows the sequence of message transfers when quality of service (QoS) is APS un-acknowledged.

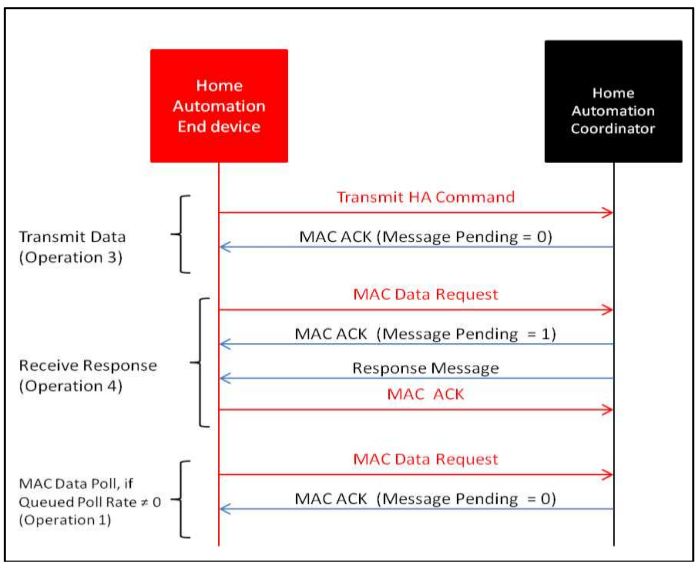

Figure 1. Message Sequence Diagram When APS ACK is Disabled

2.2 Case 2

Figure 2 shows the sequence of message transfers when quality of service is APS acknowledged.

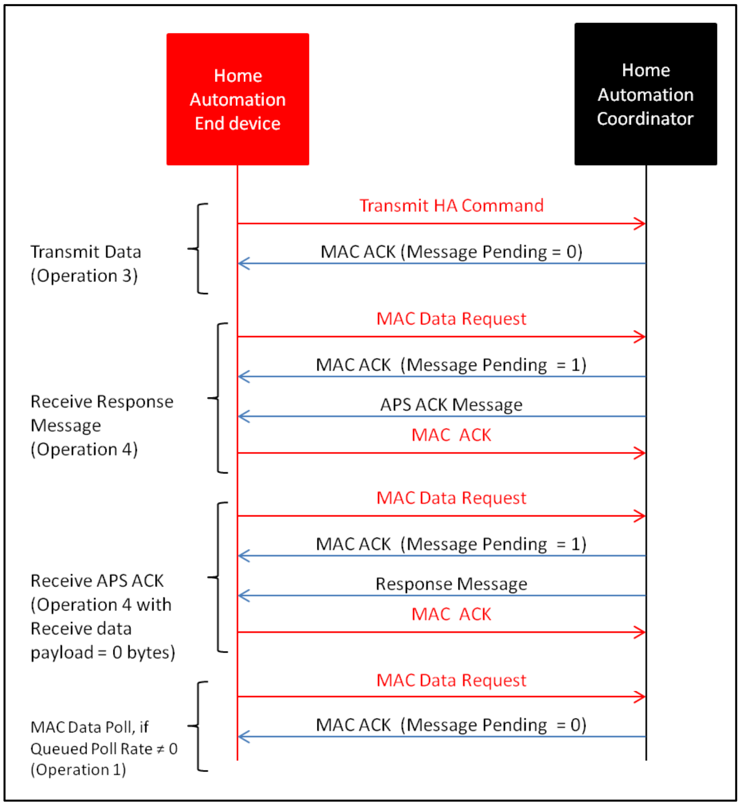

Figure 2. Message Sequence Diagram When APS ACK is Enabled

3 Suggestions on Setting the Knobs on the Calculator

- For ZigBee Home Automation networks, network layer security is always enabled (mandated by the ZigBee Home automation specification), whereas, the application layer security is typically disabled.
- The calculator was modeled to have the ZCL default response as the response message for the purpose of getting application layer acknowledgments to ensure end-to-end message transfers. Typically, for home automation networks, this is the only acknowledgment used for ensuring reliable end-to-end communication at application layer. Enabling APS ACK, in addition to ZCL Default response, would increase power consumption and is typically not done. Typically, either APS ACK or default response messages are used to ensure reliable end-to-end message transfer in ZigBee Home Automation networks.

4 Notes on the Results From the Power Calculator Tool

- This tool is attempted to provide a comprehensive means that will account for the most fundamental contributors, however, being a static analysis tool there is no attempt to model cycle accurate behavior.
- Approximations were used in multiple cases where it seems fit in order to reduce the calculation complexity and ease the readability. This was done in a prudent manner making sure that the effect on the overall result is negligible.
- Results do not include the first time network join operation, and do not include the power consumption (if any) due to end device losing the parent and associating either doing the Orphan Scan or the network layer rejoin.
- Results do not include current consumptions due to any peripherals such as LED, LCD, Key Press being done on the end device. Having those on the system will increase the power consumption, which would have to be taken in to account for estimating the battery life.

- Results do not consider retires for message transfers.
- Calculations are made with an assumption that average CSMA-CA back-off duration will be of 1msec. Heavy traffic environment where CSMA-CA times are longer may cause the power consumption to increase.
- Measurement results for CC2538 are made with the CPU running on an 8 MHz clock frequency for the active part, while using the 32 MHz clock when entering the sleep and exiting the sleep mode as described in [2].
- The provided battery life is a theoretical estimate; however, actual battery life is affected by various factors such as internal self discharge, type of battery, and so forth. Therefore, the observed battery life may be less than the estimated battery life value provided by the ZigBee Power Calculator tool.
- Average current per polling interval, where the polling interval is the time period including the one mac data poll by the end device and sleep duration before the next poll, provides average current consumed by the end device during one polling interval.

5 References

1. *Measuring Power Consumption of CC2530 with Z-Stack* (SWRA292)
2. *Power Consumption Measurements and Optimization for CC2538 End Device with Z-Stack* (SWRA456)