Demo: Low-cost, Low-power Testbed for Establishing Network of LoRaWAN Nodes

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Abstract

The Internet of Things (IoT) is a fusion of many technologies and it has spanned across diverse and multidisciplinary application domains. In order to evaluate various wireless technologies and components one needs to perform experimental field studies in order to gain further practical insights like - power, range, interference, RSSI, etc. which is otherwise difficult to obtain from simulation. The demo will showcase the details of our hardware platform to establish a cost effective, low-power testbed for experimenting with network of LoRaWAN/LoRa nodes.

1 Introduction

Modeling power consumption of IoT devices is not an easy task as it requires many technology dependent parameters [6], nevertheless the power models are good for comparing various wireless technologies at an early stage of technology selection. On the other hand, [5] presents analytical models of LoRaWAN end-device's current consumptions derived from measurements performed on existing LoRaWAN hardware platform, these models are useful to study the impact of various LoRaWAN physical and Medium Access Control parameters (data rates, acknowledge transmission, payload size and bit error rate) on power consumption and ultimately to have a rough estimate of battery life.

In this demo, we showcase a cost effective (<12€), low-power (≈150nW in sleep) and battery operated hardware platform for experimental LoRaWAN [4] field studies and can also be used to validate the power models (such as [5,6]) of LoRaWAN technology and better estimate battery life.

Moreover, as mentioned in [5] many prevalent LoRaWAN hardware platforms have sleep currents in the order of $10\mu A$ to $40mA$ due to suboptimal hardware design. In our platform low power is achieved using a technique known as *"power gating"* [7] to reduce sleep (inactive) current down to ≈50nA. Our low-cost hardware platform can also be used to complement projects like, WAZIUP [8] that allows the deployment of low-cost LPWAN infrastructure in developing countries.

2 Platform Details

The platform consist of two boards that together forms a LoRaWAN/LoRa enabled wireless node. As shown in Figure 1, the *first board* (referred to as B1) combines on a single board an Arduino compatible MCU (Atmega328p) with LoRa transceiver (RFM95W module). The bootloader inside the MCU is same as *Arduino Pro Mini 3.3V-8MHz* therefore it is possible to use Arduino IDE to create applications and debug via external FTDI serial adapter, similar to Arduino Pro Mini. The *second board* (referred to as B2) is a power-supply and power-management board for B1. It uses nanoPower boost converter (MAX17223) to convert voltage from two 1.5V AAA battery (3.0V in series) into regulated 3.3V output voltage for B1. The value of the boost converter inductor is carefully selected to reliably convert input voltage ranging from 2.0V to 3.0V into regulated 3.3V at 200 mA output current. For power management (Section 3), a nano-power system timer (TPL5111) is used for power gating B1, the timer's time interval is programmable using external resistor.

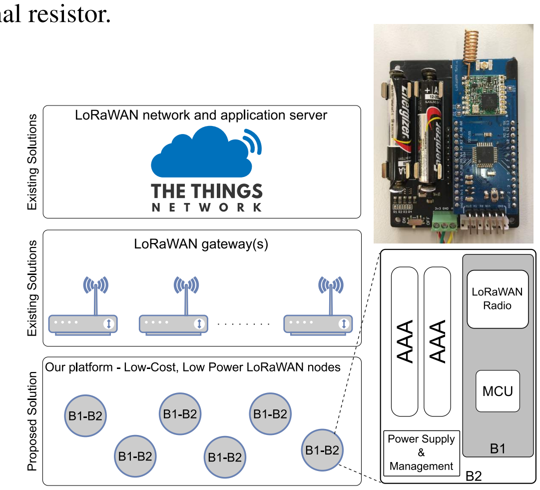

Figure 1. Illustration of Proposed Demo

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3 Platform Operation and Power Management

The power management of our platform is based on the principle of power gating [7], where the power is temporarily removed from the circuit when it is not required (inactive state) and making sure the power is back again when the circuit requires power for operation. The power management is purely in hardware and is independent of wireless technology. As illustrated in Figure 2, the B2 has two important components - boost converter and system timer. The boost converter generates the regulated 3.3V for the proper functioning of B1 and the system timer. The system timer waits for the MCU (B1) to generate power disable signal and after receiving the signal, the timer disables the boost converter, thereby removing power from B1, this process is called *"self destruction"*. Since the system timer is continuously powered, therefore it is still ticking and after a predefined time interval it enables the boost converter and the power is back again. Before disabling the power the MCU performs the necessary IoT application task as programmed by the user. Figure 3 shows the timing diagram of platform operation. This technique is useful for star networks like LPWAN (LoRaWAN, Sigfox, etc.) and for applications with infrequent transmission, for example - Smart Cities, Smart Agriculture, etc.

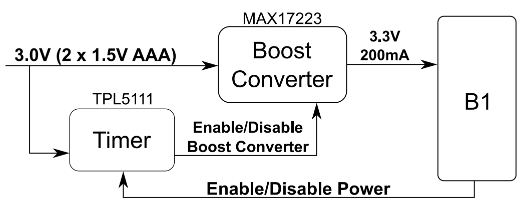

Figure 2. B2 Circuit Block Diagram

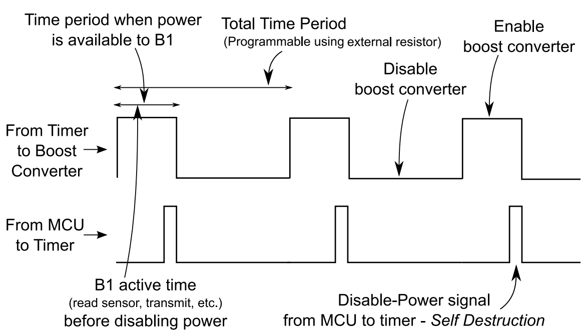

Figure 3. Platform Timing Diagram

4 Power Consumption

The advantage of the technique mentioned in Section 3 is that between two consecutive transmit the total shutdown current drawn $I_{T_{SD}}$ from the batteries is effectively reduced to the current consumed by the system timer I_{ST}, shutdown current of boost converter $I_{BC_{SD}}$ and an unknown leakage current $\delta_{leakage}$ of the platform (see Eq. 1). After obtaining the values of I_{ST} and $I_{BC_{SD}}$ from their respective datasheet, the $I_{T_{SD}}$ is approx. equals to Eq. 2.

$$I_{T_{SD}} = I_{ST} + I_{BC_{SD}} + \delta_{leakage} \tag{1}$$

$$I_{T_{SD}} = 35nA + 0.5nA + \delta_{leakage} \tag{2}$$

In contrast with other techniques, where we utilize various power down modes of the components to reduce effective power during sleep, the total power down current ($I_{T_{PD}}$) consumed is given by Eq. 3. (I_{BC_A} - boost converter active current, $I_{MCU_{PD}}$ & $I_{R_{PD}}$ - MCU & Radio power down currents respectively). The system timer (I_{ST}) is used to wake up MCU from sleep. After obtaining the values of I_{ST}, I_{BC_A}, $I_{MCU_{PD}}$ & $I_{R_{PD}}$ from their respective datasheet, the $I_{T_{PD}}$ is approx. equals to Eq. 4.

$$I_{T_{PD}} = I_{ST} + I_{BC_A} + I_{MCU_{PD}} + I_{R_{PD}} + \delta_{leakage} \tag{3}$$

$$I_{T_{PD}} = 35nA + 500nA + 100nA + 200nA + \delta_{leakage} \tag{4}$$

Eq. 1 and Eq. 3 does not include current consumed by external components attached to B2 such as sensors or actuators as they are application dependent. One can imagine the addition of more sleep currents if these external components are attached to the platform, where as Eq. (1) is independent of various sub-system sleep and leakage currents. As we can see from Eq. 2 & Eq. 4, the *power gating* technique used in our platform saves 90-95% of sleep current.

Our platform can achieve ≈781 days of battery life while sending one LoRaWAN message every 30 mins. The battery life is calculated based on the measured average average current consumed over a period of 30 mins and assuming the capacity of AAA battery is $1000mAh$. Without power gating technique the battery life is ≈650 days, this difference in battery life is more pronounced as the rate of message transmission is further increased because for very infrequent transmission sleep current starts to dominate battery life.

5 Demo Setup

As Figure 1 illustrates, the proposed demo uses our hardware platform along with existing solutions for gateway and cloud infrastructure. We used IMST iC880a [1] as LoRaWAN 868 MHz concentrator (gateway) and Things Network [3] for LoRaWAN network and application server. For LoRaWAN application development the platform uses existing open source LoRaWAN library - *Arduino-LMIC* [2] to compliment our hardware platform. The application code is slightly modified to include power management features as discussed in Section 3.

6 References

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7 Demo Requirements

The demo setup requires a small table to accommodate our hardware platform, a LoRaWAN gateway and a USB oscilloscope with a laptop to demonstrate the current consumption. Although USB oscilloscope is not necessary to show the working of our hardware platform.