Power Analysis of PhyNode

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Performance of nodes in a wireless sensor network and consequently the overall network relies on balancing the current demand of the hardware and available energy. This work shortly reviews the load of the PhyNode as an embedded entity inside the research lab of PhyNetLab. Overall demand from battery is analyzed for both idle and operational cycle of the PhyNode showing a current deficit in the overall system.

1 Introduction

With the rise of Internet of Things (IoT) and Industry 4.0 as its industrial dual, multiple smart small devices are developed to collect data and act decentralized with communication as their core concept. Logistics is not an exception of this revolution with multiple cyber-physical and embedded systems developed for this field [6]. PhyNetLab [2] is a testbed developed for evaluation of different concepts in the field of materials handling and warehousing as two major pillars of the logistics branch. PhyNode is an entity for mounting on transportation boxes used in this field. More than two hundred PhyNodes with different hardware configurations are available in the PhyNetLab. All models of PhyNodes embody an ultra-low power processor, RF communication and some environmental sensors. While availability of energy harvesting module and display is dependent on the model.

Although PhyNetLab has been tested in few applications [2, 4], its optimal operation requires trade-off between service quality and available energy. This shows necessity of power analysis of the PhyNode. Some evaluations such as [1] has been done for individual sections of PhyNode. However, the overall power demand seen from the PhyNode's battery has not been analyzed yet and will be the focus of this work.

2 Power module

PhyNode's power module is made of multiple sections. An abstract overview of the complete system including PhotoVoltaic (PV) energy harvesting section is shown in Fig. 1.

Figure 1: Schematic representation of PhyNode's power chain.

An indoor photovoltaic module from *Solems* with 7 cells is used in PhyNode which its behavior and model can be found in [5]. To keep the harvester around its maximum power point while matching its voltage with the battery, a *BQ25505* IC is used. Not only its internal boost converter do the DC-DC matching, but also it keeps the battery within safe operational range. Detailed description of this IC in addition to its behavior model is presented in [3].

PhyNode uses a Li-Polymer battery with a nominal capacity of 1250 mA h, a typical 4.2 V over voltage limit and a cut-off voltage of 3.0 V. Its standard charge and discharge rates are $0.2C$. However, measurement at this rate (250 mA) has shown a higher capacity of 1283 mA h. Although this can be considered a marginal capacity difference, it is noticeable for ultra-low power applications such as PhyNode.

A *TPS65290* Power Management IC (PMIC) from Texas Instruments provides different voltage levels from the battery output. In addition to a buck-boost converter, it includes a LDO providing another voltage rail without a switching mechanism. This can be helpful for devices requiring a short term current. While the switched based mechanism requires some switching periods to provide a stable voltage, LDO can directly supply such demand. However, LDOs are generally less efficient due to excess power dissipation through heat.

3 Power levels

Measurements in the PhyNetLab has shown that the both extreme cases of photovoltaic generated current will be in the range of 30 µA to 140 µA. On the other hand, analysis of demands from sub-modules of PhyNode shows that the highest current demand will be during send procedure of the communication module. Considering operational conditions, the highest communication current demand will be about 32 mA. Moreover, processor of the PhyNode requires 100 µA per MHz with a maximum of 16 MHz; leading to the highest demand of 1.6 mA. Considering some overhead for other components, a 35 mA is a feasible peak demand.

PMIC acts as an interface between PhyNode's battery and the rest of system. While current demand seen from the battery side will be dependent to its voltage based on the behavior of the PMIC. Therefore, before using the aforementioned limits as a base for system design, real measurements has to be done directly at the output of the battery.

A measurement setup is prepared to replicate the battery with a Source Measurement Unit (SMU). It measures the voltage and current demanded by PMIC while keeping the voltage constant. These devices are connected using a 4-wire connection to enable a non-destructive measurement. A scenario is programmed on a PhyNode which includes all its possible operations; from pushing a button, sending and receiving and even updating the display. Current demands for such operation is measured at different voltage levels starting from 4.2 V with 0.1 V reducing steps. Some examples of these curves for a complete scenario are presented in Fig. 2.

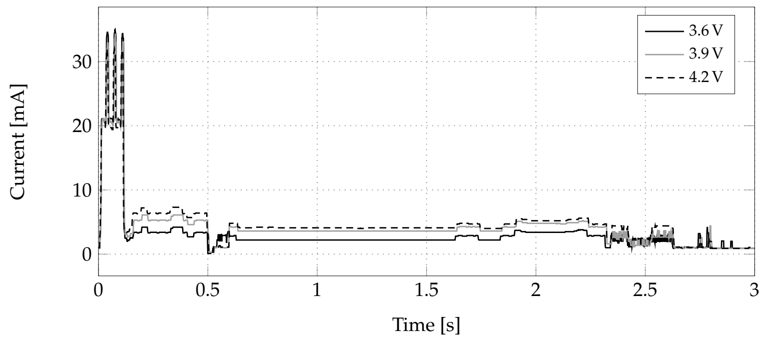

Figure 2: Measured current of PhyNode during a complete cycle at different battery voltages. Peak happens during RF communication send process.

These measurements confirm initial guess of 35 mA as the highest current demanded. Unfortunately, not only reduction of voltage level does not reduce the current demand but also it has negative effect. This is actually a consequence of feeding some parts of the PhyNode with the LDO which simply wastes the excess power. Furthermore, the idle current demand is about 1 mA and is independent from the battery voltage level.

It has been found that reduction of the voltage to the battery minimum is not possible. When the voltage is lower than 3.54 V, PhyNode cannot start all parts of the system during its start check. This effect can also be seen in its current demand shown in Fig. 3.

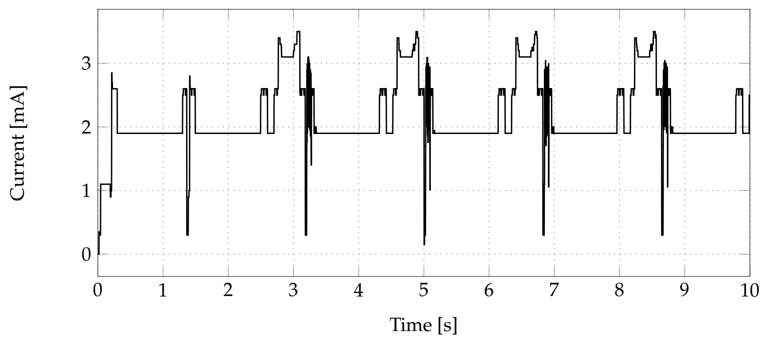

Figure 3: Measured current of PhyNode at 3.53 V causing problem in the startup loop.

4 Conclusion

According to measurements, it can be summed up that the PhyNode is only operational in the range of 3.54 V to 4.2 V. Its idle current can be considered independent from the voltage level and around 1 mA while the maximum requested current is about 35 mA. Considering maximum harvested current of 140 μA in the PhyNetLab environmental condition this PhyNode version has a current deficit and cannot be considered as an energy-neutral device. Perhaps, software improvements which can reduce the idle power, specifically in the RF module (as the main consumer) can improve this issue. Anyhow, best *idle shelf-time* with the available driver version can be estimation to be around 45 days. In case of operation, this time will be shorten according to the operation profile which its estimation requires further modeling and analysis.

References

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