Demonstration of a Low-Power Energy Management Module with Emergency Reserve for Solar-Powered DTN-Nodes

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ABSTRACT

We propose a field experiment and a demonstration of a solar powered DTN node with a power management module. This module reduces the power consumption of the node by turning it off when the node is idle. It also handles solar charge management, energy management and a discovery mechanism to wakeup sleeping nodes.

1. INTRODUCTION

Solar-powered DTN-nodes are useful in many application scenarios, especially in rural and sparsely populated areas where they sometimes can be the only cost-efficient way to setup a communication system, but also in specific urban settings due to their fast and easy setup possibilities. Yet, an important technical need for such nodes is a flexible power management. We have developed and successfully tested a power management module (PMM) for solar powered DTN nodes that handles charge management as well as a sleep/discovery/wakeup-mechanism. It is able to significantly reduce the energy consumption of a solar powered node, by powering it off when it is idle. A low power 802.15.4 discovery radio on the PMM is used to trigger a wakeup, so that the node powers on shortly before a contact with another node occurs. Therefore, smaller solar panels are required and the physical dimensions of the system can be reduced. Moreover, the PMM keeps an emergency energy reserve for urgent communications. This functionality is not limited to scenarios with solar power, it is beneficial for all scenarios with intermittent power. The details of the node and the PMM design are presented in our submitted full paper.

2. FIELD EXPERIMENT AND DEMONSTRATION PROPOSAL

The solar powered DTN node with PMM was developed for a middle European urban environment, where it currently operates reliably and stable. Now, we would like to test and demonstrate our system in a real extreme environment. However, the climate at Manaus is not only a challenge for our hardware, but also a great opportunity. The near equatorial location is almost perfectly suited for solar powered hardware, since there are no big seasonal differences in hours of daylight. Moreover, in this area the attenuation effect of the atmosphere on sunlight is small. This allows for a significant reduction of the solar panel size, which is currently dimensioned for a middle European winter.

2.1 Field Experiment

The purpose of the field experiment is to evaluate the system design and implementation in an extreme environment and with a real world load. Therefore, we propose an open field experiment, in which mobile users connect to our solar powered DTN nodes, and other DTN nodes route bundles through our nodes.

We expect the following results from the field experiment:

- traces and logfiles from real world testing
- performance evaluation under real load
- feedback on user experience with the discovery/wakeup mechanism
- validation of our assumptions on duty and idle time
- validation of calculated daily amount of harvested energy
- interoperability test between IBR-DTN on our node, DTN2 and other DTN implementations

We propose the following setup for the field experiment. Two fixed solar powered nodes (A and B) with PMM are installed well out of each others radio range. One dedicated ferry node (C) with a PMM travels sporadically between the intermittently powered solar nodes. Bundles are routed from A to B via C and vice versa. Moreover, there are several users who sporadically make contact with the solar powered nodes. Some of these users have 802.15.4 interfaces to trigger a wakeup, while other users have to rely on scheduled wakeups.

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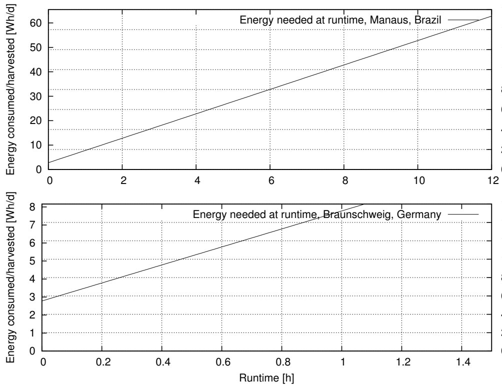

Figure 1: Function of harvested solar energy, consumption and solar panel size for Braunschweig and Manaus

2.2 Demonstration

For the demonstration we propose a setup with one solar powered DTN node. Wakeup events will be manually triggered from a laptop with an 802.15.4 USB-stick and by another PMM. The case of the solar powered DTN node will be open like in figure 3 so that the components can be presented and explained. Another laptop will monitor and visualize the currents and voltages, so that the wakeup process can be observed.

3. PLANNED SITE-SPECIFIC ADAPTATIONS

The field experiment gives us the opportunity to exploit the solar-power friendly geographic location of Manaus to reduce the panel size. This allows for smaller dimensions of the DTN node. Figure 1 shows the calculated function of panel size, the worst-case amount of harvested energy (shortest day of the year) and daily hours of operation for Manaus (upper diagram) and Braunschweig (lower diagram). The left y-axis shows the daily amount of harvested energy in Wh, which corresponds to the panel size in W (at a standardized solar radiation energy of $1kw/m^2$) shown on the right y-axis. The x-axis shows the daily hours of operation of the DTN node. The slight zero-offset of the graph is due to the PMM's own power consumption of 2.79 Wh/d, which is mostly caused by the listening discovery radio (details are given in our submitted full paper).

The current design of the solar powered DTN node in figure 2 uses a 16W panel. Figure 1 illustrates that this panel would be sufficient for 12 hours of continuous operation. The basic concept behind the PMM is that idle nodes are powered down, and we assume that stationary nodes are only active for a few hours. Under this assumption the panel size could be significantly reduced at Manaus. This would allow us to integrate the panel into the top of the node's case. Therefore, the whole panel mounting shown in figure 2 may become obsolete, and only the case below it remains.

Moreover, we plan to install an external antenna to the PMM's 802.15.4 radio and to use an 802.11a NIC with a higher transmit power. The evaluation results (presented in our full paper) have shown that the 802.15.4 discovery range is already larger than the 802.11a range. However, the more powerful NIC will likely exceed the range of the

Figure 2: Current solar powered node design with 16W panel

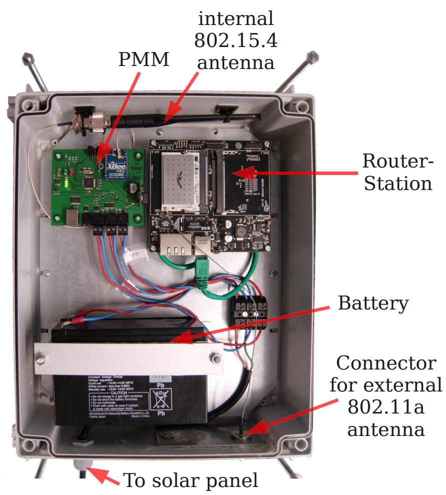

Figure 3: The case containing battery, PMM with internal antenna, and an embedded linux board with an 802.11a NIC

discovery radio. An external PMM antenna will significantly increase the discovery range without increasing the power consumption of the PMM.

4. CONCLUSIONS

The combination of a solar charging circuit with a low power radio for discovery and remote wakup mechanisms into a single module benefits from synergies, e.g. only a single MCU and a single voltage regulator is required. Therefore, our design has lower physical dimensions, costs, and a lower energy consumption than seperate modules for charging, swiching, metering and discovery. The range measurements have shown that the range of the discovery radio exceeds 802.11a and therefore our design works as intended. For mobile scenarios a sleeping node can be booted up before the 802.11a contact starts.