Demo Abstract: Energy-Aware Battery-Less Bluetooth Low Energy Device Prototype Powered By Ambient Light

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ABSTRACT

Bluetooth Low Energy (BLE) is emerging as an Internet of Things (IoT) technology that effectively connects small devices and sensors. It can enable many smart building use cases such as automation and control, environmental condition monitoring, and indoor location services. The BLE mesh standard provides a friendship feature to support Low Power Nodes (LPNs). We demonstrate how these BLE LPNs can support communication (uplink, downlink, or bidirectional) when powered by ambient indoor light using a mini solar panel and a small capacitor for energy storage. Being batteryless, it can exhibit intermittent behaviour with periodic ON and OFF states. However, with the knowledge of the capacitor voltage, an energy-aware LPN can try to avoid the OFF state. It can delay the execution of upcoming tasks by switching to an SLEEP state (consuming minimum energy) and provide some time to recharge the capacitor. We consider an example use case of monitoring temperature and room occupancy. The mesh nodes in the network can send instructions (such as turn-on an LED or a buzzer) to the batteryless LPN that should be executed by it. We study the use-case with real experiments on the communication feasibility of an energy-aware BLE LPN in a network and characterize the capacitance behaviour by placing a 6 W light bulb at 120 cm from the solar panel.

CCS CONCEPTS

• **Computer systems organization** → *Embedded software*; • **Networks** → *Network management*; • **Hardware** → **Renewable energy**.

KEYWORDS

Bluetooth low energy, Batteryless low power node, Energy harvesting, Light energy

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1 INTRODUCTION

Smart buildings are the perfect use case for the Internet of Things (IoT) technologies. Usually, one of its requirements is to enable energy-constrained devices to interact with each other reliably at a low cost. The Bluetooth Low Energy (BLE) mesh network standard, which supports a wide range of IoT use cases, provides a friendship feature. This feature allows Low Power Nodes (LPNs) (traditionally battery powered) to rely on another node in the network known as friend node (FN) to receive incoming packets and temporarily buffer them [1]. Meanwhile, the LPN can be turned-off or switch to SLEEP state and periodically wake up to poll the FN to receive the buffered packets. This enables downlink communication at very low power consumption.

As batteries have limited lifetime and recharge cycles, they need to be replaced manually and frequently. Thus, the maintenance cost of the network increases. To reduce this, we power the BLE LPN using indoor ambient light and a small capacitor to store energy. The batteryless BLE LPN can be either unaware of available voltage of its capacitor or aware of it. An energy-unaware LPN always tries to execute the task and can go into an OFF state if not enough energy is available, resulting in intermittent behaviour. Whereas, an energy-aware LPN can avoid this intermittent behaviour by executing the tasks only if it has enough energy stored in the capacitor to execute the task. This work demonstrates an energy-aware batteryless BLE LPN that can bidirectionally communicate with other nodes in the mesh network. We use off-the-shelf low-cost hardware to design the prototype. The LPN harvests from a small 4x2 cm^2 solar panel to power the BLE device. One of the benefits of such batteryless LPNs is that the existing infrastructure does not need any changes. The LPNs are fully compliant with the BLE mesh standard and only needed to be associated with the network using the network and application keys.

2 SYSTEM DESIGN

The batteryless LPN design requires a power management board (PMB) that enables charging of the capacitor, regulating the output voltage to the load, and extracting maximum power from the solar cell. Figure 1 shows the prototype of the demonstrator network and batteryless LPN. In indoor IoT scenarios, natural sunlight is often not available (e.g., during nighttime, or in rooms/corridors without windows). Therefore, we evaluate the feasibility of harvesting energy from artificial light (i.e., a 6 W Warm White LED light bulb).

A 6-cell mono-crystalline solar panel (ANYSOLAR-SM141K06L) is chosen due to its high efficiency (25%) and life. The panel is connected to the Epeas-AEM10941 PMB [2] which is configured to supply a stable voltage of 3.3 V. The PMB supplies the output voltage only when it charges the connected capacitor to a specific turn-on