Demo Abstract: Abating LPL-induced Latency with Wake-up Radio Technology

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ABSTRACT

We are concerned with IoT applications where communication among resource constrained, battery powered devices exchange data wirelessly. Traditionally, these devices keep energy consumption at bay by sending their radio to sleep according to a pre-defined duty cycle (*Low Power Listening*, or LPL). This, however, increases data latency dramatically. In order to reduce these delays, recent research has investigated the use of wake-up radios, namely, additional low-cost, ultra-low power radios operating at a different frequency than the main radio. In this way, by spending energy comparable to that of a node in sleep mode nodes can wake up their neighbors as soon as they have a packet to send, no longer needing to wait for the neighbors to wake up. This demonstration provides evidence of how by using wake-up radios we can abate the latency imposed by LPL. We show a simple chat application where messages from Alice to Bob are transmitted concurrently between two pairs of MagoNodes++, one with wake-up capabilities and the other using LPL. For each message received by Bob, latency information is shown, along with information regarding the time when the main radio is on. This allows us to clearly quantify the advantage of using wake-up radios for faster message exchange and for shortening the time the main radio is unnecessarily on.

CCS CONCEPTS

• **Computer systems organization → Sensor networks**;

KEYWORDS

Wake-up radio, low-latency IoT applications

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1 RESEARCH AND TECHNICAL APPROACH

The complex internetworking of physical objects, vehicles, structures, and other "smart" items known as the *Internet of Things* (IoT) rely on the pervasive deployment of wireless devices embedded with electronics, software, sensors, actuators, and network connectivity. For a large variety of IoT applications these devices are characterized by small form factors and limited resources, especially energy, as they are often powered by small batteries that might not be rechargeable or easily replaceable. As a consequence, these applications face the challenge of keeping the whole system operational for suitable times, which may vary from months (temporary deployments) to decades (e.g., structural health monitoring). A typical solution to the problem of reducing the energy consumption of battery-powered wireless IoT devices is that of judiciously using their networking capabilities. The idea is that of using a node communication transducers only when needed, i.e., for transmitting and receiving information. The rest of the time, the transducer should be turned off (sleep mode), consuming orders of magnitude less energy than when on. This technique, called *Low Power Listening* (LPL), allows a node to turn on the radio according to a pre-set duty cycle [4]. Once on, the node samples the wireless channel for a carrier: If a transmission is in progress, the node keeps its radio on and receives a packet. Otherwise, it turns off the radio and goes back to sleep. In LPL, if a node wants to transmit a packet it has to be sure that the destination has turned its radio on. Therefore, the packet is preceded by a preamble whose transmission time has to be as long as the wake-up interval of the destination node. In this way, the destination node will listen to the channel during the preamble transmission. The power-saving benefits of LPL have been widely demonstrated by a large amount of theoretical and experimental investigations. However, since sender nodes have to wait for the receiver to turn on their radio, packets incur large Latency, easily in the tens of seconds, which are unacceptable for many critical applications [5]. Furthermore, the improvement in system lifetime provided by LPL is often inadequate to sustain these applications [1].

Recent research has pursued ways for obviating to these fundamental drawbacks, attempting at eliminating both extra sources of energy consumption (e.g., idle listening) and the long Latency imposed by LPL. One effective way to do so is by equipping nodes with *wake-up radios*, i.e., additional transducers designed to achieve power consumption comparable to that of sleep mode (a few μW) [3]. When a node wants to transmit data it uses its wake-up radio to request its neighbors to turn on their main radio. The packet is then transmitted and received using the main radio. With a wake-up radio nodes activate their main radios only when needed (i.e., when a packet has to be transmitted or received). This eliminates the need for duty-cycling and clearly eliminates the latency it induces.

The usage of wake-up radio technology has been shown beneficial for several IoT applications, where it has been primarily demonstrated via simulations [1, 3, 6]. The aim of our contribution here is to validate these initial simulation results by demonstrating the working functionality of a wake-up radio of our design and its benefits over solutions with nodes using LPL. The demo comprises four IoT nodes (called motes in the following). Each mote is a MagoNode++, namely, a 802.15.4-compliant device [2]. The MagoNode++ has a main radio operating in the ISM 2.4GHz band, and it is also equipped with an ultra-low power wake-up radio. Using a simple chat application among the two pairs of motes, we show that chat messages incur different Latency depending on whether they are transmitted between the pair with the wake-up or the one using LPL. Our demo also shows the activation times of the main radio of each mote, which confirms the added benefit of using wake-up radio for eliminating idle listening.

2 HARDWARE DESCRIPTION

The MagoNode++ is a platform for IoT wirelessly networked systems designed for low-energy consumption applications [2]. The mote is equipped with a wake-up module designed to use On-Off Keying (OOK) modulation at the operating frequency of 868MHz. The module comprises a wake-up transmitter (whose data rate is set to 1kbps) and an ultra-low power wake-up receiver, consuming 560nA of current at 3V. The receiver is characterized by high sensitivity (up to -55dBm) and selective addressing capability [6]. A picture of a MagoNode++ is shown in Figure 1.

Figure 1: A MagoNode++ mote.

To mitigate the potential effects of radio interference during the transmission of a wake-up message, the MagoNode++ can encode it with a Hamming code H(8,4), capable of correcting single-bit errors and detect double-bit errors.

3 DEMO SCENARIO

Our demo is a simple python-based chat application between the users of two laptops, Alice and Bob. When Alice wants to send a message to Bob, she types it on her laptop and the message is wirelessly sent through the MagoNode++.

In order to demonstrate the advantages of using a wake-up radio, each laptop is equipped with two motes: One with wake-up radio capabilities, and the other using LPL. On the MagoNode++ with the wake-up radio the main radio is turned on only after the transmission/reception of a wake-up message. Once the chat message is transmitted/received the main radio is turned off.

When Alice types a message, it is forwarded by the application to both motes. At this point, each mote handles the message according to its capabilities: The MagoNode++ with the wake-up transmits a wake-up message, turns on the main radio and transmits the chat message. The MagoNode++ using LPL starts sending the chat message preceded by a preamble. On Bob's side, when each mote receives the message it sends it to the laptop it is connected to and the chat application prints it on the screen.

Along with the received message, the application shows additional information such as the difference between the message arrival time at the two receiving motes and the time their radios have spent in active state. In this way Bob can evaluate the impact of a wake-up radio on latency and radio usage.

The demo scenario is schematically depicted in Figure 2.

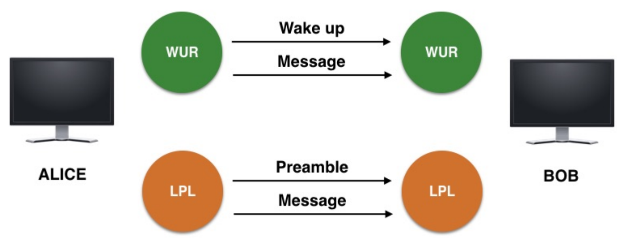

Figure 2: Demo scenario: Four nodes and two laptops.

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