OpenMote+: a Range-Agile Multi-Radio Mote

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Abstract

This article introduces OpenMote+, a prototyping platform designed for the Industrial Internet of Things (IIoT). The OpenMote+ offers a dual-radio interface for short- and long-range communications, supporting the most prominent physical and MAC (Medium Access Control) layer standards, such as IEEE 802.15.4e, IEEE 802.15.4g and 6TiSCH, and a contact-based interface based on NFC (Near Field Communications) to address the operational aspects of a network deployment, such as security key distribution and in-situ reprogramming. The OpenMote+ platform is complemented by support of the most popular open-source IIoT implementations today, such as OpenWSN, Contiki and RiOT.

1 Introduction

We are seeing an unprecedented increment of wireless technologies in the industry. For instance, smart factories are installing wireless sensing and actuating devices to improve their operation by gathering and combining information to extract new knowledge that enables to reduce costs. This trend is also being corroborated by the standardization efforts conducted at the IETF (Internet Engineering Task Force) to bring IP (Internet Protocol) to embedded devices. For example, the IETF 6TiSCH working group [2] is standardizing tomorrow's "Industrial Internet of Things" (IIoT) and promoting interoperability events between vendors to accelerate the development of such technologies. In this process, prototyping and experimentation platforms are becoming key enabling tools for adopters to evaluate, develop and integrate such emerging technologies.

Based on the experience gathered from the last ten years of developing prototyping platforms for WSN (Wireless Sensor Networks), this paper introduces the OpenMote+[1], a novel open-hardware board specifically designed for the IIoT. The OpenMote+ board is designed to efficiently implement IIoT standards, such as IEEE 802.15.4e, IEEE 802.15.4g and IETF 6TiSCH, thus enabling to target a wider set of application scenarios with short- and long-range communication requirements. In addition, the OpenMote+ provides a contact-based communication interface that is devoted to enable security key distribution and in-situ reprogramming. In terms of software, work is being done to ensure the the OpenMote+ board is supported by major open-source IIoT communities, such as OpenWSN [5], Contiki [3] and RIOT [1].

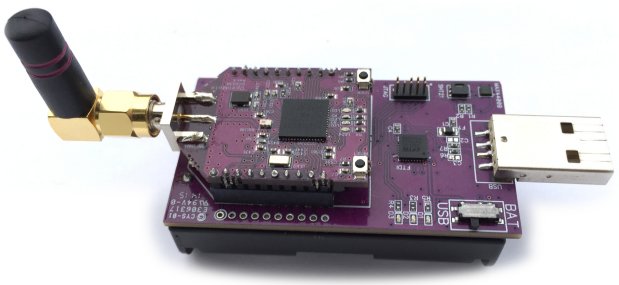

Figure 1. The OpenMote-CC2538 and OpenUSB boards.

The remainder of this paper is organized as follows. Section 2 presents the previous boards from which OpenMote+ is derived. Section 3 introduces the OpenMote+ hardware platform and its interfaces. Section 4 introduces the tools and software developed around OpenMote+. Finally, Section 5 concludes this position paper.

2 The OpenMote Ecosystem

The OpenMote+ is a natural evolution of the most widespread prototyping platform for the WSN, the TelosB, which was also originally developed at UC Berkeley. However, the driving idea of the OpenMote ecosystem is to separate the computation/communication module from the interface boards, resulting in a simple, modular and elegant solution.

Currently, the OpenMote ecosystem [4] is composed of four boards that simplify and favour quick network prototyping and cutting edge research on IIoT networks. As an example of its wide use, the OpenMote ecosystem has been adopted in the latest ETSI interoperability events to serve as a golden board and execute the reference implementation of

[1] http://www.openmote.com/

EWSN'16, February 15–17, 2016, Graz, Austria.

the IETF 6TiSCH standards under development.

The core of the ecosystem is the OpenMote-CC2538 board, which provides the computation and communication capabilities. The OpenMote-CC2538 board features the CC2538 System-on-Chip (SoC) from Texas Instruments, which integrates an ARM Cortex-M3 micro-controller and a IEEE 802.15.4 compliant radio interface operating at the 2.4 GHz band. Its standardized pin-out, based on the XBee form-factor, enables it to interface to the other elements of the OpenMote ecosystem using analog and digital interfaces (ADC, GPIO, I2C, SPI, UART), as well as other off-the-shelf elements, i.e., the Sparkfun XBee Explorer.

The OpenMote-CC2538 can be interfaced with three companion boards: OpenBattery, OpenBase and OpenUSB. First, with the OpenBattery, which includes four digital sensors (temperature and relative humidity, acceleration and light) and a 2xAA battery-holder to provide energy. Second, with the OpenBase, which acts as a docking board and features advanced programming and debugging interfaces, such as a JTAG, and connectivity, such as as USB and Ethernet. Last but not least, the OpenMote-CC2538 can be interfaced with the OpenUSB, which transforms an OpenMote-CC2538 board to a TelosB clone, thus enabling to easily create testbeds for experimental purposes.

3 The OpenMote+ Hardware

The OpenMote+ is a novel multi-radio platform designed for the most demanding IIoT prototyping scenarios. The core of the OpenMote+ board is an EZR32WG System-on-Chip (SoC) from Silicon Labs, which combines an ARM Cortex-M4 micro-controller with a Sub-GHz radio transceiver. The ARM Cortex-M4 micro-controller runs at 48 MHz (225 uA/MHz) and packs 32 kbytes of RAM and 256 kbytes of Flash memory. It also integrates a FPU (Floating Point Unit) that enables to complete arithmetic instructions, i.e., multiply and accumulate, in a single clock, giving unprecedented capabilities to process digital data from connected sensors. The micro-controller also provides true low-power peripherals (Timer, UART, Sensor and Counter) and integrates advanced security peripherals (AES 128/256). On its behalf, the EZRadioPRO radio transceiver operates at the Sub-GHz band (142 MHz - 1050 MHz) and supports amplitude (OOK, ASK) and frequency (2/4-FSK, 2/4-GFSK) modulations schemes with data rates from 100 bps to 1 Mbps. The maximum transmit power is 20 dBm and sensitivity values are as low as -133 dBm at 100 bps, giving ranges in the order of kilometres. The receive current consumption is 10 mA and the transmit current consumption is 18 mA at 10 dBm.

In addition to the Sub-GHz radio interface, the OpenMote+ board also includes two additional radio interfaces, one for short-range communications and the other for contact-based communications. Regarding the short range radio interface, it is implemented using the high-performance and low-energy Atmel AT86RF233 radio transceiver. The AT86RF233 operates at the 2.4 GHz band and supports the IEEE 802.15.4-2011 standard. The maximum transmit power is 4 dBm and the sensitivity is as low as -101 dBm, giving ranges of hundreds of meters. The receive current consumption is 11.8 mA and the transmit current consumption is 13.8 mA at 4 dBm. Regarding the contact-based interface, it is implemented using the NXP NT3H1201 integrated circuit. The NT3H1201 operates at the 13.56 MHz band with data rate of 106 kbps and supports the NFC standard (Type 2 Tag). The NFC integrated circuit provides 1094 bytes for user data, which enables interactions with phones to be used for security key distribution and in-situ reprogramming before, during and after deployment.

4 Supported stacks and software tools

The OpenMote+ is integrated in the OpenMote software ecosystem which includes a full port of the OpenWSN protocol stack [5], enabling TSCH on both 2.4 GHz and Sub-GHz radios. This is achieved by an Eclipse integrated development environment and all the debugging tools based on arm-gdb and hardware debugging through JTAG. In addition, the OpenWSN build system contains the necessary scripts to upload pre-compiled binaries onto the through a bootloader, when in-circuit debugging is not needed.

As the OpenMote team continues to believe in community-driven open-source hardware and software, in addition to the mentioned support for the OpenWSN project, there are plans for the OpenMote+ to be supported by Contiki and RiOT as well.

5 Conclusion

This article has introduced the OpenMote+, an open-hardware prototyping board designed to accelerate the development of the IIoT by implementing the most prominent physical and MAC layer standards, namely IEEE 802.15.4e, IEEE 802.15.4g and 6TiSCH. The OpenMote+ board integrates a powerful ARM Cortex-M4 processor with a versatile dual-radio interface for short- and long-range communications. In addition, the OpenMote+ board integrates a contact-based NFC interface to address the operational aspects of a network deployment, such as security key distribution or in-situ reprogramming. Finally, the OpenMote+ board is complemented by ports to popular open-source IIoT stack implementations, such as OpenWSN, Contiki and RiOT, positioning it as the most advanced IIoT prototyping platform currently available today.

6 References

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