NFC-WISP: An Open Source Software Defined Near Field RFID Sensing Platform

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Abstract
Near-field radio frequency identification (RFID) tags have a number of unique features such as being wirelessly powered, having ultra low power communication capabilities, small size and low cost. These qualities paired with the increasing availability of commodity near field communication (NFC) enabled smart phones presents a significant opportunity to enable a wide range of new applications and usage scenarios. However, existing NFC tags are mainly used for identification.

This demo presents the NFC-WISP, which is an programmable, sensing and computationally enhanced platform designed to explore new RFID enabled sensing and user interface applications. Two example applications using NFC-WISP are showed: one is a battery-free display tag; the other is a real-time temperature tracking and motion indicating tag for cold chain monitoring application.

Author Keywords
Battery-free display; NFC; Sensing; Open source hardware; Wireless power

ACM Classification Keywords
C.2.4 [Distributed Systems]: Distributed Applications

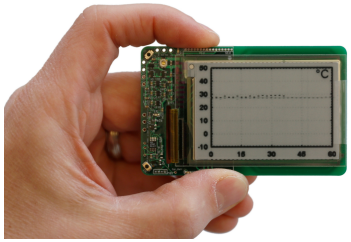

Figure 1: Overview of the NFC-WISP

Introduction

Near-field Radio Frequency Identification (RFID) technology has achieved wide spread adoption in traditional application spaces such as access control, inventory management, and secure payment [2]. With high quality, mobile NFC readers readily available, there is the opportunity to develop new tag hardware with enhanced capabilities to enable further innovation in these application spaces.

This demo presents the NFC-WISP, which is an programmable, sensing and computationally enhanced platform designed to explore new RFID enabled sensing and user interface applications. A primary note about using the initial version of NFC-WISP as a bi-stable display with an E-ink and battery is published in Ubicomp 2013 initially [5]. The latest generation of NFC-WISP updates its hardware and firmware design, therefore offer much more functionalities while consuming less power. The latest hardware and firmware design has already been published [7] and open-source recently [1]. After another optimization of the published system, we have achieved a brand new unpublished feature using NFC-WISP: a 2.0" E-ink display on a battery-free NFC-WISP can be wirelessly powered up and updated by using NFC-enabled smart phone.

The NFC-WISP in general is a software defined sensing and display platform, which is wirelessly powered and read by commercially available RFID readers (including NFC enabled smart phones) I. Excess harvested power can be stored in an optional super-capacitor or thin-film battery to enable operation away from the reader or power hungry sensing.

This open-source platform includes a programmable micro-controller, temperature and acceleration sensors, 2MB of FRAM, LEDs, bottoms and an optional 2.7" or 2.0" active matrix E-ink display. Expansion headers allow access to the micro-controller allowing for rapid prototyping of new applications. Besides, NFC-WISP has wireless charging capability when using rechargeable Li-ion battery. In our demonstration, a battery-free 2.0" E-ink display tag will be updated by a NFC-enabled cell-phone. In addition, a real-time temperature tracking and motion indicating tag with the assistance of wirelessly charged battery will be demonstrated, in which shows one example of using NFC-WISP for cold chain monitoring application.

Hardware Architecture

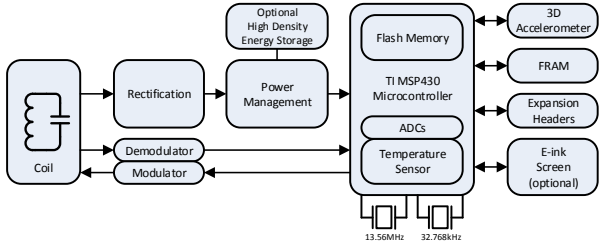

Figure 2: Block diagram of the NFC-WISP

The NFC-WISP is a credit card size PCB board with surface mount components on both sides (Figure 1). A block diagram of the NFC-WISP is shown in Figure 2. The coil antenna and tuning network feed the power harvesting block which rectifies the incoming RF energy into DC voltage to power the system. An optional high-density storage element in the form of a battery or super capacitor can be used for long-term storage of wireless power. The demodulator follows the envelope of the RF carrier wave to extract the amplitude shift-keyed 106kHz data stream from the NFC-RFID reader. This base-band waveform is read by the TI MSP430F5310 MCU and a 13.56MHz internal clock is used for data recovery. An additional low power and low

Figure 3: 2.0" battery-free NFC-WISP display tag

frequency 32.768kHz watch crystal is used to enable real-time clocking functionality with lower power cost. Up-link data is sent back to the reader from the tag via load modulation. On-board peripherals such as accelerometer and non-volatile FRAM are powered and managed by the MCU. Finally an option 2.7 inch or 2.0 inch E-ink screen can be used for user interface.

The NFC-WISP tag can work as two mode: passive mode and semi-passive mode. When NFC-WISP work in passive mode (by disconnect the thin-film battery), it will only be powered up and run some low-power tasks when the NFC reader is in its proximity. The tasks can be support by NFC-WISP tag depending on the power level continuously delivered by NFC reader. By connecting NFC-WISP with thin-film battery, the NFC-WISP is working in semi-passive mode, which the extra energy obtained from NFC reader during NFC communication can be charged in the battery and used for high power or long time tasks with absent of NFC reader.

Application of NFC-WISP

The NFC-WISP is a programmable NFC tag and has a optional ultra-low power display, large data storage, as well as computing and sensing capability. A user can either create customize applications using current hardware or add other peripherals through the extension headers to add new functionality to the base platform. In the demo section, two example application is demonstrated using the current NFC-WISP hardware. But the application of NFC-WISP is not limited by those two examples.

Battery-free Display Tag

The use of smaller 2.0 inch E-ink screen and further system optimization make the display tag can be powered and updated by a NFC enabled cell-phone. No large energy storage media, like battery or super capacitor rather than 300 μF capacitor is used to buffer enough energy to update the image in run time. Because, the cell-phone is continuously sending dummy data to power the tag even after the the image transmission, therefore the board can keep collecting more energy while E-ink is updating. The updating process of E-ink is also heavily duty-cycled to avoid system brown out.

Cold Chain Data Logging

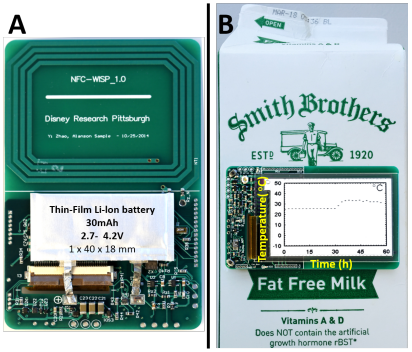

Figure 4: Image of a NFC-WISP configured with the E-ink display and rechargeable thin-film battery for monitoring and displaying the temperature of milk, in an example cold supply chain monitoring scenario.

Another application using the NFC-WISP as a data logger and display for a cold chain monitoring application is shown below. Since the tag needs to operate away from the RFID reader a high density storage device (in the form of a $30mAh$ thin-film battery) is included as shown in Figure 4 panel A. Panel B shows the NFC-WISP mounted to a milk container with the optional E-ink screen included.

It should be noted that the E-ink screen does not have any noticeable effect on the performance of the coil antenna.

NFC reader or NFC enabled cell-phone can charge the battery in advance to start the system. Once the tag is powered up, it will continuously sample temperature and 3D acceleration from on-board sensors every 3 seconds. Besides, the sampled temperature and motion states (in static or in motion) will be real-time plotted in the 2.7 inch E-ink screen without reader. Once the container and tag is returned to the RFID reader, the recorded data can be downloaded via NFC interface to a host computer or cell-phone for post processing. Additionally, the latest 30 temperature samples are displayed on the E-ink screen. The temperature and 3D acceleration sample intervals can be modified in software, here it is configured for 3 seconds for demonstration purposes.

The NFC-WISP allows personnel to both download the food temperature history using a NFC enabled smart phone, as well as visually check the E-ink screen. This is important in cold chain monitoring applications where a person can immediately see the temperature history of a product and can take immediate steps to prevent further food born contamination down the line, rather then waiting for post processing needed for typical data loggers.

Conclusion

This demo will describe the design and performance of the NFC-WISP which is a reconfigurable open-sourced platform designed to explore enhanced near-field RFID tags and applications. To the the best of the authors knowledge the NFC-WISP is the first battery-free bi-stable display tag which can be completely powered and updated by NFC enabled phone. Additionally, a real time data logger & display is demoed using NFC-WISP.[1]

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