The Moo and Cement Shoes: Future Directions of A Practical Sense-Control-Actuate Application

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1 Context

Passively-powered computational RFIDs (CRFID) have dispelled the assumption that only simple computations are possible under harvested RF power. This class of RFIDs feature reprogrammable microcontrollers, electronic sensors and actuators, and nonvolatile memory. Most importantly, the sensors and actuators provide the foundation for a not-too-distant paradigm shift toward the integration of cyber-physical worlds. This integration has been defined as a network called *TerraSwarm* [2].

2 Problem

A classical approach in civil engineering is to address the structural integrity of an infrastructure retroactively. This process often requires human intervention, introducing non-negligible error, and is restricted to a limited set of data points subject to interpolation. In an attempt to gauge the gap between research and industry, we immersed devices built on our research platform in a real-world application. Our observed results were not what we had initially expected, motivating the need for a more robust platform in futurely deployed devices.

3 Application

In a real world application, we embedded 19 epoxied CRFIDs, Moo Platform 1.1 [4], inside the concrete walls of a residential basement. Each Moo was placed inside a concrete-filled cinderblock at parallel diagonals, along three distinct heights. We immediately began sampling from the Moo's external temperature and accelerometer sensors. The temperature sensor was used to capture the concrete curing process, while the three-dimensional accelerometer measured the structural alignment.

Our experience in the real-world deployment was very different than what we anticipated inside the lab environment. The tag rate, packets received per second, was noticeably worse than within the confines of our controlled lab environment, making it difficult to communicate with the implanted devices. A 25 percent verifiable working device yield can be attributed to two factors: the attenuation of the UHF signals through the solid concrete mass and the limitations of backscattering [3] through concrete. Additionally, we found that communication with the Moo was significantly worse in the presence of moisture and steadily improved as the concreted dried. Redesigning the Moo to operate more efficiently on a reduced power budget, as is the case in concrete, may improve it's performance in harsh environments.

4 Lesssons Learned and Future Steps

Deploying embedded devices in real-world applications is challenging because of unforeseen variables and harsh operating conditions that may exceed the limitations of the current platform. The introduction of new variables such as ambient noise and lossy mediums strain their utility in useful applications. By targeting the most power-hungry component on the current platform, the MCU, we can overcome the aforementioned challenges.

Our new design for the CRFID platform, Moo 2.0, will achieve greater performance in real-world applications due to a more energy-efficient platform provided by Texas Instrument's MSP430 Wolverine[1] MCU. As can be seen from Table 1, the Wolverine MCU significantly improves both the active mode current consumption as well as the clock speed. This new MCU departs from its predecessor by using integrated Ferroelectric RAM (FRAM) in favor of the more inefficient flash memory. Additionally, the nearly unlimited endurance of FRAM means that it can be accessed more frequently without worrying about degrading the memory over time — a legitimate concern for RFID devices that may be storing data in memory for decades on end. Furthermore, the Wolverine's AES256 accelerator module is able to support advanced encryption or decryption in hardware.

	Moo Platform	
Features	1.1	2.0
Microcontroller	F2618	FR5969
Active Mode @1 MHz	365 uA	100 uA
Max Clock Speed at 1.8v	4MHz	16MHz
Crypto Co-processor	No	Yes

Table 1: Moo Platform Comparison

References

[1] Texas Instruments. MSP430FR59xx Mixed Signal Microcontroller Datasheet, October 2012.

[2] Edward A. Lee et al. The TerraSwarm Research Center. Technical Report UCB/EECS-2012-207, EECS Department, University of California, Berkeley, Nov 2012.

[3] K. V S Rao. An overview of backscattered radio frequency identification system (rfid). In *Microwave Conference, 1999 Asia Pacific*, 1999.

[4] Hong Zhang et al. Moo: A batteryless computational RFID and sensing platform. Technical Report UM-CS-2011-020, Department of Computer Science, University of Massachusetts Amherst, Jun 2011.

[1] Fun Fact: The MCU was named Wolverine for its aggressive stance on power improvement.