Low-Cost and Perpetual Sensing Systems Enabled by Ambient RF Energy Harvesting

Yoshihiro Kawahara

The University of Tokyo

kawahara@akg.t.u-tokyo.ac.jp

INTRODUCTION

Sensors are ubiquitous in our daily lives although they are usually invisible. Sooner or later seven billion people on the globe will take advantage of 150 sensors, which means trillions of sensors will assist the life of human being. Power supply is one of the most critical issues for the perpetual operation of such electrical devices. Although performance of batteries is significantly improved, the cost to replace batteries is still high. Due to reduced power consumption of electrical devices, quite a few battery-operated devices only consumes a few dozen microwatts. As energy efficiency continues to improve, the energy requirements to power electronic devices will continue to drop; this in turn means it is feasible to power more devices by a small amount of energy of about a few dozen microwatts. In this paper, we discuss the feasibility of harvesting a few hundred microwatts of energy out of ambient radio signals and electromagnetic noise as an alternative energy source to autonomous wireless sensing systems. The applications benefited from this concept includes but not limited to agricultural monitoring, structural monitoring for building and bridges, and environmental monitoring.

AMBIENT RF ENERGY HARVESTING

Harvesting small amount of energy is not a new idea. For instance, in passive radio frequency identification (RFID) systems, radio wave radiated from an interrogator is rectified and used to activate a transponder (RFID card). The radio wave received by antenna is fed to a rectifier and the energy is then converted to DC current which can be used as an alternative energy of batteries. In the case of RFID, however, the chip only requires 5 μW and there are fewer challenges in terms of power harvesting. For the electronics devices such as sensor networks, however, energy of as low as 100 μW is required for the device to autonomously capture the information in the real world. Radio waves are used everywhere in our daily lives. Wireless broadcasting and communication systems such as TV, radio, mobile phones, and WiFi are typical examples. We have demonstrated that it is possible to harvest power from TV broadcasting tower at 6.5km away[1]. We also showed electromagnetic leakage from a microwave oven is also sufficient to power electrical devices[2].

SENSPROUT

Water is essential for the growth of plants. However water is important for industry and city water. Thus, water saving or irrigation has been one of the most important challenges for modern agriculture. We present a low-cost, inkjet-printed sensor that makes it possible to densely monitor soil moisture and detect rainfall or frost over a wireless link. Different from existing sensors, electrodes and antennas are printed on paper

substrate that degrades in the soil due to bacteria after the growing season. This is important for keeping the manufacturing cost low and eliminating the need to collect the densely deployed sensors over vast fields.

Figure 1 illustrates the concept of SenSprout As previously mentioned, sensor electrodes and an antenna are printed using an inkjet printer[3]. Different from typical printed circuit board fabrication processes using etching, the necessary amount of silver nano-particle ink is directly printed onto the paper surface.

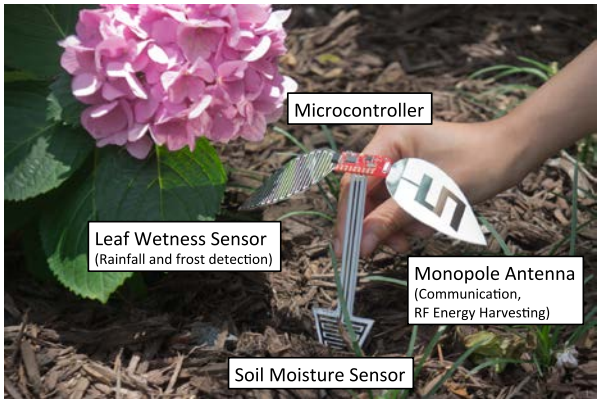

Figure 1. Prototype of the inkjet-printed sensor SenSprout.

Soil moisture can be detected by monitoring the change of capacitance of the electrodes embedded in the soil. Because capacitance increases proportionally to the permittivity, the amount of water in the soil can be determined. Wireless power transmitters are installed on the beam of the irrigation machine and the radio wave radiated along with the water are used to charge a capacitor on the sensor node. The system is currently prepared for demonstration at a corn field in Tifton, Georgia, U.S.A.

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