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IOT: ENHANCING THE APPLICABILITY TO ANTICIPATE THE CONTROL METRICS IN AN AMBIENCE

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ABSTRACT

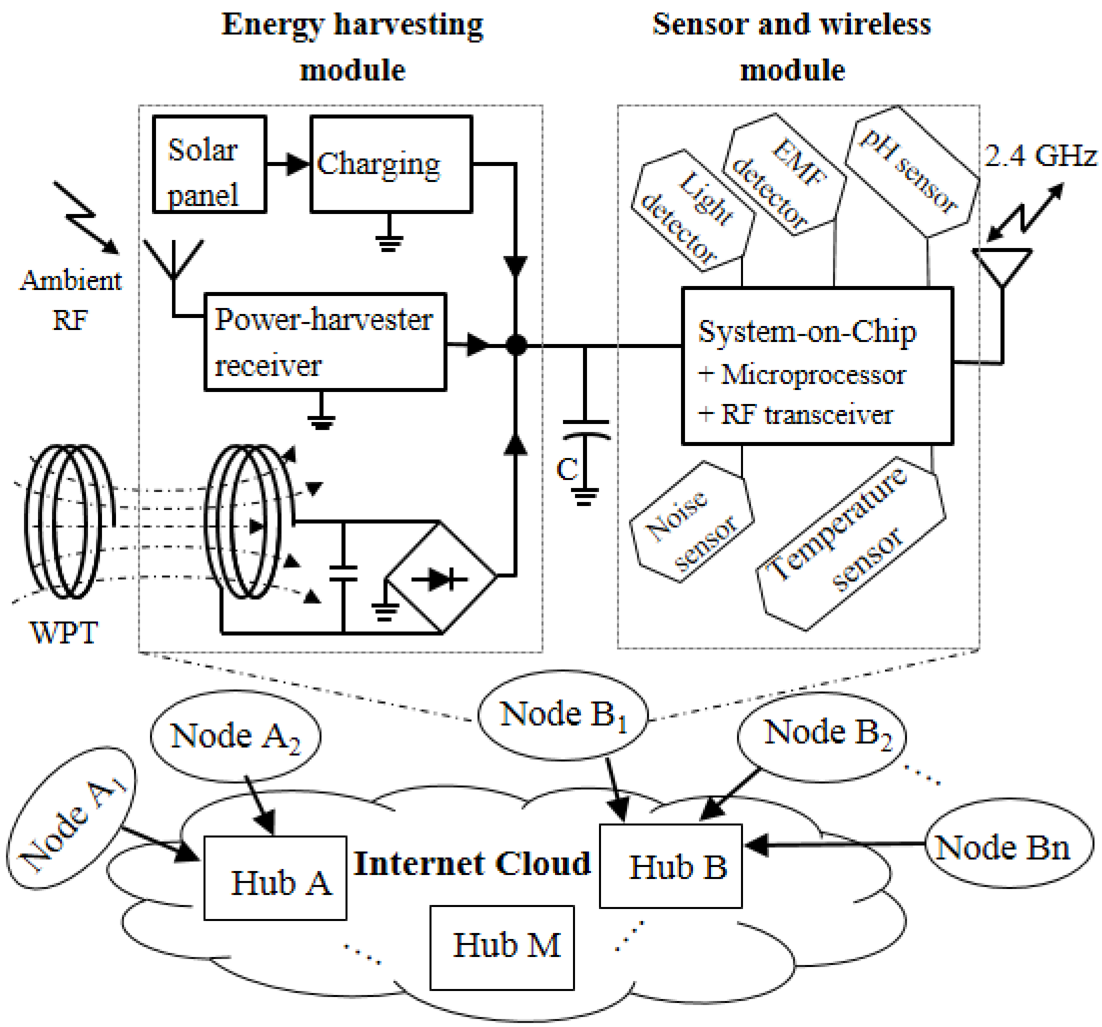
Remote systems administration sensor hubs for condition observing in Internet of Things (IOT) are accounted for in this work. The IOT organize incorporates singular self-supporting hubs remotely transmitting sensor signs to centers that can be partaken in the Internet Cloud. Every hub comprises of an upgraded vitality collecting module, a System-on-Chip (SoC) incorporated low-control Bluetooth Smart handset, and multi-utilitarian sensor exhibit to screen ecological parameters. The vitality gathering module can adjust and gather vitality from sun oriented power, surrounding radio waves, and direct remote power transmission (WPT). The sensor exhibits incorporate pH sensor, temperature sensor, photograph identifier, electromagnetic wave indicator and acoustic commotion finder. The SoC forms information and transmits compacted data about ecological conditions to the center. This stage exhibited the ideas of joining power collecting methods and low-control sensors for the IoT applications.

Terms *— Acid rain; electromagnetic pollution; Internet of Things; light pollution; noise pollution; power harvesting; remote monitoring*

INTRODUCTION

Climate changes and environmental conditions have direct impacts on human health, quality of life and societal productivity. For example, high acidity rainwater causes damage to the ecosystem such as death of plants and forests, contamination of river water and soils, and decay of buildings and bridges. The World Bank estimates that $11−32 billion in human health is related to air pollution and acid rain in China [1]. The distribution of acid rain is particularly of interest to residents near factories or power plants, as quantitative evidence is needed for zoning reasons. Noise pollution is another major environmental concern. According to the latest European Environment Agency data, over 103 million people suffer from road-traffic noises in Europe. High noise levels could lead to sleep disturbance, cognitive impairment in children, and even cardiovascular disease [2].

These days, individuals are encompassed by versatile remote specialized gadgets, for example, advanced cells, savvy watches, and tablets. Electromagnetic fields (EMF) emanated from these gadgets, high-control transmitters in base stations, and radio communicate stations have raised worries about potential effects to human and creature wellbeing, and impedances to basic electronic gear.



Other natural issues, for example, light and warmth contamination are additionally basic. It has turned out to be critical to acquire data about their impacts on our living conditions. All previously mentioned elements have critical financial and social impact, not to mention the effects they have on sustainability of our world. In order to analyze them using statistical methods, it is important to obtain accurate data with sufficient spatial resolution temporal resolution and coverage. The sensor devices should be deployable in many environments and self-powered without manual battery replacement. Therefore, multi-modality energy harvesting is needed. Wireless communication is required to relay sensor data from the remote node to a hub or base station linked to the Internet. As

3G, 4G and Wi-Fi communication systems have been widely deployed in our society and their connections to the Internet are well established through private and public networks such as the Cloud computing, the wireless network can be an effective yet complex system to obtain, store and analyze sensor data. Such an "Internet of Things" device could therefore be an instrumental contribution to the "big data" of environmental parameters for optimization and improvement of our world.

Sensors	Model	Size	Sensitivity	Dynamic Range
pH sensor	In [7]	1×1 mm^2	−51 mV/pH	pH = 2 − 10
Noise detector	2735P-R (*PUI Audio*)	2.7×6 mm^2	−35 dB	—
Temperature sensor	MPC9700 (*Microchip*)	2.6×2.1 mm^2	20 mV/°C	−40 to +125 °C
Light detector	TEMT6000 (*Vishay*)	2×4 mm^2	1.8 log(mV)/ log(lx)	10 lx to 1000 lx
EMF detector	LT5504 (*Linear Tech.*)	3×3 mm^2	23 mV/dB	−70 to 0 dBm

In this work, cost-effective and self-powered networking devices for an Internet-accessible wireless environment monitoring system have been developed. The devices can harvest energy from various sources including solar and ambient RF radiation, and wireless power transmission (WPT). Multiple sensors consisting of, but not limited to, miniature pH sensor, thermometer, microphone, photo-detector and EMF receiver to detect environment pollutants were integrated. Information from these sensors was processed and transmitted wirelessly to a base station using the low-power Bluetooth Smart protocol. Nodes forming an active network were accessed via Internet with a Cloud configuration in which data were stored with time and location information for real-time and off-line analysis.

SYSTEMS ARCHITECTURE

A. System overview

The system architecture of each node in the Cloud network is described in Fig. 1. Each node included two parts: power harvesting module and sensor/processor module. In this application, three main methods to harvest energy were integrated. A solar panel (5×20 cm2) mounted on the external case of the node was suitable for outdoor setup where sunlight was available during the day. If the sensor node is located inside a building, a similar technique has been demonstrated to wirelessly power interior devices with solar panels and a wireless power transmitter mounted on the exterior wall without wire connection [3]. A power harvester receiver was connected to a 17-cm long dipole antenna to harvest ambient RF energy at the frequency range of 915−1550 MHz in free space from nearby RF transceivers or cellphone towers. In addition, a wireless power transmission (WPT) mechanism utilizing inductive coupling was used for transferring energy over short distances [4]. The design was practical for mounting the sensor nodes outside a building, and the wireless energy could be transferred through walls to power the node without deploying wires. Flying drones or robots can also be used to deliver energy to remote nodes with wireless charging. In our system, a supercapacitor (C in Fig. 1) for energy storage was chosen due to its advantages of high power

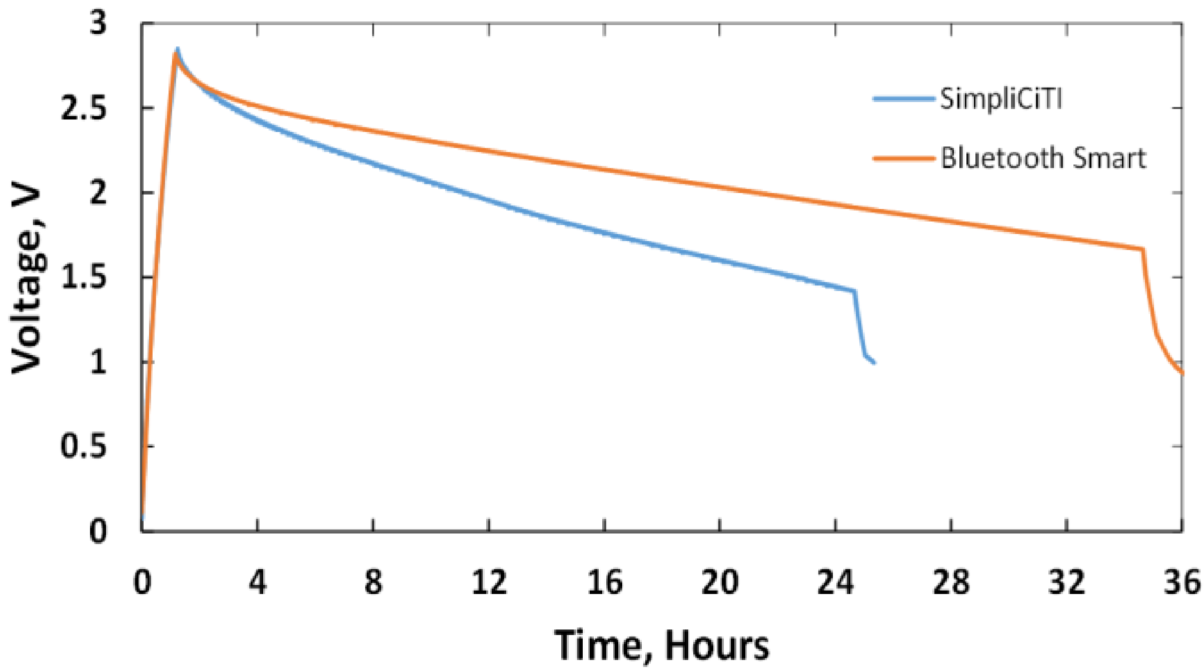


Fig. 2. The 4-F supercapacitor was charged using WPT density, high charging rate, high number of charge/discharge cycles.

TABLE II.
SUMMARY OF SIGNAL RECEPTION

Distance (m)	Power reception (dBm)		
	Monopole PCB antenna	Helical antenna (1.6 dBi)	SMD chip antenna (1.3 dBi)
1	−77	−56	−70
10	−94	−72	−91
43	Disconnect	−89	−98
55	Disconnect	−98	Disconnect

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System-on-Chip (SoC) nRF51822 (Nordic Semi.), which included an ARM M0 Cortex processor and supported the low-power Bluetooth Smart protocol was chosen. The power consumption was reduced by modifying transmitting power, switching to a low-power mode, and decreasing advertising time. The chip collected data from the sensor array of a pH sensor, a microphone, a photo-detector, an EMF sensor and a thermistor. More sensors might be added based on applications or requirements. The information from the sensors was processed, according to data format requirements, and transmitted wirelessly to a transceiver hub (Hub A or B in Fig. 1) which updated the Cloud data over the Internet. Each hub was able to communicate with eight nodes simultaneously. Repeater nodes could be implemented to extend the wireless transmission range in order to expand the coverage of remote wireless nodes.

B. Self-power management

Solar energy was harvested from a solar panel through an ultra-low power charger BQ25504 (TI) featured with a built-in maximum power point tracking (MPPT) algorithm. The MPPT algorithm optimized charging process by continuously sensing the open-circuit voltage from the solar panel, calculating an optimized charging voltage and using a high efficiency DC/DC boost converter to generate the necessary charging voltage. Therefore, the power charger was able to detect changes in solar irradiance, temperature, and voltage levels to match the load impedance.

Ambient RF energy harvesting was implemented with a P2110 (PowerCast) harvester utilizing an RF-to-DC converter. The device could receive input power as low as −10 dBm with an efficiency of 30%. The maximum efficiency of the harvester could reach 55% when the input power is 5 dBm [5,6].

WPT method was implemented to wirelessly charge the supercapacitor using two inductive coupling coils to transmit energy through walls with thickness less than 30 cm. The receiver and transmitter coils had a radius of 10 cm. The transmitter class-E amplifier transferred 320 mW tuned to the resonant frequency at 1.3 MHz.

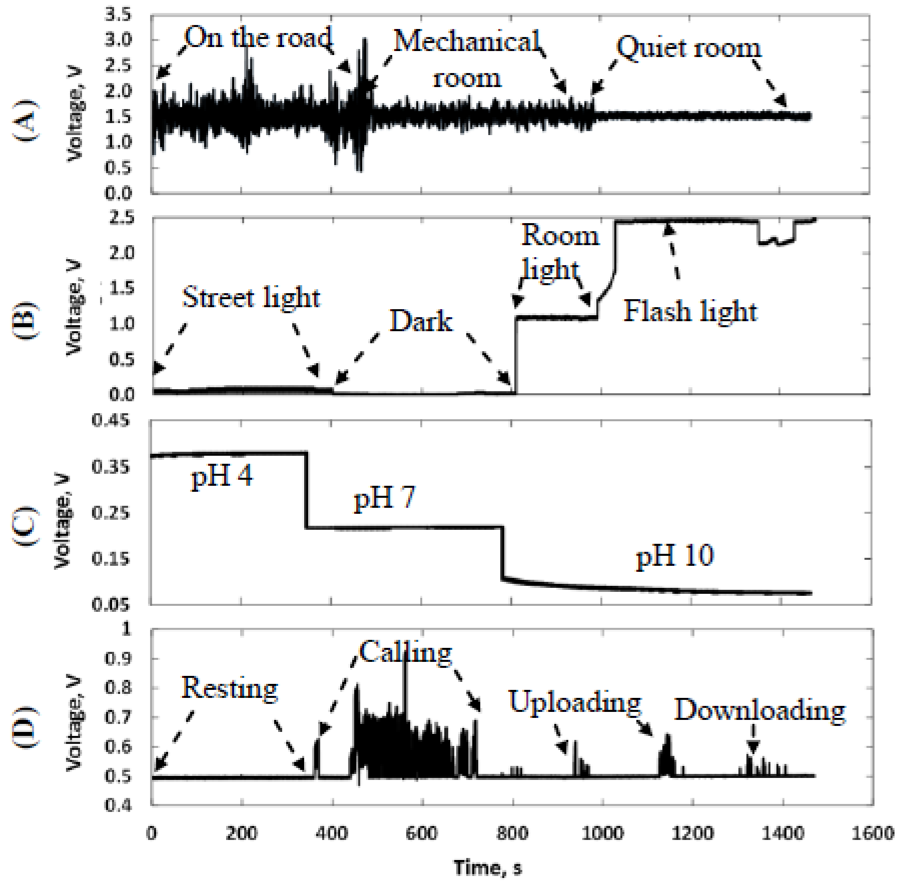

Fig. 3. Responses of the multi-functional environmental sensor node including (A) noises, (B) light, (C) pH level of solution dripped on the electrode, and (D) ambient electromagnetic fields.

C. Sensors

Each node consisted of five sensors with characteristics described in Table I. More sensors can be added based on individual requirement. Each node can support up to 31 sensors.

EXPERIMENTS AND RESULTS

Charging curves were examined with different power harvesting methods. The energy harvested was stored in the 4-F supercapacitor. Experiments were conducted using only one method at a time while the other two were switched off. With the solar panel, results showed a charging time of around 2 minutes at noon and 5 minutes in the afternoon in North Texas in the winter when the module was attached on the roof. In the

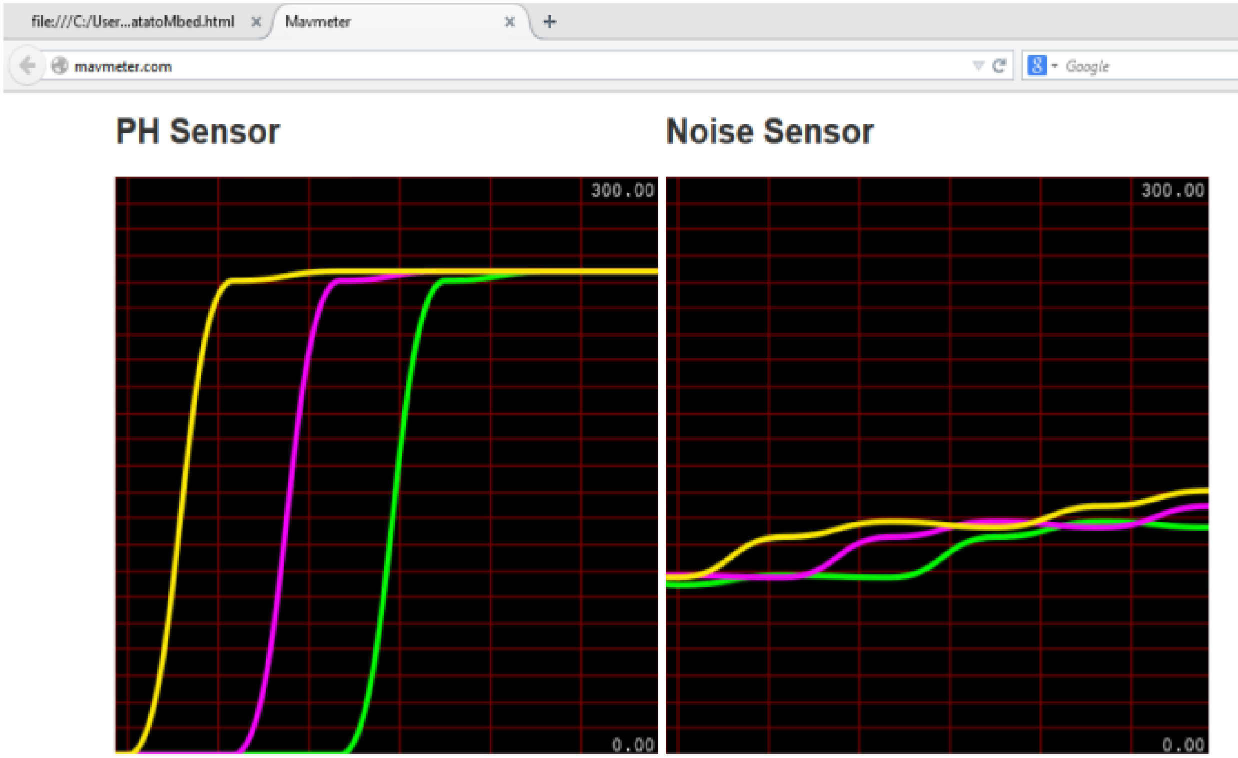

Fig. 4. Webcast interface for on-line monitoring of environmental parameters using the wireless sensor networkcase of WPT, it took less than 2 minutes when the wireless power was transmitting through a 10-cm dry wall (Fig. 2). Empirical experiments to charge the supercapacitor using ambient RF energy were done with an iPhone 4 (Apple) placed 2 cm away from the receiver antenna. The voltage of the supercapacitor increased with an average rate of 0.175 mV/s and 10 µV/s during calling and resting, respectively.

The energy from the supercapacitor sustained the operation of the SoC. Power saving mode was enabled by programming the SoC to sleep and wake up for measurements every 20 ms. Power consumptions of the SoC in the off- and on-modes were 0.4 and 2.3 µA, respectively. The low-power Bluetooth Smart protocol was compared with the SimpliCiTI protocol utilizing a MSP430 microprocessor (TI) with the same sampling and transmitting rates. Fig. 2 shows that Bluetooth Smart protocol drained less current than SimpliCiTI. Signal reception recorded at the hub using the Bluetooth Smart protocol was tested indoor with different transmission antenna configurations. Transmit-ting power of each node was 0 dBm with an on-air data rate of 1 Mb/s. Average power reception is shown in Table II. The hub lost communication when the power reception was below −100 dBm. A helical antenna with a peak gain of 1.6 dBi was used to maintain connection up to a distance of 55 m with the worst-case scenario of cross-polarization. The transmission range can be extended by using repeater nodes to create a bridge connection to the hub.

The node performance is shown in Fig. 3 with designed scenarios. Each sensor was tested in different conditions individually. The raw data of the audio detector show that the ambient noise level close to the road was stronger than those in a mechanical room or a quiet room (Fig. 3(A)). After transmitting the raw data, the processor was re-programmed to calculate the root-square-mean noise power magnitude levels within 625 ms, which indicated the envelope shapes of noise magnitudes. The photodetector detected four different light intensities as shown in Fig. 3(B). In case of the pH sensor, three buffer solutions pH= 4, 7, and 10 were dripped on the electrode and fast responses were observed (Fig. 3(C)). The EMF sensor detected electromagnetic field strengths radiating from a smart phone placed 20 cm away, shown in Fig. 3(D). When the phone was in the idle mode, output voltages of the sensor indicated that the radiated field magnitudes was around −70 dBm. While the phone was in the calling mode, the field magnitudes reached −50 dBm on average. The power levels of the radiated field varied abruptly from −65 dBm to −60 dBm while the phone was in the uploading or downloading modes.

A screen capture of the Webcast interface is illustrated in Fig. 4 showing on-line data streams. The three colors in each graph indicate information from different nodes. For example, drops of acidic solution was dripped on each node with an intervals of 6 s. The experiment was carried out with Node #1, Node #2 and Node #3, successively. The response curves indicate the measurement data recorded in each node, with the accurate time spacing. Node #1 was moved toward a speaker that is driven with white sound noises until 5 cm away. Node #2 repeated the same motion before the node #3 was moved. The recording on the right panel of Fig. 4 shows the noise levels increased in the correct time sequence for each node. The recorded data were also indexed and stored for off-line analysis.

CONCLUSION

Multi-functional environmental sensors for an autonomous wireless monitoring node that can be used in a cloud-computing network were integrated. Node power can be harvested through three means. Sensor data can be transmitted wirelessly to a hub connected to the Internet. Networking data streams were demonstrated. This concept for Internet of Things provides a massively-deployable method to monitor environment in order to gain statistically significant data over a wide area at any time.

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