Full-Wireless Field Monitoring Server for Advanced Sensor-network

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Abstract

Field Server (FS) is a rugged server which can be installed in fields. Field Monitoring Server (FMS) is a kind of FS for monitoring. So far, solar cell embedded on the top of FMSs have been used only as a light intensity sensors. The power source for FMS is supplied by a cable, since the solar cell's power alone is not sufficient to run conventional FMSs. To construct a massively distributed monitoring system by using wireless sensor network in fields - especially in paddy fields, a power supply cable is obstructive. We developed power-saving technologies so that the solar cell can drive the FMS. New network architecture was developed which combined access-point (*hotspot*), ad-hoc network among access-points (*repeating mode*) and *client connection* to access-point. Conventional wired FMSs function as a backbone by using an ad-hoc network, where power is usually supplied by cable or larger solar cell. Simultaneously, the conventional FMSs provide a *hotspot*, where residents, gussets and full-wireless FMSs also can connect to the Internet by *client connection*. Energy consumption of full-wireless FMSs is half that of conventional FMSs. Yet energy consumption must be reduced up to 1/200-1/1000 for embedded solar cell to drive the FMS. Sleep mode also is introduced, and FMS is switched off immediately after the Fieldserver-agent collects data.

Keywords: Sensor-network, Wireless LAN, Field Server

Introduction

For wireless sensor networks, data acquisition devices such as Mote (Khan, 1999) or TINI (http://www.ibutton.com/TINI/), have been employed. However, casing and combination with sensors are important and, in fact, difficult in the field. Generally conventional sensor network devices support only a few sensors and slow speed communication. They are insufficient for agricultural applications such as model-base systems (Hirafuji, Tanaka, Kiura and Otsuka, 2000) and do not meet the needs of farmers. Some applications require much faster communication speed, and other applications require data such as air temperature, humidity, PPFD (Photosynthesis Photon Flux Density), UV, CO_2 concentration, soil-moisture, EC, leaf-wetness, wind speed/direction and GPS. Farmers and researchers require high resolution images to monitor plant growth, insect pests, biodiversity of ecosystems, farm accidents and so on. Such requirements are similar to those applications for the NASA space program (Delin and Jackson, 2000). Moreover, sensor-network for agriculture should function as an ubiquitous computing infrastructure in a wide area over rural zones performing ad-hoc network and hotspot (Hirafuji, 2000). Therefore, we have developed a multifunctional outdoor server, Field Server (FS), which is compact, rugged and economical (Hirafuji and Fukatsu, 2002). In particular, FS must be water-proof, dust-proof and heat-resistant. Field Monitoring Server

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(FMS) is FS for monitoring combined with a Web-server board, sensors, a wireless-LAN board and a special housing (Fukatsu and Hirafuji, 2003). FS can be a node of a sensor network installed at fields (Figure 1, 2). However, so far, power for FMS is supplied by cable, although solar cell is embedded on the top of the case; it has been used as a light intensity sensor, since the power of the solar cell is not sufficient to drive conventional FMSs. To construct massively distributed monitoring system, that is a sensor-network using FMS, we developed power saving technology to drive FMS only by the embedded solar cell.

Power Saving Mechanisms

Power of the solar cell depends on various factors such as season, weather condition, surroundings, latitude and orientation of solar cell. The typical method to estimate total power of a solar cell is computer simulation using weather data. However computational results also must be verified by experiments. Skipping such simulation to accelerate development, we developed a prototype using a FMS on which solar cells were mounted and number of solar cells was gradually increased (Table 1). As a result, we roughly estimated that 60W solar cells and 600Wh battery were needed to drive the FMS, which consumes about 5W. Power consumption of FMS must be reduced below 1/200(25mW) at least and 1/1000 (5mW) for safety, if only the embedded solar cell (110 x 110mm) was used to drive FMS continuously. We introduced three ways to accomplish such power-saving:

1. *Client connection*
   Power consumption of Ethernet media converter such as Buffalo's WLI-T1-S11G (3W) or Planex's GW-EN11X (2W) is half that of the access point board.
2. *Sleep mode*
   Sleep mode reduces the power consumption. FMS runs periodically by timer circuit (Figure 3). Timing is determined by time constant CR as shown in Table 2.
3. *Remote termination*
   FMS is switched off immediately after Fieldserver-agent (Fukatsu and Hirafuji, 2004) collects data from the FMS.

By combining these techniques, the power of the FMS is dramatically reduced.

Network Architecture

Field servers should provide *ad-hoc network* as infrastructure, *hotspot* (wireless Internet connection service for guests and residents) and *sensor network* for farming and scientific researches simultaneously. Such advanced wireless sensor-networks can be realized as shown in Figure 5 by combining conventional field servers (Figure 1, 2) and a full-wireless FMS (Figure 4). That is, conventional field servers produce an *ad-hoc network* and *hotspot*, where power for conventional field servers must be supplied by cable or large enough solar cells as shown in Table 1. A full-wireless FMS was installed in a *hotspot* created by conventional field servers.

Results and Discussions

A full-wireless FMS with battery (6V, 27Wh) could run for three months as shown in Figure 5 and 6. Battery voltage was stable. This means total power consumption by the FMS is smaller than the total power generated by the embedded solar cell. The full-wireless FMS can be installed easily, not only in upland fields (Figure 4a) also even in paddy fields (Figure 4b).

However, we found a few problems. The first one was related to dew condensation in the FMS when the inside temperature of the FMS was lower than outside air temperature. We solved this problem by wrapping the board in the housing with plastic film. Another problem was the bird dropping. We cleaned the rooftop panel of FMS every season.

The total cost of the full-wireless FMS (without fabrication charge) is about 400 USD, which is cheaper than conventional FMS. It helps us to create local sensor network and global monitoring systems.

References

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Tables

Photos					
Experiment date	2001, Jun.	2001, July	2001, Aug.	2002, Mar.	2002, Jun. – 2003, Nov.
Solar cell [W]	18	27	45	53	63
Battery [Wh]	144	144	144	288	576
Termination [day]	1	2	2 (rainy)	3-7(rainy)	>365

Table 1. Experimental trials to estimate of approximate relationship among power of solar cells, battery capacity, energy consumption and meteorological environment at Tsukuba, Japan. Energy consumption was 4-5W.

			C (C1, C2)		
			1000pF	0.01uF	0.1uF
R (R1+R2, R3+R4)	Max.	51k + 0 = 51k	40 sec	6 min	1 hour
	Min.	51k + 500k = 551k	400 sec	1 hour	10 hour

Table 2. Time of the timer with combination of C and R

Figures

(a)FMS at upland farm in Tsukuba, Japan

(b) FMS at UCC coffee Farm in Kona, Hawaii USA

Figure 1. Standard type of FMS, which require DC12V power supply to maintain backbone connection and hotspot with Wi-Fi(IEEE802.11b/g).

(a) Access point garden-lighting FMS

(b) Client-connection garden-lighting FMS at a garden

Figure2. Garden-lighting FMS. To produce backbone and hotspot in fields, sometime FS must be installed at gardens around private houses or buildings. Garden-lifting type FMS (a) can fit to such locations. Client-connection garden-lighting FMS (b) can be easily installed at a hotspot and function as a garden light controlled remotely by Fieldserver-Agent.

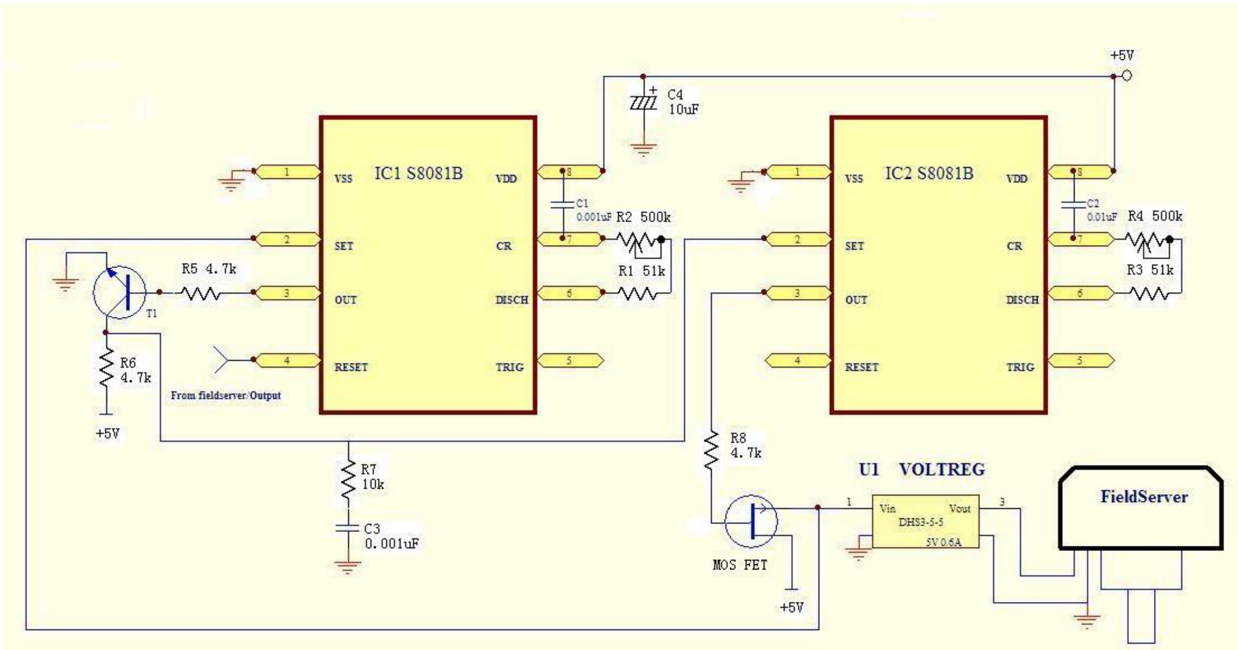

Figure 3. Circuit of timer control for intermittently operation of Field servers. +5V is supplied from batteries directly. U1 VOLTREG is a DC-DC converter, which regulates voltage of batteries from 4V-6V into 5V. Most MOS FET and NPN transistor can be available. Analog timer IC (S8081B) is employed in this circuit, but actually digital timer such as real-time clock LSI is also available.

(a)At upland farm of NARC *(b) At paddy field of NARC*

Figure 4. Full-wireless Field Monitoring Servers. Solar cells embedded on the rooftop of FMS charge a battery and drive field servers periodically.

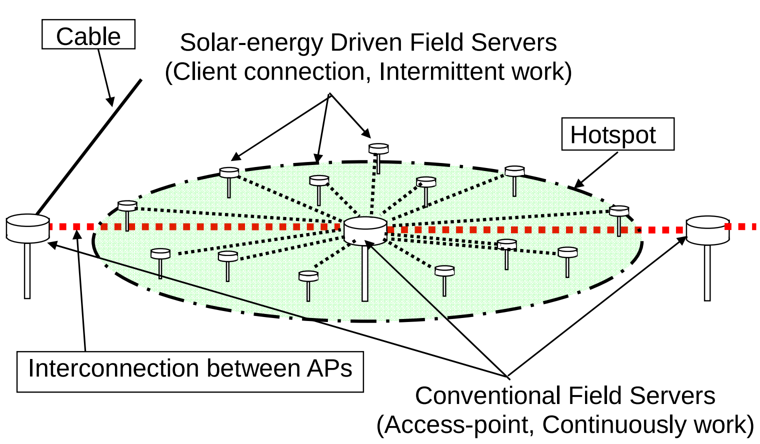

Figure 5. Network architecture with tow types of FMS: conventional FMS works continually and full-wireless FMS works intermittently to save power.

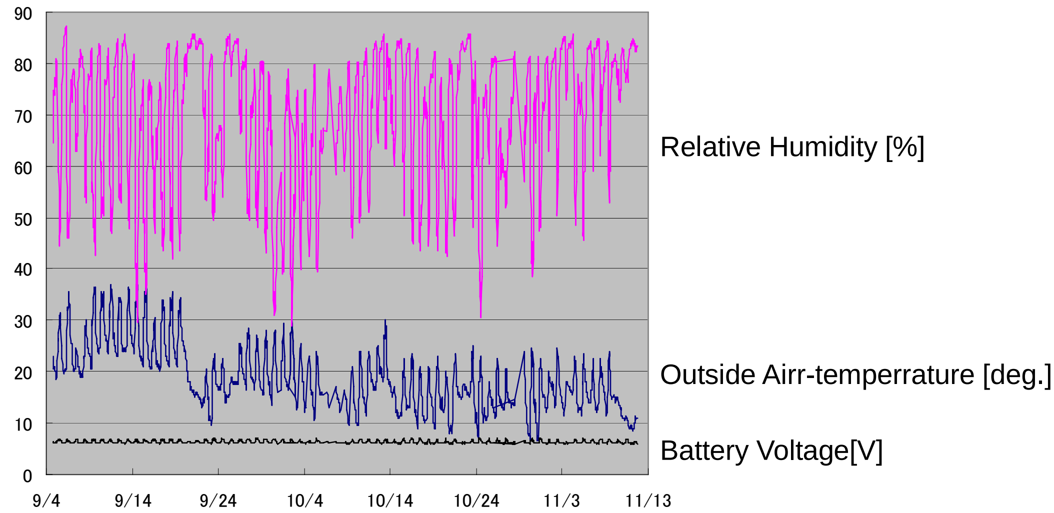

Figure 6. An example of measured data by the full-wireless FMS. Battery voltage had been stable for three months.