Advanced Sensor-Network with Field Monitoring Servers and MetBroker

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Abstract. *Field Server is a Web server which can be installed in fields semi-permanently, and Field Monitoring Server (FMS) is a kind of Field Servers for real-time monitoring working as a node of sensor networks. Sensors embedded in FMSs are air-temperature, humidity, intensity of solar radiation, leaf wetness, soil moisture,* CO_2 *concentration, UV, IR, CCD/CMOS camera and so on. Field Servers are connected by Wi-Fi (Wireless-LAN) respectively as Ad-Hoc network, and simultaneously Field Servers provide hotspots, where residents and gussets can connect to the Internet by client connection, are available around each Field Servers. So FMSs are both wireless sensor network and infrastructure for ubiquitous networking. Measured data by FMSs are stored as distributed XML databases by Fieldserver-Agent, which is a AI system to control Field Servers automatically. The collected data and other weather data of conventional weather databases are combined as a virtual database by MetBroker, which is a middle ware for data-grid. So far FMSs have been installed at dozens of sites in several countries such as Japan, USA, Thailand, China and Korea for long term experiments and long distance connection tests. Data measured by 30 Field Monitoring Servers was 1TB/year, that is, Terabyte-class data is available for a farmer personally if he installed 30 FMSs at his fields. PetaByte-class data will be* *collected by groups of framers, and ExaByte-class data will be unified by MetBroker. Such virtually unified huge database will be employed for data mining and Web applications.*

Keywords. Sensor Network, Wireless, Wi-Fi, Field Monitoring, Web, XML, Agent, Ubiquitous Network

Introduction

Real-time data collection in rural area and farms is need for management of agricultural production, production history disclosure system and traceability system for food security. Sensor network can be one of the best solutions. Conventionally many kinds of sensor-network solutions such as Mote (Khan *et al.*, 1999) or TINI (http://www.ibutton.com/TINI/) have been proposed, but specification of them is not sufficient for practical applications such as agriculture and Earth-monitoring. So we developed Field Server for wireless sensor network. Required specification of Field Server for such practical applications is:

1. Casing: heat-resistant, water-proof, dust-proof and suitable to landscape
2. Sensor: precise enough and multiple (digital-camera, air-temperature, humidity, PPFD, soil temperature, soil moisture, EC, CO_2 concentration, leaf-wetness, UV, IR, 3D air flow)
3. Communication range: 300m-10km for last-one-mile problem using standard technologies such as Wi-Fi
4. Band width: 54/11Mbps for high-resolution digital image and video
5. Energy supply: Solar-battery
6. Size: smaller than 30 cm for easy installation and easy maintenance
7. Total weight: lighter than 10 kg for shipping or baggage on flight
8. Cost: less than $500-$1000 per a module for massively distributed monitoring
9. Data handling: fully automatic and free internet-service for end users such as farmers

Field Server is a Web server which can be installed in fields semi-permanently, and Field Monitoring Server (FMS) is a kind of Field Servers for real-time monitoring working as a node of sensor networks. The Field Monitoring Server (FMS) shown in Fig.1 was designed to solve these problems. FMS can monitor fields in real-time and to perform wireless LAN hotspots as shown in Fig. 2 (Hirafuji, 2000; Fukatsu and Hirafuji, 2003). The FMS consists of Fieldserver-Engine (micro web-server with data acquisition), wireless LAN access-point, network-camera and sensors such as air-temperature, humidity, solar-radiation intensity (PPFD), soil temperature, soil moisture, CO_2 concentration, UV, IR, leaf-wetness and soil moisture.

Fieldserver-Engine

Fieldserver-Engine is a main board which has many functions such as a Web server, analog I/O, digital I/O, DDS (Direct Digital synthesizer), FPAA (Field Programmable Analog Array) and analog multipliers. DDS can generate alternative signal up to 70MHz. FPAA serves to construct dynamically analog circuits such as low-pass filter and super-heterodyne radio receiver using its embedded 20 CABs (Configurable Analog Block) and analog multipliers. Combining these factions FMS can be connected to sensors and probes directly.

Architecture of Field Server

Architecture of Field Servers is much different from conventional PCs as listed in Table 1. This architecture is extremely simpler and more robust than conventional PCs and also Mainframe servers. Complicated action of Field Servers is controlled by Fieldserver-Agent (Fukatsu, Hirafuji, 2003) instead of complicated programming for conventional PCs. Applications using MetBroker (Laurenson, Kiura and Ninomiya, 2002) can use data FMSs and conventional weather databases automatically. If new FMSs are installed, the measured data is also available without any revises in source codes.

Current measured data by FMSs at fields are shown by browsers such as Internet Explorer via the Internet and FMS's wireless-LAN. The data which is a web page (HTML) is collected by Fieldserver-Agent automatically, and stored in public database servers such as a PC-cluster in NARC or a computer center. The agent is accessing FMSs every 1 or 10 minutes, and storing the data as distributed XML database. The data can be used easily trough MetBroker (Fig.7). MetBroker is a middleware, which can access databases automatically and find objective data as an intelligent agent. Applications and users with using Excel can get objective data in databases trough MetBroker.

FMSs, which are driven by small solar-cell embedded on rooftop of the FMSs, connect other FSMs as clients using function of hotspots easily (Fig. 3). The client connection FMS is truly cable-less, so they can be quite easily installed even at paddy fields as shown Fig. 4 and 5. Standard FMSs (Fig. 1) and Garden-light FMSs (Fig.6), which consume more energy to maintain backbone and to perform hotspots around the FMSs, are driven by larger solar-cells or electric cables. Combining these types of FMSs wide-area wireless sensor-networks for practical applications can be created. Such wide-area sensor networks are also connected on the Internet, so MetBroker performs global sensor network automatically.

Results and Discussions

So far, FMSs have been installed at many experimental sites in several countries such as Japan, USA, Thailand, Denmark, China and Korea. We isolated wireless LAN of FMS from the global network using private IP for security, and we developed FieldServerGateway for secure connection among Fieldserver-Agent and FMSs via the Internet(Kiura, Fukatsu, Hirafuji, 2002).

By combining FMS, MetBroker, Fieldserver-Agent and Fieldserver-Gateway, wireless smart sensor-networks could be created (Fig. 8). We have tested the sensor-networks in different situations for practical applications since 2001. They could monitor environment and entrances of buildings, private houses and farms. Fieldserver-Agent could control equipments such as digital-cameras, lighting and greenhouses remotely. For security system, FMSs could watch fields against thieves continuously. Function of FMSs of hotspot and Ad-Hoc network (repeating-mode of access-points) could provide Internet connection infrastructure in rural areas to solve last-one-mile problem and to create ubiquitous network environment instantly.

Data measured by about 30 FMSs was 1TB/year, that is, TeraByte-class data is available for a farmer personally if he installed 30 FMSs at his fields. So PetaByte-class data will be collected by groups of framers, and ExaByte-class data will be unified by MetBroker. Such virtually unified huge database will be employed for data mining and Web applications. Also global sensor-network could be also easily created by FMSs and MetBroker.

Data-mining is available using such enormous data and conventional weather databases using MetBroker. We concluded that the architecture was easy to use, robust, sufficiently reliable and extremely economical, and the proposed sensor-network system can be an important tool to establish new informatics.

Now data storage is becoming serous problem. For distributed on-site storage system, Field Storage Server is under developing.

Conclusion

Agriculture is absolutely complex system, so extremely enormous data is required for scientific analysis and management. However, so far, we are short of fact data in fields, so remote sensing data of satellites and estimation based on numerical models have been employed in agricultural science. Field Servers can be powerful tools to solve this fundamental problem in agricultural science and environment science. Moreover, combination of Field Servers, MetBroker, computational models, data mingling, remote sensing data and biological information such as genome databases can be really powerful tool to analyze agricultural systems, eco-systems and earth environment based on fact data scientifically. We named this approach as “Field Informatics”.

Table1 Difference between Conventional PCs and Field Monitoring Servers

	Conventional PCs	Field Monitoring Servers
Working Place	Indoor	Outdoor
OS	Multi-task OS & Device Drivers	Not Needed (Embedded Web-Servers)
Connection to Devices	PCI, IDE, USB, IEEE1394	Only Ethernet
Power-Up Method	Powerful-CPU & Fast Chipset	Analogue Multiplier Reconfigurable Device (FPAA)
Error Occurrence	Blue-Screen	Non-Stop by Watch Dog Timer
User Interface	GUI	HTML
Required Knowledge for Programming	Enormous Manuals of OS and Language	K&R textbook of C
Users' Satisfaction	Rich-contents	Rich-sensors

Fig. 1 Field Monitoring Server consists of a solar cell, Web server card, Wi-Fi access-point card, sensors, a network camera and fan. They are connected by wireless LAN.

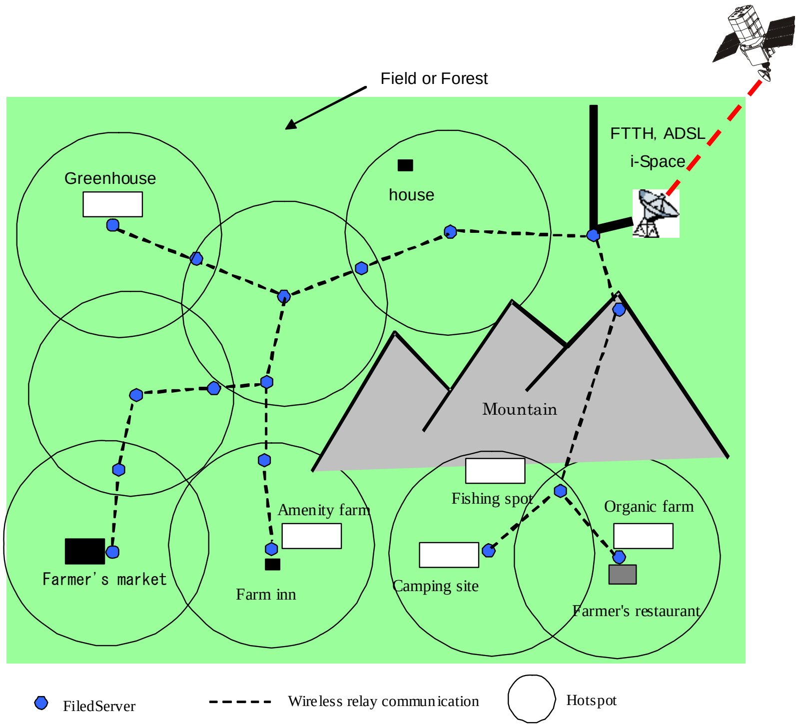

Fig. 2 Ubiquitous monitoring, networking and computing in rural area were realized by sensor network with distributed field monitoring servers. Each node has private IP address, and the wireless network is connected to the Internet. Private networks of field monitoring servers in other areas are connected through the Internet by VPN (Virtual Private Network).

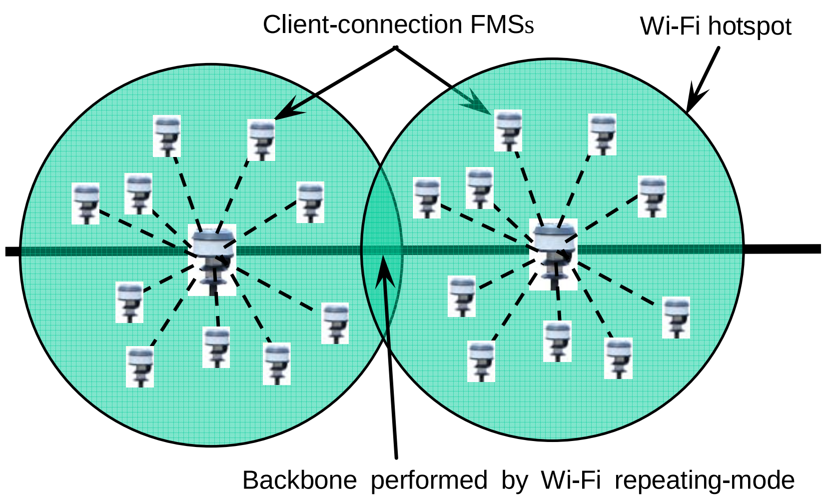

Fig. 3 Two types of Field Monitoring Servers, repeating-mode connection and client-connection Field Monitoring Servers, are developed. Repeating-mode connection Field Monitoring Servers perform a backbone network by wireless-LAN and hot spot, where internet is available by wireless-LAN and client-connection Field Monitoring Servers can be installed easily.

Fig. 4 Fill-wireless Field Monitoring Servers installed in a paddy field.

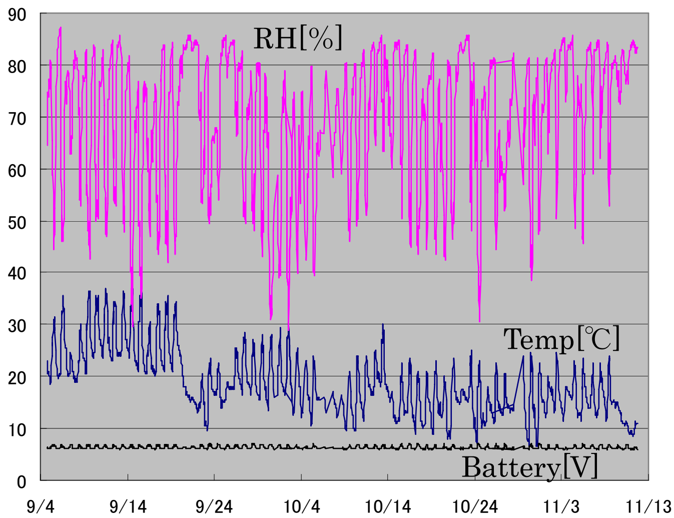

Fig. 5 Example of Measured Data by a Full-wireless Field Monitoring Server

Fig. 6 Garden-Light Field Monitoring Servers

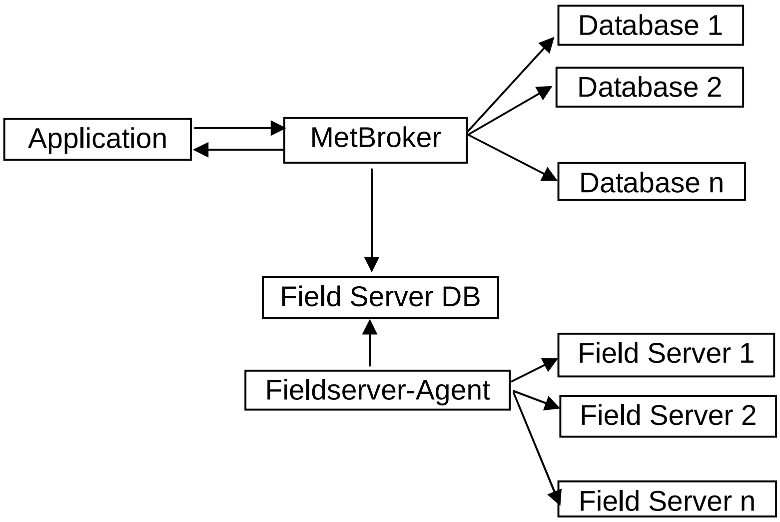

Fig. 7 MetBroker combines databases of conventional weather databases and data of Field Monitoring Servers

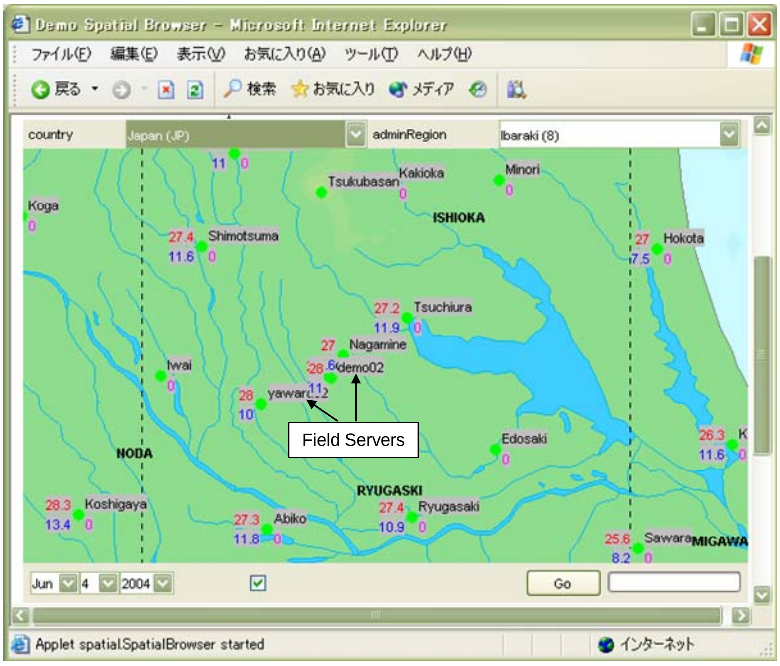

Fig. 8 Example of a Web application with Field Servers and MetBroker. This application shows distributed whether data provided by MetBroker on a map. Map data is also provided by Chizu-broker; chizu means map.

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