Sensor Data Analysis and Sensor Management for Crop Monitoring

Raquel Sosa[1], Andres Vera[1], Maite Ibarburu[1], Leonardo Steinfeld[2], Javier Schandy[2], Fernando Silveira[2]

[1] Universidad de la República
Julio Herrera y Reissig 565 - Instituto de Computación
raquels@fing.edu.uy

[2] Universidad de la República
Julio Herrera y Reissig 565 - Instituto de Ingeniería Eléctrica
{leo,jschandy,silveira}@fing.edu.uy

Abstract

During crop growth there are microclimate variations that can affect them. Some variations, such as slight frost, if repeated many times can affect the yield of the crops. These variations can be monitored by a wireless sensor network and the estimated yield of the crop can be adjusted by analyzing the data. This work proposes a system that manages a wireless sensor network to monitor environmental variables, stores the data it receives and enables different types of users to analyze data. The users can be network admins or agronomists. The proposal includes the use of Geographic Information Technologies to display the data.

1 Introduction

During the crop growth microclimate variations could occur in different zones of the fields and affect the yield of the crop. Agronomists could learn about the real effect of those variations on crops if they had detailed data about them. To really know about those variations the deployment of a wireless sensor network (WSN) on the field can take measurements of environment variables, like temperature or humidity. The development of that kind of WSN applied to agriculture is part of a research project of the Electrical Engineering Institute [1] (IIE)[3] and is supported by INIA[2].

In the last few years there has been a collaboration between the IIE and the Computer Science Institute [3] (InCo) on different uses of the data provided by the WSN on the field. The main user of the data generated by the WSN is the agronomist who needs to analyze them. Besides, the network administrator needs to monitor the WSN status and know how it is working through time during the test phase of the deployment.

There is some work on the analysis of sensor data, like [2] that focuses on the scientific applications of environmental data provided by several data sources, including meteorological stations. Its applications are terrestrial ecology and oceanography. This work is based on the IIE research project considering agronomists as one of the main users of the system proposed but also considering the needs of the researcher on networks.

2 Wireless Sensor Network

Wireless sensor networks [4](WSN) comprised sensor nodes that measure the environment and send the information to a root node. A key feature is the ad-hoc formation of a mesh network, where all nodes can route information to the root node.

The WSN was developed based on free and open-source software (FOSS). The protocols adopted for the communication stack are standardized by IEEE and IETF. The sensor nodes embedded software was

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[1] Instituto de Ingeniería Eléctrica - Facultad de Ingeniería - http://iie.fing.edu.uy/

[2] Instituto Nacional de Investigaciones Agropecuarias - http://www.inia.uy

[3] Instituto de Computación - Facultad de Ingeniería - http://www.fing.edu.uy/inco

build using Contiki [4], an event-driven operating system oriented to WSN and Internet of Things (IoT) applications using constrained hardware.

The communication stack adopted is the full-stack usually known as 6LoWPAN, since it uses IPv6 over IEEE 802.15.4 wireless personal network (low power WPAN).

The physical and MAC layer is based on the IEEE 802.15.4 standard operating in the 2.4 GHz unlicensed band. The access mechanism is Carrier Sense Multiple Access with Collision Avoidance (CSMACA) where the node does carrier sensing before transmitting packets to check whether the channel is idle or not. The upper layers are standardized by the IETF. In order to transport of IPv6 packets over 802.15.4 links, the 6LoWPAN adaptation layer protocol is used.

On top of 6LoWPAN, RPL is adopted (IPv6 Routing Protocol for Low-Power and Lossy Networks), a proactive routing protocol based on a tree-oriented strategy. The distance metric is usually based on some link quality indicator. RPL enables different operation modes. In this case, each network node's storing the default route to the root and table entries to route packets to all the nodes downwards the tree was selected.

At the application layer the Constrained Application Protocol (CoAP) [5] is used, which is a RESTful protocol for use with constrained hardware such as WSN nodes. It relies on UDP on transport layer. CoAP follows a REST model in which the nodes, as servers, make resources available to clients under a URL. In this case the client is the root node which is connected to a gateway that sends the information to a server via cellular network. CoAP uses methods such as GET, PUT, POST, etc. and a special OBSERVE mechanism that allows client nodes to retrieve a resource value from a server without a explicit GET.

The WSN generate data from their sensors at variable (configurable) rates and these date are transmitted to the base node through different routes across several nodes. The base node has limited storage capacity and limited computing power, but it is the node that connects the network to the internet. The base node receives all the data collected by the node sensors including the battery level and routing information.

3 System Description

This work focuses on the system that communicates with the base node and manages the data generated by the WSN. The system proposed also manages the data on the status of the WSN and the nodes, allowing the WSN administrators to monitorize the network and set parameters. Some of the functionalities required of the system were the georeferencing of the node position and the spatial analysis of the data provided, mainly of the WSN status data and in relation with other spatial data (hills, roads, wind map). We propose the graphical analysis of the variables measured (air humidity, soil humidity, temperature) and also the spatial analysis. One interesting function of the system is the capacity of setting alarms associated with threshold values for the observed variables (for example soil humidity below 30% could mean a drought and the agronomist could reinforce artificial irrigation). Some non-functional considerations of the system are that it has to be connection fault tolerant, considering that the base node has low computing power and has to store historical data (several years).

To achieve the needs of data analysis and WSN management, given that this kind of network is in an development phase, we designed a system with a distributed architecture and using several technologies that enable the extension of the system. As shown in Figure1, the system has a component (sensors-daemon) that receives the data from the network. The sensors-daemon runs in a limited hardware component near the network, provides temporal storage of the data, and communicates the sensors-core with the network. Sensors-core and sensors-daemon have two ways of communicating.One of them is asyncronous to deal with internet connection losses and efficient use of the bandwidth. When the system needs to handle serveral WSN in different deployments, the component sensors-daemon will be replicated near each network. Sensors-core runs in a server and stores the data using two types of databases:

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[4] www.contiki-os.org

a relational one for system operation and a non-relational one for storing measured data. This second database allows the system to use diverse analysis tools related to Big Data technologies.

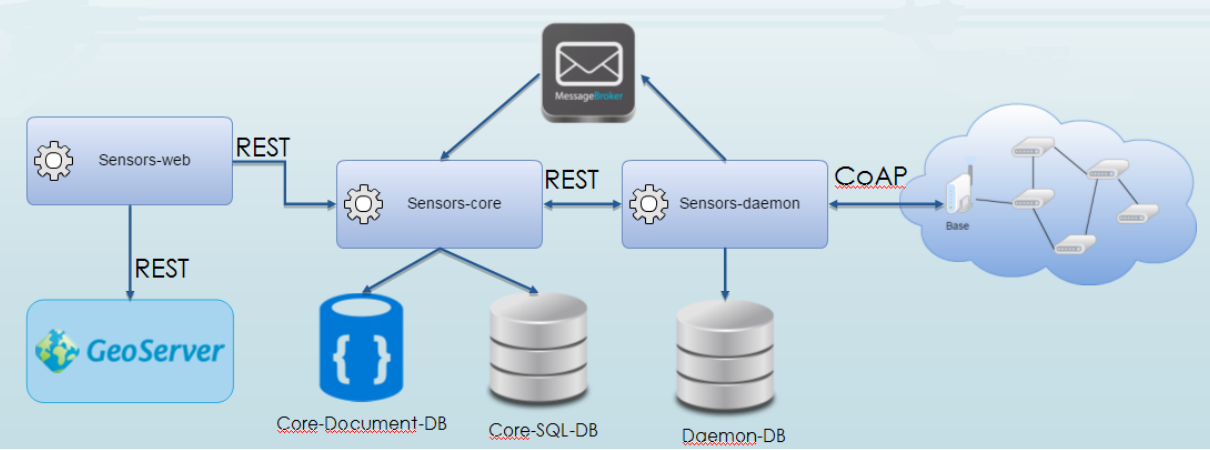

Figure 1: System Arquitecture

The system provides the different users with a web interface so that they can access the system through the Internet. The sensor-web component uses a MapServer (GeoServer[5]) to overlay sensor data with context spatial data in a flexible way. Geoserver also provides the standar Web Processing Service (WPS)[1] that allows the system a further spatial analysis of the data.

4 Conclusions and Future Work

This work is the first prototype of a system that allows users to analyze crop field data in terms of time and location. From the very beginning of the project, the possibility of generating alarms for users when unusual situations are detected was considered (for example, very high temperatures which could be indicators of fire). Our proposal relates the data gathered by the sensors with its spatial location, allowing users to perform different types of GIS analyses (such as heatmaps) and cross it with other spatial data. The inmediate future work is to test the system with real test fields since the system reached a alfa test in the IIE.

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