A Wireless Sensor Network System

For Monitoring Trees' Health Related Parameters in a University Campus

Luis Eduardo Pérez, Jorge Arturo Pardiñas-Mir, Omar Guerra, Javier de la Mora, Mauricio Pimienta, Nestor Hernández and Manuel de Atocha Lopez

Electronics, Systems and Informatics, ITESO University, Periférico Sur 8585, 45604, Tlaquepaque, Mexico

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Abstract: This paper presents an experimental Wireless Sensors Network system which aims to contribute to the transformation of a university campus into a living lab to experiment with applications in the context of a smart city. The system acquires environmental data related to the campus trees' health, stores it in a server to be analysed and makes it available to be displayed in a mobile application. Details are given to the design and results of the server's system and the MobApp.

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1 INTRODUCTION

Our cities around the world are having currently a significant growth, the UN estimates that by year 2050 70% of the population will live in cities (UN, 2010). This will create significant pressure for cities to efficiently provide services for the population: water, energy, transportation, health care, education and security. Cities must become "smart" (Naphade et al., 2011) in how they manage their infrastructure and resources to meet current and future needs.

The intelligence of cities is on the basis of innovation and new working practices, primarily, on the use of communication technologies and information as a mean to achieve it. In this aspect, the concept of all objects connected via internet forms a technological basis for collecting information from the city centers: water meters, electricity meters, traffic sensors, parking meters, temperature sensors, GPS devices, mobile phones, etc. It is the concept called "Internet of Things" (or IoT) (Foschini et al., 2011).

One of the key components of IoT is undoubtedly wireless sensor networks of different types (architecture, size, extent) which connect to the Internet. They are able to provide the collected information facing several challenges such as holding systems' owners and operational standards that are not open, which prevents, for example, the integration with other systems (Jiang et al., 2013).

We are developing a campus wide wireless sensor network as an experimental platform to research and implement solutions oriented to turn the university campus into an intelligent community, being a living lab to experiment with applications that could be adapted in the context of a smart city. One of such applications that we are using at the same time as a demo of a living lab possibilities, as a real laboratory for student lab work and research and as a running service, is a system conceived to collect, store and present information concerning the health of the trees in the campus. This paper focuses on the development of the computing and information process stage of the application, leaving for a later publication the details of the platform hardware.

The system aims to collect information from a network of wireless sensors making it available for immediate query through a mobile application. At the same time the information is stored in a web server for later analysis. This represents the integration of various emerging technologies; first of all, the network of sensors reads temperature and humidity data, secondly, the data is stored and managed in a database on a server and, finally, through a web service, a mobile application requests the data from the server and presents it graphically. It is expected that lab work from students and research could be driven in these subjects under real conditions. Some studies (Dospinescu, 2013), (Moreira, 2011), (Choi, 2013), (Koo, 2011) which refer to using a mechanism for sending / receiving information through the use of web services using REST and HTTP, are similar to our purpose.

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2 ELEMENTS OF THE SYSTEM

The university campus to be monitored has a surface of over 41 hectares where 22 hectares correspond to green areas. Here there are over three thousand trees of over 280 different species. In order to maintain in good health this valuable natural resource of the university it is necessary to periodically monitor some physical parameters that bring information related to the conditions at which trees become susceptible to contracting a disease or pest. According to the requirements provided by the office in charge of the gardens of the campus, the parameters to be sensed in a first stage, are the moisture and temperature of soil and the temperature of trees.

The system that we are developing, Figure 1, has already been concept tested in a first stage. It is based on a wireless network of sensors distributed all over the campus to collect the physical parameters from the trees' environment. This data is transmitted to a station (server) in charge of storing it and providing it to the users for its analysis. The information is then looked up and displayed through a mobile application via internet. An additional feature is to show the route to go from any location in the campus to a specific tree.

2.1 The Campus Wide Wireless Sensor Network

At the base of the system there´s an experimental wireless sensor network consisting of several sensor nodes (SN). Each sensor node has the possibility of sensing the values corresponding to the soil moisture, humidity sensor (HS), and temperature of soil (ST), and the temperature of trees (TT).

According to the requirements, some samples of these values are sensed in a specific gardens' area, meaning that there's no need of having a sensor node for each and every tree of the campus.

The sensors are grouped into areas of trees concentration and they communicate wirelessly to a router node (RN). The router, one for each area, manages the communication between sensors and a coordinator node (CN) in charge of the whole network. This coordinator node has also the possibility of performing as a gateway to let the network communicate with the system's server by internet. Figure 2 shows, as an example, a tested WSN architecture comprising a coordinator, 3 routers and 3 sensor nodes per router. Each router covers a specific tree-covered zone of the campus where the monitoring is required. This architecture is changing as we make the network grows and test for the best results.

The WSN uses Zigbee technology to communicate wirelessly between nodes while the coordinator, at present, is connected to the internet through an Ethernet port. We use XBee ZB RF Modules from Digi International working at the ISM 2.4 GHz band. The low version is used in the sensor nodes, running on batteries, while the PRO version (more power) is used for the Router and the Coordinator nodes running on electric power. A more detailed description of the WSN is planned in a coming publication.

2.2 The Server

The main functions of the systems' server are: to communicate with the WSN, to interact with the mobile application (MobApp), and to manage the database and to calculate the route to go from any location in the campus to a specific tree.

The communication with the WSN is made with the networks' coordinator, through a TCP/IP connection. It sends the required commands to read the sensors' values.

The interaction between server and the mobile application uses web services based on REST and SOAP. Here we are using SOAP as an educative strategy for the students participating in the project. The MobApp sends requests to the server for tree information: species, georeference, planting date, height, and health related variables (tree's temperature, soil's temperature and soil's moisture). The sever has the possibility to respond with a XML or JSON format file.

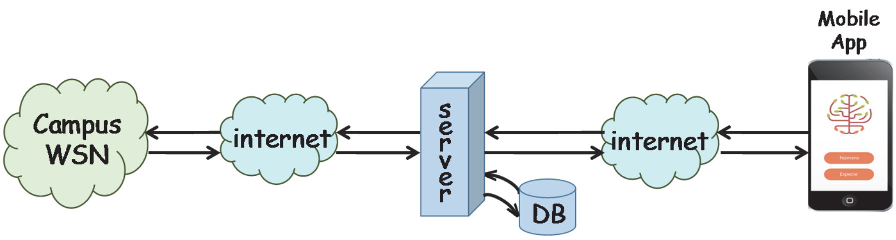

Figure 1: Components of the system.

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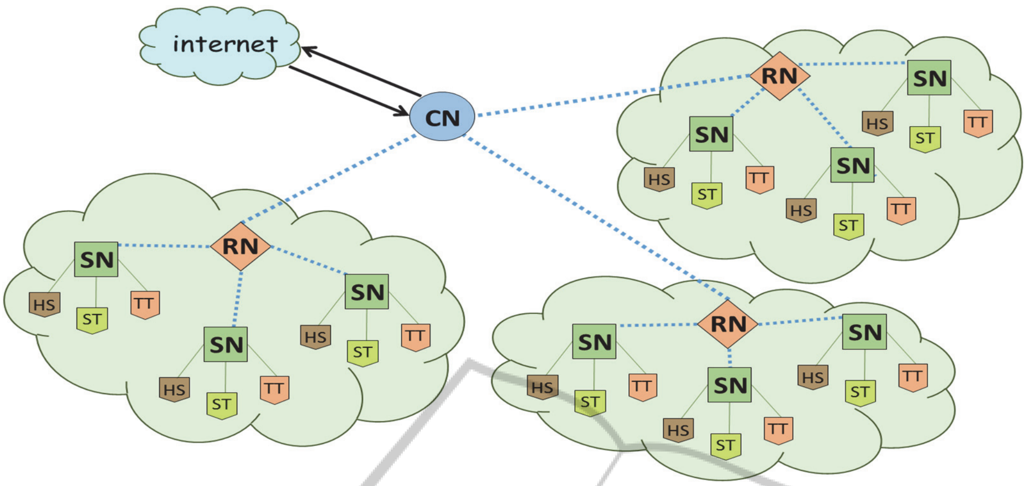

Figure 2: The Wireless Sensor Network Architecture.

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The data base design takes into account an existing old database of trees in the campus, still at work, in order to normalize it and assure data consistency. This data was linked to the sensors' positions. In addition, a small program was made to have the possibility of managing new entries and relations between trees and sensors.

Due to the fact that main maps' providers don't take into account the route path computation into private spaces, like the University campus in this case, it was necessary to develop in the server a web service to compute the route to go from any point in the campus to a targeted tree. For this means it was necessary to consider the internal map of the campus.

2.3 The Mobile Application

The Mobile Application was developed at the same time for the iOS and Android platforms. Both of them were designed with the same looking and functionalities. The design process includes the application requirements determination, the design concept definition, and the user experience (UX) and the user interface (UI) tests.

The entry data to the application is either the number of a tree (all trees in the campus have a plate with a number) or the name of a tree species. The MobApp establishes an HTTP connection to send the identifier. The server responds with the related information from the database which is formatted in one of two requested formats: XML or JSON. The MobApp displays this information in a graphical way. In the case of an inquiry using the tree's identifier the response includes all the tree's characteristics. For the case of an inquiry with a tree species' name the response is the map of the campus showing the positions of all trees belonging to that species. These results can be filtered for different zones of the campus. Each tag on the map, representing one tree, is sensitive to show the information of that specific tree.

In the case of a route inquiry to go from any location in the campus to a specific tree, the MobApp sends to the server the user's location and the target tree's location. The algorithm in the server searches for the shortest route from the user to the tree and sends the location of points of a valid path to the MobApp in order to be displayed on the campus map.

3 IMPLEMENTATION AND RESULTS

The center of the system is a Linux server which communicates with the WSN coordinator through a TCP/IP connection. The communication program is coded in Python, performing the necessary commands to interact with the WSN protocol: IEEE 802.15.4. At this first stage of development we acquire only the temperature and moisture of soil; tree's temperature as well as other environmental variables will be added in a next stage.

The database was developed using MySQL technology. It manages four kinds of information, each one defined in a data table: information related to the tree (rssy_arboles_inventario), information related to the tree species (rssy_arboles_taxnonomias), information related to the garden zones (rssy_arboles_jardines) and information related to the sensors (rssy_arboles_inspeccion).

The web services are accessed through an API running in the server that was developed in PHP. This API lets the server receive a request for a specific tree or for a tree's species. In the case of the tree, the syntax needed to be used by the MobApp to get the information in XML format is:

```
http://papvidadigital.com/risi_app/?
nid=ID
```

where ID is the tree identifier, while for getting the JSON format, for example, the tree with identifier 99, is:

```
http://papvidadigital.com/risi_app/?
nid=99&format=json
```

The response received by the MobApp from the server includes the whole information related to the tree: identifier, species, planting date, diameter, height, estimated health status (according to temperature and moisture data), latitude, longitude, garden's zone, and image. Figure 3 shows the page of the MobApp which displays the tree's information.

An example of a response for both XML and JSON format are:


```
▼<web_service>
  ▼<dato>
     <NID>99</NID>
     <taxonomia>Moringa</taxonomia>
     <plantado>2010</plantado>
     <diametro>8</diametro>
     <altura>2</altura>
     <valoracion>100</valoracion>
     <latitud>20.606712</latitud>
     <longitud>-103.415931</longitud>
     <jardin>1</jardin>
     <imagen/>
   </dato>
 </web_service>
```

```
{"dato":[{"dato":{"NID":"99","taxono
mia":"Moringa","plantado":"2010","di
ámetro":"8,"altura":"2","valoración"
:"100","latitud":"20.606712","longit
ud":"-103.415931","jardin":"1","imag
en":""}}]}
```


In the case of a species request, the inquiry is constructed from the tree identifier and the name of the species, as shown here for both formats:

```
http://papvidadigital.com/risi_app/?
id_taxonomia=ID

http://papvidadigital.com/risi_app/?
id_taxonomia=2&format=json
```

The response, as said before, is the location of every tree belonging to that species, as shown here for the XML format case:


```
▼<web_service>
  ▼<dato>
     <NID>96</NID>
     <latitud>20.606967</latitud>
     <longitud>-103.415878</longitud>
   </dato>
  ▼<dato>
     <NID>331</NID>
     <latitud>20.606791</latitud>
     <longitud>-103.414926</longitud>
   </dato>
  ▼<dato>
     <NID>537</NID>
     <latitud>20.606302</latitud>
     <longitud>-103.414113</longitud>
   </dato>
  ▼<dato>
     <NID>538</NID>
     <latitud>20.6063</latitud>
     <longitud>-103.414151</longitud>
   </dato>
  ▼<dato>
     <NID>539</NID>
```


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The process of showing the route from the user's location to the target tree was divided in two: first, the path is calculated in the server after an inquiry from the MobApp, and then, the server returns the latitude and longitude corresponding to all points of the path. Second, the MobApp takes these points and shows them graphically on the campus map.

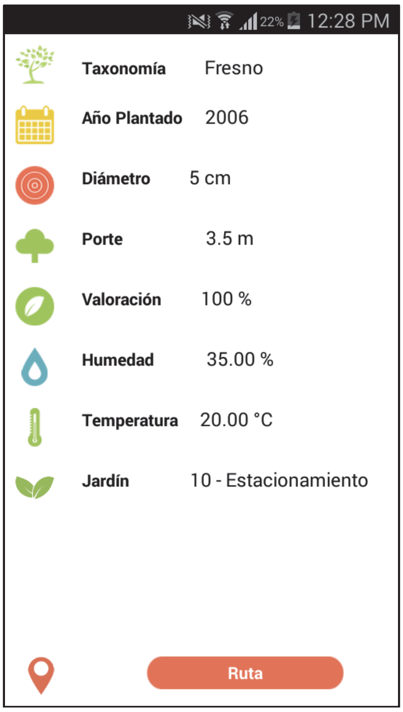

Figure 3: Mobile display of tree's information.

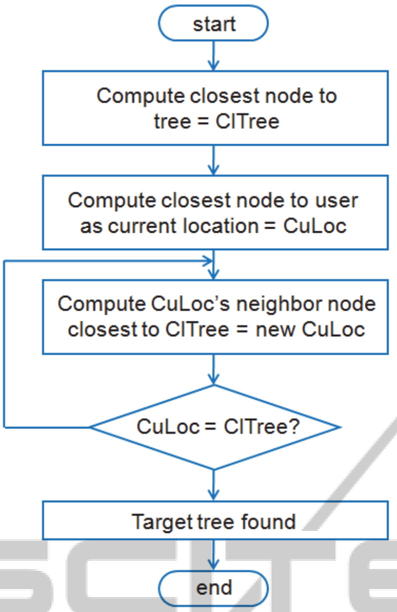

Figure 4: Flow diagram to compute the route from the user to a target tree.

Figure 5: Display of the result of a route computing.

We programmed a simple algorithm for calculating a path from the user to the target tree following the possible real routes of the campus. For this aim it was necessary to acquire and store in advance the georeferenced data related to the location points of campus' valid walking routes. The algorithm corresponding to the route computing is shown in figure 4 while a display of a route result is shown in figure 5. At this moment, the algorithm is not yet optimal for analyzing all possible routes and be able to know which the shortest one is.

4 CONCLUSIONS

We have presented a complete system consisting of a wireless sensor network, a server provider of web services, and a mobile application, that provides information of some environmental parameters related to the tree's health in a university campus. We have described details concerning the design of the server and the MobApp based on the paradigm of web services using REST and SOAP.

The project has a double objective. First, to develop a system that provides a service for the university. Second, to allow to experience with real applications related to wireless sensor networks, web services, and mobile applications. In this context, the future work is first, to optimize the hardware and management of the wireless network, second, to link to the system a culture house belonging to the university which is located at the center of the city and, third, to develop an application that lets the university's office in charge of the campus' gardens to process and analyze the information.

All of this contributes to transform the campus into a living lab for experimenting with applications that could be in turn adapted in the context of a smart city.

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REFERENCES

Choi, M., Jeong, Y., Park, J., 2013. Improving Performance through REST Open API Grouping for Wireless Sensor Network. In *International Journal of Distributed Sensor Networks* Volume 2013, Article ID 958241. http://dx.doi.org/10.1155/2013/958241

Dospinescu, O., and Perca, M., 2013. Web Services in Mobile Applications. In *Informatica Economica*, vol. 17. DOI:10.12948/issn1431305/17.2.2013.02

Foschini, L.; Taleb, T.; Corradi, A.; Bottazzi, D., 2011. M2M-based metropolitan platform for IMS-enabled road traffic management in IoT. In *Communications Magazine, IEEE* , vol.49, no.11, pp.50,57, November 2011. doi: 10.1109/MCOM.2011.6069709

Koo, B., Han, K., James, J., Shon, T., 2011. Design and implementation of a wireless sensor network architecture using smart mobile devices. In *Telecommun Syst* (2013) 52:2311–2320. DOI 10.1007/s11235-011-9535-z

Jiang, Y., Zhang, L., and Wang, L., 2013. Wireless Sensor Networks and the Internet of Things. In *International Journal of Distributed Sensor Networks*, vol. 2013, Article ID 589750. doi:10.1155/2013/589750

Moreira, N., Venda, M., Silva, C., Marcelino, L., Pereira, A., 2011. @Sensor – Mobile Application to Monitor a WSN. In *CISTI (Iberian Conference on Information Systems & Technologies / Conferência Ibérica de Sistemas e Tecnologias de Informação) Proceedings*, July.2011.

Naphade, M.; Banavar, G.; Harrison, C.; Paraszczak, J.; Morris, R., 2011. Smarter Cities and Their Innovation Challenges. In *Computer* , vol.44, no.6, pp.32,39, June 2011. doi: 10.1109/MC.2011.187

United Nations, 2010. World Urbanization Prospects: The 2009 Revision—Highlights, 2010; http://esa.un.org/unpd/wup/doc_highlights.htm.

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