Wireless Sensor Network to Help Low Incomes Farmers to Face Drought Impacts

Fantazi Walid, Ezzedine Tahar, Bargaoui Zoubeida

Abstract—This research presents the main ideas to implement an intelligent system composed by communicating wireless sensors measuring environmental data linked to drought indicators (such as air temperature, soil moisture , etc...). On the other hand, the setting up of a spatio temporal database communicating with a Web mapping application for a monitoring in real time in activity 24:00 /day, 7 days/week is proposed to allow the screening of the drought parameters time evolution and their extraction. Thus this system helps detecting surfaces touched by the phenomenon of drought. Spatio-temporal conceptual models seek to answer the users who need to manage soil water content for irrigating or fertilizing or other activities pursuing crop yield augmentation. Effectively, spatio-temporal conceptual models enable users to obtain a diagram of readable and easy data to apprehend. Based on socio-economic information, it helps identifying people impacted by the phenomena with the corresponding severity especially that this information is accessible by farmers and stakeholders themselves. The study will be applied in Siliana watershed Northern Tunisia.

Keywords—WSN, database spatio-temporal, GIS, web-mapping, indicator of drought.

I. INTRODUCTION

DROUGH is a natural phenomenon, which may be dramatic for poorer farmers and people because it results in both farmer incomes reductions and food prices increasing. Advanced technologies nowadays help toward an integrated assessment of drought. More specifically, data collected by wireless sensor networks may constitute an important source of information [1] for drought monitoring and mitigation. Moreover, the merging of sensor network data in a GIS system helps making decisions concerning the management of drought impacts. Reducing drought impacts is an important step towards reducing poverty especially in developing countries with scarce water resources and with rainfall harvesting agriculture. Drought management represents a domain activity where stakeholders from various economic activities, various social groups and various territorial origins must be connected to face related adverse and diffuse impacts. Information about drought risk may help populations to better manage their activities and incomes as well as to adapt their social networks. The connection between innovation techniques represented by wireless sensor implementation and drought assessment is made possible by the easiness of using

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the database provided by the GIS information operation. Thus, implementation of such an observation system may help achieving inclusive development objectives. The wireless sensor networks have become a tremendous discipline for the acquisition, the use and the manipulation of information [2]. They consist of a technique observation of the terrestrial surface that is less expensive than classical equipment and provide further information for many fields such as earth occupation, distant surveillance and environmental surveillance. Drought surveillance is of prime importance for farmers as well as crop and trade stakeholders. Thus the paper is focused on the setting up of wireless networks achieving the climatic conditions and soil water availability conditions surveillance in order to help drought identification and management. Wireless networks that are freely deployed like WiFi, BlueTooth, ZigBee, etc. or related to infrastructure operators such as 3G and 4G have become very popular. These technologies are spread worldwide. They have been used in various contexts and it is even common for an autonomous system to use the sensor networks in order to exchange information automatically, without being commanded by humans. The wireless sensors networks (WSN) is actually used in the agriculture field to monitor the climate, the crops, the control of the crop inputs and the irrigation supply. A good control of these parameters would make it possible to the farmers to carry out proactive actions in order to better improve the crop yield [3]–[6]. Soil moisture sensing network is used to monitor the moisture contained in soil and help irrigation decisions in drip irrigation systems. Evapotranspiration is directly linked to soil moisture from one part and to crop yield from the other part [7]. Generally, three different sensors are used to monitor three layers of soil [17] (and they indicate whether the soil is dry or wet). In irrigation applications, a microcontroller controls the overall irrigation system. It takes the input from moisture sensor (watermark Soil Moisture Sensor). According to a specify program (rules of functioning) it turns ON or OFF the irrigation pump. When soil is dry, the motor is ON and when soil is wet, motor is OFF. ZigBee module is used generally to have wireless link between computer and the main irrigation system so data can be logged into the computer.

This research paper consists of the study of the evolution and the extraction of drought parameters as well as the detection of surfaces affected by the drought phenomenon.

In Section II, we present the methodology, we present the different components of the network of sensors implemented and functioning as the conceptual modeling spatio temporal database. In Section III, we describe in details as the

architectural proposal application software and handling some consultation interfaces and data manipulation.

II. Methodology

A. Distributed Sensor Network

Nine environmental parameters are proposed for monitoring: solar radiation, air temperature and humidity, precipitation, wind speed, soil moisture at three depths and surface soil temperature. The developed interface allows viewing statistics and graphs for each indicator (parameter), accessing, manipulating and exporting data and controlling the operation of the sensors in real time. It also facilitates the spatial integration of online data/metadata sensors. The proposed system consists of a monitoring application, based on material and software architecture (SOA). The sensors are allowed to harvest the environmental parameters without sound. This information is transmitted to a spatiotemporal database via a configured secure WiFi connection between the database and the Gateway. This communicating base is connected to a GIS-WEB application, the objective of which is to facilitate the data exchange between users and the evaluation of information in a context of decision-making aid in critical situation.

A collection of sensors is set in two measurement stations to validate research results. Every station contains a mount (Waspmote 868 SMA 4.5 DBI), which is interconnected with the module XBee 802.15.4 Pro SMA 5dBi that plays the role of the IEEE 802.15.4 communication interface and the Waspmote Agriculture Sensor Board PRO, that sets the links between different sensors as it is shown in Fig. 2. The first measurement station contains 5 sensors: Solar radiation sensor, air temperature sensor, air humidity sensor, and weather Station WS-3000 (composed by anemometer, wind vane and raingage sensors). The second measurement station contains 4 sensors: three Watermark Soil Moisture Sensors (30 cm, 60 cm, and 100 cm) and a Soil temperature (PT 1000) probe. These sensors communicate between each other via a Zigbee interface (using XBee802.15.4 SMA 5dBi) and interconnected via a bridge (see Fig. 1) that enables the transfer of the collected measurements by the sensors to the spatio temporal database via a 3G connection. Their components are supplied by a solar panel (Solar panel 7.4) and chargers. Moreover, auto-configuration, energetic autonomy, reliability and security of information exchange will be carefully examined.

Fig. 1 Meshlium ZigBee-PRO-3G-AP

B. Real-Time Spatio-Temporal Metadata Analyses

The spatio-temporal conceptual model is designed to capture the essential semantics of the change of information over time. It should be compatible with the traditional model in order to allow the modeling of data that are neither spatial nor temporal [8]. In a spatio-temporal conceptual model, the various types of links (conventional, spatial and temporal) between entities in the real world are known.

There are various spatial Conceptual Models of Data (CMD) among which two different approaches were investigated for application here: Perceptory [9] and Modeling of Application Data with Spatiotemporal (MADS) [10], [11]. They are based on CMD that originates from the databases, respectively UML and ER (Entity/Association). They are extended to the spatial concepts.
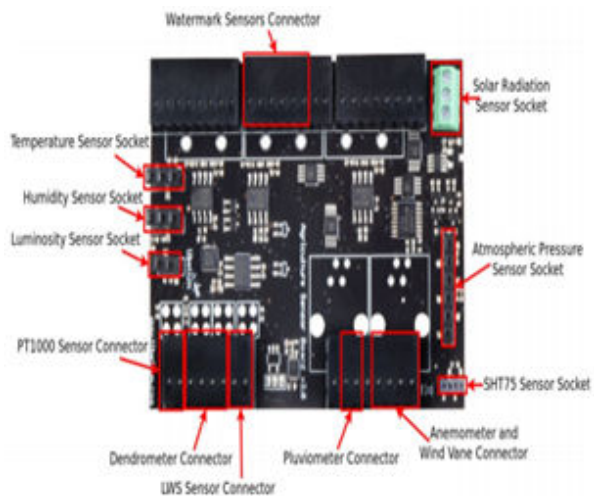

Fig. 2 Waspmote Agriculture Sensor Board PRO

Considering the limitations related to MADS [12], the Perceptory tool was preferred. This tool that is able to be integrated into the Engineering Software Workshop (ESW) Visio, offers more effectiveness in the visual modeling of Spatial Data Bases (DBS) and the basic of spatio-temporal data [9], [13]. Perceptory was developed starting from a standard Directed-Object formalism. Later, it was undergone and was enriched to support the spatial reference and to take into account the norms ISO-TC211.

In this research, spatial Modeling GeoUML with the Perceptory tool using as a model "Real-time Spatio-Temporal Data model" [14] already carried out by UML language was applied. The model presented in Fig. 3 is an enhanced version of the model described authors previous works [15] with a slight modification. The parts that were added describe mainly the aspects of monitoring environment.

In this model of the Real-Time Spatio-Temporal Data (RTSTD), a structure of the space-time data in real-time as well as the interaction of their static, spatial and dynamic characteristics is presented. The data collected by a sensor node (fixed or mobile) are called according to their locations and their dates of acquisition. The sensors are located in the

same medium of observation, which allows having concomitant data of different types (air temperature, air humidity, etc.).

The data collected from the sensors are integrated primarily into visualization and management systems of the phenomenon. Besides, the system will be automatically configured during the detection of the event. These systems will be set up to able to adapt to users having diverse objectives and degrees of competence. Here as low incomes farmers are targed, the objectives are: monitor climate data to inform the farmer about climatic conditions representing forcing conditions for his crop and his livestock; another objective calibrating irrigation inputs using the information provided by the monitoring of soil moisture. To take account for the various degrees of competences, thresholds accompanied by various color levels and figures will be used.
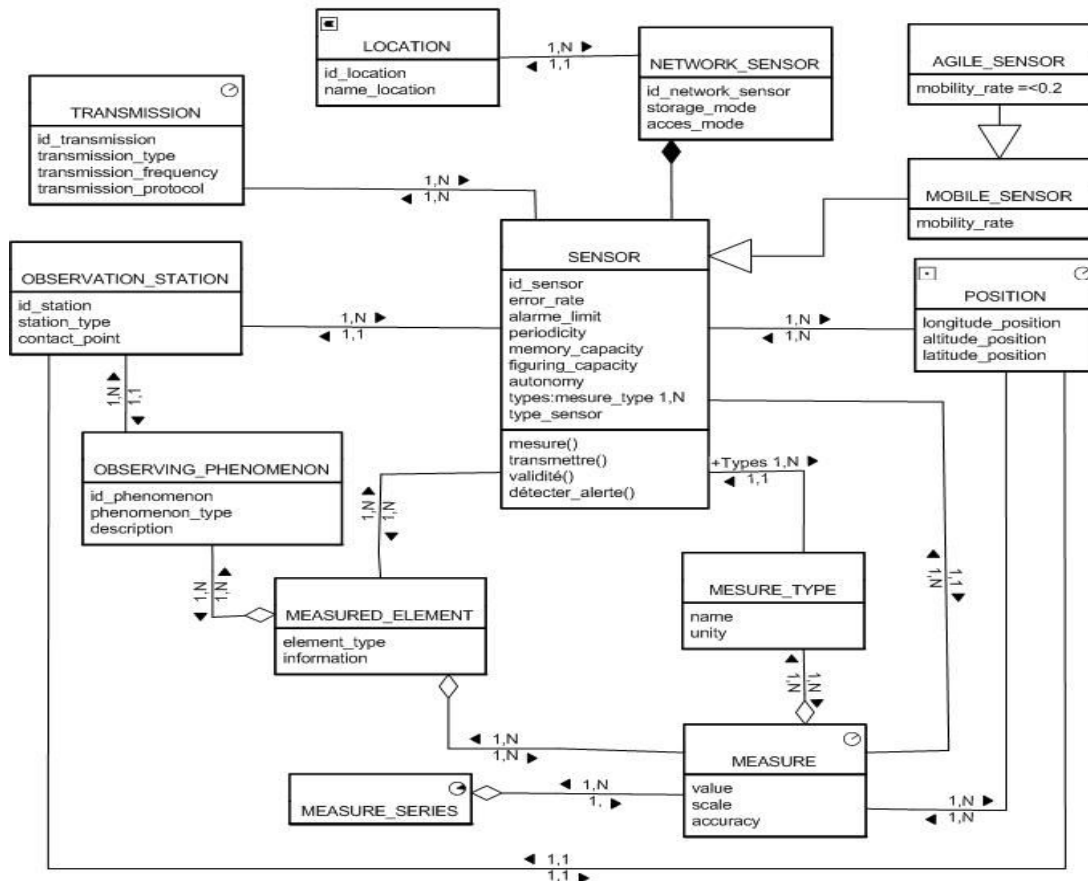

Fig. 3 Real-Time Spatio-Temporal Data Model (adapted from [16])

III. PROPOSED SOFTWARE ARCHITECTURE

A. Architecture

In this work, a solution based on an Orientated Architecture Service (OAS), which allows the integration of Geographical Information in other information systems is adopted. It will also be based on the components of a Web customer Flex. The architecture of the system will be made up of the three following sections illustrated in Fig. 4.

Module 1: The acquisition of information (air temperature and humidity, solar radiation, precipitation, wind speed, etc) is operated. It consists in determining the phenomena to observe as well as the elements to measure that are collected first using sensors and then sent to a database via a secure connection configured between the database and the gateway.

Module 2: A server of geographic database that allows the storage and the management of spatio-temporal data are implemented. The storage and management will be in real time as well as periodically (decadal resolution), depending on the situation. In order to ensure the acquisition of information while avoiding its loss, this module allows some users, called Heavy Users, to edit (import and export) and update the descriptive and vectorial data to the data already collected. Afterword's, these data will be put into users' disposal.

Module 3: A GIS-WEB that allows a safe access to the various layers is put in place. This module permits the post clients, called Light Clients (because the use web mapping), to request the database with spatial or

alphanumeric reference and to visualize the data of the sensor networks in a Web environment.

It will be based on the use of a Web server and a Server of application according to the standards of the market for the distribution of users and loads by ensuring a great availability.

The module will be also based on the use of a Cartographic Server of data certified by Open Geospatial Consortium that respects ISO/TC 211 standards for handling and posting the diffusion of geographical data in a Web environment. The architecture of the proposed model is demonstrated in Fig. 4.
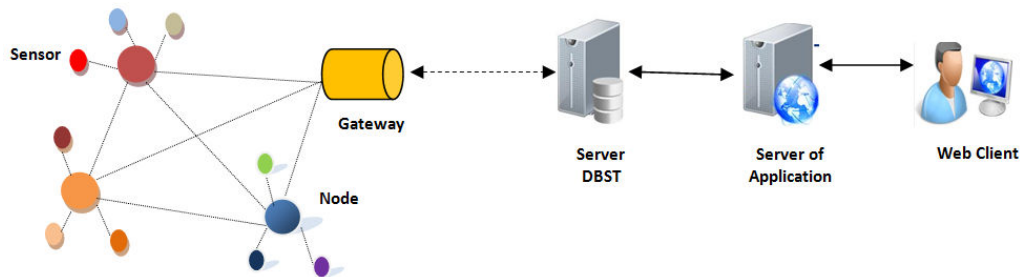

Fig. 4 Architecture patterns of the system

B. Interface Application

On the other hand, the interface application in Fig. 5 allows visualizing in a Web environment the data of sensors network and enabling the users to consult the different observations sent by the sensors. Interactive interface represents a user who can directly select one of the sensors on a map, which can be accessed by pan and zoom or by browser to visualize their temporal distribution in an attribute table.
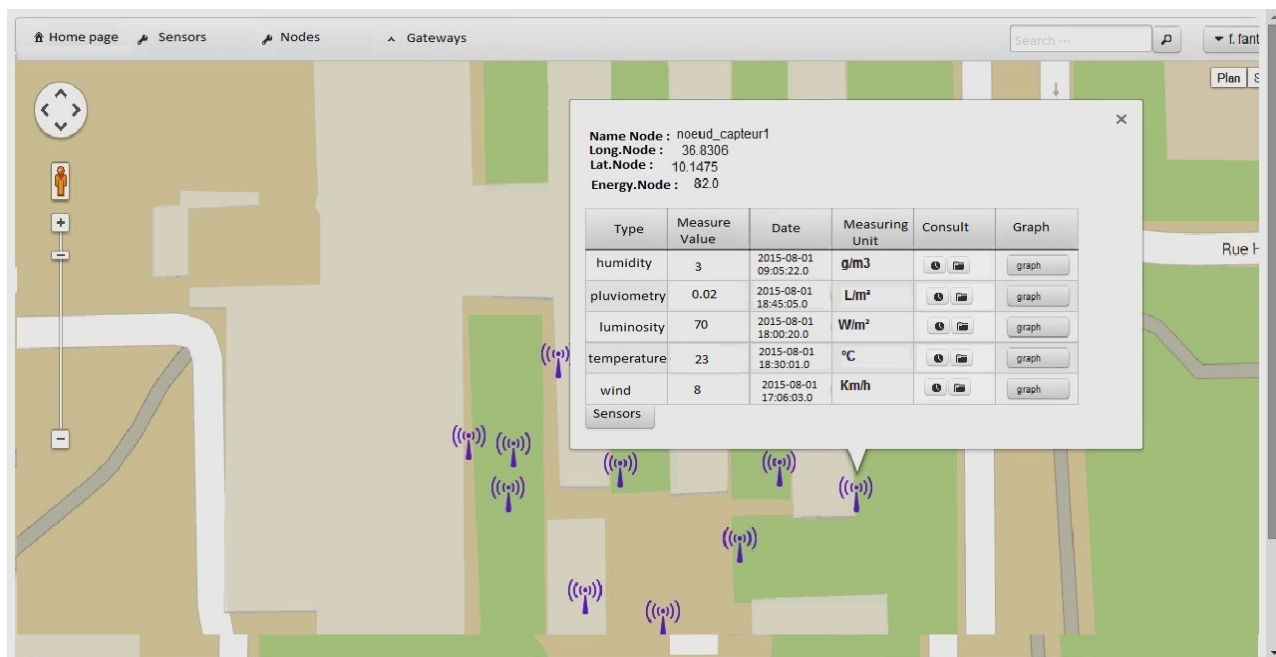

Fig. 5 Interface posting of the sensors (adapted from [16])

Interactive interface of Fig. 6 represents a user who may view the collected data in a graphical representation by clicking on the graphic button; graphics display the variation of the data in real time or the target time spell (like the decade or the month). The data can be displayed in a numeric representation if the tab button has been clicked.

IV. CONCLUSION

In this paper we proposed solutions to the problems related to the drought surveillance in order to help either low or high incomes farmers to face drought. This technology is nowadays available but it is expensive. This project aims to develop a pilot study and to address the equipment monitoring to selected low incomes farmers. The proposed system of information centralizes the relevant spatiotemporal data using the wireless sensor networks. These technologies, fixed or mobile, allowed the multiplication of acquisition resources of spatiotemporal data. Moreover, they can be provided with a capacity of calculation in order to condition data for time

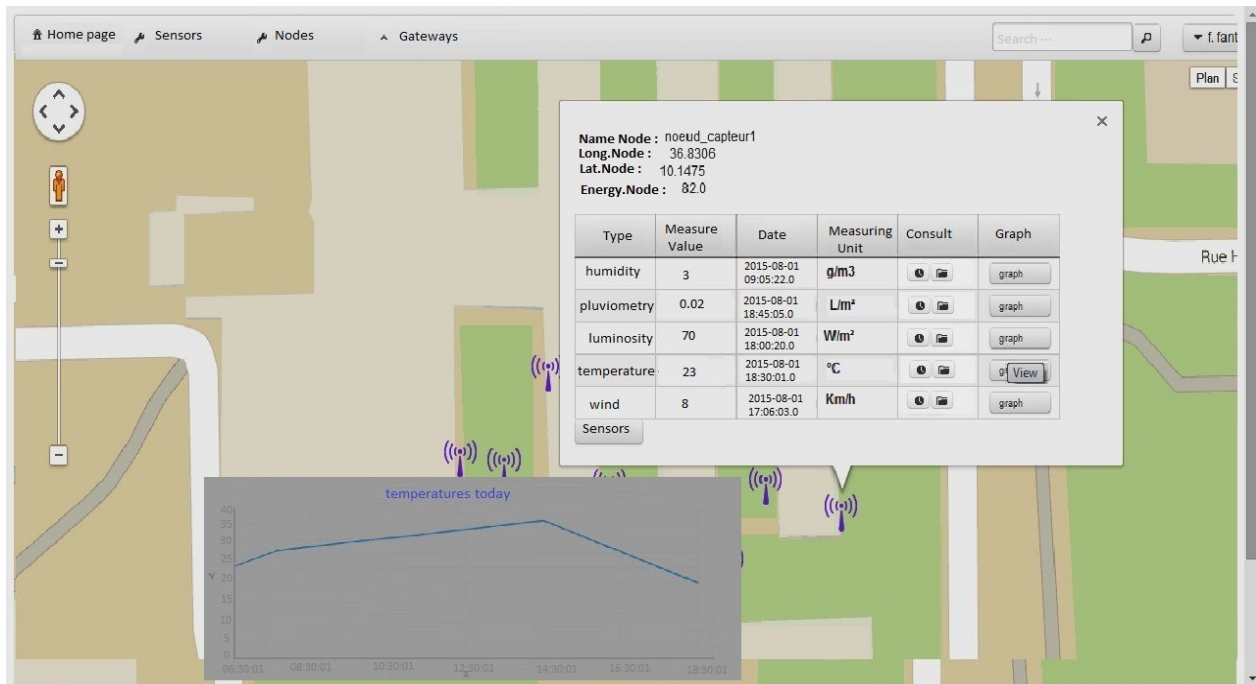transfer optimization, energetic consumption management and relay insurance in a specific network.

Fig. 6 Interface consulting different information sent by the sensor node

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