Inicio network design for data transmission of weather sensors

Juan Reyes-Coellar, Mauricio Tene, Darwin Astudillo-Salinas, Gabriel Barros, Lizandro Solano-Quinde

DEET, Departamento de Ingeniería Eléctrica, Electrónica y Telecomunicaciones, Universidad de Cuenca, Agustín Cueva, Av. 12 de Abril, Cuenca, Ecuador, 010150.

Autores para correspondencia: juan.reyesc@ucuenca.ec, fabian.astudillos@ucuenca.edu.ec, lizandro.solano@ucuenca.edu.ec, gabriel.barros@ucuenca.edu.ec, efren.tene@ucuenca.ec

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ABSTRACT

To acquire information from the environment in a large area of the south PROMAS[1] has deployed weather sensors in a large area to acquire information from the environment, which must be collected from the remote locations and transferred to data center? Currently, the data collection is done manually, which means that PROMAS staff needs to go to the actual sensor location and download the data, which involves time invested and recurring costs for them. Therefore, in this work, a network design to automate the data collection and transfer is proposed. The goal is to get data with the lowest possible latency, so data is available as soon as information is generated. The proposed network transfers data using the standard IEEE 802.11 or IEEE 802.15.4, which involve the analysis of three fundamental parameters as distance, energy and deployment cost.

Keywords: IEEE 802.15.4, IEEE 802.11, PROMAS, weather sensors, WSN.

RESUMEN

El PROMAS ha desplegado sensores meteorológicos para adquirir información del medio ambiente, esta información es recolectada en lugares remotos y transferida al centro de datos. En la actualidad, este proceso se realiza de forma manual, lo que significa que el personal de PROMAS se desplaza a los distintos lugares donde se encuentran los sensores y descargan los datos, lo cual implica una inversión de tiempo y recursos, de manera recurrente. En este manuscrito, se propone el diseño de una red que permita recolectar automáticamente los datos adquiridos a través de los sensores. La meta es conseguir que los datos estén disponibles con la menor latencia posible, de manera que estos se encuentren disponibles tan pronto como se generen. La red propuesta transmitirá los datos usando el estándar IEEE 802.11 o el IEEE 802.15.4, lo cual requiere el análisis de tres parámetros fundamentales como la distancia, la energía y costo de implementación.

Palabras clave: IEEE 802.15.4, IEEE 802.11, PROMAS, sensores meteorológicos, WSN.

1. INTRODUCTION

One area of great applicability in the last years is wireless communications, because of many factors, such as new data compression methods, standardization of technologies in a global level, more effective methods as media access, new routing protocols, etc. The advances in this field have gone in the same pace with the hardware development, which has helped to introduce wireless communications on a variety of application fields.

[1] PROMAS (Programa para el manejo del Agua y el Suelo)

PROMAS, to do research in the fields of water and soil, has deployed weather sensors in a large area to acquire data, which must be collected from the remote locations and transferred to a central location. Few years ago a first approach for automatic data transmission was implemented by the PROMAS, it was based on the *General Mobile Technology Packet Radio Service (GPRS)*. The main idea of this approach is to send a SMS message, containing information for each station data entry. This approach presented problems mainly due to message saturation as data is generated at a faster pace. However, it did represent the beginning of a search for different solutions to solve this problem. In this context, it is important to propose, analyze and implement an approach for automatic data transmission, supported by the appropriate theoretical basis (Ingelrest *et al*., 2010).

The proposed approach should be based on a network, in order to transmit the collected data acquired by the weather sensors. A wireless network for transporting data allows for resource optimization, both financial and human, as well as improving research by allowing access to data at the time that is generated.

2. OVERVIEW

Over the years, PROMAS have deployed a number of weather stations over the Paute River Basin area. Each station has one or more sensors with different measurement capabilities. To store the data, these stations incorporate data loggers with limited storage capacity. Currently, the stored data is collected manually by the staff of PROMAS, which requires people to go to the station location and download the information, this is the mechanism nowadays. Then, after picking all the information as a plain file in a flash memory, it is saved on servers located in the main office of PROMAS and finally the data is processed.

3. PROMAS HARDWARE

PROMAS has arranged several weather stations, which are composed of different types of sensors, each one for measuring a particular parameter. It is important to know the characteristics of this equipment to determine the way in which measurement is performed, and the data type is delivered. This knowledge helps to choose the way in which the information can be accessed through the proposed network. It has sensors to measure parameters such as rainfall, temperature, wind speed, air pressure, among others. They are currently working with various brands of sensors as Davis, Baro and Campbell (Renault *et al*., 1991).

- **Pluviometer:** A pluviometer is an instrument that measures the amount of water falling on a place over a period time. It has an internal mechanism that allows data collection.
- **Level Sensor:** The level and temperature sensor implemented is a *Baro-Diver*. It is a data logger consisting of a pressure and temperature sensors. It is used to measure the level of water and to store the data in an internal memory.
- **Weather station:** A weather station, depending on its configuration, can obtain data about temperature, humidity or wind. The model used is the Vantage Pro2 weather station.
- **Wind sensor:** The wind sensor measures the horizontal component of the wind speed. It has a weather vane to determine wind direction. This sensor is considered robust, even in months when it has to face to extreme conditions. Currently this weather station keeps records every 60 minutes.

4. NETWORK DESIGN

The Paute River Basin is located in the southern part of the country north between “Portete” and “Curiquingue” knots to the south, and between eastern and western mountain ranges east of the Andes to the west, with an area of 5000 km^2. This is the area of interest, where PROMAS have deployed sensors and depending on their specific location, the type of measurement varies (Reyes *et al*., 2014), which is taken into consideration when doing the network design.

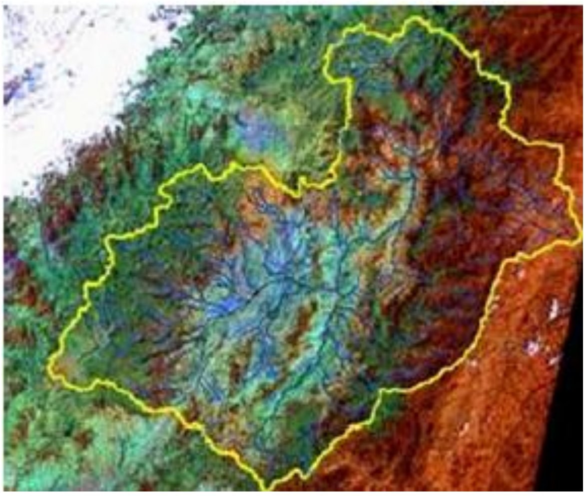

Figure 1. Network location.

4.1. Network requirements

- **Network Usage:** The target of the network is to provide a way to transmit the collected data to the PROMAS.
- **Network data:** The inspection of the sensors has been performed and managed by PROMAS. Data provided by the sensors is stored in the datalogger as text files.
- **Network availability**: Availability is defined as the time that the network operates without interruption. The ideal availability of a network achieves the “five nines”. It is expected that 99.999 % of the time the network is available, which means that in one year an acceptable down time is 5 minutes and 15 seconds at the most.
- **Scalability:** Since the PROMAS plans to deploy more stations during the next years, the network scalability is important. In this context, the network must be designed to support a planned growth, and also must have the ability to migrate to other technologies in the future.

4.2. Types of weather stations

Table 1 presents the types of weather stations that PROMAS have deployed, and therefore, the proposed network will have to provide support for them.

Table 1. Detail of the weather stations.

Type	Location
Rainfall	Bermejos alto, Bermejos bajo, Bermejos medio, Calluncay, Emac, Aguarongo, Turupamba bajo, Caldera, Baños, Huagrauma medio, Huagrauma alto, Ningar bajo, Ningar medio, Marianza bajo, Marianza alto, Marianza pinos.
Weather	Quimsacocha 1, Quimsacocha, Marianza, Huagrauma.
Hydrological	Mazán pinos, Mazán pajonal

5. NETWORK FEATURES

This section describes the key features of the network design that makes possible communication between sensors and data transmission. The network design is based basically in two technologies which are IEEE 802.11 and 802.15.4.

5.1. Network proposal using IEEE 802.11

Given the requirements, it has been determined that the network design should be based on the IEEE 802.11 protocol, known commercially as WiFi. This technology has been chosen because of the following reasons:

- WiFi is an economical alternative to deploy the PROMAS infrastructure, taking into consideration that there is not infrastructure deployed at the time of this writing. It is standardized and there are plenty of equipment supporting it, which makes WiFi affordable at a reasonable price.
- IEEE 802.11 standard can cover long distances depending on the gain of the antennas and transmission power, which is needed given the distances between concentrators and stations.
- Data loggers store the data on plain text files which can be large, depending on the number of collected data. That data requires an acceptable transfer data rate. The transmission data rate of WiFi is ideal for such applications.
- It is needed to consider the topology, addressing and routing. WiFi can be configured in a star topology and equipment support different routing protocols thereby can guarantee an efficient network.

<u>Process design</u>

It has been performed an inspection to weather stations to verify their real conditions, and the way that data collection is performed, as it is shown in Figure 2 (Marianza Alto station).

Figure 2: Data collection.

After the inspection, it has been conducted a verification of coordinates of the stations, and it has been sought the best alternative regarding the topology. It has been found that there are stations deployed in relatively nearby sectors, therefore, it has been considered to build a star topology gathering the nearby stations in one concentrator.

Also, it has been considered working with the standard 802.11 at the 5GHz band, because there is equipment approved for working in this frequency band in our country. This equipment is operating at that frequency and gives a good performance.

After selecting the operating frequency, one of the biggest challenges was choosing the points where the concentrators need to be located. Since they operate at a high frequency, line of sight is required between stations and concentrators, which minimize the number of links of the network.

There are two alternatives to connect the network to PROMAS. The first alternative is a wireless link with the same protocol from the concentrator, this alternative was discarded because in urban areas exists a proliferation of links that use the same spectrum space of the designed network, and it is likely that interference will degrade the quality of link and in the worst case communication cannot be performed. To solve this problem ETAPA EP provider was inquired about the places where infrastructure is available. The idea is to use the infrastructure of ETAPA to get a link to PROMAS. From the entire list of points of ETAPA EP, the following locations were selected: Bueran, Cruz Loma and Nero, because those sites can be reached with a direct link from the concentrators. Then, all stations transmit their data to the concentrators, and from here the data is sent to the PROMAS through the network of ETAPA EP.

The next step was to calculate the link margin for each of the raised links, taking into account the characteristics of the equipment, and geographical conditions. With this procedure, it must be ensured that the links are available for the worst case (Ramirez *et al*., 2014). The proposed structure for the network is shown in the Figure 3.

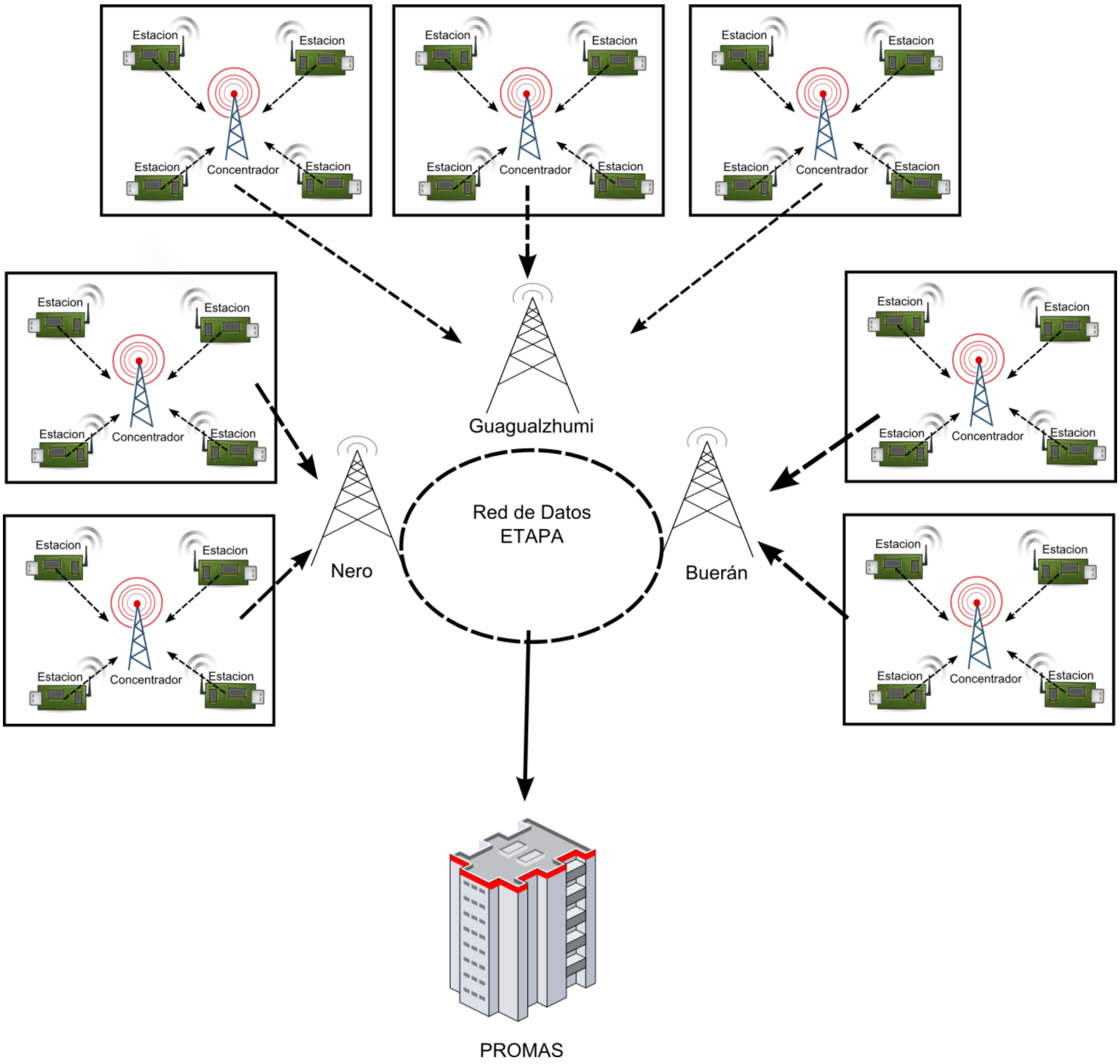

Figure 3. General structure of the network.

Interfaces between elements of the hardware

Stations

The sensing devices have a data logger to store the acquired data; however, they do not have the ability to connect to a network (Ingelrest *et al*., 2010). Hence, it is necessary to change the data logger by a module Raspberry Pi, which is used as data logger and a network connector. Raspberry Pi basically is an open source plate of small size, low power consumption and low commercial cost. It runs a Linux operating system that provides all main functions of a normal computer. Additionally it has analog and digital ports for several applications (Electrocomponents, 2010). The purpose of this device is to provide an interface between the sensor of the weather station and the transmission network. It collects the data from station, stores data in memory, and provides an IP address to connect to the network. The programming environment for additional applications is Python. The application can control for example the time interval to store information, the format in which data is stored, etc.

Access Point (AP)

The Raspberry Pi has an Ethernet port. An antenna is connected to the Ethernet port. It makes the link with the AP that provides the network access. The addressing of the network will be explained in a later section.

Access to the data

Once defined de access network, it is needed to define the application to transfer the data. Each network element has its own IP address, the first alternative is to implement a SSH server on each Raspberry Pi and a client at PROMAS. The stored data in the memory of the module is transferred using this application. It can be implemented any file transfer protocol supported by the application layer of the OSI model. The next alternative requires the installation of a web server over one of the Raspberry Pi. All the stations access to server through their IP address, so each censed data is transmitted immediately to the server. The server is responsible for storing and retransmitting the data to the PROMAS (see Figure 4). The disadvantage is that this single station is hot spot of the network and has to have a large memory to store information coming from all the stations.

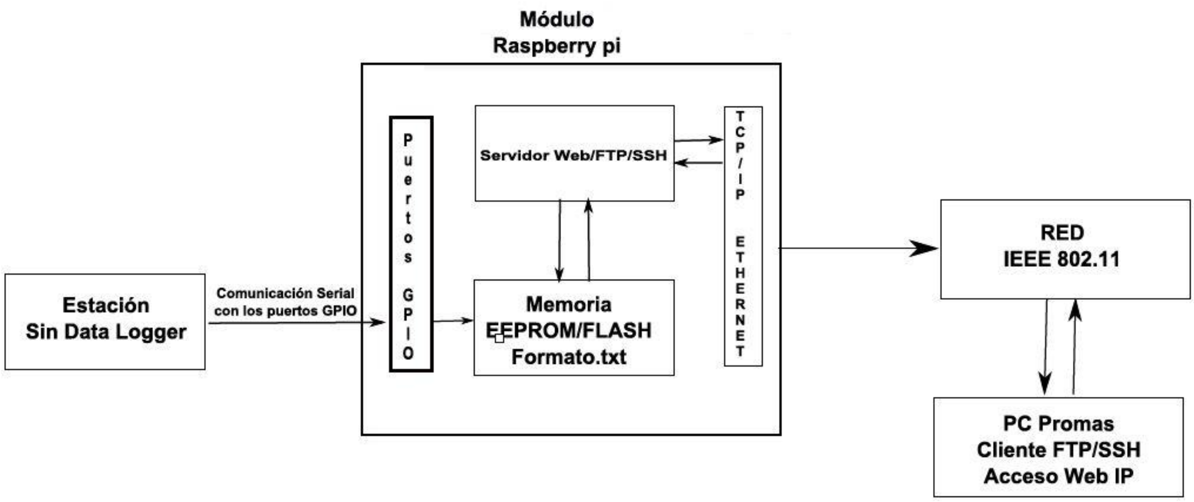

Figure 4. Interaction from Raspberry Pi module to the network.

5.2. Calculation of links and profiles

The links are described according to the concentrator to which they belong. There exist a number of stations associated with each concentrator. There are a significant number of links that have long distances. The equipment used for those links are different from the short links. All the information of the link budgets and the profiles is presented on Reyes *et al.* (2014).

5.3. Network proposal using 802.15.4

The previous section introduced the reasons for establishing an 802.11 network-protocol based, however, there is also the possibility of using the standard 802.15.4, commercially known as ZigBee. The main parameters to choose a particular wireless technology, such as: topology, distance of the links, needed bandwidth, and the cost of equipment, are analyzed next.

- The ZigBee technology has an advantage in connection, since it supports several types of topology and it is highly used for wireless sensor networks. It is used to make a mesh network to connect all sensors. The star topology is required for the proposed network design, and ZigBee is a good fit for that topology.
- The transfer data rate available of ZigBee is 250 Kbps, which is enough for transmitting the data generated by sensors of PROMAS.
- ZigBee is a cheap alternative and in recent years its implementation is growing, despite the low power consumed by the devices. It can reach distances up to 12 km depending on the antenna gain is chosen.

Process design

In this case, a direct link to the PROMAS's building using ZigBee was considered. Although, ZigBee operate at a frequency of 2.4 GHz, it is possible to achieve a good connection even in environments with interference of WiFi. Another aspect of this technology is the dynamic method for channel selection for data transmission. In network design was considered links smaller than 13 kilometers. The capacity of the ZigBee is used to create a mesh topology. Using this topology the remote stations can be accessed.

The equipment needed is an element that acts as coordinator, a station configured as end device, and a concentrator configured as router mode. The next step after selecting the equipment is to calculate the link margin, taking into account the characteristics of the selected equipment.

Interfaces between elements of the hardware

Sensor - Transmitter

An interface between the sensing device and the transmitter is required. The data is sent from the station to the sensing device through that interface. It is recommended that an Arduino module is used for this purpose. The Arduino sends the received data using a transmitter, which is the module PRO ZB XBEE.

Station - Router

The device associated with the sensing device must be set up as end device and it has to be specified the address of the coordinator of the destination network. The transmitter links to the router by location. The same module can be configured as router. There exist studies where a link of 13 km is achieved, using other types of antennas (Ramirez *et al*., 2014). Those antennas have to operate at the ZigBee frequency, and it has to be a bigger gain.

5. CONCLUSIONS

In this manuscript, the design of a wireless network that connects different sensing devices has been proposed. In this context, wireless networks are crucial for data transmission from remote places. These remote locations are reached thanks to the usage of different protocols and technologies. Depending on the application, the network design has taken into account the power requirements, distance and available bandwidth. The sensing devices and network elements allow to establish guidelines and constraints for the design of specific scenarios, with the goal of reliable transmission of the data.

It is important to notice that the designed network uses wireless technologies whose scope does not depend on factors such as mobile coverage. Finally, the implementation of this network will allow automatic data transmission from the weather stations of PROMAS, which will benefit, in the medium and long term, both economically and operationally.

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