IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 13, Issue 1, Ver. I (Jan.- Feb. 2018), PP 04-13
www.iosrjournals.org

Remote Monitoring System of Automatic Rain Gauges using Machine-to-Machine application

Daisy Cañiza[1], Felipe Mitjans[2]
(Polytechnic School/ Asunción National University, Paraguay)[1]
(Engineering School/Asunción National University, Paraguay)[2]
Corresponding Author: Daisy Cañiza

Abstract: *This article describe the development of a prototype of an automatic system that is able to acquire, process and store the amount of rain precipitated. Using an automatic rain gauge of high precision and low cost, it has been made, from March to November 2013, a descriptive research with application component supported by field tests. As a result it was constructed a double tipping bucket rain gauge with data acquisition system employing an Arduino module and a GSM / GPRS shield. This ensemble sends data to a control center, which runs an application, developed on Labview platform. This application has the ability to display data in real time and store it in a database in the direction of record historical thereof. It is concluded that the implementation of the proposed system can contribute to automate the process of acquisition, processing and storage of rainfall data so that they can be used as needed. It is recommended to use the same system to monitor different meteorological variables.*

Keywords: *Rain Gauge, Data Acquisition, LabVIEW, Data Center, Arduino, Communication Networks, Communication Systems, GSM/GPRS, Graphical User Interface, Database, World Meteorological Organization.*

Date of Submission: 05-01-2018 Date of acceptance: 25-01-2018

I. Introduction

Meteorological conditions have a great impact on human activities. These activities in the social and/or economic sectors are affected by atmospheric events. The relationship between meteorology and human activities is one of the factors that determines the success of the results. Currently, a reliable rainfall database is not available in Paraguay, as the systems and / or method used to collect rainfall data do not comply with the standards and recommendations of the World Meteorological Organization (DINAC web page, 2013).

The project aims at accurately collecting rainfall data and generating historical database, implementing a data acquisition, processing and storage system; in order to make use of this information according to the needs of those involved.

The research refers to three main parts, the first part consists of the design of an automatic rain gauge at a lower cost, compared to one commercialized in the market. The second part refers to the determination of the best transmission medium in order to design an interface for transmitting the data already processed to an application that makes the information available in a database. The third part consists of the design of a central station for the processing and storage of data and a terminal with dedicated software, so that users can view the information in real time, and can access the database to use the Rain statistic information.

The purpose of the research is to have accurate and reliable data that can be used according to the needs of the beneficiaries.

This project aims to design a prototype of an automatic system for collecting the amount of rainfall and the transmission to a data center for the storage and management of data.

Using an automatic double tipping bucket rain gauge, constructed under the recommendations of the World Meteorological Organization (WMO) and a magnetic sensor that generates pulses with each tilting of the buckets. This allow the amount of rain to be counted. These generated pulses are received by one of the digital inputs of the Arduino UNO that processes the acquired data. This information is included into a metadata frame to be transmitted via SMS by the GSM module. The GSM module located in the control center acts as a data concentrator, receiving information from all the transmitters belonging to the network.

The Arduino UNO, which works in conjunction with the GSM module of the control center, sends the data through a serial connection to a server, where it is storage and requested by the software designed on the Labview platform. This software is able to display the amount of precipitation in the different localities where the rain gauges are installed, also permits to remotely monitor the operation and the current state of rain gauges. The information is stored in a database that can be accessed for queries and comparisons on rainy days.

II. General System Model

The system of remote monitoring of automatic rain gauges that is presented in this project is composed of five main components that work together to fulfill the main goal of the project. These components are: the rain gauge network, the data acquisition, processing and transmission system, the GSM network, the reception system, the GUI and data storage.

The schematic of the conceptual design in which it is possible to contemplate how the five components work together, is shown in Figure 1. When it rains and a certain amount of water accumulates in the buckets, it is overturned, causing the closing of a magnetic sensor. The pulses that are generated by the oscillation of the buckets are sent to the data acquisition, processing and transmission system. This system is composed by an Arduino UNO and a GSM module. The information is sent via GSM to the GUI and data storage system.

The reception system is composed by an Arduino UNO and a GSM module. The data is sent to the PC through a serial connection, in which the software designed in the LabVIEW platform is installed. The software displays the processed data and the information acquired by the system and it is stored in a database.

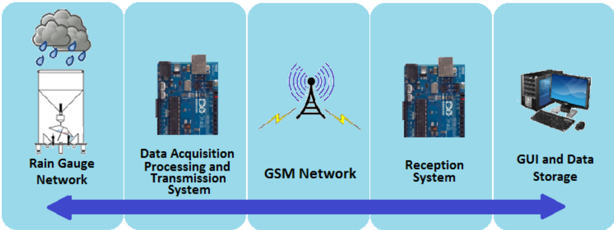

Figure 1. General System Model Diagram. Own Elaboration, 2014.

III. Rain Gauge

The Guide to Meteorological Instruments and Methods of Observation from WMO states that the rain gauge with discharge pipe or double tipping bucket is particularly suitable for automatic weather stations, as it lends itself to the digital methods.

For this project, it was chosen the double tipping bucket rain gauge, built in stainless steel due to the high corrosion resistance of this material, it is highly resistant to oxidation.

The catchment area will measure 200 cm^2. Most commercial rain gauges use this measurement. What is recommended by the WMO in its Guide to Hydrological Practices is a catchment area between 200 cm^2 and 500 cm^2. A 0,2 mm of resolution was selected for the rain gauge, which is the minimum resolution recommended by the WMO in its Guide to Hydrological Practices. In addition, most commercial pluviometers adopt this resolution.

The rain gauge will have a reed switch to detect the overturning of the buckets. The reed switch is activated when the coil is energized with a magnet, and closes the contacts that are into a vacuum glass tube. The coil, which is normally open, closes its contacts when the buckets with a magnet move from side to side.

Rain Gauge Characteristics

In order to have comparable measurements, standardized rain gauges should be used. The WMO recommendations should be taken into account for their construction.

The most important requirements according to the WMO when constructing a rain gauge are the following:

• The edge should have a sharp edge, drop vertically on the inside and be abruptly beveled on the outside.
• The catchment area must be accurately known and the construction of the device must be such that it does not deform.
• The funnel must be designed in such a way as to avoid any kind of splash; This can be achieved by giving depth to the vertical wall and a fairly steep inclination to the proper funnel (at least 45º).
• The pipe of the funnel must be narrow and well protected from radiation to minimize water loss through evaporation.

Operational requirements.

The operational requirements according to the WMO are as follows.

• Range

The operational range of the dimensions for observations of total amount of liquid water is: 0 to> 400mm (WMO, 2008).

• Resolution

The resolution recommended by WMO for synoptic meteorology and climatological observations on the amount of precipitation is 0.2 mm.

• Accuracy
According to the WMO Guide to Hydrological Practices, the recommended accuracy depends primarily on the intended use of the measured data, the potentially available instruments, and the available financial resources. Therefore, it can not be a constant value, but a flexible range. The following figure contains recommended accuracy levels as a general guide for observing instruments and methods.

Precipitation (amount and form)	3–7%
Rainfall intensity	1 mm h^{-1}
Snow depth (point)	1 cm below 20 cm or 10% above 20 cm
Water content of snow	2.5–10%
Evaporation (point)	2–5%, 0.5 mm
Wind speed	0.5 m s^{-1}
Water level	10–20 min
Wave height	10%
Water depth	0.1 m, 2%
Width of water surface	0.5%
Velocity of flow	2–5%
Discharge	5%
Suspended sediment concentration	10%
Suspended sediment transport	10%
Bed-load transport	25%
Water temperature	0.1–0.5°C
Dissolved oxygen (water temperature is more than 10°C)	3%
Turbidity	5–10%
Colour	5%
pH	0.05–0.1 pH unit
Electrical conductivity	5%
Ice thickness	1–2 cm, 5%
Ice coverage	5% for ≥ 20 kg m^{-3}
Soil moisture	1 kg m^{-3} ≥ 20 kg m^{-3}

Figure 2. Recommended accuracy expressed at the 95 percent confidence interval. (WMO N° 168, 2009)

Design and Construction of the Rain Gauge
For the design and construction the WMO recommendations already mentioned were fulfilled.
• Case

The casewas constructed in stainless steel with the measures that can be observed in figures 3 and 4. All the measurements are in mm. The catchment area, as explained before, is 200 cm^2 and it is circular. Therefore, the diameter length can be calculated through the formula r=√((Circunference area)/π)=7.98 cm and d=2r=15.96 cm. This means that the diameter of the catchment area must have a length of 15,96 cm. Figure 4 shows a top view of the case.

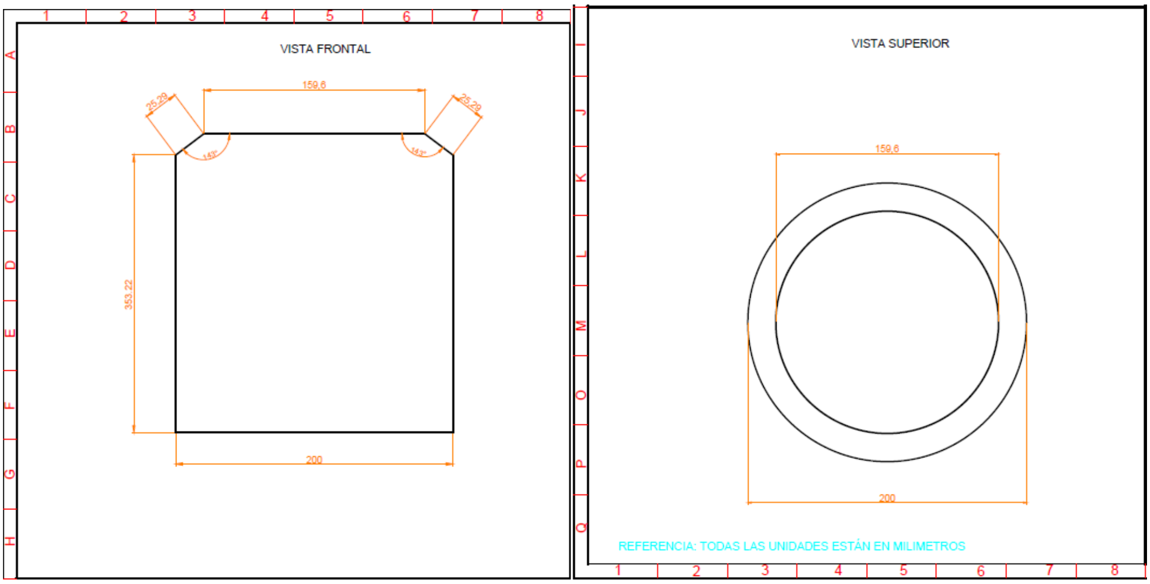

Figure 3: Front view of the case. Own Elaboration using Software AutoCAD, 2014.

• Buckets
The bucketswere constructed in stainless steel, because of the high corrosion resistance of the material. The measurements can be seen in Figure 5.

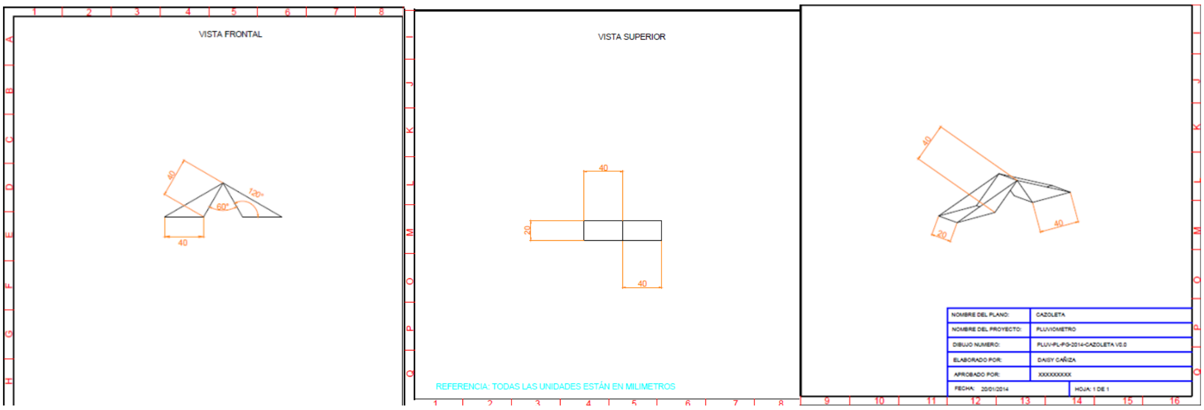

Figure 5: Front, top and general view of the buckets. Own Elaboration using Software AutoCAD, 2014.

Calculation of the water volume.

The rain gauge has a resolution of $0,2l/m^2$. This means that $0,2l$ in $1m^2$is the minimum precipitation of water that can be detected by the rain gauge. The catchment area is $200cm^2$, so to obtain a resolution of 0,2 $l$on a surface of $200cm^2$, the volume of water that will fall will be 4 ml. This means that the buckets must move from side to side whenever that $4ml$ of water falls inside of one of them.

• Funnel

For calculate the height of the collecting funnel, it is necessary to consider the maximum rainfall intensity on the Paraguayan territoryIt is approximately 300 mm/h (information provided by DINAC).

This means that$300 \frac{l}{m^2}$of rain fallsin 1 hour and the catchment area is 200 cm^2.

The volume of water that will fall into the collector funnel, assuming it is a closed vessel and the water is stagnant is 6 liters. The funnel volume must be 6000 cm^3. And the collector area must be approximately 272 cm^2. The height must be approximately of 23 cm in order to make sure that the water does not exceed the height of the collecting funnel.

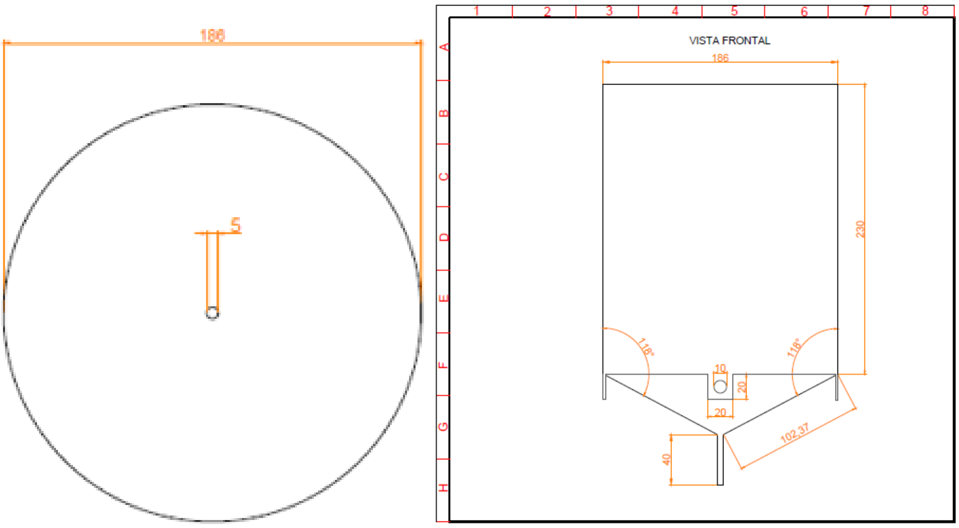

Figure 6: Top and front view of the collector funnel. Own Elaboration using Software AutoCAD, 2014.

General Layout

After all the calculation of the main parts of the rain gauge, the general layout it is shown in the figure 7.

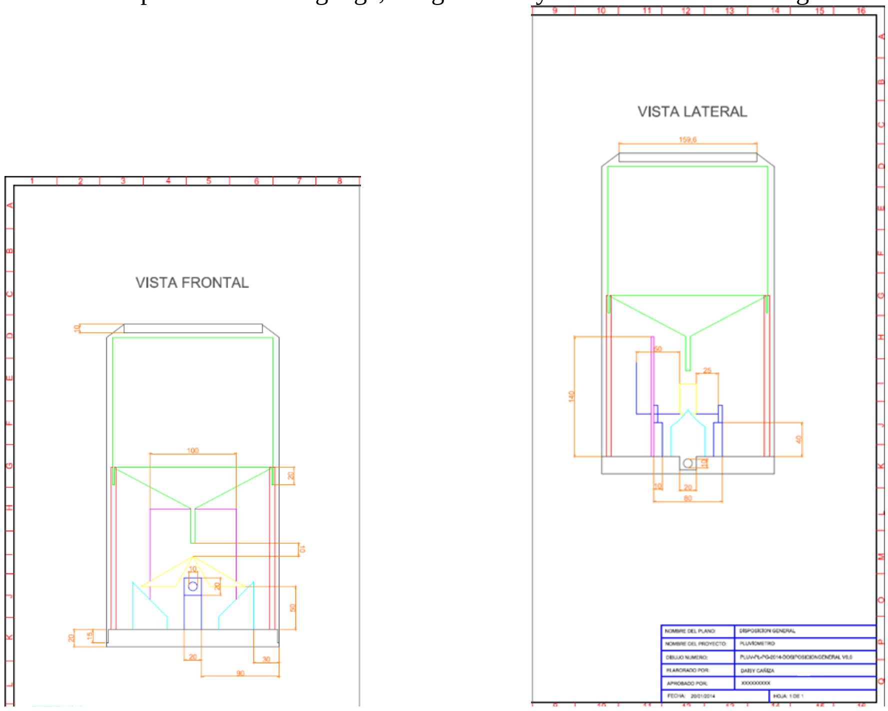

Figure 7: Front and side view of the Rain Gauge. Own Elaboration using Software AutoCAD, 2014.

IV. Data Transmission and Reception System

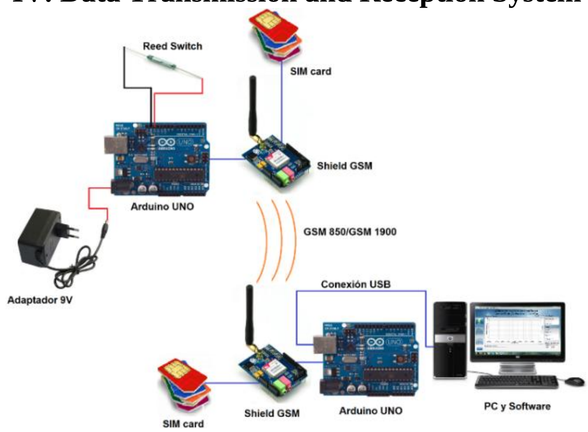

Figure 8: Architecture of the electronic system. Own Elaboration, 2014.

Data Acquisition

To measure the amount of rain falling, a normally open reed switch was used, which is activated by the presence of a magnetic field induced by a magnet that is in the holder of the buckets. The pulses generated by the tilting of the buckets caused by the rain are sent to the Arduino where the data is processed and then transmitted to the GUI and storage system via the GSM module. monitoring and management system located in the other corner.

Transmission and reception of data

For data processing an Arduino UNO was used, one of the pins of the reed switch is connected to pin 13 of the Arduino, every time the switch is activated, it indicates that 0,2 mm of rain has fallen. A GSM/GPRS shield was used for the transmission and reception of data using GSM technology along with a SIM card from a telephone company.

With the module, an antenna and an external power supply must be purchased, since the Arduino board cannot supply the current needed to power the GSM module. Therefore, the following items also were acquired for the project:• Antena GSM/GPRS.• External Power Supply.

The data transmission takes place every 10 minutes, this time is random, since the WMO stipulates that the frequency of the reading of the data depends on the application that is given to the system. The data is received in the Arduino that is installed in the GUI and storage system. For this prototype, it is connected via USB to a PC that contains the visualization software, the database and the storage disks.

Programming the Arduinos

For the programming of the Arduino UNO is used the free software Arduino 1.0.5 for Windows. To start programming, a sketchbook is created (written software programs) and then the programming is done in C language.The program is written, starting with the configuration of the variables to be used (variable type and initial value) and serial communication UART.Two programs were written for the proposed monitoring system, one for the Arduino data transmitter and one for the Arduino data receiver.Once the programs are completed, the code is loaded into the Arduino via the USB port.

Programming the Arduino data transmitter.

The pulses are counted for a period of time, which was defined in 10 minutes, then the frame to be sent is generated, it contains the metadata, such as the rain gauge identification number, the installation location, etc., This will be explained in more detail in next paragraphs. The frame is sent via SMS using the AT commands. In case the GSM network is not available (no signal), the data is stored in the Arduino buffer until the network is available, then the messages are sent.

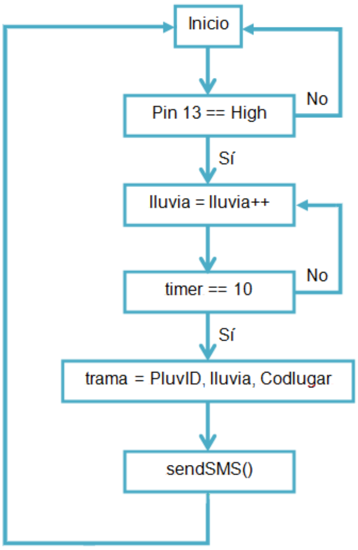

Figure 9: Flow chart of the transmitter Arduino program. Own Elaboration using Visio, 2014.

Programming the Arduino data receiver.

Iterations are used in order to verify if there are available data in the serial port, if there is some data, it is analyzed if it corresponds to a valid frame, then the frame is sent to the USB port of the PC for the processing and storage of the data.

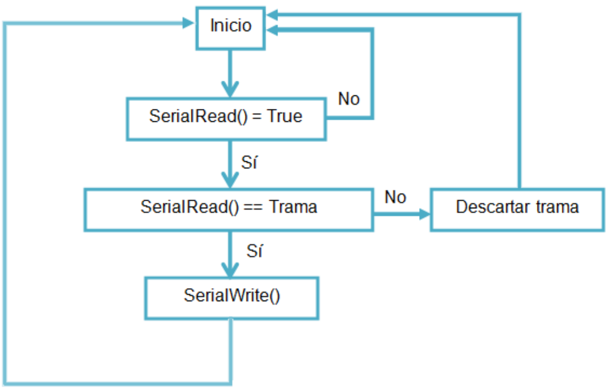

Figure 10: Flow chart of the receiver Arduino program. Own Elaboration using Visio, 2014.

Power System.
Two uninterruptible power supply solutions are proposed:

The first consists of an automatic battery charger connected to the mains, a 9V battery and a 9V regulator and the second by a 9V solar panel, a voltage regulator and a 9V battery.The first option corresponds to an automatic battery charger that is constantly connected to the mains and to the battery. This performs the function of recharging the battery when it needs it; Instead the regulator performs the function of controlling the voltage coming from both the automatic charger and the battery to the communication module. In view of the fact that most EMAs have a connection to the electricity grid, this power supply is the one taken as a reference in the realization of this project, leaving the second option as a solution for those stations where there is no connection to the Electric network.

Figure 11: Power system supply with backup battery. Own elaboration, 2014.

The solar panel performs the function of delivering energy and recharging the battery during the time it receives the photons from the solar radiation, the regulator instead performs the function of control of the voltage coming from the solar panel to charge the battery and from it to the communication module.

Figure 12: Power system supply with solar panel. Own Elaboration, 2014.

V. Data Visualization and Storage System

For the visualization of rainfall information, software designed on the LabVIEW platform, installed on a PC, is used. This application also allows to store the data in a database originated in an Excel worksheet. The data that are sent to the PC by the receiving Arduino are processed and stored by the software so as to have statistical records about the rain parameters. It also offers a dynamic and user friendly interface in Windows environment. It is composed of several windows through which different functions of the system can be accessed. In the main window a dynamic graph corresponding to the accumulated daily value of the amount of rain in mm and the intensity of the rain in mm/h can be observed.

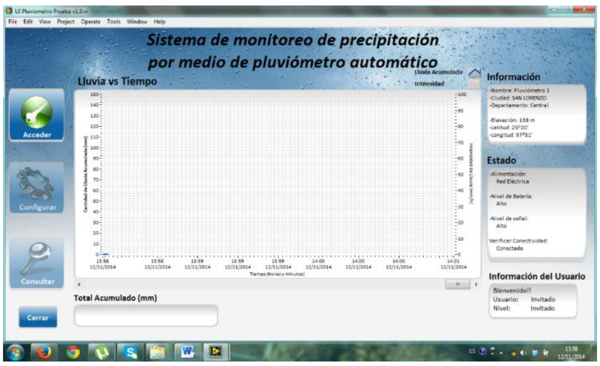

Figure 13: Graphical User Interface Main Window. Own Elaboration using LabVIEW programming platform.

Data Storage.

The maximum size of the file generated in Excel is 4 KB, if you generate 1 file per day for a year, the amount of information you will have is:4KB × 365 = 1460KB ≈1.5 GB.

This is roughly equal to 1.5GB of information stored per year.It is proposed to have two disks with 1TB (1000GB) capacity with RAID 1 (mirroring) configuration. This proposal has storage capacity for approximately 500 years and redundancy of information.

VI. General Implementation of the Project

As a first phase the project contemplates 34 rain gauges located in the meteorological stations of the Hydrology and Meteorology Department (DHM), using GSM as a communication technology through Machine to Machine application.

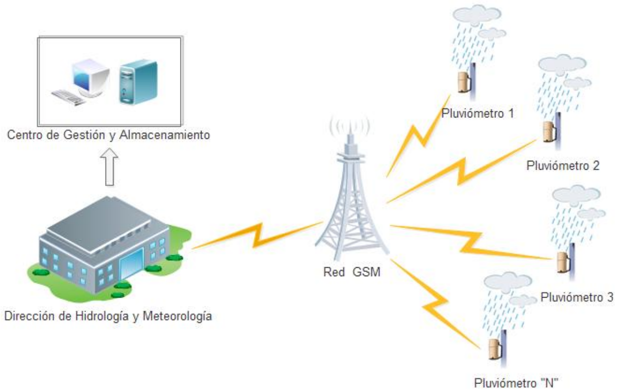

Figure 14: Rain Gauge Network Schematic Diagram. Own Elaboration using SamartDraw software, 2014.

Figure 14 shows the general scheme of the rain gauge station network. The topology adopted for it is the star topology. Each rain gauge using the data transmission module will communicate directly with the information management software that is located in the management and storage center in the Directorate of Hydrology and Meteorology.The contracted telephony company will provide the SIM cards for each communication module that will provide the service information and the network identification of each module.

Frame Format.

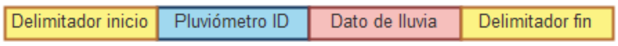

Figure 15: Frame format sent by the transmitter.

The frame sent by the transmission module is shown in figure 15. It consists of four fields:
- Start flag: The frame start flag indicates that the frame starts from it.
- Rain gauge ID: It is the identifier of each rain gauge. It consists of a code of 4 characters. This field allows to identify to which rain gauge the data that is received correspond, to store them in the database.
- Rain data: Rain data is transported in this field.
- End flag: The end of frame flag indicates the end of the frame.

This makes it possible to identify the data coming from each rain gauge by the software and thus correctly store the information in the database.

VII. Field Tests and Results

The field tests were carried out at the meteorological station located at the campus of the Polytechnic Faculty of the National University of Asunción. In this way the readings could be contrasted with the readings of the automatic rain gauge of the EMA, and the conventional rain gauge.The rain gauge was designed according to the proposed design, under the recommendations of the World Meteorological Organization.

Figure 16: FP-UNA weather station. The prototype can be observed next to the automatic rain gauge of the EMA. Own Elaboration, 2014.

Prototype Design

As transmission and reception modules, two Arduinos UNO were used as proposed in the design. Two SIM cards with GSM services from the company Claro were used to enable communication between them.

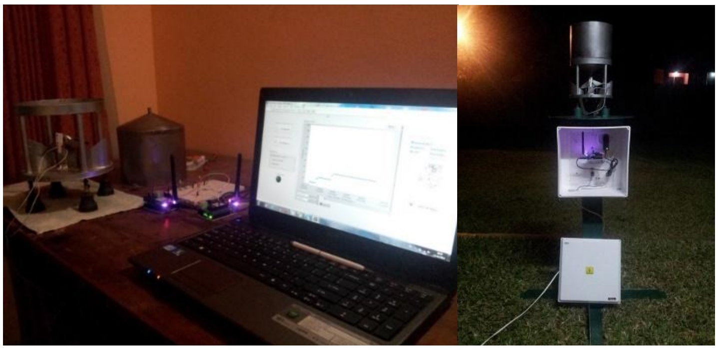

Figure 17: Management software with Arduino transmitter and prototype rain gauge with Arduino receiver. Own Elaboration, 2014.

Calibration of the rain gauge

As mention above, it was verified that 4 ml of water is equal to 0.2 mm of rain for the prototype.
100 ml of water equals 5 mm of rainfall. If we divide the amount of rain by the resolution of our prototype gives us a total of 25 tilts for this amount of water. The same criteria was applied to obtained the exact amount of water for 50 and 75 tilts. With these measurements the calibration screws are adjusted until the desired number of tilts are obtained.

Assembly of the prototype

Once all the resources, hardware and software were obtained, the prototype was assembled.The rain gauge was mounted on an iron base, which complies with the height measurement recommended by the World Meteorological Organization. In the meteorological station of the FP-UNA with the following coordinates:
• Latitude: 25º20 '• Length: 57º31 '• Elevation: 138 m.
An outdoor enclosure with IP 65 protection was used to protect the transmission module from weather agents.

Field Tests

Completed the assembly and all the necessary configurations for the demonstration of the prototype, as next stage, the calibration and connectivity checks are carried out between the transmitter module and the receiver. To do this, using the standard test specimen from the FPUNA meteorological station, random quantities of water are measured and then poured into the collecting funnel.
On November 11 of 2014a rainy event begins where the following results are obtained:

Date: 11/11/2014			
Hour	**Prototype**	**StandardRain Gauge**	**Diference**
15:00	14,6 mm	14,5 mm	0,1 mm
18:00	11,4 mm	11,5 mm	-0,1 mm

Table 1: Comparison of results between the prototype and the standard rain gauge. Own Elaboration, 2014.

VIII. Conclusion

Having reliable and accurate data and information about precipitation, allows the sectors affected by this meteorological condition to carry out studies and trends that help solve problems that have to date.

To detect precipitation, a low-cost, high-precision rain gauge was designed according to the standards established by the World Meteorological Organization. With the possibility of detecting these data by means of the rain gauge, a system for processing, transmitting and receiving the detected data was designed. An application that processes and displays the acquired data was designed in order to be able to monitor different rain gauges installed in different zones, in order to determine the amount of rain precipitated in different regions of the country. This application allows to create a historical database, whose information can be used for different types of analysis according to needs. In order to verify the correct operation of the system, it was field tested, subject to the various atmospheric conditions over which it will be operating;obtaining satisfactory results with which it was possible to validate the functionalities of the system.

Concatenating all these aspects, an automatic precipitation acquisition, processing and storage system was designed, using a low-cost, high-precision automatic rain gauge complying with the WMO recommendations, in order to automate the measurement system of Rainfall in Paraguay.

To manage the certifications of the corresponding authorities like the National Institute of Technology and Standardization and the Direction of Meteorology and Hydrology with respect to the rain gauge.

References

[1]. World Meteorological Organization. 2008. Guide to Meteorological Instruments and Methods of Observation. Part I - Measurement of meteorological variables. 2008..

[2]. Strangeways, Ian. 2007. Precipitation. Theory, measurement and distribution. New York : Cambridge University Press, 2007.

[3]. "Python Software Foundation," https://www.python.org/psf/."

[4]. WMO-No. 168 .GUIDE TO HYDROLOGICAL PRACTICES. Volume I Hydrology – From Measurement to Hydrological Information. I.2-18. Sixth edition.

[5]. R. H. Glitho, "Application architectures for machine to machine communications: Research agenda vs. state-of-the art," 7th International Conference on Broadband Communications and Biomedical Applications, Melbourne, VIC, 2011, pp. 1-5.

[6]. Organización Mundial de Meteorología. 1994. Guía de prácticas hidrológicas. Adquisición y procesos de datos, análisis, predicción y otras aplicaciones. 1994.

[7]. J. Kim-Sung and L. Ming, Computer vision based real-time information acquisition for transport traffic, IEEE, 2005.

[8]. Gonzálea G., Juan. 2002. EL SERVICIO SMS: Un enfoque práctico. 2002.

[9]. ETSI. 1996. GSM 03.40. Digital cellular telecommunications system (Phase 2+); technical realization of the Short Message Service (SMS) Point-to-Point (PP) . 1996..

[10]. 1996. GSM 04.08. Digital cellular telecommunications system (Phase 2+); Mobile radio interface layer 3 specification. 1996.

[11]. Basualdo B., Adriana. 2013. Manual de buenas prácticas para la generación, almacenamiento y difusión de información climática en instituciones y organismos del mercosur. s.l. : IICA, 2013.

[12]. Miguel Rueda Barranco, Socket: Comunicación entre Procesos Distribuidos, "http://es.tldp.org/Universitarios/seminario-2-sockets.html".

[13]. Anual MeteorologicalBuletin. 2012., 2013. "https://www.meteorologia.gov.py/publicaciones.php"

Daisy Cañiza "Remote Monitoring System of Automatic Rain Gauges using Machine-to-Machine application." IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) 13.1 (2018): 04-13.