Leveraging Inter-Institutional Connectivity to Facilitate Weather Data Transmission from Automatic Weather Stations in Uganda

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Abstract

The use of Automatic Weather Stations (AWS) for Environment monitoring by the Uganda National Meteorological Authority has increased massively over the past 15 years. This increase is mainly due to the savings in time, energy and money that are usually accompanied by the use of Information Technology to replace manual organizational processes. These stations collect various weather data and automatically transmit this data to a central repository, usually a physical server in a relatively remote location. The transmission of this data, in Uganda, is achieved primary by GSM/GPRS over the backbone of one of the national service provider. While GPRS speeds are probably sufficient for the small amounts of data from these AWS, the consequence of this is a regular cost to the authority, not only in financial terms but also poor connectivity in remote areas, downtime and high power consumption.

Since universities in Uganda are spread across the country with considerable spatial separation, it is possible that the UNMA (Uganda National Meteorological Authority) could place a number of AWSs at these campuses and still cover many climatological zones and, equally importantly, benefit from transmitting the AWS data through the networks at these universities that have been set-up by the national NREN, RENU. Because this data volume is very low, the cost of such transmission would be almost zero and other advantages would be manifested, such as the very limited involvement in communication channel maintenance and a higher availability of power.

In this paper, we investigate the practical consequences that leveraging inter-institutional NREN connectivity would bring to a government authority like UNMA. We analyze the impact that this would have on the cost, operation and reliability of the whole AWS.

Keywords: Automatic Weather Station, NRENs, Weather, Gateway, Wireless

1. Introduction

1.1 Structure of an Automatic Weather Stations

In general, an AWS consists of several sensors, a central processing unit, a power source and a communication device. Figure 1 shows one possible set-up. The sensors measure various environmental parameters such as wind, temperature, solar insolation, humidity, wind speed, wind direction and others. The data from these sensors is read by the central processing unit and stored locally or transmitted to a remote location. The pair of the CPU and communication device is typically called the gateway. The communication device (sometimes called the uplink in this paper) enables radio telemetry and is responsible for transmitting data central repository, usually over the internet to server computer.

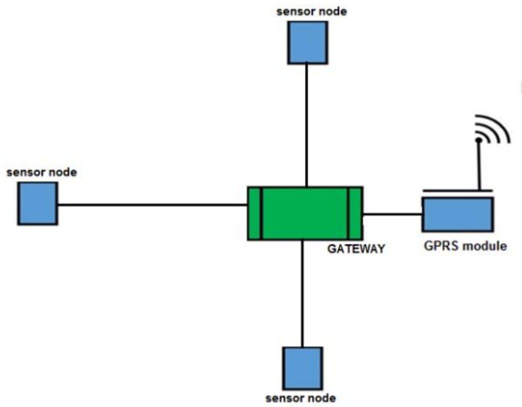

Figure 1: Schematic o of an Automatic Weather Station

1.2 The State of Environment monitoring in Uganda

Automatic Weather stations in Uganda are run by several organizations. The mandate of weather data collection and dissemination for public use lies solely on UNMA. However, there are several other private organizations that man their own AWS, such as NARO (National Agricultural Research Organization).

Within the UNMA, AWS are characterized by poor lifetime usually due to vandalism, which is common in many developing countries (Rogers & Tsikunov, 2013) (Moura & de Rezende, 2008) (Japan Meteorological Agency), lack of maintenance due to insufficient funds or ignorance of the mode of operation and lack of skilled manpower to manage them. Of 37 stations installed as per October 2014, 6 stations were affected by various power and communication issues and 5 stations had been vandalized with the intention of stealing the solar panel (Nsabagwa, Byamukama, Sansa-Otim, & Okou, 2016).

2. Problem Statement and Motivation

Automatic Weather Station data needs to reach the remote destination server promptly at the smallest possible cost. The current costs of GPRS connectivity are not regularly covered by UNMA due to the constant cost and the administrative procedures involved obtaining these funds. Further, cellular networks are very unreliable especially for 2G connectivity, which most AWS use. They suffer connection breakages and downtime.

Secondly, the gateway is the single most power hungry device in the whole AWS and this is majorly because of the uplink device. In our previous work, we have analysed the availability of a Raspberry Pi gateway connected to 12V battery sources and cellular connectivity. We

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obtained a downtime of almost 12 hours every day due to lack of sufficient power at night. compared to powering it from the grid in which downtime less than a few minutes each day.

As such, remote measurement and communication reliability is an issue because of cost, downtime and power. The motivation for this work therefore comes from the need to re-engineer how these AWS can send out data packets to the remote destination effectively.

3. Collaborators and Funding

This work is being carried out under the WIMEA-ICT project, a beneficiary of funding from the Norwegian Agency for Development Cooperation (NORAD) under its NORHED (Norwegian Programme for Capacity Development in Higher Education and Research for Development) programme to enhance research capacity in institutions of higher learning in East Africa (Sciences, 2016).

WIMEA-ICT is being implemented by four academic institutions namely Makerere University (MAK), Dar es Salaam Institute of Technology (DIT), University of Bergen (UiB) and the University of Juba (UoJ), in collaboration with their respective National Meteorological services, and is aiming to improve weather information management through the use of suitable ICTs. The project intends to set up seventy (70) Automatic Weather Stations (AWS) in the three partner African countries. Of the 70 AWS, Uganda and Tanzania shall each receive 30 while South Sudan shall receive 10. Between October 2014 and January 2015, Uganda had 37 weather stations directly under UNMA (Uganda National Meteorological Authority) (Nsabagwa, Byamukama, Sansa-Otim, & Okou, 2016). The project shall therefore contribute about 45% of the total number of weather stations.

While UNMA has the mandate to densify the network of AWSs in Uganda, one of the expected outcomes of the WIMEA-ICT project is to assist UNMA achieve that goal.

4. Related Work

The only similar work we found was from the WACREN proceedings in 2016 in which Pehrson, (2016), discusses the possible contributions of RENs in environment monitoring in Africa. It is mentioned that RENs can facilitate the deployment of access points to which remote wireless sensor network gateways can connect.

5. Methodology

5.1 Deployment strategy

In the deployment of AWS, several issues must be put into consideration to locate the ideal point of installment. We have devised a technique that involves a scientific approach of finding the intersection location at which several constraints are fulfilled (Nsabagwa, Byamukama, Sansa-Otim, & Okou, 2016). These are

- the climatological zones – geographical expanses of land that demarcate areas of similar weather patterns
- Internet availability
- Land ownership policies
- Security
- Power availability

In our analysis, we discovered that deploying AWS on university premises solved almost all of the constraints mentioned. In particular, the following were identified.

First, universities and other educational and research institutions usually have more reliable internet connectivity than their surroundings. In Uganda, this is especially so because most universities are connected to the network provided by the RENU.

Secondly, university land is usually managed by a single stakeholder—either government (for public institutions) or individual entities (for private institutions). As such, land ownership policies and the administrative process to acquire permission to install these devices are more straightforward.

Thirdly, these institutions have more intellectually cultivated mindsets. There is thus a lower probability of vandalism and security will be largely higher than the surroundings.

In addition, the availability of power is also a major requirement for any university to operate. This is one of the constraints whose achievement solves major obstacles in data transmission.

The issue that remains thus is that of climatological zones. For the analysis to be complete, we needed to compare the climatological zones and the locations of various universities.

Figure 2 shows the various climatological zones in Uganda and Fig. 3 shows the penetration of the RENU network and indicates that there is penetration of RENU in a number of climate zones in Uganda.

Fig. 4 shows the approximate location of various universities in Uganda. Coupled with the fact that RENU is the largest internet service provider to universities in Uganda, we concluded that the deployment technique of AWS at academic and research institutions in Uganda would represent the majority of the climate zones and thus have balanced distribution of these AWS.

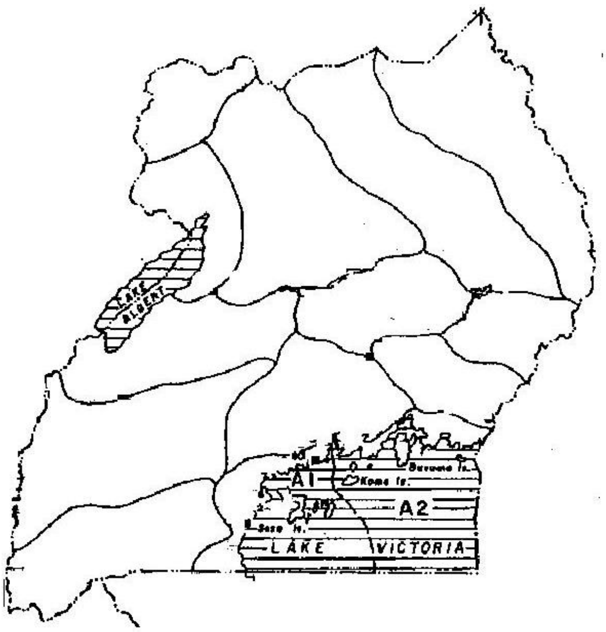

Figure 2: Climate zones of Uganda

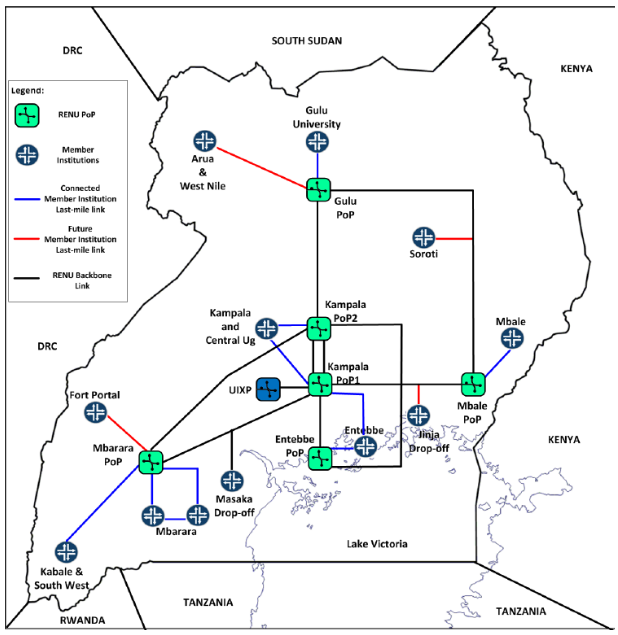

Figure 3: RENU reach in Uganda

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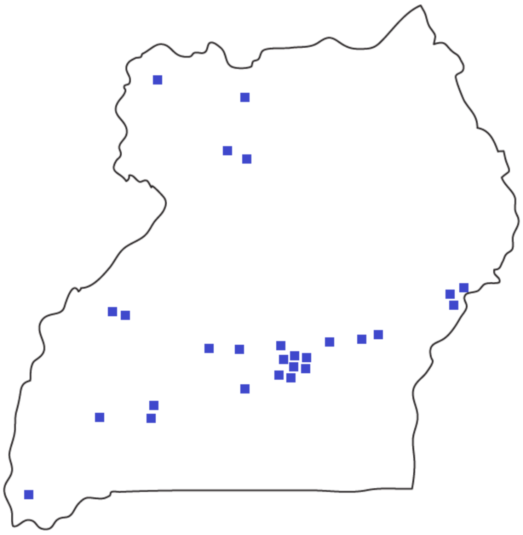

Figure 4: University locations in Uganda

5.2 Cost Analysis

We now proceed to analyze the extra cost of establishing such a network, compared to the current cost. To analyze this, little or no fore knowledge of the current cost is necessary. The cost of running an AWS involves the initial cost of deployment, which applies for all cases, and the added cost of data transmission, and regular maintenance. The last cost is also independent of any other factors.

The cost of data transmission using a university network would be close to zero. This is because, compared to the university internet traffic, it is very small. As a reference, we take a sample station deployed at Makerere University. This is a weather station, designed by WIMEA-ICT from scratch. The data received by the CPU to send over the uplink is about 1000 bytes/minute. This amounts to 58kB each hour. In comparison, a typical university will pass through traffic of several hundred gigabytes of data each hour. There is no other immediate cost that we could identify in this set-up.

There are many benefits though that we identified, such as a higher probability of data reaching the destination, the possibility of Real-time data, the availability of reliable back-up at local university servers, the possibility of opening the data up to several mirrors, on-site power and a smaller probability of vandalism.

5.3 Network Architecture

The network architecture for an AWS benefitting from a RENU network would not be complicated. The first constraint that needs to be overcome is the last-mile solution—how the CPU gets the data to the university servers. We have experimented with WiFi and Ethernet at Makerere University and all have shown good reliability. WiFi may be necessary when the power connection point is far away from the Ethernet connection point. The extra reliability obtained from using optical fibre for the last mile is not sufficient to justify the cost of the civil works and other requirements such as technical network deployment labour. Once the connection is established, the next question is on the technique to access the data. There are two options: the data can remain on the local storage on the gateway CPU and accessed from there over TCP/IP or the data can be sent to local storage on the server. The latter option may be more optimal when speed of access of data from multiple clients is paramount. Lastly, the issue of centralization of data from multiple stations will be important for managers of AWS networks. There are many solutions to this. One rudimentary solution is to implement a

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dedicated application that runs on one server at one institution that pulls data from the servers of other institutions regularly. If only the new data is requested, the data traffic will still be negligible.

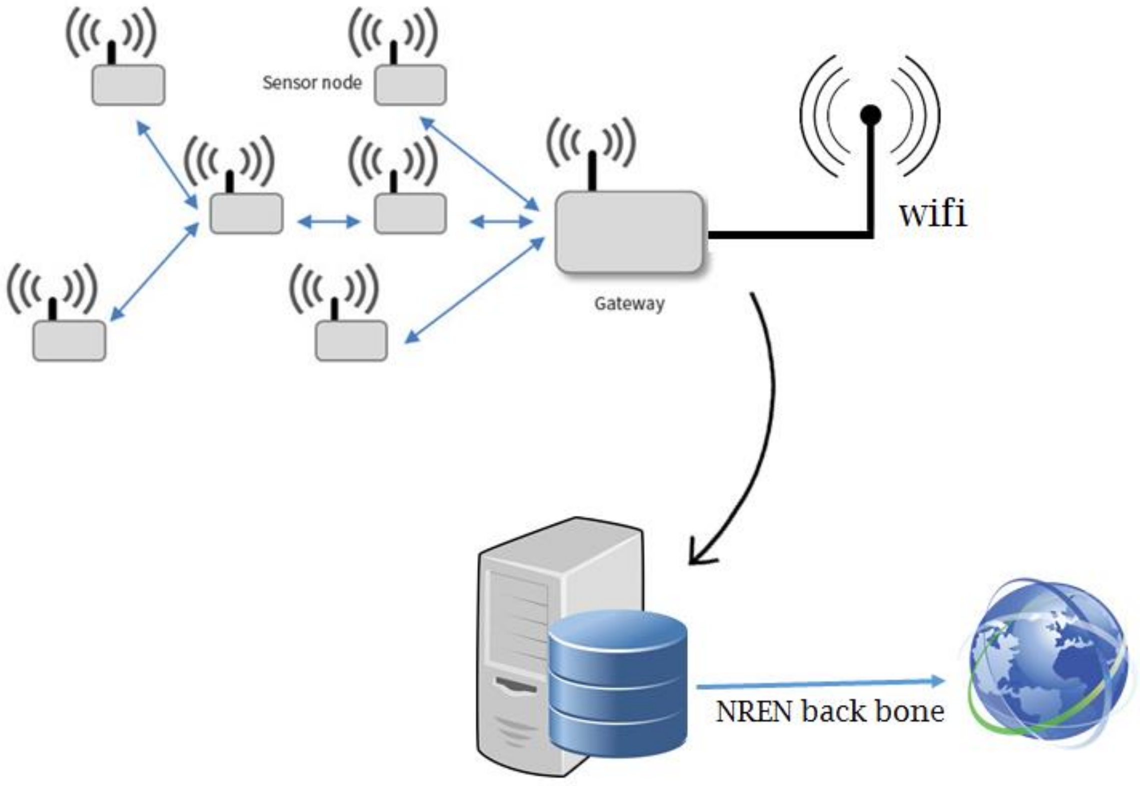

Figure 5: AWS network architecture

6. Conclusion and Recommendations

In conclusion, it is clear that using existing networks managed by NRENs can greatly reduce the cost that meteorological authorities incur in keeping their automatic weather stations on-line, along with several other benefits.

Because the joining the NREN network is a very affordable option for the educational and other research institutions, NRENs like RENU can include contractual closes that mandate the universities to support research that needs very little bandwidth It is a very small cost to the institutions but a very large saving for meteorological and research institutions.

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