On Improvement of the Weather Information Management in Uganda

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Abstract

Weather forecasts are used to make important decisions (e.g. reduce crop damage, reduce property damage, save lives, safety in the aviation industry) that can enhance a country's economy. This paper presents the challenges faced in managing Uganda's weather information which are: a sparse meteorology network, manual data processing and lack of access to the weather information by most stakeholders. This paper then goes ahead to propose an integrated approach that combines off-the-shelf (cheap) wireless sensor technology, free satellite data, earth science grid infrastructure and mobile computing to address the identified challenges. It is anticipated that these efforts will improve accessibility and accuracy of weather information to all that need it and hence have a positive impact on the economy.

Keywords: Weather forecasts, Earth science grids, weather information dissemination, Uganda

1. Introduction

The World Meteorological Organization (WMO) recommends that each country have a National Meteorology Service (NMS), to provide weather, hydrologic, and climate forecasts and warnings that are locally relevant. In addition each NMS sends some of its collected data to the World Meteorological Centres (WMCs). The WMCs then process the data by analysing it, drawing maps and charts, and running computer models to produce globally important weather / climate information, which is sent back to the NMSs. This work is part of the AGLaRBRI (Pehrson, 2012) initiative with partners from Uganda, Kenya and Sweden. Also recently funds are being sought to include partners from South Sudan and Norway.

2. Uganda's Status

The NMS in Uganda is the Department of Meteorology (DOM), which is a government department in the Ministry of Water and Environment. The weather stations operated by the DOM can be categorized into two broad classifications based on (i) the mode of operation, or (ii) the purpose of weather data collection. Considering the mode of operation, there are two types of weather stations namely; the manual (sometimes referred to as manned)[1] and the automatic weather stations (AWS also called unmanned)[2]. Considering the purpose of weather data collection, there are four types of

[1] The manual stations are manned 24 hours a day by trained employees of the DOM who record the weather data and update the DOM headquarters accordingly.
[2] In the unmanned stations weather data is recorded automatically, however, the transmission of the data to the DOM involves a human in differing ways determined by the model of the AWS.

weather stations namely; the synoptic[3], rainfall[4,] agromet[5] and hydromet[6] weather stations. These stations are spread throughout the country as shown in Figure 1. It is clear from Figure 1 that the weather station distribution is uneven with some regions especially the north being sparser than others.

Figure 1: The Distribution of Established Weather stations in Uganda (source: DOM)

It should also be noted that of all the established weather stations, the operational stations that report their observations regularly are much fewer as summarised in Table 1. Table 1 indicates that less than 50% of the established stations are currently operational. This implies that the operational weather station map is even sparser than shown in Figure 1 above.

[3] Collects weather data of several parameters (wind, atmospheric pressure, temperature, clouds, humidity and precipitation) for purpose of global weather forecasting thus it must be transmitted to the regional and world meteorology centres

[4] Records only rainfall data and these are mainly manual stations & depend on volunteers to report the observations

[5] Records weather parameters that affect agricultural productivity e.g soil temperature, soil moisture and evapo-transpiration

[6] Measures water levels, ground & water temperatures in addition to the six weather elements measured by the synoptic stations

Table 1: Established Vs Operational Weather Stations in Uganda (source: DOM)

Weather station	No. Established	No. Operational	% Operational
Synoptic	12	12	100
Agroment	16	8	50
Hydromet	14	5	36
Rainfall	300	35	12
Total			49.5

Following data collection at the weather stations, it is reported to the DOM headquarters for processing. The data flow from the various weather stations showing the method and regularity of reporting is shown in Figure 2.

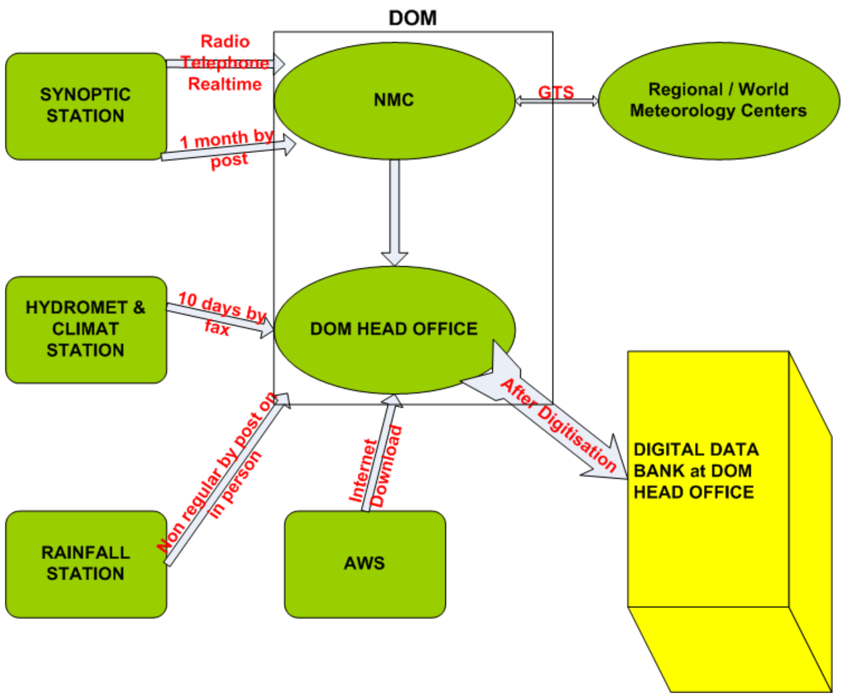

Figure 2: Data Flow from Weather stations in Uganda (source: DOM)

Figure 2 shows that the methods of reporting the collected data include: by person, post, fax, radio, telephone and Internet download. Timely processing of weather information requires that the amount of time taken between the observation of the weather data and the arrival of the observed data at the DOM is minimal. This therefore means that some methods of reporting weather data such as by person and post are inappropriate since they are very slow. Data received at the DOM by fax, radio or telephone needs to be digitized before storage and processing in the digital bank. This creates a loophole for errors as the data may be altered during digitisation. In addition extra delay is experienced before digital data is available for processing useful weather products. The data received through Internet download is already digital thus it is passed to the digital bank directly. Transmission of data through the Internet is therefore the most efficient. Accurate weather information is important to several stakeholders. The accuracy of this information is further determined by the distribution of weather stations across a given area as well as the regularity with which these stations provide information for processing at the NMS. It is a reasonable assumption that each district in Uganda should have an operational station in order to ensure that the weather information is representative. The current coverage is 40 out of the 114 districts; therefore the distribution of weather stations in Uganda is short by 65 %.

3. The Problem

The challenges faced by Uganda's DOM in executing its mandate of managing weather information are:

1. A sparse Meteorology Network (the coverage of weather stations is at 35% of which only 49.5 % are operational) yet the cost of standard weather stations is prohibitive (10,000 - 50,000 USD per station)
2. Manual data processing therefore delayed analysis
3. The few Automatic Weather Stations (AWS) are not fully automated i.e. require a person to switch on/off a computer for weather date to be reported back to the DOM headquarters.
4. The available weather information is neither properly packaged nor readily accessible to the various stakeholders

The above have led to the following problems:

1. Failure to provide sufficient advise to some stakeholders especially the farming communities who then have no choice but deal with unpredictable farming seasons leading to food insecurity and financial losses.
2. Inappropriate response to weather related disasters e.g. Mudslides, floods etc… that have been on the increase in recent times.

4. Approach

We are following the outlined approach in order to improve the timeliness, accuracy and access of weather information in Uganda:

1. Field study & Brainstorming sessions so as to include several stakeholders' concerns.
2. Experimental research:
   - Design, program, deploy and test the appropriate weather off-the-shelf (cheap) wireless sensor nodes, including uplinks from remote wireless sensor networks in areas without other connectivity. Wireless Sensors have been shown to improve operations in several applications including Agriculture production (Burrel, 2004), Habitat Monitoring ([Mainwaring, 2002), Volcano activity observation,(Werner-Allen, 2006) etc…
   - Integrate the data from the existing weather stations and the wireless sensor stations with weather relevant satellite data especially for places where there is no weather station coverage.
3. Implementation:
   - Setting up of an operational numerical weather prediction model thus automatic processing of the weather data through a national or international earth science grid infrastructure such as highlighted in Mallikarjuna,(2007) and [Quiruelas, (2011).
   - Develop the weather information dissemination tool through requirements solicitation, design and implementation of appropriate software for packaging, and providing the different stakeholders with access to the relevant (appropriate) weather information, particularly though mobile phones since they readily accessible to the target group.
4. Deployment: Test and deploy the weather information system in an incremental manner.
5. Dissemination & Sensitization: Workshops and publications.

5. Expected Output

5.1 The proposed System

An improved weather information management system is the expected output of this study. The operation of this proposed system is illustrated in Figure 3. Figure 3 shows that the proposed system consists of combined data collection through the use of custom-made weather sensors[7], cheap of-the-shelf sensors[8] and satellite data. For the custom-made weather sensor station, our contribution will be the full automation of the data transmission so the challenge of turning the computer on and off for each transmission is addressed especially in the remote places. For the cheap off-the-shelf sensors our contribution will be programming and calibrating them to return weather data that is comparable to that from the standard weather stations. The data from these two types of weather stations will combined together with the satellite data in a national and /or international grid infrastructure, in which a numerical weather prediction model will reside for appropriate weather forecasts and analysis. The analysed weather information will then be displayed at DOM stations[9] and/or mobile phones[10] depending on how critical the situation is.

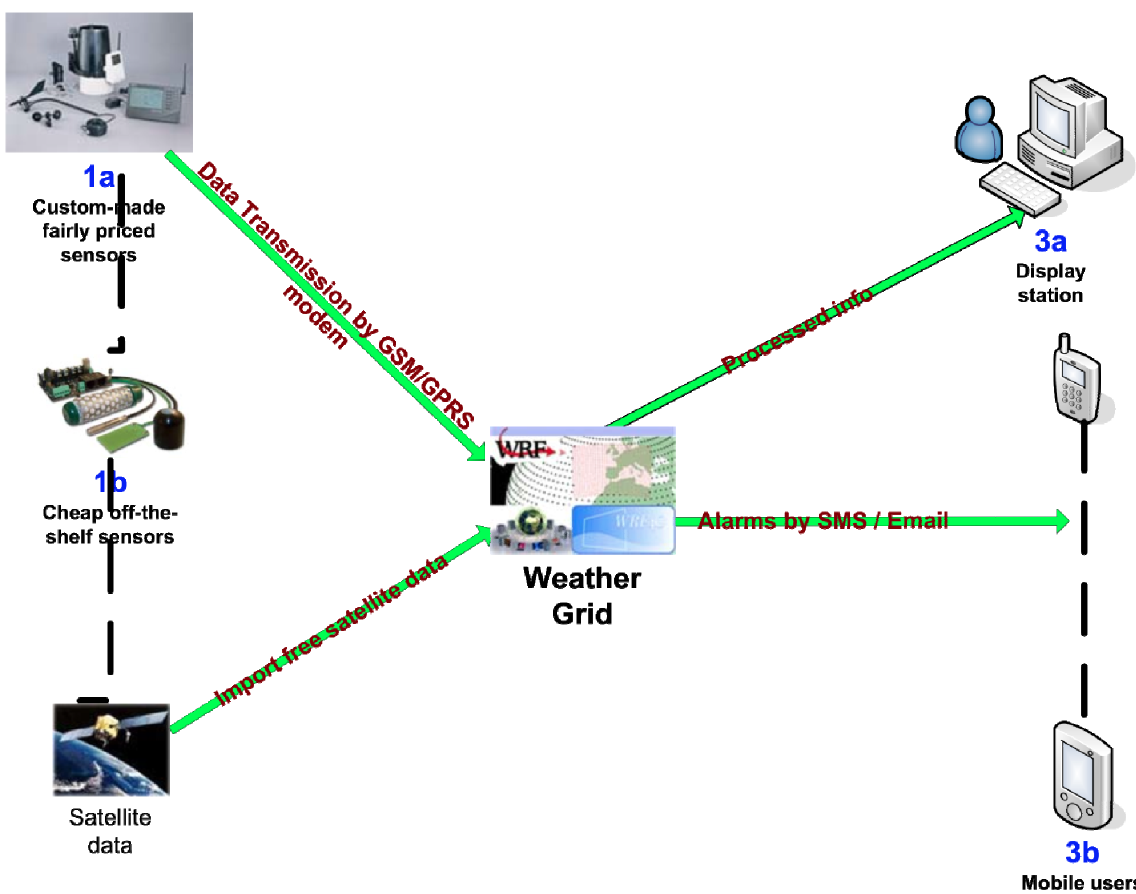

Figure 3: The proposed Weather Information Management System

[7] Indicated as 1a in Figure 3
[8] Indicated as 1b in Figure 3
[9] Indicated as 3a in Figure 3
[10] Indicated as 3b in Figure 3

5.2 The resulting outcome

It is anticipated that the following will be the results of this improved weather information management system:

1. More accurate and conveniently processed weather predictions based on a numerical Weather Prediction model. This will ensure timely processing of the weather data and result into appropriate weather information packages based on earth science grid infrastructures particularly WRF or the Earth System Grid.
2. Affordable and sustainable Technology based on off-the-shelf (cheap) wireless sensors and free satellite data since it designed in such a way that it provides for full automation and is self-sustainable on renewable energy.
3. Improved access to weather information by the different stakeholders especially the farming communities.

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Biography

Julianne Sansa-Otim (Uganda) is a Researcher and Lecturer at Makerere University in Uganda, where she also heads the Department of Networks in the School of Computing and IT. She started her Internet industry career as a Cisco Academy instructor at Makerere University in 2002. She later did her MSc and PhD research in Internet Technology related fields. Her research interests include Internet Protocols, Telecommunications Policies & Standards, and appropriate e-services for rural communities. Her research passion has led her to winning several research awards including: a NORHED research grant on "Improving East Africa's Weather Information Management through the Application of Suitable ICTs", an Internet Society Fellowship to participate in the 85th Internet Engineering Taskforce Meeting that took place in Atlanta, Georgia, USA; a United Nations Office of Outer Space Affairs (UN-OOSA)/ International Astronautical Federation (IAF) award to present at the 22nd UN/IAF Workshop on "Space Technologies Applied to the Needs of Humanity" in Naples, Italy; and a Google conference award to present at the African Conference of Software Engineering and Applied Computing (ACSEAC) 2012 in Gaborone, Botswana