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Design and Development of an Integrated Web-based System for Tropical Rainfall Monitoring

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Abstract

This study is about the design and development of an integrated web-based system for tropical rainfall monitoring. The system gathers data using a network of low-cost, Android-based acoustic rainfall sensors, a nationwide infrastructure of 5 GHz wireless broadband links, and remote weather stations. The low-cost Android-based acoustic rainfall sensors are deployed at high densities over a local area and the 5 GHz wireless broadband sensors gather rainfall information on a nationwide scale. The sensor network provides information about spatial-variations that are characteristics of tropical rain rates, and complement data from the scarcely deployed remote weather stations. Gathered data is then processed and displayed on a web interface.

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Keywords: Rainfall monitoring; web technologies; acoustic sensors; wireless broadband links; wireless sensors

1. Introduction

Tropical rainfall is characterized by variations in intensities over sub-kilometer distances. Rainfall intensity variation is an important parameter in engineering high-frequency, high-bandwidth wireless spatial diversity schemes. Monitoring spatial variations in rain rate is also critical in disaster management and alarm systems. For instance, landslides may be triggered if high-intensity rain falls over an already saturated slope [1,2,3].

Previous studies have used wireless communications networks for rainfall monitoring in temperate climates [5,6]. The current study is about an integrated system for real-time tropical rainfall monitoring. The system imports data from a sensor network that uses a high-density deployment of low-cost, Android-based acoustic sensors, a nationwide infrastructure of 5 GHz wireless broadband links, and Davis Vantage Vue™ remote weather stations.

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The data then are transmitted to a server and displayed on a web interface. The high-density deployment of low-cost sensors and the nation-wide wireless broadband network are able to show the spatial-variations that are characteristics of tropical rain rates, and complement the measurements provided by the remote weather stations.

Gathering rainfall data at sub-kilometer scales require radar equipment and ground-based rainfall sensors, such as tipping buckets, to be deployed at high densities. However, developing tropical countries, such as the Philippines, have limited access to such equipment and need a cost-effective system to complement the scarcely deployed ground-based equipment.

Previous studies have used low-cost, Android-based acoustic point sensors for tropical rainfall monitoring. Acoustic-sensors collect rainfall data by recording the acoustic signal levels generated by raindrops. Higher rain rate values relate to higher acoustic signal levels. A high-density deployment of acoustic rainfall sensors shows the spatial variance of tropical rain intensity over sub-kilometer areas [1,3,4].

Rainfall also causes attenuation in the received signal levels (RSLs) that are directly related to rain rate. Various wireless broadband link frequencies have been used in previous studies to gather rainfall information [2-7]. In this study, RSL data from a nationwide infrastructure of 5 GHz wireless broadband links between 730 subscribers and their base stations are collected at 1-minute intervals. The gathered data provide information about the rain events that occur along the link paths.

In the current study, a system that integrates the high-density deployment of low-cost acoustic sensors and the nation-wide network of 5 GHz wireless broadband links is used to gather tropical rainfall information. The system sends the data to a server and displays data on a web-interface.

With such system, areas that lack access to rain event information (e.g. rural areas without the resources to deploy expensive and complex weather stations), can obtain the data they need to respond to rain events. The system provides data that notify users if rain events are exceeding safety thresholds (i.e. rain rates are reaching torrential levels). Given such information, users and disaster managers can react to the situation accordingly, and generate the appropriate disaster management plan. The rain data gathered from the sensor network can be used to trigger an alarm system. The whole system offers great potential to save lives and prevent property damage and loss.

2. Android-based Acoustic Rainfall Sensors

Low-cost, Android-based acoustic-sensors collect rainfall data by recording the acoustic signal levels generated by raindrops. Previous studies show how that higher rain rate values relate to higher acoustic signal levels detected by acoustic rainfall sensors [1,3,4,7]. Figure 1 shows the acoustic data that are compared with rain rate data gathered the Casella CEL Tipping Bucket Rain Gauge™. Figure 1 shows the acoustic signal power and the derived rain rates from the November 10, 2010 rain event. The rain rates were calculated from accumulated rain measurements of a tipping bucket. Time intervals of 1, 3, 6, and 12 minutes were used to derive the rain rate. As the rain rates increases to 36 mm/hr, the acoustic signal power also increases to approximately -5 dB. When the rain rate is low (i.e. 0 mm/hr), the acoustic signal power is also low (approximately -30 dB).

In the current study, a field-deployable Android-based acoustic rainfall sensor was developed. The sensor was designed for always-on remote data gathering and transfer. Software was developed that allows the Android-based acoustic sensor to gather the acoustic signal levels generated by rain events, store data files, and transmit files to a remote server. A 50-watt solar panel was connected to a solar charge controller. The controller charges a 12-volt battery. The 12-volt battery is connected to a DC converter, which produces an output of 5 V and charges the Android-based acoustic rainfall sensor. An HTC Wildfire Android 2.2 mobile device was used for acoustic data gathering. The sensor continuously gathers and writes rainfall data on *.csv files. The sensor then sends the *.csv files through a Wi-Fi or 3G network to a remote server. Figure 2 shows the Android-based acoustic sensor diagram.