Rainfall estimation by a signal attenuation analysis in mobile systems

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Abstract. Spatial measurement of rainfall are required to improve fast and heterogeneous spatial hydrological models, however, the cost of radars and atmospheric models are still high for developing countries, for this reason new alternatives of measuring rainfall on low cost technologies are needed. The process of rainfall quantification by identifying the signal attenuation from mobile phone antennas due to the moisture concentration shows that under stable conditions it is possible to reproduce the formulation of attenuation - rainfall relation. This study explores the possibility of developing a spatial rainfall variability map using the attenuation of mobile phone signals as a measure of rainfall. A design and description of signal information from mobile phones is described as well as the attenuation formulas which have been applied to quantify the rainfall. The analysis of process and distribution of an experimental setup where Wet and dry rainfall events from rain gauges are used as validation are presented. The results of this study show the potential that mobile phone signals have to estimate rainfall in real time and also how it might be implemented in hydro-meteorological models for the case study region in the Valle del Cauca, Colombia.

Keywords: Hydrology, attenuation, mobile signals, rainfall.

1. Introduction

Hydrometerological models require accurate information (Leijnse, 2007), dependable and in addition with a small time interval to generate useful information for creating forecasts and warnings. It is important to have information in real time of rainfall that might come up in the region for improving current forecasting systems. Different methodologies have been developed to estimate rainfall based on physical principles, mathematical and statistical. There have also been studies on the estimation of moisture and water drops. These methods are mostly based on the identification of wet and dry periods, in this way will find a relationship between rainfall and loss of power (Marc Shleiss, 2010).

Due to flood events recorded since 1956 in the southern city of Cali, concerns are born the studies and develop initiatives for better management of water resources in the area (Rios, 2012). The basin has suffered a rapid change in its typical characteristics, their filtering capacity and the time of runoff also the soil permeability due to deforestation and erosion, affecting the channel in turn causing increased flood events. The region of the river basin Cañaveralejo is particularly wet tropical zone, which is looking at to reactivate the hydrological cycle of the area, as well as mitigate the aforementioned problems.

Order to reach a solution seeks to before anything else know the whole hydrological information of the area, we need a constant monitoring of all water resources available in the area, and therefore it is proposed applying a method of quantifying the rain through mobile signal. Because to the high cost of existing monitoring systems such as radars and rain gauges, is seeking alternatives that may be useful in estimating rain in real time.

The method of quantification of rain by means of electromagnetic waves has the advantage that the process is used for mobile infrastructure; this greatly reduces implementation costs in urban areas like the city of Cali, Colombia. In this way explore finding basis looking to develop a model for Hydrometeorological Cañaveralejo river basin, with this would lead to better management of water resources in the basin, as well as better utilization and conservation.

2. Measuring setup

From 2000 to date there have been studies to fully explore the phenomenon that produces humidity with respect to power mobile signals. The concern was born out of the idea of improving telecommunications systems due to its weakness sandstorms occur in the city of Tel-Aviv, Israel (Messer, 2007). Upon seeing this phenomenon on signs, began to explore the possibility of estimating the size of raindrops (Rincon, 2002). Also began to study to find the tools and methods for the estimation of rain by means of telecommunication systems (Ajewole, 2008). This is a topic still early in the area of meteorology and environmental, but there are still areas of opportunity to exploit, and these works are the basis for improvements in conventional systems and prediction of precipitation forecasts. This is a topic still premature in the area of meteorology and environmental; however there are still areas of opportunity to exploit these works.

The applicability of measuring rainfall from mobile phone signals is quite unique and few researches have been reported in the literature. In our case study it is analyzed the tropical region of the Valle del Cauca in Colombia. This is done through the study of the power loss suffered by mobile phone signals, which is due to variables as rain, moisture and heat. The target is the development of maps of the spatial variability of rainfall, the first attempt presented here is to identify rain no rain in time. It is important to highlight that the data information obtained have a great potential for hydro-meteorological models which are the basis for a better management of water resources in the Cauca Valley Colombia.

2.1 Results Expected

- Find the relationship between the losses of power of mobile signal with presence of rain.
- Validate information and generate maps of spatial variability of rainfall by an extrapolation method.
- Determine the correlation between mobile phone information and information from rain gauges.

- Identify the advantages and disadvantages of the proposed method for quantification of rain.
- Develop a full report on the investigation.

3. Mathematical Formulation

The following describes how to carry out the mathematical analysis to find the relationship between signal attenuation and rainfall intensity, based on the power law.

3.1 Relation *k*-*R*

There is a relationship based *k*-*R* called power law as follows (Atlas, 1977) (equation 1):

$$K = a * R^b \tag{1}$$

The above equation describes the relationship between two quantities, which decreases the variable K increases as the random variable, in this case the variable R.The coefficients *a* and *b* are defined according to the temperature of rain and droplet size. The following table shows the possible values for *a* and *b* (Leijnse, 2007) (Wessels, 1972).

Table. 1 Coefficients *a* and *b*.

	$T = 263$ K		$T = 273$ K		$T = 293$ K	
	a_*	b_*	a_*	b_*	a_*	b_*
LP_L	0.132	1.078	0.128	1.081	0.135	1.063
LP_H	0.168	1.010	0.170	1.003	0.177	0.986
MP	0.153	1.054	0.147	1.062	0.153	1.051
J-T	0.215	0.863	0.213	0.860	0.218	0.847
J-D	0.116	0.994	0.103	1.037	0.094	1.117
W	0.125	1.104	0.126	1.097	0.135	1.066

The analysis of the relationship between rainfall and attenuation of signal is as follows. It identifies each power level reading between receiver and transmitter to *link_n link_1*, where n represents the total number of readings to be recorded. Each link will consist of a vector keep variables as (Oren Goldshtein, 2009):

- Total length of the segment between the antennas.
- Total power of the signal.
- Signal Attenuation.

In turn, each will have a link vector called A, which is defined as follows (equation 2):

$$A(dB) = aR^bL \tag{2}$$

Where *A* expresses the attenuation of the signal receptor expressed in decibels, and *R* represents the rainfall rate along *L* is the distance between the antenna and the device. This vector *A* vector becomes a R using the equation above, where represent the intensity of the rain.

4. Experiment and methodology

Before you enter fully to the topic of methodology, this section will look in detail each step of the investigation. Will explain how each objective will be fulfilled previously seen and also meet our overall objective.

The figure below shows the steps that will need to carry out for this research. At first instance carry out a collection of relevant information regarding the investigation, followed by a study of the area of study to determine where will be made the data sample. Then conduct an analysis to identify the relationship between the signal attenuation and rainfall intensity. Also initiate the validation of data and statistical analysis. Finally identify the advantages and disadvantages of the research and the proposed method.

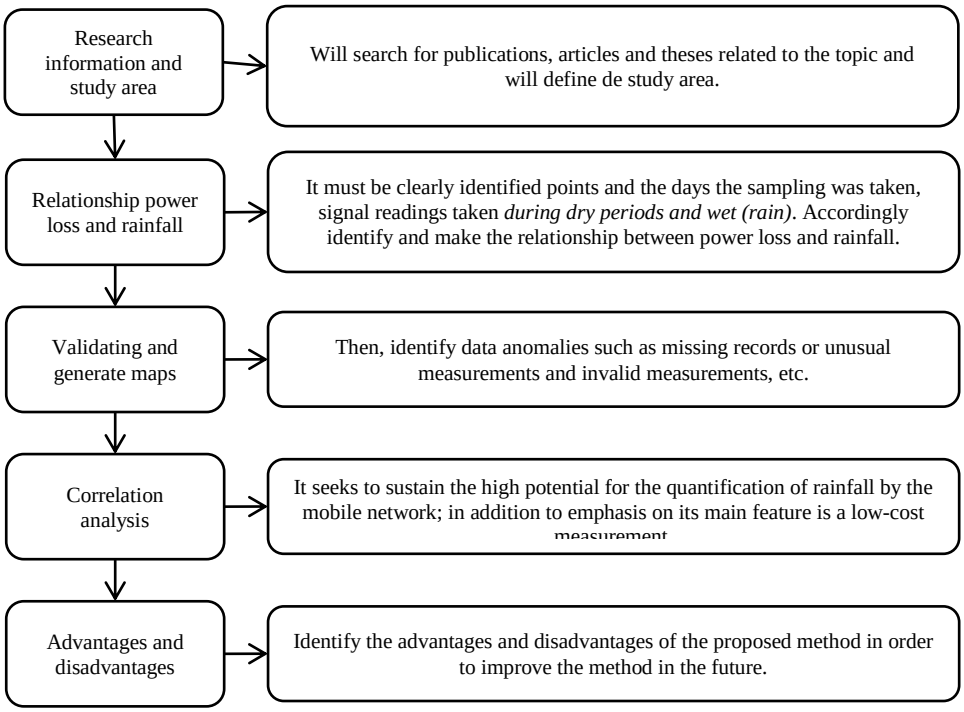

Figure 1. Diagram of the methodology

4.1 Research information and study area

Information documentation and relevant articles was compiled, on the subject of research. This will define the methodology that has to carry out.

So also obtained all necessary information about the study area, and general characteristics of the area, information available both as on rain gauge data power levels of the mobile signal. We also collected information on the basics for understanding of each particular topic. The study area is located in the southern of the city of Cali in the Valle del Cauca in Colombia. Near to building CVC, and close to two antennas.

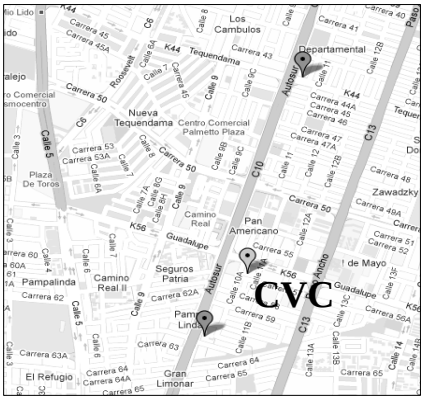

Figure 2. Area of study

The setup of the experiments was carried out as follows:

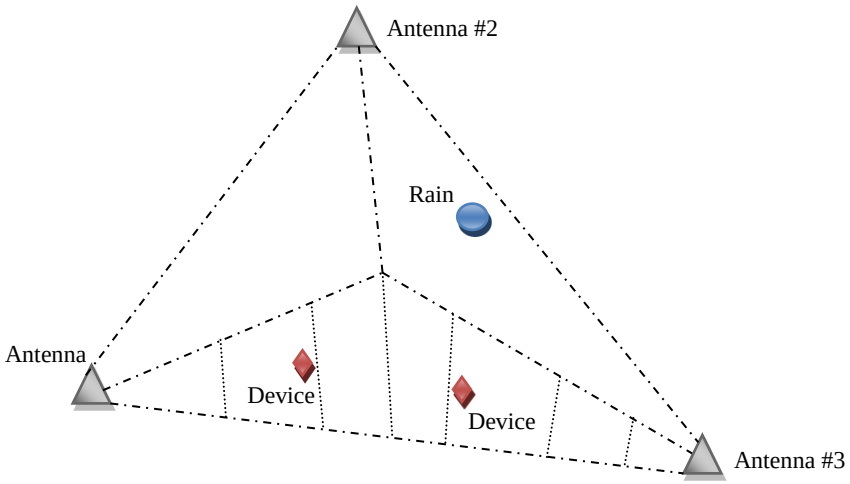

Figure 3. Setup of experiment

4.2 Relationship power loss and rainfall

We know that mobile signals suffer some type of attenuation when in presence of water vapor and oxygen (Noam David, 2009). In this wait it seeks estimating the rainfall by knowing the level of absorption suffering while traversing a zone of vapor water. According to available information will define the study area to relate the loss of signal strength with the presence of rainfall. For the above samples is loss of power expressed in decibels. Be developed field work is doing the readings at the locations where the mobile phone antennas. It must be clearly identified points and the days the sampling was taken, signal readings taken during dry periods and wet (rain). Resulting to identify and make the relationship between power loss and rainfall.

With the information collected as historical data and the sampling of mobile phone antennas combined with rain gauge data will be a mathematical analysis in order to find the relationship between loss of power and intensity of rainfall.

4.3 Validating and generate maps

After obtaining information of rainfall using the mobile system network validate the data using information from rain gauges. Then, identify data anomalies such as missing records or unusual measurements and invalid measurements, etc.

Once validated the data, develop maps of spatial variability of rainfall by a method of extrapolation. To generate maps of variability will be used computational tool Matlab.

4.4 Correlation analysis

As a parallel analysis will be a correlation of information from the mobile system network and the rain gauges. It seeks to sustain the high potential for the quantification of rainfall by the mobile network; in addition to emphasis on its main feature is a low-cost measurement.

Equation is shown below to be used for data analysis **(Solomatine, 2002)**(Equation 3):

$$\frac{\sum_{i=1}^{n}(p_i-\bar{p})(a_i-\bar{a})}{\sqrt{\sum_{i=1}^{n}(p_i-\bar{p})^2}\sqrt{\sum_{i=1}^{n}(a_i-\bar{a})^2}} \quad (3)$$

The data will be used data from the attenuation of the signal with the data recorded by the rain gauge. So in this way can be defined how accurate are the data resulting the proposed method.

4.5 Advantages and disadvantages

Identify the advantages and disadvantages of the proposed method in order to improve the method in the future. We will explore possible areas of opportunity to develop future research, also besides to seek basis for the development of hydro-meteorological model for the study area.

5. Discussion

The proposed methodology is a huge advantage over current systems for measuring rain, as radar systems and satellite. Due to its low cost of implementation, has increased the restlessness of studying more on this topic. Definitely there are still many limitations with respect to measurement and analysis in addition to the lack of cooperation of some companies operating cellular telephone service.

6. Conclusion

The implementation of this methodology in high humidity areas have high potential, because has been applied only in Nordic and dry areas. However the concern about seek new alternatives of estimating rainfall in Colombia is still a relatively new issue, without regard the high potential that the region has to develop new methodologies. It is possible to find new advantages for this methodology to be implemented in a tropical zone. Addition to the already mentioned advantages as its low cost of implementation is looking at a future replacement for costly radars, besides that this methodology would open the possibility of wider coverage than do radar systems.

Is possible to find a relationship between the signal attenuation and the presence of rain, but although necessary to develop more accurate devices to obtain more accurate measurement and make a better analysis. Was found some difficulties with respect to the configuration of the experiment, the selection of antennas near the rain gauge, find safe places to install the equipment, as well as find a device that was capable of recording data of power levels, is considered the option talk to the mobile phone companies but needed much more time to get the data directly from the mobile companies.

It was an effective way to specify the configuration of the experiment, and find a device that would give us the measurements required for the analysis and estimation of rain. Also explored in a future speak with mobile operating companies in the city of Cali to support these research projects.

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