Coverage Maps of 3G Cellular Networks Using Geographic Information Systems

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Abstract. This paper shows the procedure to obtain a continuous coverage map based on a collection of power level measurements through the combination of different models of Geographic Information Systems, using satellite photographs of the area under analysis, and a group of punctual samples of the power level of the Common Pilot Channel (CPICH); which is used to estimate the radio communications channel conditions, those measurement were taken at different positions and distances. A spectrum analyzer was used to obtain georeferenced measurements, and by a technique of statistical prediction, as the Krige Method, generate continuous coverage maps, making it possible to know the distribution of power level, and therefore understanding the behavior and configuration of a Base Station, which in third generation cellular systems is also called Node B.

Keywords: GIS, Coverage Maps, Cellular Network, Krige

1 Introduction

In the cell phone as all services must comply with the quality offered to users. That is why designers and administrators of wireless networks require an experimental analysis to determine the performance of networks.

In a cellular scheme, the analysis is done in the coverage area (cell) that is assigned to the Base Station –also called Node B-, it is precisely in this area where the service provider ensures that the Node B perform properly the transmission and reception of radio, filtering of the signal, amplification, modulation y demodulation of the signal, besides being the interface to the Controller of Radio Network (RNC). Normally a Node B has a total average power transmission of 20 w (43 dBm) [1].

Both the uplink (User Station to Base Station) as the downlink (Base Station to User Station) are implemented with WCDMA (*Wideband Code Division Multiple Access*) which is the technique of media access in third generation cellular networks (3G), through which multiple users access to a channel at the same time, but with a unique code that identifies (*Scrambling Code SC*).

The third generation cellular system operates in a unique center frequency at which power is the parameter of network control, and therefore the variable to analyze;

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specifically examine the power of the Common Pilot Channel (CPICH), which transmits a carrier used to estimate the communication channel parameters. It is the physical reference for other channels, and is used to power control, coherent transmission and detection, channel estimation, measurement of adjacent cells and obtaining of the SC [2].

Measuring equipment currently available for this purpose is capable of taking grab samples of the power levels at certain points. For adequate coverage analysis requires the proper spacing between measurements, making it easy to apply statistical techniques such as Krige Method; it is an interpolation technique based in a sample regression, which are irregularly spaced, to predict unknown values from known values. The interpolation method of Krige facilitates the task of analyzing the distribution of power radiated by an antenna, it is sufficient to take a series of grab samples with the proper equipment (which is capable of obtaining the geographic coordinates of the location and analysis parameters) to create an experimental variogram, and based on it make the most appropriate approach to the theoretical variogram to perform interpolation and move from discrete samples to a continuous measurement map [6].

For complete analysis requires the use of different models of Geographic Information Systems (GIS, *Geographic Information System*) which is an organized integration of hardware, software and geographic data, designed to capture, store, manipulate, analyze and display all forms of geographically referenced information, to solve complex problems of planning and management to meet specific information necessary for a general vision of the area of interest [3].

1.1 Geographic Information Systems

A GIS is a geographic system because allows the creation of maps and spatial analysis; is an information system because it focuses on the management, processes data previously stored and allows for efficient, repetitive and standardized spatial consultations, for adding value to the information maintained; and is an informatics system with specialized hardware and software that process the obtained data (spatial databases).

The GIS functions as a database of geographic information that is associated by a common identifier to graphic objects on a digital map. In this case the power level of the CPICH.

By separating information into different layers, are stored separately, allowing to work with them quickly and easily, to generate new information that could not otherwise be obtained [3].

There are three groups of models of GIS

- Vector GIS.

- Raster GIS.

- Object- Oriented GIS.

1.1.1 Vector Model

The focus is on the location accuracy of the elements of the space. To digitally modeling real world entities using three spatial objects: the point, the line and the polygon on a mapping system. For example, satellite photographs.

1.1.2 Raster Model

A study area is divided into small areas or array of square cells identical in size, and the "information" is stored in each bin for each attribute in the database, for example, contour. A greater number of rows and columns in the grid (higher resolution), will involve more effort in the process of capturing information and more computational cost to process it.

1.1.3 Object-Oriented Model

While data modeling vector and Raster structure their information through of layers, object-oriented systems try to organize geographic information from geographical object itself and its relationships with others. Thus, the geographic objects are subject to a number of processes and are grouped into classes, introducing a dynamic character to the information in the system. For this reason, the object-oriented model is more suitable for situations where the nature of the objects that try to model is changing in the time and/or space.

The key advantage that allows this data structure compared to the other is that from a number of parameters in the behavior of geographic objects is possible to simulate the evolution. Because it is so versatile, the area of application of geographic information systems is very broad, can be used in most activities with a spatial component [4].

That is why precisely this model was used in this study for analyzing the behavior of the power levels radiated from the Node B to user stations. With the help of a layer of the vector model (Satellite photograph of the study area) as shown in **Figure 1**, to obtain a clear idea of the obstacles in the propagation of the signal.

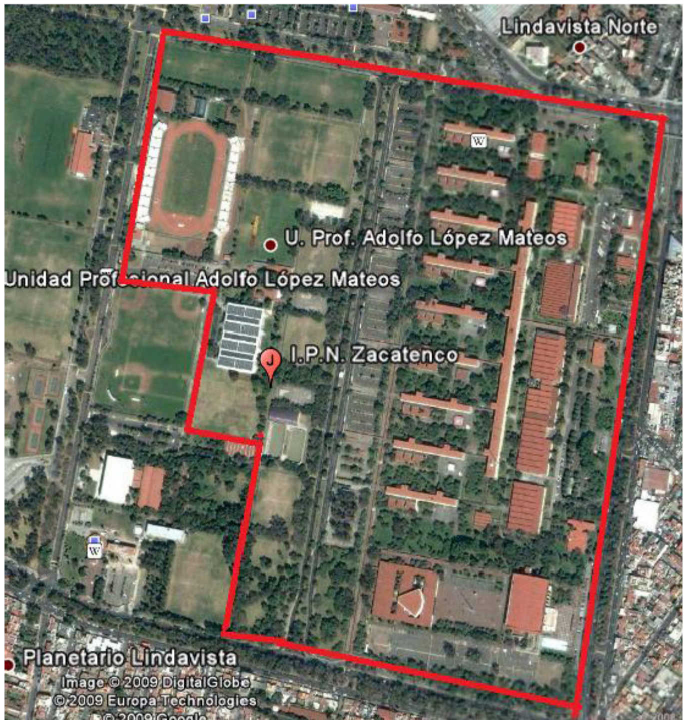

Figure 1 Satellite Photograph of the study area obtained from Google Earth

2. Methodology for the generation of GIS

To have an efficient coverage analysis, is essential that the process of creation of the coverage maps meet a set of basic criteria, ensuring the reliability and usefulness of the information contained in the system. These design criteria are shown in the following sections.

2.1 Data Selection

For this work, the latitude and longitude were selected as a geographical reference of the system, and the CPICH power level as an attribute, because through the measurement of this power level, the user terminal is able to establish a comparison between the Node B near, and decide which of them will provide the best service. This will allow that the user station know which is the dominant pilot that would define the coverage area.

2.2 Measurement process

The measurements were made with a spectrum analyzer, BTS Master MT8222A, made by ANRITSU. El BTS Master can measure the performance of Node B by connecting directly to the Node B equipment or through the air by connecting an antenna. To measure a signal WCDMA in air, you must connect the appropriate antenna to the frequency band to be measured. To know the location information of each measurement requires a GPS Antenna (Global Positioning System). The measuring equipment requires at least pick up the signal from four different satellites to ensure accurate location information of the sample [5]. Were obtained a total of 1519 measurement, the distance between them was about 3 meters, in the area shown in Figure 1, whose surface is about 0.7 Km^2. In each measurement the spectrum analyzer was placed at a height between 1.10 and 1.30 meters, since it is the average height to which the user carries his mobile equipment.

2.3 Storage or pre-processing data

The measuring equipment has an internal memory lets it store each of the measurement, and then are removed either through USB port or by networking computer equipment through Ethernet port. From the files obtained useful information is extracted with an in program language C++ and settles into a text file as shown in **Figure 2**. In which the data are arranged in descending using criteria column longitude.

LONGITUD	LATITUD	CPICH
-99.13472222	19.49777778	-82.553
-99.13472222	19.49777778	-80.167
-99.13472222	19.49777778	-83.676
-99.13472222	19.49805556	-88.068
-99.13472222	19.49833333	-84.118
-99.13472222	19.49833333	-85.757
-99.13472222	19.49833333	-88.932
-99.13472222	19.49861111	-86.631
-99.13472222	19.49861111	-83.616
-99.13472222	19.49888889	-79.743
-99.13472222	19.49916667	-82.326
-99.13472222	19.49944444	-86.039
-99.13472222	19.49972222	-84.787
-99.13472222	19.49972222	-85.6
-99.13472222	19.49972222	-87.987
-99.13472222	19.50027778	-81.967
-99.13472222	19.50027778	-81.457
-99.13472222	19.50083333	-86.443
-99.13472222	19.50083333	-88.63
-99.13472222	19.50111111	-89.686
-99.13472222	19.50111111	-91.257
-99.13472222	19.50166667	-89.88
-99.13472222	19.50166667	-93.867
-99.13472222	19.50166667	-91.075
-99.13472222	19.50166667	-88.946
-99.13472222	19.50194444	-92.528
-99.13444444	19.49583333	-59.089
-99.13444444	19.49583333	-64.401
-99.13444444	19.49583333	-61.553
-99.13444444	19.49583333	-61.553
-99.13444444	19.49583333	-59.87

Figure 2 Data file format

2.4 Data processing

Data processing is performed to obtain useful information from data previously entered into the system.

At this point coverage continuous maps are generated through **"EasyKrig"** which is a software application implemented on MatLab software platform, this makes the prediction of power levels continuously using Krige Method initially developed by Danie G. Krige in an attempt to more accurately predict ore reserves through an algorithm of least squares regression. The interpolation method of Krige facilitates the task of analyzing the distribution of power radiated by an antenna, it is sufficient to take a series of grab samples with the proper equipment (which is capable of obtaining the geographic coordinates of the location and analysis parameters) to create an experimental variogram, and based on it make the most appropriate approach to the theoretical variogram to perform interpolation and move from discrete samples to a continuous measurement map. The semivariogram provides information of the spatial behavior of a variable. Ordinary Krige was used because the mean value is not known, and we know that the value is not constant throughout the study area, but locally can be considered constant; because measurements are made at a distance will be very similar to those made in the vicinity of that point.[6]

To ensure the effectiveness of the prediction is needed validation process; included in the application of **"EasyKrig"** (as shown in the **Figure 3**) in which the approximation error is within the acceptance region determined by the variability of the measurement power.

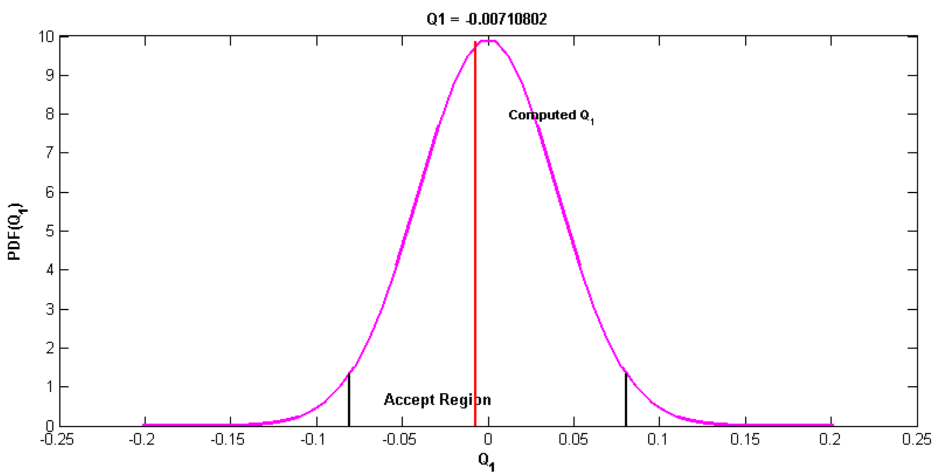

Figure 3 Graphical validation process Krige Method using the software tool "EasyKrig"

The number of measurements needed to ensure a correct prediction of the measured power levels, depend on the range of variability that this power. That is to say, if the power is very variable, must make a greater number of measurements that when the power does not change quickly.

Knowing the function most appropriate to the behavior of the measured power level the information is plotted so that the axes are defined by geographical coordinates, and the power level determines the color which represents the sample, as shown in **Figure 4**. It forming the second layer of the GIS.

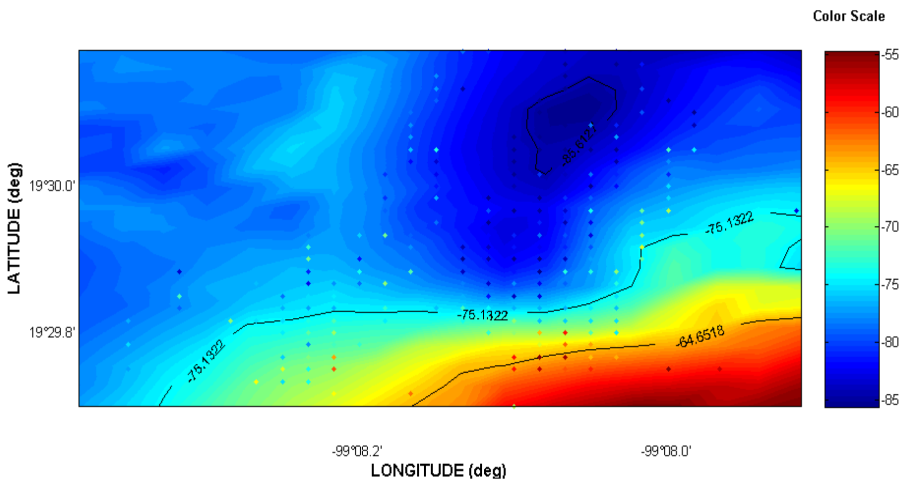

Figure 4 Continuous map of the power levels

2.5 Production data

After data processing we have two layers; satellite photography of the study area and the coverage map. These overlap to produce new data, as obstacles in propagation, the ratio of distance/attenuation of the signal, radiation pattern of transmitting antenna, to name a few. The result of the overlay is shown in **Figure 5**.

Because different Base Stations were radiating towards the area of interest, added more layers to GIS, allowing analysis expands the possibilities, because the process information of each base station in a different layer, thanks to the measuring equipment can identify each SC, it is possible to study interference between adjacent cells, as shown in **Figure 6**.

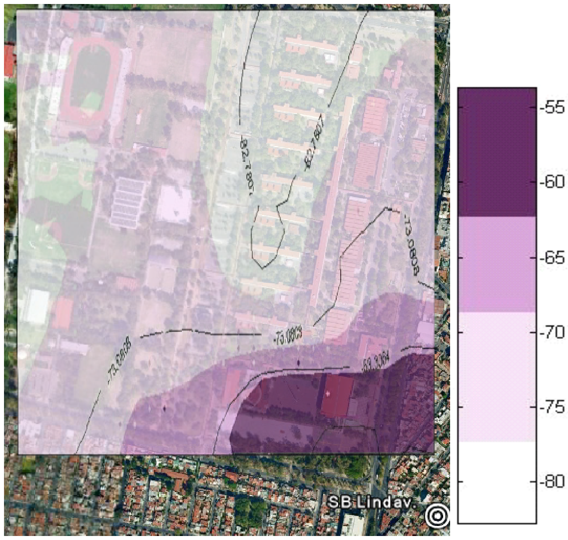

Figure 5 CPICH power distribution in dBm

Figure 6 Comparison of the coverage area of two Base Stations

3. Interpretation of Results

In each layer of the information system were analyzed separately each of the main base stations that provide service in the study area. This allowed a deeper analysis.

For example in Figure 5, we can notice that as the signal collides with building of different heights suffers attenuation proportional to the height of the same. We can explain why there is an increase in power in the upper left of Figure 5; this is due to the effect of multipath propagation, in third generation cellular systems by the type of media access is a favorable effect on propagation environments contaminated.

On the other hand, Figure 6 shows that the Pilot Dominance (strongest signal, indicating the possibility of providing better service) between two base stations with more influence in the radio signal has a conflict, since both radiate a power of similar intensity in the same area, causing the mobile device has a conflict in the choice of the base station will provide service.

Using a SIG in this work, is possible know the configuration of the segmentation of the base station antennas, as shown in **Figure 7**. And indirectly shows the areas where the call will transfer smoothly, because they will not switch to another base station, just the call is transferred to another base station sector.

Figure 7 CPICH power distribution for the sectors of the Base Station identified by the SC 224, 225, 226 [dBm]

4. Conclusions

The rapid growth of cellular networks in Mexico and throughout the world with the aim of providing more benefits to users, causing the cell outline is saturated, creating problems such as interference between base stations. Conflict can be avoided with adequate coverage analysis.

It is at this point that GIS are useful, as a perfect complement for different types of information about a specific geographic area to obtain information not previously known,

- ✓ as the coverage area of each base station system for purposes of interference analysis and transfer areas,
- ✓ obstacles in the signal propagation,
- ✓ multipath propagation effects,
- ✓ Pilot pollution, etc.

Number of parameters that can be studied depends on the capabilities of the measuring equipment, and existing vector model of GIS for the area in question, such as satellite images, contour surveys, hydrographic, etc.

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