World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:3, No:4, 2009

Qualification and Provisioning of xDSL broadband lines using a GIS approach

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Abstract**—**In this paper is presented a Geographic Information System (GIS) approach in order to qualify and monitor the broadband lines in efficient way. The methodology used for interpolation is the Delaunay Triangular Irregular Network (TIN). This method is applied for a case study in ISP Greece monitoring 120,000 broadband lines.

Keywords**—**GIS loop qualification, GIS xDSL, LLU TIN.

I. Introduction

WITH the worldwide deregulation of telecommunication system, high speed broadband lines has become a challenging task for which fast and accurate prediction of xDSL lines is essential. Since last few years, the quality of copper lines has been responsible for the data rate and for the provisioning of services. Typical problems such as the signal attenuation and crosstalk influence the quality of the triple play services. The impact of all these on the quality of the subscriber's services is described.

A GIS application combining spatial (geographic) interpolation and a spatial (database with longitude latitude and xDSL parameters) information into one "system" that allows an operator to interact with both aspects simultaneously is proposed by this paper.

Spatial interpolation is the procedure of estimating the value of properties at unsampled sites within the area covered by existing observations. The technique used for interpolation is the Delaunay triangular irregular network (TIN), or Delaunay triangulation. The Triangulated Irregular Network model [1] is a significant alternative to the regular raster of a DEM (Digital Elevation Model).

This paper is organized as follows: Following the introduction, the broadband network model is presented in section II. Then, in section III the Delaunay Method is described. In section IV the digital terrain formulation is presented. In section V a case study on an ISP in Greece with its results is demonstrated. Finally a brief conclusion is section VI is deducted.

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II. Modeling the Broadband xDSL Network

A topology of a broadband network xDSL consists out of DSLAMs, COs, and CPEs. DSLAM is the device out of which the xDSL signal is generated. DSLAMs are located in the Central Offices (CO) of telecommunication division area. The signal generated travels towards the subscribers over a copper twisted pair. These pairs expand geographically around the CO and end up to customer premises, where the CPEs are located.

At customer premises the signal arrives attenuated. The CPE is connected on the copper pair and the synchronization of CPE and DSLAM initiates. The synchronization rate, depends on the quality of the copper line, the interference and other unpredictable parameters. Though, the key value that defines the line synchronization is the attenuation. The higher the distance from the CO, the highest the attenuation is, the lower the rate. Theoretically, each 1000m of distance, impose attenuation of 13,81db in ideal theoretical loops. In reality, that value is higher.

Each line behaves differently from another as is a unique entity with unique characteristics. Lines that start from the same CO, travel from the same path, and end up at close points among them, have about the same attenuation, and are imposed about to the same interference and noise. As a result, modeling the condition of loop quality, determines in a possible location the loop condition. Continuing, the appropriate xDSL profiles, transmission types and services are provisioned based on the LLU capabilities.

III. Delaunay Method

In this section a Delaunay triangulation (DT) method is presented. The triangulation was invented by Boris Delaunay [2] in 1934. Given a set of three points (P) in the plane these points form a Delaunay triangulation DT (P) if and only if the circumcircle which passes through them contains no other points. Delaunay triangulations maximize the minimum angle of all the angles of the triangles in the triangulation and they tend to avoid skinny triangles.

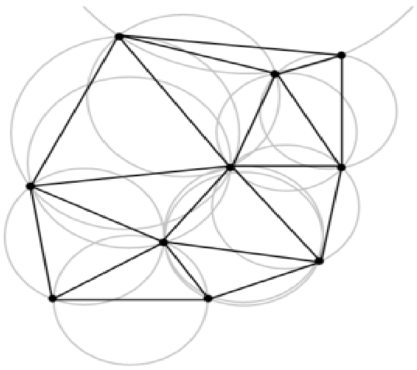

Fig. 1 A Delaunay triangulation in the plane with circumcircles shown

A triangle net for bidimensional space [3] is a Delaunay triangulation if all the circumcircles of all the triangles in the net are empty. In case of the use of tridimensional spaces we use a sphere instead of circle. For a set of points on the same line there is no Delaunay triangulation. For four points on the same circle (e.g., the vertices of a rectangle) the Delaunay triangulation is not unique, there are two possible triangulations that split the quadrangle into two triangles satisfy the Delaunay condition.

One way to identify if the point *D* lies in the circumcircle of *A*, *B*, *C* is to evaluate the determinant [4]:

$$\begin{vmatrix} A_x & A_Y & A_x^2 + & A_y^2 & 1 \\ B_x & B_Y & B_x^2 + & B_y^2 & 1 \\ C_x & C_Y & C_x^2 + & C_y^2 & 1 \\ D_x & D_Y & D_x^2 + & D_y^2 & 1 \end{vmatrix} =$$

$$\begin{vmatrix} A_x - D_x & A_y - D_y & (A_x - D_x)^2 + (A_Y - A_Y)^2 \\ B_x - D_x & B_y - D_y & (B_x - D_x)^2 + (B_Y - A_Y)^2 \\ C_x - D_x & C_y - D_y & (C_x - D_x)^2 + (C_Y - A_Y)^2 \end{vmatrix} > 0$$

Assuming *A*, *B* and *C* to lie counter-clockwise, this is positive if and only if *D* lies in the circumcircle. Assume the following values for the corners in the above triangles. A: (5, 5), B:(10,2), C: (15,5), D: (10,20). Substituting these values in the above determinant we have:

$$\begin{vmatrix} 5 & 5 & 50 & 1 \\ 10 & 2 & 104 & 1 \\ 15 & 5 & 250 & 1 \\ 10 & 20 & 500 & 1 \end{vmatrix} = \begin{vmatrix} -5 & -15 & 250 \\ 0 & -18 & 324 \\ 5 & -15 & 250 \end{vmatrix} =$$

$$\begin{array}{ccccccc} & & S_1 : -22500 & & S_2 : 24300 & S_3 : 0 \\ -5 & -15 & 250 & & -5 & -15 \\ = \; 0 & -18 & 324 & & 0 & -18 \\ 5 & -15 & 250 & & 5 & -15 \\ & & P_1 : 22500 & & P_2 : -24300 & P_3 : 0 \end{array}$$

Then determinant

$$\Delta = P_1 + P_2 + P_3 - (S_1 + S_2 + S_3) =$$

$$22500 - 24300 - (22500 + 24300 + 0) = -3600 < 0$$

The point D is out of the circumcircle.

IV. Digital Terrain Model

For the monitoring of the xDSL lines quality, a GIS system using Digital Terrain Model (DTM) is implemented. The DMT components are: data acquisition, functional requirements and data structures. The DTM model uses as inputs the xDSL line characteristics, spatial info, and TIN as data structure. Output is the visualization of all the possible conditions of the loop quality.

The TIN model [5] represents a surface using a set of continuous non-overlapping triangles. The TIN model has advantage from the regular raster of GRID model as has the ability to describe the surface simply, with economy, using different level of resolution.

The model for the map GIS application [6] using TIN methodology is given below. The input variables are the average downstream rate and the attenuation value.

- The average downstream rate is calculated. Not all subscribers visible on the respond view are used the calculation.
- For a given address, subscribers' info of a 200m circle area around is considered. If there are no subscribers around the given address, the distance towards the CO is calculated.
- For that distance ±200m, a query on the database finds the closest 15 subscribers for that CO. The highest and lowest rates are removed and the average is done by the rest 13 points of reference. If for distance ±200m, there are not 15 entries on the database, an average attenuation is calculated: 1000m correspond practically to 15db.
- For the attenuation value calculated, a query on the database with the rates of that CO for the specific value, gives an outcome of rates that can be used for the average. If, in any case, no entries are found for the average rate, the expected rate is extracted on a static table that corresponds distance to rates. This table is derived from average calculations over distance of the database info.

In every case the respond of the application is the graphical representation of subscribers in the GIS approach, an interface to search for specific location and a colorful map indicating the different loop quality conditions.

V. Case Study

The proposed method has been implemented in an Internet Service Provider (ISP) in Greece. The specific ISP provides triple play services mainly in Attica region. The xDSL statistics are being collected every 5 hours. Using this model has been monitored about 120,000 subscriber's lines.

A. Data Acquisition

The need of an assumption that on a Customer Relationships Management (CRM) system all necessary spatial (addresses, postal codes etc) and network (DSLAM IPs – slots) info are combined, is obligatory. Having all these into consideration, an application - data collector tool is needed to query all ADSL lines (from the DSLAM part) with SNMP commands and store this data in an other view of the database: xDSL profile and transmission type, Maximum Rate - Current Rate - SNR margin, Attenuation both for downstream and upstream are the valuable information that must be extracted from the DSLAM. This operation must run continuously in order to maintain the information of the database updated. All info stored on that DB is what minimizes the unpredictability of the loop condition on an area.

B. Functional Requirements

Specifying the requirements for the system to be built, is sufficiently important to mention that the tool must have both map and grid aspect. Designing and specifying the interactions of potential users can be reconsidered, based on company needs. In this paragraph, we describe a possible implementation of that system functions and propose a presentation model.

The starting layout provides a text input field. Users interface with input a full address (street name and postal code, or city). The map aspect responds with a map and a mark on the address given. In the same map, the closest existing subscribers are presented. Clicking on the given address of every mark, the distance from the central office, the xDSL profile, and the database values for downstream and upstream rates, attenuation and SNR are presented. The application must also calculate – estimate the same average area's potential rates, if on the address given there is no subscriber. The way we suggest for the calculation follows on next section.

Zoom in, zoom out and moving around are available. Zooming in after a scale, may provide the streets and the numbers of the view. Subscribers are represented in the map with different colors: ex. green are the ones whose average rate is higher than the area average, yellow are the ones with rates lower than the average and red are the ones that have no measurement ever performed. Blue is the target address and with a flag is the CO Mark. More info may be added, depending of the needs of analysis. Though, the relevant queries must be done with the data collector.

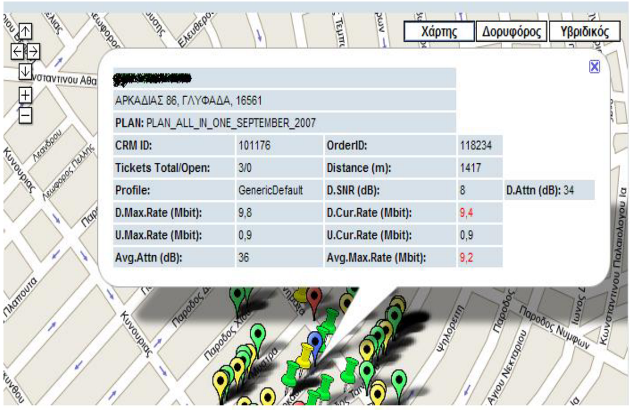

Fig. 2 Info Presentation on map application

The multi-resolution grid presentation [7] provides both the contouring of each COs and in the possible loop condition of the area categorized in the colors of the grid.

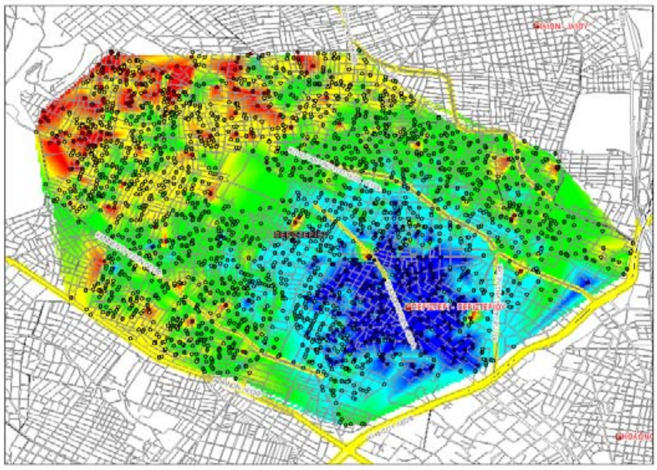

Fig. 3 CO presentation with TIN color selection

C. Data Structure

Several data structures have been developed for DTM for irregular distribution GIS points, like the xDSL subscribers geographical spread on a telecommunication division area. Triangular Irregular Network Delaunay was selected, as requires simplicity, provides economy and is a significant alternative to the regular raster of the GRID model. The data structure used, excludes a small number of points that does not follow the Delaunay rules.

VI. Conclusion

With the latest global financial crisis, new investments on telecommunication infrastructure, like fiber to the home are under sever concerns. The telecommunication operators have to struggle against the low quality copper that was not initially designed for rate demanding applications. It is of paramount importance for an operator to have access to advanced planning tools. Since distance is a factor in DSL deployment, GIS based systems are at the forefront of these tools. The ability to visualize and qualify the LLU has and will be deployed in relation to an existing customer base.

Understanding, planning and controlling the resources in coordination with finding subscribers for each LLU condition is the key to sustainable growth. With innovative geodemographic segmentation solutions from the location intelligence, penetration rates, xDSL customer profiles, comparing and analyzing direct marketing campaigns to existing and potential customers, and lots of more are available to optimize company strategies and increase sales.

Delaunay triangulation seems ideal for data structure in such a digital terrain model. It provides several advantages over other triangulation methods: The triangles are as equi-angular as possible, thus reducing potential numerical precision problems created by long skinny triangles. Furthermore ensures that any point on the surface is as close as possible to a node and last the triangulation is independent of the order the points are processed.

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