Distribution of Municipal Services Access Points over a Territory in a Scenario with Restricted Information

Mariuxi Montes*, Miguel Angel Peña†, Susana Muñoz Hernández‡
Facultad de Informática
Universidad Politécnica de Madrid, Madrid, Spain
* Email: maria.montes.chunga@alumnos.upm.es
†Email: m.pena@upm.es
‡Email: susana@fi.upm.es

***Abstract*—In developing countries we face not only technical issues, but also the lack of basic data that we are obly to obtain by using alternative paths. In the context of a local government on a developing country, this work shows two results. The first one is the procedure to obtain or deduce the needed information from alternative data sources. The second one is how to use genetic algorithms (whose input is obtained from the first result) to configure a distribution of access points for eGovernment services.**

***Index Terms*—eGovernment, Genetic Algorithm, developing countries, access to eGovernment services**

I. INTRODUCTION

This paper proposes a solution to a problem faced when planning eGovernment services for citizens of a municipality with characteristics such as: high rural population, very disperse towns, low Internet penetration and low incomes. First, the topic of eGovernment is discussed. Next, the problem facing the Santa Elena municipality is detailed. Finally, genetic algorithms are introduced as a tool to find a solution to this problem.

A. eGovernment

To successfully implement eGovernment initiatives, an evaluation of involved subsystems such as social, technical and environmental ones is needed [1]. eGovernment is not only about delivery, it is also about a cultural change in how citizens relate with the government [2].

In developing countries where access to Internet is restricted, delivery of eGovernment services raises an important question: how can it be made accessible to citizens?

B. The case of Santa Elena Municipality - Ecuador

The Municipality of Santa Elena is on the coast of Ecuador (see Fig 1.). It has a population of 144,076 where almost 72% of it is rural. These rural zones are very dispersed and every concentration of people is called a "comuna". There is only one "large" city, the municipal capital, and encompasses a bit more than the 30% of the total population.

According to data from the Integrated System of Social Indicators of Ecuador - 2010, 76% of the population of the province live in poverty (as measured by the satisfaction of basic needs including housing, health, education and employment). 63% of the population has completed basic education and 9% have obtained higher education.

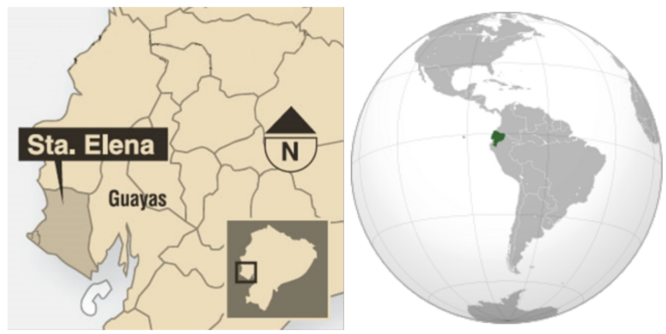

Fig. 1. location of Santa Elena Municipality. Figure based on graphics obtained from www.hoy.com.ec and www.wikipedia.com

There are 59 comunas distributed throughout the geographic territory according to the "Federación de Comunas de Santa Elena". However, lower concentrations of people still exist. These are known as "recintos", but any accessible formal statistics about the number of recintos in the territory are unavailable.

The majority of comunas are located on the coastline and they have good road access with the capital. However, the inner comunas have major access problems between them as well as with the capital due to a poor secondary road network. In addition, the connections between inner comunas are inadequate because of a lack of maintenance of existing roads.

Internet penetration in Ecuador, according to data from December 2008, is 12.3%, compared to the South American average of 30%. This ranks Ecuador 8/10 in South America [3]. The "Superintendencia de Telecomunicaciones" [4] estimates that 37,46% of the total population in Ecuador are Internet users. The province of Santa Elena represents 0,75% of this number. These percentages are growing every year, but

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these numbers are still too low.

Due to these statistics, it is necessary to take into account this low penetration when offering eGovernment services in this territory. One option for facing this issue is to use the strategy shown on [5], which is to use service access points (SAPs) to assure that citizens have access to eGovernment services. SAPs will manage the problem of low Internet penetration and make access to eGovernment services more readily available to citizens in this area. These SAPs would be geographically distributed over the territory in a way that efficiently covers the entire Municipality. This option allows the best coverage for the majority of the population instead of having all services centralized in the municipal capital.

How can this distribution be achieved across this territory? Distribution refers to the quantity and the location of the SAPs throughout the area. This is the question that guides this study. To answer this question, a Genetic Algorithm is used to show an adequate distribution.

C. Genetic Algorithm

Genetic algorithms are adaptive methods and can be used to solve search and optimization problems. John Holland introduced the term ”Genetic Algorithm” in his publication ”Adaptation in Natural and Artificial Systems” [6]. These algorithms are well defined in texts like ”Genetic Algorithms in Search, Optimization & Machine Learning” [7] or ”Modern Heuristic Techniques for Combinatorial Problems” [8].

Genetic algorithms try to mimic the genetic process of living organisms, which evolve generation after generation under the principles of natural selection and survival of the fittest based on Darwin’s Theory of Evolution. These algorithms create the most adaptable solutions for the proposed problems.

II. Material and Methods

This section will show how data was obtained, with an emphasis on the difficulty of obtaining it and the process used to acquire it. The fitness equation used to get a response to the question will also be explained.

A. Obtaining the Data

To address this task, we need some basic information. In the context of a developing country, this is the first and major problem to face because it is not always possible to obtain the necessary data.

The ”Instituto Nacional de Estadisticas y Censos” (INEC) is the institution in charge of maintaining and offering information about the demographics of Ecuador. INEC publishes this information in detailed level, including: national, provincial, cantonal and parochial. For the purposes of this study, a lower level, the zonal level, is needed to know the population of every comuna and recinto. To obtain the information needed for this level, the census database of the province was downloaded. Although this database detailed the population at the zonal level, a problem was encountered with this information. Because every zone is identified through census codes and not by name, it was impossible to obtain the census codes for all

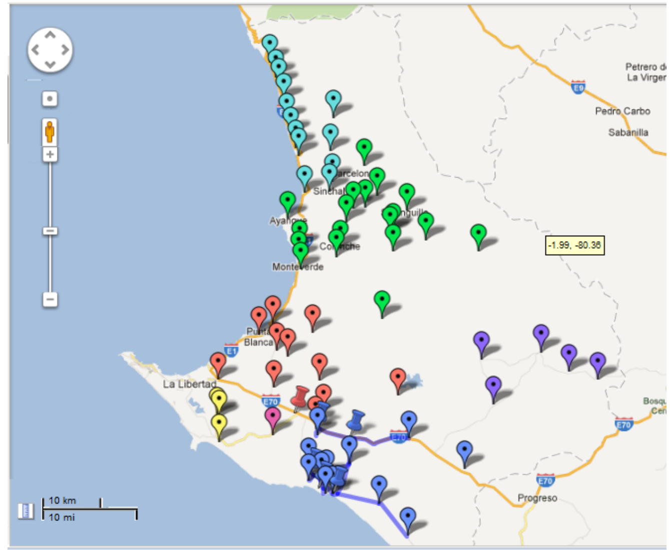

Fig. 2. Distribution of comunas through Santa Elena Municipality - Ecuador

comunas and recintos. Thus, only those comunas and recintos, which were identifiable through census codes were used.

Figure 2 shows an image of the Municipality and distribution of the comunas and recintos throughout it. On this map we can see colored points where each color represents a specific parish. There are 7 parishes that encompass a total of the 56 comunas and recintos selected to carry out this study. This figure only represents the comunas and recintos selected and not all of the existing comunas.

To measure the distances between points (comunas, recintos and crossroads), maps from Google Maps were used because of the layout of the main roads. However, Google Maps does not lay out the secondary roads and thus the use of maps in PDF format of every parish was necessary. All of these maps were downloaded from the INEC webpage. This data was obtained manually, using the measurement tools provided by Google Maps as well as by Adobe Acrobat, to measure distances between comunas and recintos and between crossroads that establish different roads to reach a determined comuna or recinto.

The identified communication roads are from various levels: (1) There is one main road connecting comunas settled on the coastline; this road is part of the E1 national highway. This road is in excellent condition and has continuous maintenance work. It is usable all year at a maximum velocity of 100Km/h. (2) There is a part of this E1 national highway that connects other groups of coastal comunas but its maximum velocity is reduced by 10 Km/h, resulting in a maximum velocity of 90 Km/h all year. (3) There are secondary roads, which connect inner comunas and recintos that are not settled on the coastline. These roads are usable all year, although they do not have good maintenance. These roads are narrower than the roads mentioned above and thus their maximum velocity is 60 Km/h usable all year. (4) Finally, there are ”summer roads” that are usable in dry season but during rain season it is difficult to

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drive over these roads. These roads have a maximum velocity of 30 Km/h. The Figure 3 details the kind of maps used to measure distances between points and the levels (types) of existing communication roads between them.

An approximation of the time needed to communicate between each comuna and recinto was made. This was done considering the distance between comunas and recintos and the road level (maximum velocity) that communicates them. To make this approximation, the Floyd-Warshall algorithm [9] was used. This process is use to assure the lowest communication time between two towns amongst all the possible communication options available.

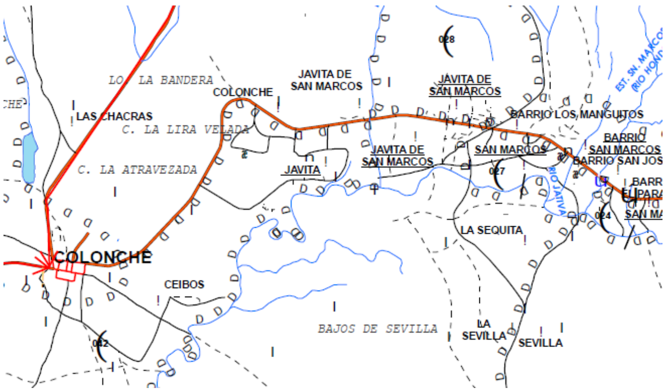

Fig. 3. Map, which details roads that connect comunas. Santa Elena - Ecuador

There is useful information about bus routes and frequencies that was unavailable.

B. Personalizing the Genetic Algorithm

It is necessary to establish a representation of the problem using the data about th number of selected comunas. Every individual has 56 genes (l=56), one for each comuna or recinto that would be able to host one SAP. If the gen is OFF, it is equivalent to a specific comuna or recinto with no SAP, and when the gen is ON, it is equivalent to a specific comuna or recinto with a host SAP. One possible configuration of an individual chromosome would be:

1100011100000000000000000000
0000110001000000111000000000

Then, the objective function is defined. To define it, information on the population of comunas or recintos and displacement times is considered. This function has to achieve a balance between citizens displacement time to the closest SAP and the cost of implementing a SAP.

An adjustment has been made to work with two distinct units: the population that moves and the cost of having more access points. The function punishes these two possibilities: moving the entire population to the main town or putting an access point in each town.

A weighting was made, giving more weight (0.6) to SAP implementation cost and a lower weight (0.4) to the citizens' displacement time.

The objective function is:

$$0,4\left(\frac{\sum_{i=0}^{l}(population_i * distance(i, CloserSAP))l}{\sum_{j=0}^{l}(population_j * distance(j, MainCity))}\right) + 0,6(TotalSAP) \quad (1)$$

where $l = 55$ (total number of comunas and recintos)

- *Initial population* would be $\lambda = 2l$, as suggested by Alander in [10]
- *Stop* or the maximum number of iterations is configured on 200
- *Crossover method* selected was one point cross.
- *Replacement method* is partial change, where a part (2 individuals) of the parents is maintained and the other part is of the children.
- *Mutation method* is aleatory mutation.
- *Mutation probability* is $1/l$ like De Jong suggest in [11].

III. Results

The first execution time took 3 seconds, and after running the algorithm, it gave a solution with a fitness value of 7.47 represented like:

0000000000000000000000100010
0000000000000000010010000100

Five comunas were selected to host a SAP from the total of 56. Translating this numerical representation to a map, the figure 4 shows a graphic where the selected comunas are highlighted.

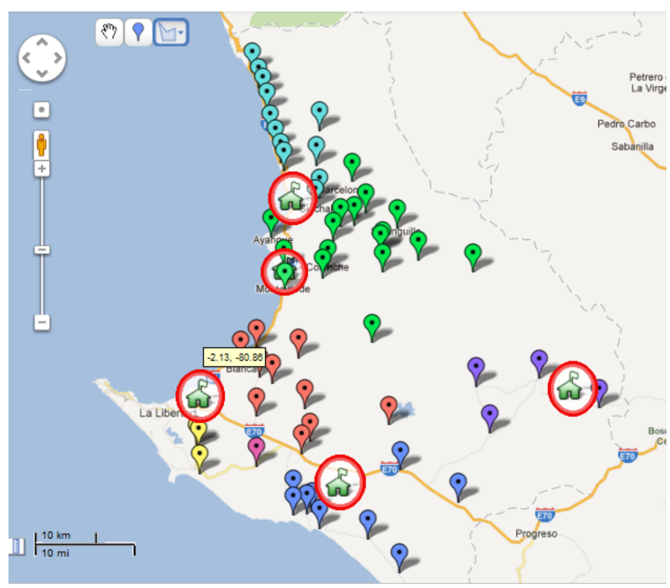

Fig. 4. Selected comunas to host a SAP

After this first execution, the algorithm was run more times, obtaining similar fitness values. Figure 5 shows that the solutions given by the genetic algorithm are improved with every iteration (population).

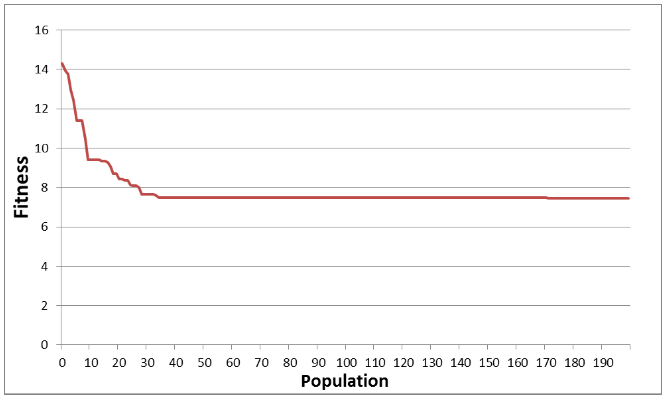

Fig. 5. Solutions improved with every iteration (population)

IV. Conclusion

Our first goal was obtaining a good distribution for public services at developing countries. Technically, the use of genetic algorithms is appropriate, but the major difficulties that we have found to use our algorithms is the inherent lack of basic information at these countries.

In Section II-A shows how the data to work with the genetic algorithm was obtained. This process makes possible to apply the algorithm to countries when the informatios is absent (general case in developing countries). One of the major problems is the rather availability of information about the public transport that connects all isolated places.

Evaluating this solution with the additional common sense based on the knowledge of the studied zone can add some deduced information. Of course, the obtained solution can be improved by adding more related information to our objective function. We can select one solution (the best) among the group of alternatives that we obtain from the algorithm.

According to Figure 5, the results are improving with the iterations of the algorithm. This is notable from the first iteration until around iteration thirty, later the solution keep stable. So, a limit of 30-50 iterations in the algorithm seems to be enough to obtain good results.

In this work, we exposed a basic study case where there is not previous constraints like existing points that must be inserted in the final solution. For future work, more complicated cases can be analized through inserting restrictions in time, distance, applying political criteria, etc.

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