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Optimal Sizing and Routing of Access Points in the Station Network of the Quito Metro as an Advance to a Smart City

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Abstract: Smart cities today have become an example of technological development progress, since they greatly improve the quality of life of its inhabitants through the use of intelligent systems and networks, in addition to communication in times very close to the real time between different access points where people could connect safely and efficiently, the Quito metro is a new project and the first underground metro built in Ecuador, so at a historical level there is no precedent for it. The following document presents the optimization, dimensioning and routing of intelligent communication networks throughout the stations of the future Quito metro, with the aim of demonstrating the advantage of having intelligent stations that allow passengers to know exactly where the unit is located. to which you want to go and the departure and arrival times of the same, together with free internet access that is visible in each of the stations, whether main or secondary in the metro, through the Dijkstra algorithm method used for the Optimum routing between access points with the aim of minimizing the cost between them starting from a central or origin point to secondary points of the same system, used mainly in communication networks of new systems and current technologies.

Keywords: Communication, Networks, Optimization, Routing, Sizing, Smart Cities, Transport

1. Introduction

The development and growth of the population in cities raises a series of concerns about the capacity of the latter to face the basic problems of the growing urban population [1]. One of these problems is public transportation. Large developing cities must have an efficient public transport system that offers users short waiting times between departures, fast travel times, punctuality and clear information [2].

The city of Quito seeks, through the construction and use of the Metro, to reduce the traffic produced by the growing increase in transport vehicles during peak hours (seven to nine in the morning and from six to eight at night), offering its users the greatest possible comfort and all the benefits that a smart station can offer today, besides, its operation requires a large amount of energy, so the management of multiple energy sources is an important issue for planning and operation [3] of it. The intelligent public transport system is an irreplaceable part of the 'Smart City' agenda [4]. The term 'Smart City' was launched as the "answer" to the rapid challenges related to urbanization, in a context of sustainable urban development [5]. Many cities and countries have formulated policy objectives regarding a change from road traffic to trains, trams and buses [6], since it represents a safe and effective option for their productive development and to ensure minimum standards of life [7] for all people. In order for the Quito metro stops to offer the greatest comfort and possible benefits to its users, it seeks to place access points to the telecommunication network, which today is characterized by a high speed of information transmission, a great dynamic of changes in the structure, a multiservice nature of information flows and strict requirements for the quality of services [8], as well as the application of loT or internet of things, these are mostly wireless devices whose function is to make the connection of several devices to each other, which provide provision of communications, detection, data collection and information analysis [9] with the aim that each person can monitor from an intelligent device, the time and distance to which their next person is located. stop or at the same time the metro you want to take.

The plan to convert a normal metro station into a smart station becomes feasible when technology and the corresponding study are applied. For the placement of the access points to the network, certain parameters must be known beforehand, such as how many people there will be per station and how many of them use a smart device. Data of this type can be obtained by applying methods such as the reversing passenger method, which proposes that the proportion of boarding passengers is equal to the proportion of passengers getting off at the same stop [10] or by using the trip chaining model that does two strong assumptions: (i) each passenger gets on board at the station where he got off on the last trip; and (ii) each passenger's daily final stop is the same as their first boarding stop of the day [11]. It is after these processes that the dimensioning for the installation of network access points can be carried out, since it allows knowing the coverage radius and the user capacity that each point must have to supply each one of them, thus obtaining more refined control of all connected devices [12]. Finally, the last step for the generation of the communication network is to carry out the routing study, since this allows finding data transmission routes with energy efficiency, maximizing the useful life of the network, improving the robustness and reliability of the routing. [13] as well as support data merging and data forwarding.

2. Intelligent Stations in the Quito Metro

In recent years, many efforts have been invested in improving the quality of life in cities. These efforts are strongly driven by advances in the fields of ICT (Information and Communication Technology) and IoT (Internet of Things). Therefore, improving all aspects of living conditions and city management seems to be a crucial element of future cities. These future cities are often called smart cities [14].

For a city to be determined as a smart city, it must have the pillars of smart buildings, smart energy and smart mobility in conjunction with the application of information and communication technologies.

This development of cities reveals the problem as indicated in [15] for which users seek a better service than they are used to and being able to offer said service in turn allows the city to be considered as an intelligent city and continue its advance towards a total complement of the system.

The transport system is one of the main intellectual systems that a smart city has. The basic idea of producing an intelligent public transport system will be developed in an ARM system using GPS / GSM technology [16, 17], this intelligent system will allow knowing the current location of the integrated vehicle and the time in which this vehicle will arrive at said stop through the telephones connected to the access point of each smart metro stop. The user will be able to observe within a map the route that the vehicle makes and in the same way where it is at the moment to know the time it will take to arrive at the boarding of the users who are visualizing the vehicle, this is achieved from the connection of the GPS installed in each vehicle with that of the application, informing the user of the specifications already detailed, in addition, this access point will allow connection to the Internet in the interval that users remain at the stop, making use of access points with a fairly large capacity equal to the radius that said access points must handle.

The most important factor of the intelligent system applied to the metro stops is ordering the existing distances between each of the intelligent stops, starting with the planning of the basic concepts of transport time to provide metro data through the application of information which users can access from the access point installed at each stop [18]. The access points are communication centers between the vehicles and the users, that is, between the installed GPS and the application that generates the data about the vehicle [19]. The Quito metro is an example of optimization of spaces and distances in each of the stations analyzed, which helps us to generate a smart city based on the improvement of transport and travel times in which a user can reach their destination. destination, thus benefiting the work of each one of them, thereby increasing the production efficiency that a smart city could generate [20].

Installing access points at each metro stop will make the transport service that will be provided to users more efficient due to the monitoring that they will be able to carry out on the units, providing information to users on staying in the station or looking for a new means of travel. to your destination.

Developing an intelligent public transportation system is to reduce the users' time problems related to the public transportation system.

In Ecuador there is a sufficient level of technological development to be able to carry out this project within Quito and the realization of said project would allow the city to get closer to being a smart city, addressing necessary developments so that in general the country can develop and obtain better levels of technology and thus achieve greater advances in the transformation towards a smart city within the aspects that would not yet be achieved. The basis for creating an intelligent system is technology, the internet and, in turn, the changes that must be made in each of the vehicles to be able to connect properly with the network and thus have good data transmission, in this case the Data to be known are the information already described for each of the vehicles and their respective stops [21].

The vehicle to be used within this project, in this case the metro, must be equipped with a microcontroller, GPS and GPRS locator to carry out the pertinent communications [22].

Reliability in public transport is of great importance for the progress of a city since it does not depend solely on private vehicles, the help generated by the use of the smart stop for users will allow them to reach their destinations more accurately or even take alternative routes in the case of observing that the transport that has the monitoring technologies will take a long time to carry out the route that the user requires [23].

Improving the public transport service, in this case the metro, allows to improve some parameters that can alleviate traffic congestion and allow the circulation of cars in a more efficient way [24].

To carry out this project, an aggregation tree is created which will serve to consult costs and necessary connections around the intelligent transport system, in addition to generating an optimization of a number of initial access points to be used, thereby achieving an optimization in the number of access points that will be used for the development of the project [25]. Thus reducing costs in equipment and connection, in the same way the coverage that will be had must be managed to be able to cover the entire system in a correct way and that there are problems in the wireless connections between the sensors of the vehicles and the application used by the users.

Offering the transportation service of the Quito metro greatly facilitates the mobilization of the city and helps to keep the user satisfied with the service that is being delivered and in turn allows progress in technological development for the city [26].

3. Problem Formulation

3.1. Variable Table

Table 1. *Table of sizing variables.*

Symbol	Specification
U	All users
A	Access point (AP's)
δ	Quantity of elements
T	Capacity
R	Coverage
p	Refers to a candidate site.
b	Refers to the user
F	Number of active sites
Q	Number of users covered
W	Existing link
H	Candidate site set
D	User set

Table 2. *Routing Variable Table.*

Symbol	Specification
U	Link weight or distance
A	Access point (AP's)
δ_f	Value taken by the candidate site.
T	Link
Q	Link set
R	Set of nodes
b	Refers to the user
f	Refers to a candidate site.
d	Source node
c	Destination node
H	Existing value if link
$Q_{f,salida}$	Set of outgoing links from candidate sites
$Q_{f,entrada}$	Set of inbound links from candidate sites

3.2. Mathematical Model

Sizing

$$min \sum_{p=1}^{A} F_p \tag{1}$$

$$Q_b = \sum_{p=1}^{A} W_{p,b} \ ; \ \forall b \in D \tag{2}$$

$$\sum_{b=1}^{U} W_{p,b} \leq T.F_p; \ \forall p \in H \tag{3}$$

$$\sum_{b=1}^{U} Q_b \geq U.R; \tag{4}$$

$$W_{p,b} \ \leq \ \delta_{p,b} F_p; \ \forall p \in H, \forall j \in D \tag{5}$$

Routing

$$min \sum_{(f,b)\varepsilon Q} U_{f,b} H_{f,b} \tag{6}$$

$$\sum_{b|T_{f,b}\varepsilon Q_{f,salida}} H_{f,b} - \sum_{j|T_{f,b}\varepsilon Q_{f,entrada}} H_{f,b} = \partial_f; \forall_f \varepsilon R \tag{7}$$

$$\partial_f = \begin{cases} 1, si\ f == d \\ -1, si\ f == c \\ 0, si\ f \neq d, f \neq c \end{cases}$$

3.3. Pseudocode

1) Start algorithm
2) Statement
   xs= vector with the lengths of each user.
   ys= vector with the latitudes of each user.
   xse= vector with the lengths of each candidate site (AP's).
   yse= vector with the latitudes of each candidate site (AP's).
3) Direct assignment
   U= get length of vector of users.
   A= obtain vector length of candidate sites (AP's)
   Z= create a single vector with the values of the length vectors of users and candidate sites.
   W= create a single vector with the values of the latitude vectors of users and candidate sites.
   loc1= create an array with the vectors W; Z
   HH= get the length of vector Z
4) Process

```
For (1 to HH)
   Obtain the haversine distance
End
For (1 to U+A)
   Node
   While (node's<U+A+1 & node's>0)
   Measure the meters of the tree
      If the length of the tree in meters = 2
      Width =0.75
      Link
      End
   End
End
For (1 to U+A)
Dijkstra
   For (1 to length)
```

Print link
End
Cost=measure the meters of the tree
End

5) Visualization

Print ("usuarios")	(Users)
Print ("Sitios candidatos AP's")	(Access point)
Print ("Enlace")	(Link)

6) End algorithm

4. Analysis of Results

4.1. Location of Access Points (AP)

Access points (AP) are network devices which allow us to connect wireless communication equipment that connects to a router by an Ethernet cable and projects a Wi-Fi signal in a designated area, capable of connecting communication devices such as cell phones, tablets, or laptops. By installing access points throughout the metro stops, users will be able to move freely thanks to the coverage that reaches the station, without suffering interruptions in service. As they move through the station, their devices seamlessly switch from one point to the next without breaking the connection. In this case, the subway station provides the benefit to users of each of its 15 stations (Quitumbe-El Labrador) as shown in Figure 1.

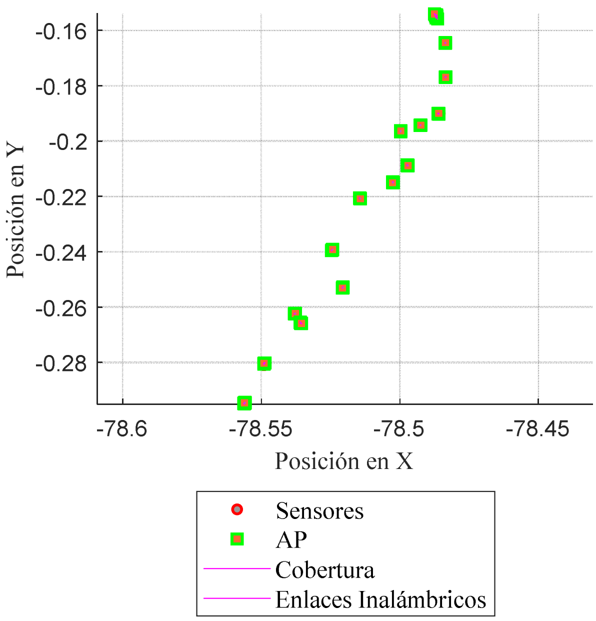

Figure 1. *Location of all stations with AP.*

4.2. Types of Stations

Taking into account the number of people who enter the stations and disembark at it. It was decided to implement main and secondary stations. The main stations have a greater number of users where the number of APs increases, as can be seen in Figure 2, where the Quitumbe stop is located. With respect to the secondary station that makes up the majority of the public system with a smaller number of users and AP, as shown in Figure 3 of the Central University stop.

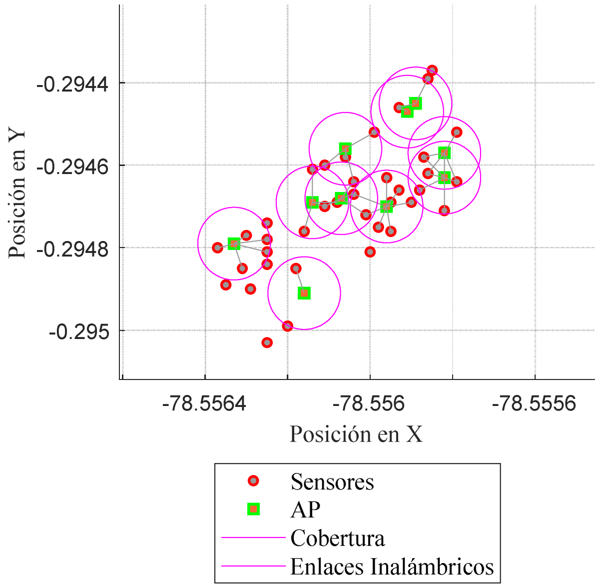

Figure 2. *Main Station (Quitumbe).*

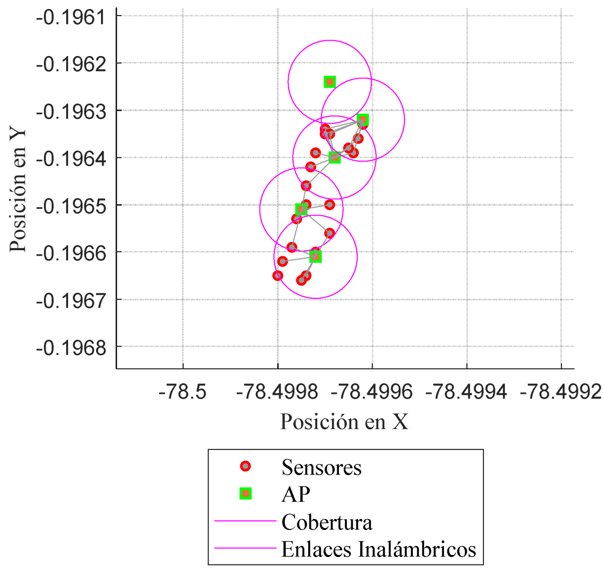

Figure 3. *Secondary Station (Central University).*

4.3. Routing

Routing is the way to search for a set of nodes, connected to each other by means of communication links, which can send information from one node to another. In each of the stations the routing is performed as shown in Figure 4. Taking the main station (Quitumbe) as an example, a set of existing links is defined in Figure 5, where a graph representing the network typology was created. From the same station we can observe the flow obtained in Figure 6.

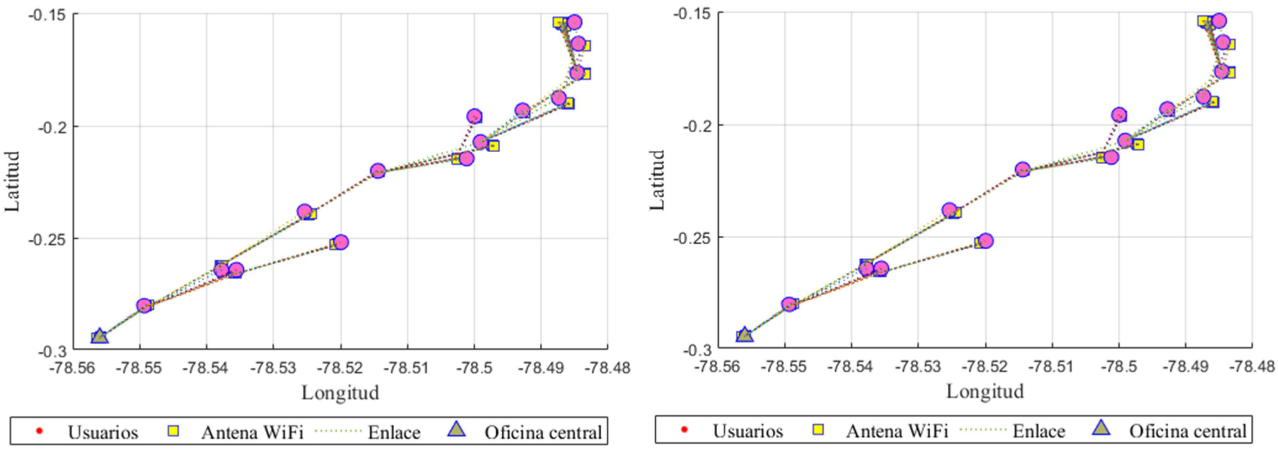

Figure 4. *Routing of each of the stations of the transport system.*

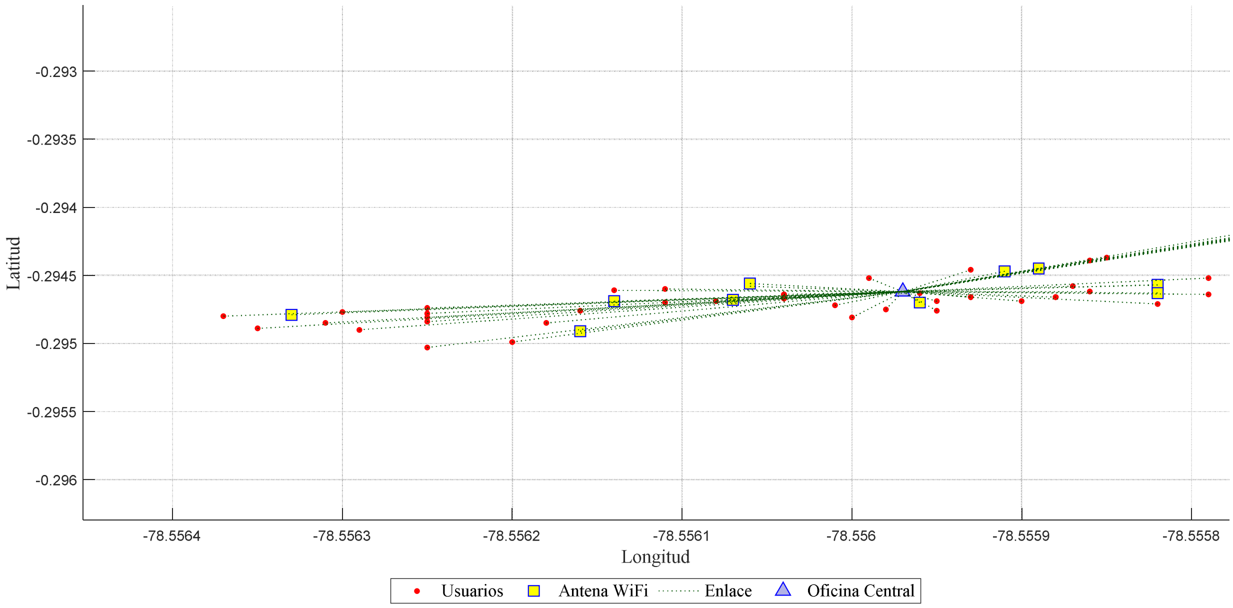

Figure 5. *Main Station (Quitumbe), existing links.*

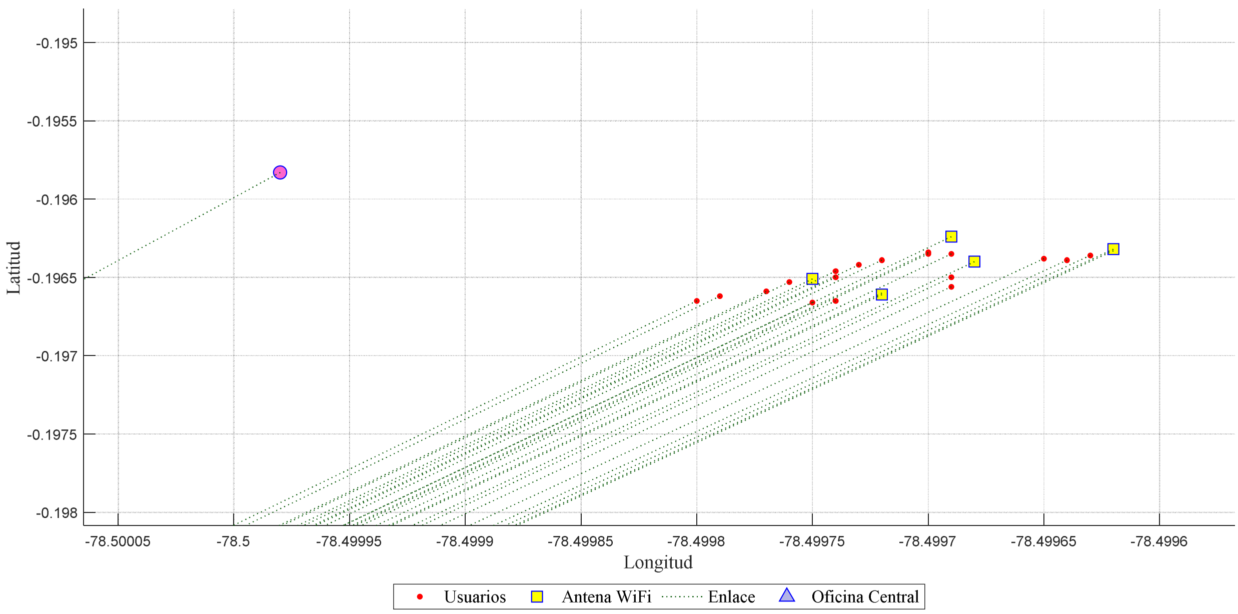

Figure 6. *Secondary Station (Central University), flows.*

5. Conclusions

For the dimensioning of possible connection points in the metro stations, important data is taken such as the radius and percentage of coverage that we want, as well as the number of users that we will have at each connection point. When developing the routing we can observe each link route that is generated, of course the program will automatically choose the fastest and lowest cost possible.

A good routing in the network guarantees us an optimal service so that the user has adequate connectivity in each of the stations of the transport system. This will allow us to improve the quality of life of each person who boards the Quito Metro, in addition to offering and fully satisfying the communication and internet connection service.

Reaching the goal of transforming the city of Quito into a Smart City entails a series of changes that involve the creation and improvement of systems that today have become basic, such as electrical and telecommunication networks. Each small advance (as in this case the creation of smart stations) means climbing one more step to meet the goal of being a smart city that provides quality services to all its inhabitants.

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Biography

Cesar Antonio Zapata Ayala, was born in Quito - Ecuador on January 30, 1999. Currently a student of the Electrical Engineering degree at the Salesian Polytechnic University. His basic education was carried out at the Rosario Gonzales de Murillo fiscal school and his baccalaureate at the Don Bosco Salesian Technical College-Kennedy House, obtaining the title of Technical Bachelor in Installations, Equipment and Electrical Machines.

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