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Research for Solving Optimization Problems of Planning and Allocation of Frequencies for Mobile Operators

Chaker Mezioud and Mohemmed Khireddine Kholladi
University Mentouri of Constantine, Laboratory MISC, Algeria
cmezioud@yahoo.fr, kholladi@yahoo.fr

***Abstract*– The radio has been a large-scale development in recent years, with the advent of GSM (Global System for Mobile Communications) mobile phone. This growth is primarily due to the emergence of internationally accepted standards which facilitated the large-scale deployment, and also control technologies involving telecommunications, electronics and computers. Deploy these networks has been a great challenge for operators who have to master radio waves to completely new applications in relation to what was done since the beginning of the century. We went from broadcasting, personalized information and requirements for quality of service. On both issues, operators have made enormous progress in research on methods and planning tools that incorporate such models radio wave propagation, models for estimating quality of service and optimization algorithms on the setting.**

***Index Terms*– Mobile, Cellular Networks, GSM, Ontologies, Optimization Methods, Color Graphs and Frequencies Allocation**

I. INTRODUCTION

THE current revolution in telecommunications involves a considerable expansion of mobile networks. The GSM (Global System for Mobile Communications), offers its subscribers the ability to communicate freely without the constraints of the fixed network. Today, millions of subscribers use a mobile phone for personal or professional activities. Time spent on the phone on the move is growing and it is difficult for many people to imagine giving up this instrument, become familiar. With nearly 99% of the population and over 90% of the territory covered by at least one mobile telecommunications network, the ability to call on the move is now in common use.

Also the design of mobile networks is a complex problem that involves both theoretical and practical aspects. It's about finding the best cellular architecture under multiple criteria, such as including the quality of coverage: ensuring a radio link at any point in the area to cover, the absorption of the charge, mobility and scalability. The main concern of the operators was to provide outdoor coverage (external environment) in terms of roads, avenues, parks, ... to maintain communication during the movement of subscribers. Planning for such solutions is the use of effective models for predicting coverage that define the main parameters: transmission power, receiver sensitivity, antenna type to use, location of antennas, etc. Such models are used to estimate the attenuation caused by different factors and to ensure that a certain quality of the received signal according to the requirements and avoid any degradation of quality or even a break in the communication. Indeed, the coverage problem or location of antennas while consider the various changes it may undergo any region at the time line is to find a cutting strategy and implementation ensure coverage up to a given geographical area, with minimum investment cost.

This work is based on a study of the various technical components necessary to operate a cellular network, in order to provide a baseline optimized in an outdoor environment, a study that leads to the presentation of a new approach , based on spatial ontologies, while using an optimization method suitable to our needs. For this we will give the steps that led to the realization of our project as follows. We will introduce the concept cell, the network structure, architecture canon and its component parts. Then we will give great importance to an important concept for our approach which is particularly ontology ontology space, we thought of a spatial integration of ontologies in our approach, this will allow us to arrive at better, which is why we ended up going to have to have a section about the world of ontologies. Next, we will consider the different optimization methods in order to propose a solution to the problem of frequency allocation and reuse. In the end, we will give a description of the proposed solution with key points, and the various constraints in a given geographical area.

II. THE GSM CELLULAR NETWORK

GSM is a digital cellular mobile telecommunications. It consists of several entities, which have specific functions and interfaces.

A. GSM Network Architecture

The architecture of a GSM network can be divided into three subsystems:

- The radio subsystem containing the mobile station, base station and its controller.
- The network subsystem or transport.

- The subsystem operational or operation and maintenance.

We can summarize the architecture of the GSM network, through the Fig. 1:

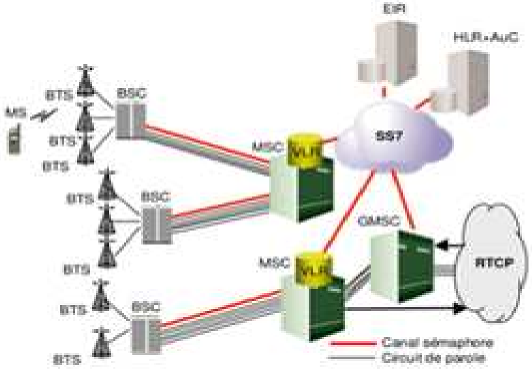

Fig. 1: Representation of the GSM network architecture [12]

1) The radio subsystem BSS (Base Station Sub-system)

It handles the radio transmission. It consists of several entities including the mobile base station (BTS Base Transceiver Station) and a base station controller (BSC Base Station Controller).

• *The base station BTS (Base Transceiver Station):* The BTS are access points to the GSM network subscribers. These are antennas at the top of buildings or on roadsides. They support the access of mobile radio coverage area which includes the operations of modulation, demodulation, and error correction coding and channel estimation. They disseminate general information about the cell and are useful for moving back and measures the quality of transmission in the cell at BSC [4].

• *The BSC (Base Station Controller):* The base station controller manages one or more base stations and communicates with them via an interface. This controller has different functions at the level of communication and operation.

For functions of communications signals from base stations, the BSC acts as a hub since transfers' communications from the different base stations to a single output. In the other direction, the controller switches the data to the correct leadership base station.

At the same time, the BSC acts as a relay for various alarm signals for the operations center and maintenance. It also feeds the database of base stations. A final important feature is the radio resource management for the area covered by different base stations that are connected. Indeed, the controller manages the handoffs of users in its coverage area.

B. The network subsystem NSS (Network Sub System)

The elements of the NSS support all the functions of monitoring and analysis of information contained in the databases needed to establish connections.

• *The MSC (Mobile Switching Center)*: The mobile switching center is connected to the radio subsystem through the interface A. Its main role is to provide switching between mobile subscribers and those of the public switched network (PSTN).

• *The HLR (Home Location Register)*: The HLR is a database containing all information relating to subscribers.

• *The VLR (Visitor Location Register)*: The VLR is a database that stores information about a particular region. We find the same information as in the HLR with the addition of the temporary identity of the user and the location area.

C. The sub-operating system or operating and maintenance OSS

This part of the network comprises three main activities of management: administration, business management and technical management.

The network is interested in technical maintenance operation of network elements. It manages alarms, faults and security [10].

III. CELLULAR COVERAGE

The GSM network has evolved since its introduction and this at different levels from which we quote the cover. Indeed, the success of an operator depends strongly on the quality of coverage it offers to its subscribers. The main concern was to provide almost complete coverage in the outdoors to maintain communications while traveling subscribers [3].

To achieve this result, we believe that the integration of ontologies and spatial optimization methods would be necessary for our approach, due to what these two concepts will be discussed in the following sections.

IV. ONTOLOGIES

"Ontology is the specification of a conceptualization of a domain of knowledge".

Ontology can be characterized as structuring concepts in a domain. We can distinguish several types of ontologies including:

• *Ontologies type thesaurus:* Also known as taxonomy, they are used to define a vocabulary of reference [2].

• *The domain ontologies:* These ontologies of domain-specific conceptualizations.

• *The application ontologies:* These ontologies contain the domain knowledge required for a given application [7].

• *The generic ontologies:* These ontologies express conceptualizations apply in different areas.

• *The representation of ontologies:* These ontologies conceptualize the primitive languages of knowledge representation.

• *The geographical ontologies:* They cover: i) the ontology of space specifically dedicated to the description of the concepts that characterize the area, ii) the geographical domain ontologies as an ontology modeling the concepts of hydraulic data, and iii) the spatialized ontologies (or space-time), which are ontologies whose concepts are located in space. A temporal component is often necessary in addition to the modeling of geographic information, as the geographic applications also often handle temporal data or space-time [7].

We will then develop the latter type of ontology is the ontology of space; these will be the subject of our study.

A. The components of an ontology space

Spatial Ontology has four components:

-The mereology: refers to the concept of party.
-Topology: the notion of connection.
-Location: place an object in space.
-Morphology: based on a primitive notion of what the hole.

B. Specification of ontologies

The specific needs of ontologies can be identified in four points:

i) information modeling and their semantics that requires rich enough models and geographic information, concepts for describing spatial characteristics both in discrete form and / or continuous.
ii) reasoning to be able to infer / classify information and check the consistency of descriptions.
iii) instances for data management if the ontology contains
iv) applications to query the ontology at both instances at the schema level.

C. The needs of an ontology

The spatial ontologies have specific needs that are related to the following requirements:

- Define the spatiality using different spatial data types (line, point, surface simple, ...), types of space objects (that is to say, having spatial attributes), spatial relations such as topological relationships and / or continuous fields (raster).

- Define intentionally spatial concepts with axioms containing spatial predicates.

- Reasoning about the spatiality of instances, that is to say, inferred from spatial relationships described the set of relations valid.

Since all ontologies, ontologies can be used for space exploration, but also information extraction and beyond for interoperable GIS (Geographic Information Systems). Subsequently we will address the second key component to our approach, these optimization methods.

V. OPTIMIZATION METHODS

To overcome the problem of frequency limitation, each geographical area to be served is divided into cells of varying size (from 100 m to 30 km) [8]. Each cell is associated with a base station whose output power varies with the size of the cell. In the following we discuss the problem of allocation of frequencies with different optimization methods.

There are two main methods of resolution (Fig. 2). On the one hand, the deterministic methods (exact methods) which ensure the probabilistic of the resolution, on the other approximate methods heuristic meta-heuristic (incomplete) who lose completeness for efficiency.

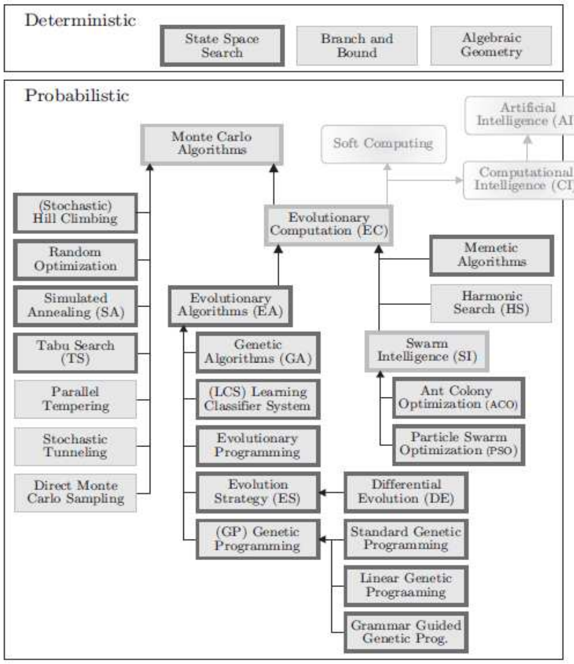

Fig. 2: The taxonomy of global optimization algorithms

A. The exact methods

We can define an exact method as a method that guarantees obtaining the optimal solution to an optimization problem. The use of these methods is particularly interesting, but they are often limited to the case of small problems [5].

B. The exact methods of coloring

The frequency assignment problem is a problem in the class of graph coloring (Graph Coloring Problem). To solve the problem of allocation of frequencies, we use the coloring of the vertices of assigning all the vertices of the graph color (frequency) so that each pair of vertices of different colors or, in other words, s 'there exists an edge [xi, xj] of E then we have c (i) = 6 c (j).
The minimum number of colors needed to color the graph respecting this constraint is called the chromatic number XG.
The application of graph theory will allow us to find the minimum number of frequencies allocated to base stations and minimizes the entire interference.

C. The approximate methods (metaheuristics)

Meta heuristics are based on the same principle of finding a solution suite step by step.
Are:

- Genetic Algorithms AG (Evolutionary Algorithms)
- The tabu search method RT (Tabu Search)
- The simulated annealing RS (Simulated Annealing).

- The algorithm of ant colony CF (ant colony).

D. Selection of the method of resolution

The combinatorial optimization problem that interests us is: X is a set of feasible solutions and a function f defined on X, is to determine a solution s * of X minimizing f on X.

Define a neighborhood N (s) for any solution s of X, we will use a technique of moving from neighboring solution s solution s' N (s), while trying to minimize the function f. Many heuristics have been developed in this context, certainly the best known being the method of descent: so that there is a solution s 'close to the current solution s such that f (s') <f (s) one moves from s to s' which becomes the new current solution. This method of descent then stops at the first local minimum encountered. The main disadvantage of this technique comes from the fact that while the value of this local optimum may be much higher than that of a global optimum [11].

A general method other combinatorial optimization was proposed by Glover: This is the technique which we denote Tabou TS (Tabu Search in English). One of the main ideas that constitute the method is to choose the best solution every move neighbor s' of the current solution s. As long as one is not in a local optimum, TS behaves as the method of descent and improves at each step the value of the objective function. When reached by an optimum cons, TS chooses the least bad neighbors, that is to say one that gives an increase as small as possible to the objective function.

The disadvantage of this method based on a single principle is that if a local minimum s is at the bottom of a deep valley, it would be impossible out of it in a single iteration, and a shift of the solution s to a solution s' N '(s) with f (s')> f (s) may result in the next iteration, since the reverse movement of N s (s') and f (s') <f (s) is therefore likely to cycle around the local minimum.

For this reason, TS is based on a second principle is to remember the last visited solutions and prohibit a return to them for a fixed number of iterations. The goal is to give enough time for the algorithm to allow it to exit from any valley containing a local minimum. In other words, at each stage TS keeps a list of solutions T "taboo", to which it is forbidden to move temporarily.

Subsequently, we will adapt to the TS determination of k - coloring in a graph G for a fixed number of colors k. The algorithm thus obtained will be the main ingredient of our meta-heuristic.

In the next section we will discuss some of our contribution.

VI. APPROACH

Planning a cellular network is a very delicate process whose outcome determines the operator sucked, the purpose of this step is to provide a baseline optimized to meet the needs of operators in terms of cost and performance users in terms of good communication. Reason why proper planning is based on the comprehensive study of the spatial characteristics of a geographic area.

Our work will be mainly divided into two main stages, the first being to provide an optimal division of a geographical area; the second is to solve the problem of allocation and frequency reuse.

A. First Step "a baseline"

The beginning of our work marks the clear need for a description of the geographical area to cover, we will use as input a satellite capture of an area taken with an onboard sensor, it must undergo several subsequent treatment prior to use we can separate the spatial data contained in the capture of two types:

i). The semantic data: in terms of attribute data and data.

ii). The geometric data: in two formats: raster model: mesh or a space is cut in a regular grid of predetermined size (resolution); the model vector: Vector data are a form of decomposition of the basic geographic information objects (points, segments, polygons) directly related to the descriptive attributes.

In this model there are two types: the model spaghetti and topological model.

For our work, the choice of a model of representation as the vector model seemed most appropriate for various reasons including the fact that it allows to associate to each spatial object semantic information in the form of attributes or relationships, necessary for the extraction of spatial information to our ontology. This mode of representation is the most widely used in GIS (geographic information system) [6].

Later we will give a representation of a city by the ontology space, The purpose of this is to represent knowledge about a specific area, our ontology will include all kinds of constraints in our geographic area, as barriers but also the population density and its exact location in the same area, this in order to realize an optimized cell-cutting plan.

We will proceed generally corresponding to any geographical area as follows:

- Schematic representation of the ontology.
- Set the dictionary of attributes and relations dictionary.
- Extract the axioms.
- Remove the space axioms.

Fig. 3: Extraction of spatial information

▪ *Schematic representation of a region by an ontology*

It is interesting to recall some concepts, such as [9]:

Concept: A class describing a task, function, object, etc ...

Relation: Allows the association of concepts to construct complex representations.

Axiom: is a logical assertion accepted in a real field, and may intervene in the definition of concepts and relationships.

Instance: This is an individual with particular values.

▪ *The axioms space:* In this section we will extract some space axioms of the study area, through the use of components of spatial ontologies.

a. Mereology Axioms

The primitive of mereology is the notion of party. $PP(x, y) = P(x, y) \neg \wedge P(y, x)$

Deduction: As long as: Rural, urban, mountain roads are all parts of the region, we must ensure coverage of each (start with the installation of Macro-Cell).

b. Topology Axioms

The primitive basis of the topology is the notion of connection.

$C(x, y) \rightarrow C(y, x)$

Deduction: As long as the Urban and Rural areas are connected to each other, we must ensure the relay pass from one cell to the cell next to "Hand over".

c. Location Axioms

Locate an object returns to the position in space. $PL(x, y) = \exists z (P(z, x) \wedge L(z, y))$

Deduction: This leads us to think about the places of location of BTS, the idea is: as long as it is at least one polygon, it is a point to ensure coverage in the Region.

1) Algorithm for initial planning

```
Initialisation
Int i
Int j
Int  m      // width of the geographical area
Int  n     // height of the geographical area
Int r=30km   // radius of the macrocell
Int r*=500m  // radius of the microcell
Int nbr=0    //counter for the number of macrocells
Int nbr*=0   //counter for the number of microcells

String macroBTS
String microBTS
Type macro is record
   localisation: double (0,0)
   enum:integer
   nom:string
end record
type micro is record
   localisation:double (0,0)
   num:integer
   pop:integer
   nom:string
end record

BEGIN
For i ranging from 0 to m not r do
      For j ranging from 0 to n not r do
         P←m-r
         u←n-r
         nbr←nbr+1
         localisation.macro(nbr)←[i j]
         num.macro(nbr)←nbr
         nom.macro(nbr) ='macro';
         pop.macro(nbr)←pop.macro(nbr)
         num.macro(nbr)←macroBTS
For i ranging from 0 to m not r *do
      For j ranging from 0 to n not r *do
         Pp←m-r*
         uu←n-r*
         nb←nb+1
         if pop.macro(nb)>=1000 then
            nbr*←nbr*+1
            localisation.micro(nbr*)←[i j]
            pop.micro(nbr*)←pop.macro(nbr)
            num.micro(nbr*)←nbr*
            nom.micro(nbr*)←'micro'
            num.micro(nbr*)←microBTS
        end if
     end for
end for
END
```

We have developed an algorithm, as a first step, a division of our geographical area macro cells and installation of macro BTS in these sites for our study, the radius of these cells will be equal to R = 30KM then it scans the study area, each time we find a surface with a high density (and therefore we consider the parameter population) we proceed to a second cutting in these parts here in the form of microcells (the radius of these cells is equal to 500 meters) and we install micro-BTS at the center of these cells.

For each of these cells, they will have their contact information as a parameter which will help us and make our job easier in the second part of our algorithm. At the end of this first stage we will have a result like the following Fig. 4:

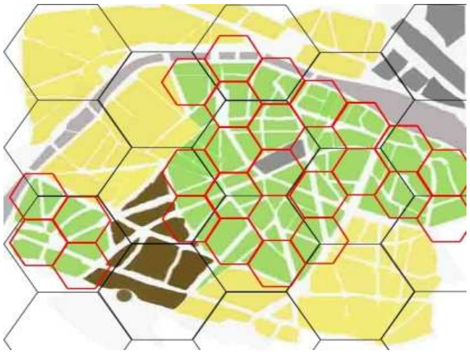

Fig. 4: initial planning of an area

B. Second Step "assignment and frequency reuse"

Design a frequency plan is allocating frequencies between the different cells of a geographic area. We try to provide maximum coverage with a minimum number of frequencies for this solution we will use the meta-heuristics algorithms with frequency re-use, thus allowing an operator to cover a geographic area with unlimited scope use a frequency band of limited width, so this would create a potentially unlimited capacity frequency.

The second step is the assignment and frequency reuse for this we have chosen as optimization method, the tabu search algorithm adapted to the K-coloring of graphs for reasons we have mentioned above.

We will adapt the tabu search algorithm for the determination of k - coloring in a graph G for a fixed number of colors k.

Knowing that a good coverage depends primarily to optimize initial meeting the needs of customers in terms of quality of communication and those of operators in terms of cost (BTS and frequency band).

To present the second part of our algorithm, we proceed as follows:

Our goal is to minimize two factors:

- "i": the number of interferences (two adjacent cells of the same color).

- "C": number of colors used.

These two factors will be used in an objective function is defined as follows:

$$F(C, i) = (i / C) + (i + C)$$

Whose purpose and minimize this function. Given a graph G, the following procedure is used to find a value of f (S). The number of colors is set to a specific value, ex. C = 4. Then a K-coloring is sought for that value of C. The algorithm stops when no longer possible to solve the problem. The last K for which the algorithm found a coloring is the chromatic number of G. Approximate For the K-coloring problem (so for a fixed G and C), the algorithm starts with a Taboo K-coloring initial conflict that can be generated randomly. Then, at each iteration, it chooses a high 'cell' in conflict to replace color "C" with a new color "C '" to generate a K-coloring neighbor. According to the principle of Tabu Search, the choice is made among the best neighbors allowed. If several choices are possible, and C i are equal, our objective function chosen as the optimal outcome with minimal interference. Local search ends when we find an acceptable solution, or when you reach the maximum number of iterations set a priori.

Algorithm: Assign and frequency reuse

```
Input : graphe G, C □ N* ;
Return value: f(S*);
Variables :
i : number of interferences
C : colors
C' : color assigned
S=(C, i)    / initial solution/
S* : best solution found
T, Tl : Table tabu and duration tabu
I : iteration
Imax : number of iterations max
Cell : cell
BEGIN
 I = 0      /* iterations*/
 T = 0      /* no movement is Tabu */
 S    / k-coloring random set up to 4 colors /
 S*=S
 Imax=100
 Until (f(i, C) > 0 and stopping condition not reached « optimal solution or I>=Imax »)
-Randomly assign colors to the cells (taken as a starting point the upper left corner).
-Select the best move in the neighborhood.
T(I,C(cell)) = I+Tl
C(cell) = C'(cell)
F(S) = (i/C) + (i+C)
If (f(S) < f(S*) then S* = S
   Renvoyer f(S*)
  End if
End until
END
```

The algorithm describes the procedure Tabou k-coloring with all the components listed above. For an instance of k-coloring given (G, k), Tabu algorithm first generates an initial random k-coloring C to start your search.

Then the main steps of an iteration are: (i) selecting the best move acceptable <i, c '(i)> in the neighborhood, (ii) the pair <i, c (i)> is Taboo, (iii) the performance of motion c (i) = c '(i). The process stops when a legal coloring is found or when a time limit is reached.

Subsequently we will reproduce the same process to obtain five solutions (samples), each with a different starting point, of course the return value of each sample will be different in terms of "i" and "C" So in terms f (S *).

A comparison between the five return values of the objective function, we choose the sample where the solution f (S *), which minimizes the function f (S) therefore minimize the number of colors and noise. The problem of assignment and frequency re-use, take more complex if it will be a multi-layer planning in terms of: Macro-Cells containing microcells. At this level, the description of the parameter "i" number of interference changes according to the following two cases:
-Two adjacent cells of the same color.

-A micro cell included in a macro cell with both the same color.

"C" number of colors allocated, fixed a priori to 7 colors mean.

We will follow the same concept seen in the previous section, and we will choose among the samples, the one who gives us the most optimal result.

The desired result looks like Fig. 5:

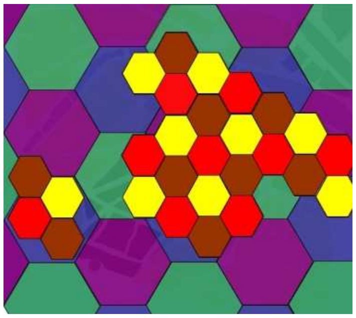

Fig. 5: Example of an optimal configuration outdoor

VII. CONCLUSION

We have presented throughout this paper a solution of outdoor coverage. Indeed this environment is characterized by a variety of propagation phenomena and additional mitigation provided by the nature of the geographical area to cover. This makes the task of planning more difficult and requires a thorough knowledge of these environments and engineering rules that govern them.

Our work was carried out following several steps. We began by introducing the concept of GSM network, giving the various parameters which composes, we presented later ontologies and especially ontology space as a new concept designed to solve our problem in terms of population, polygon , roads .... Then we moved toward the extraction of geographic information on an area intended to exploit them by the spatial relations of ontologies, the latter becoming predicates in the initial planning algorithm proposed .

In a second step, we studied several optimization methods used for frequency allocation and reuse it. To minimize the cost in terms of frequency, and interference. This idea is also the subject of integration in our algorithm. The main objective of the operator is to achieve good coverage, increase the number of subscribers and to reduce interference and cost (BTS and frequency band). The realization of this compromise is highly dependent on engineering rules used reason, during our work we have used several disciplines to meet those needs, including ontologies and spatial optimization methods.

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