From π-Calcul towards a Dynamic architecture for the resolution of the problems of optimization for mobile telephony operators

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Abstract

The operators of the mobile telephony are more and more demanding towards their applications. They wait for a big reliability, for a number ceaselessly increasing of services, the respect for the constraints of conviviality, for cost, etc. Therefore, the size and the complexity of the applications increase. The current techniques do not allow protecting us from problems of conception. That is why we need a high-level modelling, which will allow us to analyze the organization between the various elements of the system and the interactions between these elements. The interest of the systems multi agents ensues from collective behaviour produced by the interactions of several autonomous and flexible entities called agents, whom these interactions turn around the cooperation, around the competition or of it. However techniques come from this domain, concentrate more on the expression of the relations inter-agents. The expression of the mobility from the point of view of the distributed systems is not described. A property acquired time, will allow processes to choose themselves to move on the sites of a network to work locally on the resources and be exchanged their interactions. Reason for which, we are going to propose in this paper a formalization which appeals to an algebra of process, which is π-calcul, to conceive systems automobile adaptive which can react to the shape of the problem.

Keywords: *GSM, Cellular Networks, Multi Agents Systems, Process Algebra, Dynamic Optimization.*

1. Introduction

During these last years, the systems of communication knew an exceptional growth, that it is about systems of communication between mobile subscribers (GSM) or customers of phone replaced network (network RTC-fixes) [9]. The cellular networks are systems with strong factors of tensions [10]. The real-time adaptation of the solution being at present impossible. The dynamic aspect adds a new dimension to the problem of conception (design) of the cellular networks. The optimization serves then for anticipating the modifications to be operated on the network to optimize the performances of the network during its evolution and to reduce the costs of its reorganization. The system not only has to supply a solution, but also be able to react to the breakdowns and to the chances by straightening the solution, or still be capable of handling problems the data of which are only partially known, and for which the information arrives in time. At first, the idea led to us to think about the development of a process of design capable of managing the changes arising on the network during its phases of growth and maturation. The demand in traffic varies in the time and in the space.

The network is subject, besides, to changes long term, required by the rise of the traffic, relative to the growth of the clientele, to the behavioural changes of the users as well as to the evolution of the cover. For landing in these requirements, the network is brought to adapt itself and to grow. The call to a process of dynamic optimization seems a promising exit. This process is periodically launched during the points of decision, for objective the preparation of the system for the adaptation to the changes of the current period, while trying to take into account later periods, by predicting the zones where the increase of capacities is required and by realizing the necessary intelligent changes. Reason for which we met ourselves in front of the need to bring in the multi-systems agents. The general architecture of the system of proposed reorganization, bases itself on a set of agents of various types. Every agent is responsible for the resolution of a problem or the execution of a particular task, an approach which seemed the best adapted at first [3]. We thought afterward, that the integration of the notion of mobility, in terms of process or interactions at the level of the architecture of the proposed system, will allow ending in better results.

The composed question was to find the adequate executive explicit, for the specification and the conception of the system. The choice was made for the algebra of process π-calcul, for its capacity to be able to develop dynamically the topology of the applications.

In a first part of this article we place the context of the networks of the mobile telephony, its problem, and the main concepts which refer to it. A brief section will be intended for the presentation of the Multi- Agents Systems. We grant a particular interest to the algebra of process π-calcul, in particular the most suitable versions for our study. To arrive at the development of the proposed approach and that optimized through the integration of the concept of mobility. The last section will make the objective of a conclusion and a perspective.

2. Mobile Phones

We will first define the concepts of GSM mobile network, and then see its equipment and its hardware architecture.

2.1 GSM Network

GSM is a network that enables communication of individuals moving through a link or a radio channel. The general architecture of a GSM network [9], can be divided into three systems:

The radio subsystem (BSS): The radio subsystem consists of several entities: mobile, the base station (BTS) controller and a base station (BSC).

The network subsystem (NSS) : plays a key role in a mobile network, its components support all the functions of monitoring and analysis of information contained in databases needed to establish connection.

The system in operation and maintenance (OSS): it comprises three main activities of management: administration, business management and technical management.

2.2. Equipments of a network GSM

The material architecture of a network GSM, as well as the various existing streams of data between the previous equipments is illustrated by the figure1.

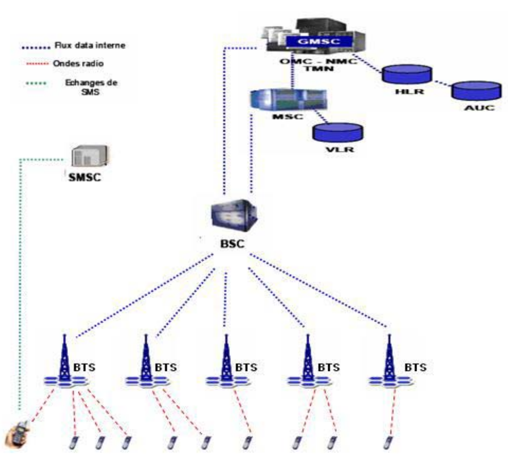

Fig. 1. Material architecture of a network GSM

For our study we will look at radio subsystem and its main entities.

2.3. Material architecture of under system radio BSS

The BSS includes the BTS which are transmitter-receivers, but having a minimum of intelligence, and the BSC assures the control of a set of BTS.

2.3.1. Function of the BTS

The BTS is a set of transmitter-receivers called TRX. A BTS has for function the management of the transmissions radio (modulation, demodulating, equalization, coding and correction of errors). It also manages the coat connection of data for the exchange of road marking between motives and network infrastructure of the operator. So a BTS can manage at most hundred of simultaneous communications.

2.3.2. Function of the BSC

The BSC is the intelligent organ of under system radio. It has a relay role for the alarms and the statistics emanating from BTS towards the centre of exploitation and from maintenance. The BSC is a data bank for the software versions and the data of configuration downloaded by the operators on the BTS. The BSC pilots transfers between two cells (zone of the territory lit by an antenna" BTS "): it informs on one hand the new BTS who is going to take care of the subscriber “the mobile” while informing the back-end system (HLR) of the new localization of the subscriber.

2.4. Material architecture of subsystem fixed NSS

The NSS includes data bases and switches.

2.4.1. Function of the HLR

The HLR is a data base of localization and characteristics of the subscribers. It is considered as recorder of nominal localization by opposition to the VLR which is the recorder of localization of the visitors.

2.4.2. Function of the MSC

The MSC assures the interconnection between the mobile network and the fixed network. It manages the establishment of the communications between a mobile and another MSC.

- The handover is a mechanism grace to which a mobile can transfer its connection of a BTS towards the other one, who is in that case called “handover inter BTS”.
- Or on the same BTS of a canal radio towards the other one " handover intra BTS ".

2.4.3. Function of the VLR

The VLR has for mission the recording of the dynamic information relative to the subscribers of passage in the network, so the operator can know all the time in which cell is each of his subscribers. The update of the HLR is very important because when the network tries to join a subscriber, he always questions the HLR of the subscriber to know his last localization.

Integration of the world of the agents, will allow us to conceive methods adaptive automobile, this last idea will make the objective of the next section.

3. Multi-Agents Systems

The subject of the Multi-Agents Systems (MAS), if it is not recent, is at present a very active field of research. This discipline is for the connection of several domains in particular of the artificial intelligence, distributed computer systems and software engineering. It is the discipline which is interested in the collective behaviour produced by the interactions of several called autonomous and flexible entities: "agents", whom these interactions turn around the cooperation, around the competition or around the coexistence between these agents.

3.1. Definition of an agent

According to an increasing number of researchers defines an agent, as being a computer system situated in an environment [11], of which it is capable of acting in perfect autonomy on its actions, with the aim of making meet the objectives of its conception, with the following characteristics:

- An agent is an entity situated in a particular environment, which perceives the state of the environment through his sensors, and which acts on its environment through its effecters.
- It is conceived to carry out specific objectives, and it has particular purposes to be affected.
- It is autonomous, since it has the control of its internal state, and its own behaviour.
- It is capable of explaining and of producing solutions for flexible problems. It needs to be at the same moment reactive (capable of answering in opportunity, in changes which arise in the environment, it is capable of acting by anticipating the future purposes).

3.2. Different types of interactions

The interaction is the mechanism which returns set existing agents in the more dynamic system, by the fact than it brings to light the mechanisms of communication and cooperation [10] . With the means of the interaction all the entities plunged into an environment, can interact according to various forms:

3.4.1. Interaction without communication

It bases itself on the inference of the actions of the others.

- ***Example:***

- Use of the theory of the games with matrices of gain.
- Updating of a constraint or an updating of dependence.

3.4.2. Interaction via the communication

It is a set finished by signals without interpretation and by fixed syntax.

- ***Example:*** multi-planning agents.

- ***Example:*** communication by the environment via tracks (signals) which leave the agents and who can be perceived by the other agents.

3.4.3 Interaction via the sending of messages and plans

- The interaction is made by sending of messages, such as calls of methods of object-oriented languages.
- In the sending of plans, exchanges of partial plans are made so that one a knot of exchange of the partial plans of interpretation with the other knots of the system.

3.4.4 Interaction via a blackboard

The interaction via a blackboard is a technique which proved its efficiency in the conception of the systems, and this used type of technique so that the various existing agents in a given system can to communicate itself through a common space called " blackboard ", From which the mechanism and to deposit the information or the knowledge in this zone, the concerned agent will come to get back this information. We introduce this technique of communication, when all the agents are in centralized or distributed architecture. The main characteristics of this type of interaction (blackboard) are the following ones:

✓ No direct communication.
✓ Interaction via the sharing of the same space of work or system.

The figure 2 illustrates this mechanism. A system containing a set of agents based on this type of interaction possesses the following elements:

- The knowledge·
- The blackboard·
- The control mechanism.

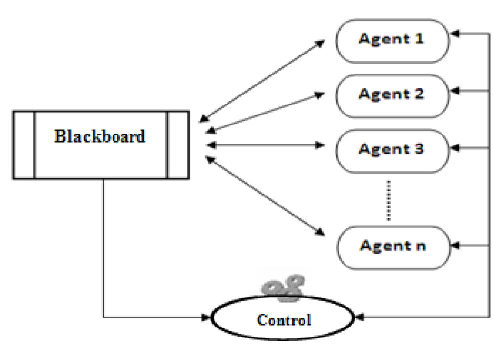

Fig 2. Agents' interaction by the blackboard

The next section presents the domain of the ontologies, while showing the type the most suitable to our problem that is the spatial ontologies.

3.3. Mobile Agents

The plan of mobility of the mobile agents derives from two different domains, the agents coming from the artificial intelligence with the multi-systems agents [5] and systems distributed with the migration of process [4]. To simplify, we can say that the plan to mobile agents is a generalization of the migration of process where the movement is for the initiative of the code. We speak then about a proactive migration. The main characteristic of a mobile agent is to have certain autonomy thanks to the proactive migration, that it is strong or weak.

4. Presentation of π-calcul

To develop a safe software, it is necessary to manage at first at the good formalization, that is why we appeal to formal languages how π-calcul [2]. This last one who allows us to establish a mathematical model to verify certain properties expected from the software (safety, no-blocking, and liveliness). The algebras of process are adequate executives for the specification and the check of reagent systems. This domain knew various approaches: CSP [1], CCS [6], π-calcul [8].
The fundamental abstraction is that we are interested in the behaviour of a process only through a certain number of points of interaction called "canals". The synchronization and the communication are then expressed by internal and external laws of composition. It is necessary to note that both in CCS and π-calcul, we make no hypothesis on the relative speeds of execution of the various processes, which are thus presumed to progress each with their rhythm. π-calcul is a formal language, to argue about the communicating distributed systems. It allows furthermore describing systems of mobile processes that are systems links of communication between processes of which the processes as well as can change place in time.

The purpose looked for by π-calcul is the introduction of the concept of mobility, which was non-existent in CCS. The objective is to authorize the dynamic reconfiguration of the topology of the applications. There are different versions of the π-Calcul; we quote the most essential for study notes.

4.1. Polyadic π-calcul

This version allows the transmission of a tuple of values during an interaction, to benefit from an important property that is the parameterization, through the simultaneous emission of a consecutives series, in an order given to a process. Numerous software exceeds the million lines of code. It is difficult to take into account such sizes with the old formal methods. By the use of some formal techniques of π-calcul and more exactly polyadic π-calcul, the abstraction of numerous details through the parameterization allows to reduce the specification of the system to an acceptable size.
The reserved syntax is the following one:

$$P ::= 0 \mid \alpha.P \mid P \mid P \mid P+P \mid [x=y]P \mid [x \neq y]P \mid (\nu \vec{u})P \mid \vec{A}(u)$$

Where prefixes α (actions) are defined as follows:

$$p ::= \tau \mid \alpha(\vec{u}) \mid \bar{\alpha}<\vec{u}>$$

With:

$\vec{u}$ **:** Denote a list of variables also called "names".

$\alpha(\vec{u})$ **::** reception of a list of variable ***u*** on the canal α

$\alpha<\vec{u}>$**:** emission of a list of variable ***u*** on the canal α

4.2. π-Calcul higher order

It can not only provide variables and channels but also the process [12].
Example:

P | Q avec $P \equiv \alpha(x,y,z) \bullet 0$ and $Q \equiv \alpha(u,v,R) \bullet v(u) \bullet R$

$$P \mid Q \equiv \bar{\alpha}(x,y,S) \bullet 0 \mid \alpha(u,v,R) \bullet \bar{v}(u) \bullet R$$

In the example above, the process S was transferred from the process P in Q.

5. Presentation of the approach

A BTS is an element of emission and reception, having a minimum of intelligence, which has for function the management of the transmissions radios. It is the first component of the network, Person in charge on the coverage of the request of a broadcasting subscriber. So that another BTS which will be informed to take care of the receiving subscriber. The relative load of a cell corresponds to the report between the demand in traffic on this cell and its actual capacity . A cell which serves many motives sees its coverage area being reduced, thus holes of cover appear and appeals will be thrown back. To avoid this type of problems, connected to the increase of the traffic, the resource BTS must be exploited in a reliable way (increase its intelligence).
Cells having a load approaching the 100 % see each other applicants of help of the other nearby BST having no load “cells candidates”. What can lead an automatic reorganization of the plan of frequencies, without the attribution of new cards TRX or the insertion of new BTS. A mobile becomes attached to the cell which offers him the best quality radio on the experimental canal (see figure 3: cell with intermittent line).

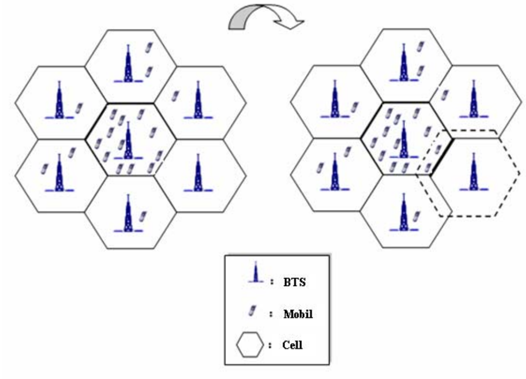

Fig 3. Process of optimization of the cellular network

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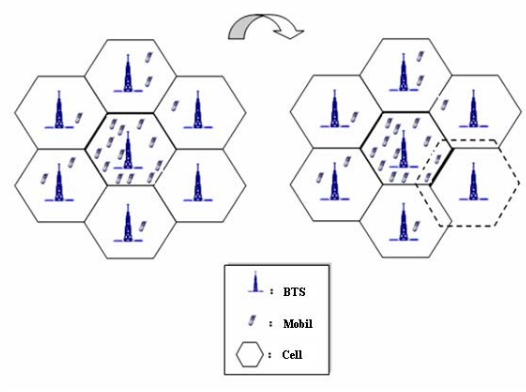

Fig 3. Process of optimization of the cellular network

When a mobile passes from a cell to the other one, he sees the pilot of the first cell weakening, and that of second to grow gradually. The affectation of an appeal of a mobile to a BTS is a process which involves several parameters (ex: azimut, tilt, power pilots) [7].

- **Tilt:** angle of inclination of an antenna in a vertical plan. The zone covered by the antenna decreases and the intensity of the power averages received in the cell increase.

- **Azimut:** orientation of the main lobe of the antenna in the horizontal plan. A modification of the angle azimut can be useful further to an effect of mask connected to the landscape or to the buildings (problem of interferences).

- **Power of the pilots:** indicate to the mobile the cell with which he has to be connected (the extent of the cell).

The objective of the proposed process of optimization is to supply from the beginning, a plan of expansion of the cellular network spreading out over several periods, according to the received changes. So, as shows it the figure 4, the system receives as entered an initial configuration of the network and elaborates an optimized network. To maintain a collection of diversified solutions (history) will allow a better and faster adaptation of the network to the registered changes, during the next phases.

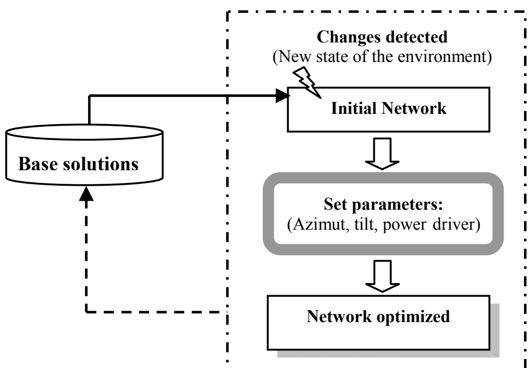

Fig 4. General principle of the process of optimization

The adjustment of the solution is begun only in the recording of the changes on the environment. The approach is defined by a succession of states of the environment E = {state 1, state 2, state n}. Every state is characterized by:

5.1. General architecture of the system

The general architecture of the system of optimization consists of agents' various types. Every agent is responsible on the resolution of a problem or the execution of a particular task.

- **Cell Agent:** this agent is in charge of by the detection of the overload of a cell (model: reactive agent), through the calculation of the following function:

With: $$L = \frac{A}{C}$$

L: Load with the cell.

A: Demand in traffic on the cell.

C: Actual capacity of the cell.

If the load affects the 100 %, the cell is declared "Applicant" otherwise it is declared "Candidate" with a degree of participation (number of communications to be able to take care).

- **Supervisor Agent:** the role of this agent (model: deliberative agent) is to list every time which are the cells of type: "applicant" and "Candidate". After collaboration with GIS Agent, Supervisor Agent will decide what is the nearby cell (the closest in the localization of the subscriber) which has to cover the zone of overload. And delegate to the Evaluator Agent the task to calculate the necessary parameters (azimut, tilt, power of the pilots). These last ones will be again sent to the Supervisor Agent to assure a remote customization of the BTS (regulation of antennas) of the concerned cell. And demand for Historic Agent to make a saving of this configuration of the network (solution) according to the state registered by the environment.

- **GIS Agent:** this agent (model: cognitive agent) possesses a geographical representation of the region of the cellular network (line, surface, dimensions), with its various changes (in case of appearance of obstacles or new constructions).

➢ **Remark:**
GIS Agent possesses a geographical representation in the form of cells in 3D, for every moment t. what we call: *cell3D - t*.

- **Evaluator Agent:** according to the dimensions of the zone to be covered, this agent takes the initiative to calculate the necessary parameters at the level of: the azimut, the tilt and powers of the pilots. It sends these parameters to Supervisor Agent.

- **Historic Agent:** this agent preservation the history of the previous solutions, according to the arisen events. What will allow the re-use of the good solutions for a better and faster adaptation of the network during the future phases.

➢ **Remark:**
Once the overload is crossed (the subscriber moved towards another cell, either decrease of the communications), the network returns again to its initial configuration.

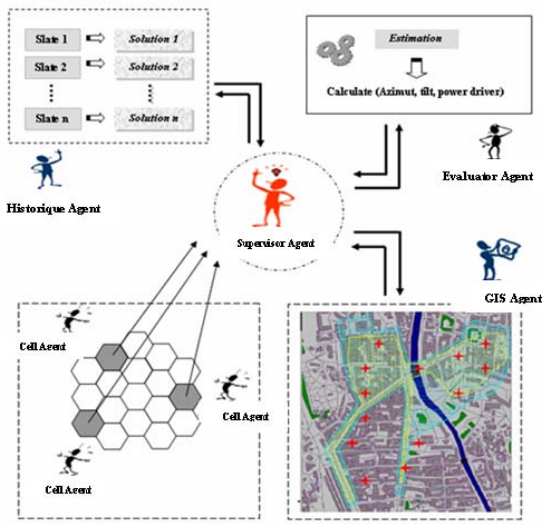

Fig 5. General architecture of the System

5.2. Dynamic Architecture

If we want to give a model of the previous architecture, in terms of process. It will be illustrated in Figure 6.

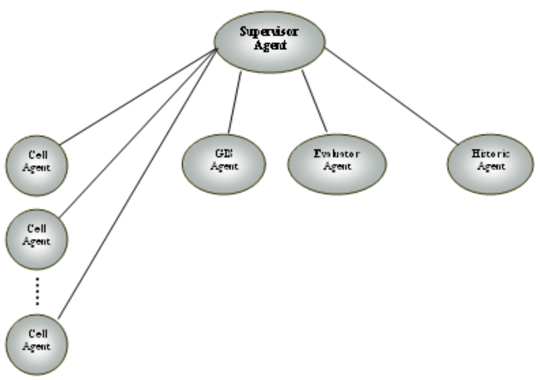

Fig 6. Modelling of the previous system

One of the issues:

1. In the event of a loss of a link between the agents. How can we intervene?

2. And if we talk in terms of value, is there a way to reduce the communication time between these agents?

On the basis of π-calcul as language, in the formal specification of agents of the previous system, we will certainly lead to better results. For example: if the Agent Supervisor loses its communication link with the GIS Officer, but the expected optimization process will not be achieved.

The answer to such a concern π-calcul as formal language provides a dynamic reconfiguration ofπis this: The topology of applications. It means that Evaluator Agent may delegate its link to one of his agents to complete the task required (see Figure 7).

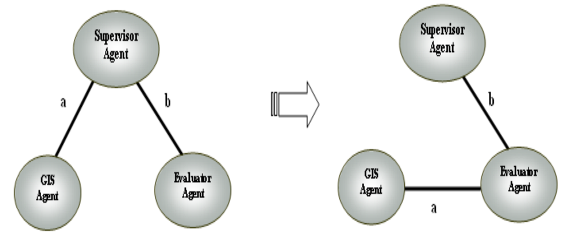

Fig 7. The mobility of links between Agents

We can translate this mobility of links in π-Calcul, as follows:

$\mathbf{S \equiv b\ a \bullet S'}$ and $\mathbf{G \equiv a\,(x) \bullet G'}$

and $\mathbf{E \equiv \overline{b}\,(x) \bullet\ a\ x \bullet E'}$

With: **S :** Supervisor Agent
G : GIS Agent
E : Evaluator Agent

A second opportunity to be able to negotiate, it is in case the Evaluator Agent can move to the Cells Agents, which surround the overloaded cell, to intervene in every detected saturation. The nearby cells deliver their three parameters: azimuth, tilt, power signal, to be able to assure with regard to their current loads. In that case, the Evaluator Agent possesses the update to be applied and is going to move from a cell to the other one (by crossing six cells), and by getting back three parameters of every cell. As shows it the following figure:

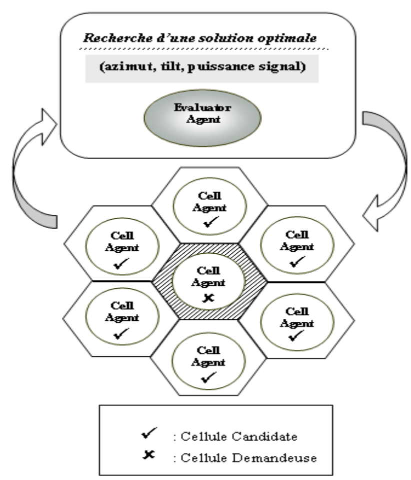

Fig 8. Movement of the Evaluator Agent

5.3. Advantages

Through this new approach of dynamic architecture, various advantages will be gained, we quote the most essential:

- ✓ The first advantage to be quoted, it is the decrease of the intensity of information exchange between the various agents.
- ✓ The second considerable advantage is the decrease of waiting times. It happens frequently that the waiting time of the answer of a request is longer than the time of treatment necessary for the realization of the service.
- ✓ We decrease considerably the cases of problems of connection (breaks of links), and in case of a break, the agent can delegate his link to another agent.

The general architecture of the proposed system is illustrated by the present figure:

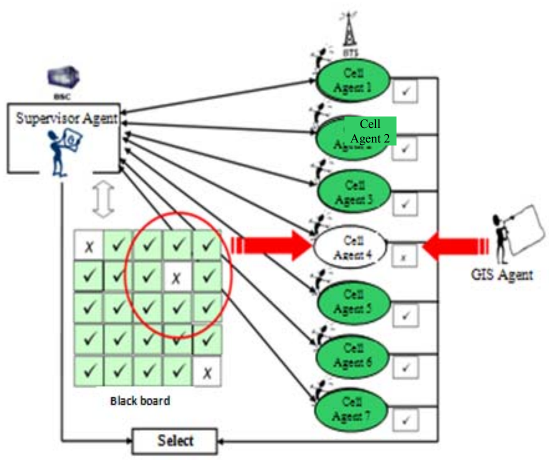

Fig 9. General architecture of the System

6. Conclusion and perspectives

Through this paper, we presented a new solution of a problem which enough took time researchers, in the field of optimization and which was the major concern of mobile phone operators. A solution of agents' base, which assures revisions and recycling of the network through an effective cooperation with various agents, where every agent is responsible on the resolution of a problem or the execution of a well determined task. Our work knew several stages. Having spoken about the domain of the networks of the mobile telephony and its main concepts, we thought of a presentation of domain of the multi-systems of agents and the formal language π-calcul . To arrive at the nucleus of our work that is the description of the solution proposed with its main points, in particular the presentation of the general architecture of the proposed system. We are not satisfied to us with the solutions acquired through this approach; we thought that the integration of the notion of mobility, at the level of the architecture of the proposed system, will allow ending in better results. Reason for which we appealed to the algebra of process π-calcul , for its capacity to be able to develop dynamically the topology of the applications. As perspectives, we think that the development of a software which bases itself on a method of optimization, which supports the important concepts and the techniques already revealed through our study, guide the mobile network to improve network quality optimized manually, and a reduction in the time required for this repetitive task for experts radio. The gain in performance is also reflected in the reduction for the operator investments in infrastructure.

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