International Journal of Scientific and Technical Advancements
ISSN: 2454-1532

Frequency Assignment in GSM Networks an Intelligent Approach

Amaechi Chineke
Computer Engineering Department Michael Okpara University of Agriculture, Umudike
Email address: tchiagunye2@yahoo.com

Abstract**—**The rapid increase in radio communication, the increasing demand for capacity by network users coupled with the limitation of required electromagnetic spectrum creates a big challenge for frequency planning and allocation. This challenge borders more on the frequency assignment problem. This paper proposes an intelligent agent approach for the optimal assignment of frequencies to transceivers in a GSM network cell. The paper specifies the Belief, Desire, Intention (BDI) agent framework for frequency assignment that optimally meets frequency demand while satisfying the electromagnetic constant.

Keywords**—**Frequency assignment; intelligent agent; BDI GSM.

I. Introduction

Meeting the increasing demand for high capacity in existing networks at low cost presents a huge challenge for telecommunication operators due to traffic growth. With growth in the demand of mobile telephone services, the efficient use of available spectrum is becoming increasingly important. This puts pressure on the research for optimal frequency assignment techniques since radio frequencies are limited resource.

An overview of the frequency assignment problem is as follows [1]: For an existing set of, geographically divided, region (called cells-typically hexagonal), frequencies (channels) must be assigned to each cell according to the number of call request. Three types of electromagnetic separation constraints exist.

- Co-channel constraint, the same frequency cannot be assigned to pair of the cells that are geographically close to each other.
- Adjacent channel constraint; similar frequencies cannot be simultaneously assigned to adjacent cells.
- Co-site constraint: any pair of frequencies assigned to the same cell most have a certain separation.

The goal is to find a frequency assignment that satisfies the above constraints using a minimum number of frequencies (more precisely, using the minimum span of the frequencies).

In the slow frequency hopping model, every transceiver is required to change it's frequency periodically. That is to say, a cell is not handled on a single channel but alternates its frequency periodically. This presents the challenge of dynamically determining a spectrum-efficient and conflict free allocation of frequencies among the cell sites, while satisfying both the traffic demands and interference constraints (Electra-magnetic constraints). The studies of a frequency assignment problem (also called a channel assignment problem) in cellular mobile systems are abundant [1-6]. Various Artificial intelligence (AI) techniques, including constraint satisfaction, simulated annealing, neural networks, taboo search, and genetic algorithms, have been applied to this problem [7-13].

The implanting of these AI technique into the agents deliberation as its domain expertise, coupled with the ability of the agent to logically reason and adapt to new circumstances in the radio environment and work as a team to achieve more than what any of these AI techniques can achieve as an independent unit.

This paper proposes the Belief, Desire, Intention agent framework to the dynamic frequency assignment problem. The core concept of the framework rest on the basis of the use of the multi-layered feed-forward neural network (MFNN) to predict spectrum demand while achieving adaptability by reforming the prediction within the Jason Reasoning Circle Algorithm. This ensures the systematic coordination and integration of the predictor strength of the MFNN and the autonomy, adaptiveness, reasoning and collaborative abilities of the agent.

II. Communication in GSM Networks

Global system for mobile communication (GSM) is a technical standard, which specifies interfaces and settings for mobile communication [14]. GSM was originally introduced in the second generation of wireless communication technology. The GSM standard is incorporated and built open in the third and four generation of mobile communication systems as well. It specifies, how two mobile partners communicate via mobile devices, such as mobile phones or laptops, by organizing and standardizing the process of communication within (typically) large scale infrastructures like (public) telephone network. Figure 1 [15] depicts the GSM communication principle.

Every mobile call is passed to some antenna, which then forwards the call. Since a call can take place everywhere in a given region equipped with a GSM infrastructure, every spot within the region must have access to at least one antenna. Due to territorial issues, it might not be possible to reach an antenna everywhere. Mobile communication companies try to establish a sufficient degree of coverage and capacity, that is, they build more antennas or acquires additional frequencies (if possible) for their network.

Amaechi Chineke, "Frequency assignment in GSM networks an intelligent approach," *International Journal of Scientific and Technical Advancements*, Volume 2, Issue 1, pp. 89-93, 2016.

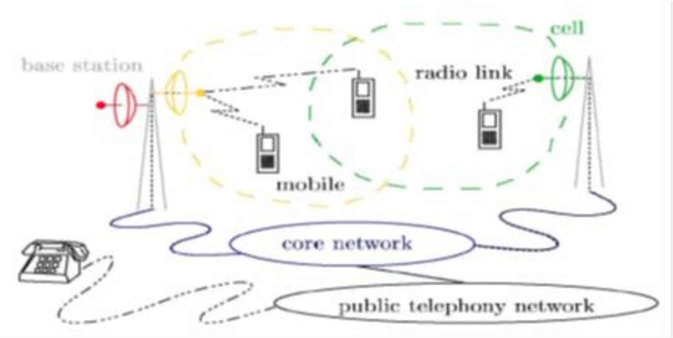

Fig. 1. GSM in principle.

Figure 2 provides an idea of the coverage structure of GSM network. The regional unit seen in figure 3 is called a site. At one site, there may be multiple antennas, which serve all calls of the whole site. Each of this antennas define one sector. For example, one antenna can form one sector (360^0 opening angle), three antennas may form 3 sectors with an opening angle of 120^0 each. In each sector, the antenna has certain number of transceivers, abbreviated TRX. Each of which operates on it's own frequency and is responsible for the communication with the (mobile) participant. Every TRX communicates in up to eight different time slots, so it can handle up to 8 different cells (one the same frequency) at the same time.

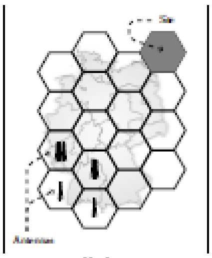
Fig. 2. Cellular structure.

The concept is, to "cover" a certain area with TRX, but due to territorial influences, the area covered by TRX has no hexagonal shape in reality. Nevertheless, from a theoretical point of view, the hexagonal forms are a useful model to do some research on. GSM communication needs the radio spectrum. This spectrum spans from zero (physical extremely long wave length) to 300GHz. It is divided into several parts due to the fact that many different users depend on it; radio, television, radar, the military and GSM all have exclusive access in a unique part of this spectrum. Till date, it is impractical to use higher frequencies due to the fact that the earth's electromagnetic radiation disrupts signals sent at this wave length.

Whereas the exact spectrum of a special purpose (e.g mergence frequencies) might differ among national borders, in Europe, GSM may generally be used within 880 to 915, 925 – 960 MHZ (GSM 900) as well as within 1710 – 1785 and 1805 – 1880 MH2 (GSM 1800) (more detailed presentation in [16]. Table 1 list the precise frequency bands for mobile station to base station (up-link) and base station to mobile station (down-link) radio communication for all GSM variants. The GSM 900 spectrum comprises 124 channels (uplink, outgoing data) between 890 – 915MHZ and 124 channels (downlink, incoming data) between 935 – 960 MHZ, each channels having a bandwidth of 200 KHZ. Each of these channels operates on eight time slots, such that it can serve eight different calls at once.

TABLE I. GSM ratio frequency bands.

System	Up-link band	Down-Link band
GSM 900	890-915 MH2	935-960MH2
GSM 1800	1710-1985 MH2	s1805-1880MH2
GSM 1900	1850-1910 MH	1930-1990MH2
GSM 400	450.4 – 457.6MH	460.4-467.6MH2
	478.8-486.0MH2	488.8-496.0MH2

III. Transmission Quality in Radio Networks

The quality in a radio network depends on many different factors. Most of this influencing factors do not only appear in GSM networks, but can be found. Similarly in normal radio transmission [17]. As a first example, land scope (mountains, building etc) can be mentioned. Another factor might be the strength of an emitted signal or just the number of simultaneous calls at a certain time and place.

In the specification of the agent fragments for dynamic frequency assignment proposed in this paper, the influence of interference is considered. Interference or mutual signal/transmission disruption arises if (two or more) transmissions are too close to each other in the frequency spectrum and (both) participants can receive both transmission. The bigger the difference within the spectrum, the smaller the possible amount of disruption. The most important question, when installing a GSM network is: How can calls be placed in the available frequency spectrum, so that their mutual interference is acceptable? In other words, since the TRX determines, where in the spectrum the call is placed: which frequencies must be assigned to each TRX, so that the transmission quality will be the best? Here, the special site/cell structure, illustrated in figure 2 needs to be taken into account. Regarding the network organization, this translate into: each TRX potentially disturb each other to a significant degree and marry the use of a certain frequency at special TRX prohibit the use of that frequency on another TRX? In most cases, it is not possible to form an assignment with on interference induced (since the number of TRX/the demanded capacity is far too big). So the aim is to minimize the total interference in an assignment, therefore reducing the average interference, which is the standard approach (see [18]) for frequency assignment.

The question which forms the basis of the agent framework proposed in this paper is: ignoring all other influences but interference, given all data about the available spectrum and all potential interferences between two sites as well as demanded amount of frequencies at the sites, how can the available frequencies be assigned optimally. Optimally in the sense that the overall existing interference between each pair of transmitters is minimized. This problem is well known as the (classical) frequency assignment problem (FAP). To put

Amaechi Chineke, "Frequency assignment in GSM networks an intelligent approach," *International Journal of Scientific and Technical Advancements*, Volume 2, Issue 1, pp. 89-93, 2016.

ISSN: 2454-1532

the focus of this paper into perspective, in the next section, a short description, which formalizes the FAP model and explains the relation between the site/cell structure and the interference occurrence is given.

IV. THE CLASSICAL FREQUENCY ASSIGNMENT PROBLEM (FAP)

The definition of FAP presented here is taken from [19] the classical frequency assignment problem can be described in the following way: Given the set of all TRX (eg. TRX: = [a,b,c]) and the available frequency spectrum (eg. F; = [1,….,5]). Given the possible interference data between all pairs of TRX (e.g. co(a,b)=0.5 and ad (a,b) = 0.3) and separation constraints (e.g. da = 2, frequencies A and B most have a distances of two channels in the radio spectrum). Further, given a list of locally blocked channels (e.g. Ba = { 2,4}) for each TRX, the frequency assignment problem is the following: Assign a channel to each TRX, such that separation constraints are met and local blockings are obeyed, with minimal total interference (between all pairs of TRX).

The input of the FAP problem consists of a seven-temple (carrier network)

$$N = (V,E,F, \{B_v\}_v EV,d,co,ad)$$

Therefore, G = (V, E) is a graph, with a vertex for every TRX. The edge are defined by the three functions d, co and ad, giving to each edge the corresponding separation, and the co-channel (co) and adjacent channel (ad) Interference (greater or equal to zero).

F denotes the set of available frequency (positive integers) and Bv denotes the set of blocked frequencies for every TRX.

A feasible solution (frequency assignment) for such carrier network is a function

$$Y: V \longrightarrow F,$$

Such that

$$Y(V)\ E\ F \backslash Bv \qquad \forall v\ E\ V,$$

$$|Y(v) - Y(w) \geq |d(vw) \qquad V(v,\overline{w})\ E\ E.$$

Then the FAP can be formulated as: given a carrier Network, the problem

$$\text{Min: } \sum_{(v,w)\,EE} co(v,w) + \sum_{(v,w)EE} ad(v,w)$$

$$Y(v) = y(w) \qquad |y(v) - Y(w)| = 1$$

For a feasible solution Y is called the frequency assignment problem (FAP).

V. INTELLIGENT AGENTS

Intelligent agents fall within the discussion relating to artificial intelligible [19], [20]. It has emerged as a next significances breakthrough in software development and a new revolution in software [21]. An agent has its own characteristics such as autonomous, social ability, reactivity, pro-activeness, cooperative, learnable and adaptable [22], [23]. Agent is a natural abstraction of the real world. It can model the real world, with its own goals, communicating and often working together with other agents to achieve mutual benefits. In this paper the Belief-Desire-Intention (BDI) agent architecture is adopted. The BDI agent model has come to be possibly the best known and best studied model of practical reasoning agents [24], [25] by combining a reputable philosophical model of human practical reasoning and agent software implementations. In BDI terms, Beliefs represent knowledge of the world that is the informational state of the agent. However, in computational terms, belief represent the state of the world, such as the value of a variable, a relational database, or symbol expressions in predict calculus, and can also include inference rules that allow forward chaining to lead to new beliefs. Desire (or goals) forms another essential component of system state. Desire represents the motivational state of the agent, objectives, situations or goal that the agent, objectives, situations or goal that the agent would like to accomplish. In computational terms, a goal may simply be the value of a variable, a record structure, or a symbolic expression in some logic. The important point is that a goal represents some desired end state [20]. The committed plans or procedures are called intentions, which represent the third component of system state. Intentions represent the deliberative state of the agent, the agent chosen actions, which means the agent has begun executing a plan.

Plans are sequences of actions that an agent can do to achieve one or more of its intentions. Events are triggers for reactive activity by the agent, and may update beliefs, trigger plans or modify goals, [26]. Beliefs, Desires, Intentions are the basic components of an agent system resigned for a dynamic, uncertain world. So, as BDI agents, they most have explicit goals to achieve or events to handle (desires); a set of plans (intentions) is used to describe how agents achieve their goals, a set of data called beliefs describe the state of the environment [27].

VI. DESIGN OF THE AGENT STRUCTURE

The framework comprises cooperative agents at the network sector level and cell level. The structure of any one of these agents is specified as follows:

Definition

STRX: A Group of TRX that hop over the same frequencies.

Specifying the BDI Structure of the Agents

Beliefs: The following are part of the attributes of the agent's belief:

- Predicted spectrum demand
- Set of available frequencies at time to
- Set of frequencies not locally not available at STRXi (i= 1,2,..N)
- Number of TRX and corresponding interference relations
- Frequency separation of the TRX in the cell
- Set of all STRX
- Number of (different) frequencies demanded by STRXi (i=1,2,..N)
- Probability distribution of expected interference: probability that TR Xv in STRXi (gets frequency f at a certain time slot t (v, I = 1, 2, 3….. N).
- From this an Agent Belief attributes the expected interference with another TRXw in STRXi which can be computed. (W, j = 1,2,3…N).

Amaechi Chineke, "Frequency assignment in GSM networks an intelligent approach," *International Journal of Scientific and Technical Advancements*, Volume 2, Issue 1, pp. 89-93, 2016.

- Traffic demand record (traffic demand statistics)
- Set of assigned frequencies.

Desire

- The agent wants to achieve the goal of satisfying the electromagnetic separation constraints:
- Satisfy co-channel constraint
- Satisfy Adjacent channel constraint
- Satisfy co-site constraint
- Minimization of frequency assigned to $STRX_i$ (i=1,2,3…N)
- Frequency allocation

Intentions

- Predict spectrum demand
- Evaluate interference (check interference)
- Evaluate constraint (check constraint)
- Compute expected interference probability of TRXr in STRXi and TRXw in STRXj.
- Translate the spectrum demand into traffic load measurements in Erlangs and desire the associated radio traffic channel requirement.

Note: for the intention: predict spectrum demand, the agent requires domain expertise. For this it uses the multi-layered Neural Network (MFNN). See [28], this reference designed a MFNN specifically for predicting spectrum demand in a cellular network.

Upon initialization (booting), the agent makes resource demand prediction, the prediction are made for each cell based on previous load characteristics and the system resource allocation. The number of frequencies allocated to each cell in the network depends on the resource prediction. It has been shown that the MFNNs have the capability to predict future values based on training sets composed of sufficient historical data [28]. The agent engages in periodic prediction (preferrebly every one hour). Based on the prediction, spectrum are assigned to every TRX in the cell. The agents computes the spectrum assignment such that to meet its Desire for electromagnetic spectrum constraint satisfaction. If quality of service was not met using the prediction the agent refines it's belief (up dates its belief). It uses the Jason Reasony Cycle Algorithm to refine its prediction. The Jason Reasoning Cycle Algorithm is given in figure 3.

The Agent uses the Jason Reasoning Cycle algorithm to sequence its operations while interacting with its environment. The Janson reason Cycle enables the agent to systematically structure its execution of it's intention list, structure updates to its belief, structure the generations of new desire (like a user initiating a cell that requires channel allocation) and the requirement of its prediction.

1. Initialize initial beliefs, B $\leftarrow$ B_0
2. Initialize initial intentions, 1 $\leftarrow$ 1_0
3. While true do
   - 3.1 get next precept, p thru sensors
   - 3.2 update belief, B $\leftarrow$ brf (b,p)
   - 3.3 agent determine desires or options, D $\leftarrow$ options (B, 1)
   - 3.4 agent choose options, selecting some to become intentions, 1 $\leftarrow$ filter (B,D,1)
   - 3.5 generate a plan to achieve intentions based on set of actions, π $\leftarrow$ plan (B, I, Ac)
   - 3.6 White not (plan is empty, empty (π)] do

3.6.1 process first plan element, α $\leftarrow$ π
3.6.2 execute plan element, execute (α)
3.6.3 pause to preserve environment, π $\leftarrow$ tail of π
3.6.4 observe environment to get next percept, p
3.6.5 update belief, B $\leftarrow$ brf (b,p)
3.6.6 if reconsider (1,B) then
3.6.1 D $\leftarrow$ options (B,1)
3.6.2 1 $\leftarrow$ filter (B,D,I)
3.6.7 end-if
3.6.8 if not sound (π, 1, B) the
3.6.8.1 π $\leftarrow$ plan (B,I,Ac)
3.6.9 end-if
3.7 end-while
if end-while

Fig. 3. Jason reasoning cycle algorithm.

The Jason reasoning cycle algorithm is presented in figure 3. The variables B.D and I is the agents current belief, desire and intentions. In the outer loop on lines (3)-(4), the agent observes its environment to get the next pallet. This could be co-channel, adjacent channel interference or site interference, calls being placed (which requires channel assignment). Event from the infrastructure signaling availability or no availability to spectrum etc. On lines (3.0- 3-5), the variables B,D and I is processed and a plan π is generated or selected (from intention list) to achieve the intention based on a set of actions the agent would do which include: select frequencies from list of available frequencies, translate resource demand into traffic load measurement in erlangs and derive the associated radio channel requirements, compute expected probability of TRX, evaluate for interference, make frequency assignment etc.

The inner loop on lines (3.6) – (3.7), captures the execution of a plan to achieve the agents Desire or Intension. If no problem exists, the agents execute it's action from its plan until all the plan has been executed. This is represented in lines (3.6.1) – (3.6.2).

However, after executing an action from the plan, on lines (3.6.3) – (3.6.5), the agent pauses to observe its environment, and update its belief. lines (3.6-6) – (3.6.7) are executed if the agent needs to reconsider it intentions that lead to a change of intentions. The intentions that can be reconsidered includes reassignment of frequency that are interfering and re-evaluation of interference, re running the MFNN prediction of the spectrum demand based on up dated belief. Finally, if the plan is no longer a sound one, the agent re-plans i.e lines (3.6.8) – (3.6-5). This re-planning can be designed to include retraining of the Natural Network, re-predicting, updating the belief and Desires based on new computed parameter values.

VII. Conclusion

The work specified an agent framework for tackling the dynamic frequency assignment problem for the GSM networks. The paper demonstrated how the network parameters required for the modeling of dynamic assignment of frequencies to transceivers into the cellular network system can be specified in terms of agents Belief, Desire and intentions. The harassing and integration of the forecast capability of the multi-layered feed-forward neural network (MFNN) with the autonomy, adaptiveness and collaborative capability of agents presents and Hybrid. The enhanced technique for the optimal dynamic assignment of frequencies in the cellular network.

REFERENCES

[1] J. Elhachmi and Z. Guenoun, "Distributed frequency assignment using hierarchical cooperative multi-agent system," *International I Communications, Network and System sciences*, vol. 4, pp. 727-734, 2011.

[2] M. da S. Maximiano, M. A. Vega-Rodinguez, J. A. Gormezpulido and J. M. Sanchez-Pesez, "A hybrid differential evolution algorithm to solve a real-world frequency assignment problem," *International Multiconference on Computer Science and Information Technology*, Wisia, pp. 201-205, 2008.

[3] M. Yoko o and K. Hirayama, "Frequency assignment for cellular mobile systems using constraint satisfaction technique," *Principles and Practice of Constraints Programming, Lecture Notes in Computer Science*, vol. 1713, pp. 490–491, 1999.

[4] A Ganist, "Some lower bounds for a class of frequency assignment problems," *IEEE Transactions on Vehicular Technology*, vol. 35, no. 1, pp. 8-14, 1986.

[5] J. K. Hao, R. Dorne, and P. Gulinier, "Tabu search for frequency assignment in mobile radio networks," *Journal of Heuristics*, vol. 4, no. 1, pp. 47-62, 1998.

[6] K. N. Silvarajan, R. J. McEliee, and J. W. Ketechum, "Channel assignment in cellular radio," *Proceedings of 39th IEEE Vehicular Technology Society Conference*, San Francisco, pp. 346-850, 1989.

[7] N. Funabiki, N. Okutani, and S. Nishikawa, "A three stage henistic combined neural networks algorithm for channel assignment in cellular mobile systems," *IEEE Transactions on Vehicular Technology*, vol. 9, no. 2, pp. 397-403, 2000.

[8] M. Carisson and M. Grirital, "Automatic frequency assignment for cellular telephone using constraint satisfaction techniques," *Proceedings of the Tenth International Conference on Logic Programming*, MIT Press Cambridge, pp. 647-663, 1993.

[9] W. K. Hale, "Frequency assignments: theory and application," *Proceedings of the IEEE*, vol. 68, no. 12, pp. 1497-1513, 1980.

[10] S. Harkey, D. H. Smith, and S. V. Thief: A Soft: A system for discrete channel frequency assignment," *Radio Science*, vol. 32, no. 5, pp. 1921-1939, 1997.

[11] D. H. Smith, S. Hurley, and S. U. Thiel, "Improving henristics for the frequency assignment problem," *European Journal of Operational Research*, vol. 107, no. 1, 1998, pp. 76-86.

[12] D. Kunz, "Channel assignment for cellular radio using neural networks," *IEEE Transaction on Vehicular Technology*, vol. 40, no. 1, PP. 188-193, 1991.

[13] N. Funabiki and Y. Takefuji, "A neural network parallel algorithm for channel assignment problems in cellular radio networks," *IEEE Transactions on Vehicular Technology*, vol. 41, no. 4, pp. 430-437, 1992.

[14] M. Tieves, "Frequency assignments in slow frequency-hopping GSM networks – A MIP approach," pp. 13, 2011.

[15] V. Von "Frequency assignment in GSM Network: models, heuristics, and lower bonds," D83, pp. 2 Berlin Jun. 2001

[16] Support officer: S. Antipols 3g pp to 45.005v9, 0.0 Technical report, 3GPP, 2009.

[17] Peter T. H. Chain, M. Palaniswarni, and D. Everitt, "Neural network-based dynamic channel assignment for cellular mobile communication systems," *IEEE Trans-Veh. Technology*, vol. 43, pp. 279-288, 1994.

[18] A. Eisienblactter, "Frequency assignment in GSM networks; models, heuristics and lower bounds," PhD thesis, Technische Inversitae Berlin, 2001.

[19] D. Poole, A. Mackwrith, and R. Goebel, Computational Intelligence, A Logical Approach, Oxford an oversight press, New York, NY, 1998.

[20] G. Liu, "The application of intelligent agents in Libraries: a survey," Leddy Library Publications, University of Windsor, 2011.

[21] C. Hyuing, G. Clan, and J. Choi, "A framework for BDI agents based software engineering," Studia Informatics Universities, 2004.

[22] H. S. Nwana, "Software agents, an overview, knowledge engineering review," pp. 205-244, 1996.

[23] M. Wooldridge, *Reasoning About Rational Agents*, MIT, 2000.

[24] M. George, B, Pell, M. Pollack, M. Tambe, and M. Wooldridge, "The belief-desire-intention model of agency," *Proceedings of the 5th Interactional Workshop on Intelligent Agents V: Agent Theories, Architecture, and Layrayes*, 1999.

[25] D. Kinny, M. Geneff, and A. Rao, "A methodology and modeling techniques for systems of BDI Agents," *Agent Breaking Away: 7th European Workshop on modeling Autonomous Agents in a Multi-Agent world, MAAMAW 196*, Eindhoveen, the Netherlands, January, 22-25, lecture Notes in Artificial intelligent, vol. 61, 1996.

[26] T. N. M. Aris, "Object –oriented programming semantics representation utilizing agents," *Journal of Theoretical and Applied Information Technology*, vol. 31, no. 1, pp. 8-12, 2011.

[27] C.-H. Jo, "A seanless approach to the agent development," *ACM 2001 15th Annual Symposivm on Applied computing (HCM SAC'01)*, has regas, pp. 641-647, 2001.

[28] M. N. Faruque and Dr. S.N. Ahmad. "An innovative approach to increase capacity of a typical GSM network," *IJECT*, vol. 2, issue 4, pp. 55-60, 2011.

Amaechi Chineke, "Frequency assignment in GSM networks an intelligent approach," *International Journal of Scientific and Technical Advancements*, Volume 2, Issue 1, pp. 89-93, 2016.