UNIVERSITY OF JOHANNESBURG

FACULTY OF SCIENCE

PROPOSAL FOR MASTER’S / DOCTORAL STUDY

PARTICULARS OF STUDENT

<table>
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Institution and year in which Qualification was obtained.</td><td colspan="3">Bsc. (Hons) IT

University of Johannesburg</td></tr>
<tr><td colspan="2">Degree for which Registered</td><td colspan="3">Msc. IT</td></tr>
<tr><td colspan="2">Date of First Registration for this Degree</td><td colspan="3">29 January 2009</td></tr>
<tr><td colspan="2">MINOR DISSERTATION</td><td colspan="2">DISSERTATION X</td><td>THESIS</td></tr>
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The supervisor(s) confirm/s that:

- The supervisor(s) consider(s) the student competent to undertake the study
- The supervisor(s) and assessor(s) have at least M-degrees (for Master’s students) or D-degrees (for Doctoral students) or their equivalent
- The proposed field of study falls within the department’s or supervisors(s’) field of research
- The proposed field of study is of sufficient academic merit to justify a Master’s/Doctoral degree
- That the proposed study can be undertaken with available equipment and facilities without delays to allow the study to be completed in the specified time
- The study will be undertaken in compliance with all applicable statutory and ethical guidelines
- An adequate budget has been provided for this study

Does the research involve research		

on humans or animals?	**YES**	**NO X**
Proposed Title (or proposed study field if title is not yet available)	Utilizing Particle Swarm variants to optimize the Frequency Assignment Problem	
Problem statement or hypothesis and results expected.	The aim of this study is to utilize the Particle Swarm Optimization (PSO) algorithm to develop an algorithm that will be used to efficiently optimize the Frequency Assignment Problem (FAP). Optimization of the FAP will be done by minimizing the total interference by means of a heuristic or cost function. Currently no-one to our knowledge has attempted this. Using this approach the PSO would involve us development of the following techniques: • How to represent the particles flying over an n-dimensional search space. • How to calculate the new velocity vector for each particle. • PSO algorithm tailored for the FAP domain The developed algorithm would be tested against the De Jong Suite, to see how the developed PSO compares to other PSO variants. We will also test our final algorithm with the COST259 benchmarks which can be found at (Andreas Eisenblätter, 2007) in order to evaluate the efficiency of the algorithm proposed in this study.	
Justification of study with reference to relevant and recent literature (Contextualise the study in terms of the broader field and literature, including preliminary research conducted), ending with the anticipated contribution of the proposed study).	In the information age we currently live in almost every device has some sort of wireless technology it uses to provide a specific service. Radios for audio entertainment; Television remotes to change channels; Cellular phones for communication; Wireless access points to create wireless LAN's. (Aardal, van Hoesel, Koster, Mannino, & Sassano, 2007) (Dupont, Artigues, Feillet, Michelon, & Vasquez, 2009) Wireless technology is now part of our everyday life. Wireless technology more specifically wireless communication has a underlying problem, which is known as the Frequency Assignment Problem (FAP) / Channel Assignment Problem (CAP) which is defined as the process of assigning frequencies to transceivers (TRX) while keeping interference to a minimum. The FAP is similar to the graph coloring problem and is an NP-complete problem (Aardal, van Hoesel, Koster, Mannino, & Sassano, 2007). This is because one has a finite amount of frequencies which needs to be assigned to transceivers where the amount of transceivers to be assigned frequencies greatly outweighs the amount of available frequencies (Aardal, van Hoesel, Koster, Mannino, & Sassano, 2007). Thus it is inevitable that a network will have interference and we can only minimize the amount of interference that might occur on the network - an optimization problem. Interference occurs when frequencies assigned to connections differ by a small margin. The amount of inference on a connection defines the quality of service. One can naturally make the deduction that the more frequencies differ used on connections in a area, the better quality of service one will experience in that area. All application domains that use wireless communication are also affected by the FAP as well as interference. New found interest in the FAP is due to the more widespread use of wireless technology in the media industry as well as military and cellular communication. Both of these respective disciplines have fuelled new research in the FAP domain. Within each application domain where wireless technology is used, different models and instances are used to address the problems encountered in the respective application domain. Even though these different domains utilize different models in their respective domains, they still share the same base; namely Wireless Technology more specifically wireless communication (Aardal, van Hoesel, Koster, Mannino, & Sassano, 2007). The FAP is most notable in the cellular telecommunications industry due to the large transceivers base they use to serve their respective clients with their limited amount of frequencies allocated to them in	

their licenses (Aardal, van Hoesel, Koster, Mannino, & Sassano, 2007) (Luna, et al., 2008). Depending on the GSM network type used the FAP gets more complex since the GSM900 band propagates further than GSM900 because the signal is stronger, thus in a GSM1800 network frequencies would interfere more than in a GSM1800 network depending on how far the cellular towers (cells) are separated geographically (Aardal, van Hoesel, Koster, Mannino, & Sassano, 2007).

Due to this signal loss over a distance, cellular networks operators can re-use frequencies in their networks as long as the assigned frequencies comply with the expected traffic demand as well as the electromagnetic compatibility (EMC) constraints (Hassan M., Hassan M., & Mina A., 2006) (Zhang & O'Brien, 2005). In general there are three standard constraints in the FAP:

- **Co channel constraint**: Two channels cannot use the same frequency
- **Adjacent channel constraint**: Frequencies assigned to two channels must differ by a certain margin usually one.
- **Co Cell constraint:** Any pair of frequencies assigned to a cell must have certain distance in the frequency domain to prohibit the cell from interfering with other cells on the same site.

The FAP can be classified into two categories:

(a) Fixed Frequency/Channel Assignment (FFA/FCA) is the process of permanently assigning frequencies to cells (cellular towers). The frequencies assigned are fixed and cannot be changed on the fly while the network is active, since the frequencies assigned to the cell form part of a delicate frequency plan designed to keep interference to minimum (Zhang & O'Brien, 2005).

(b) Dynamic Frequency/Channel Assignment (DFA/DCA) is the process of allocating channels to cells as they require it to meet the current traffic demand imposed on them by clients (Zhang & O'Brien, 2005).

Each cell (cellular towers) can be assigned multiple frequencies based on the amount of transmitters or TRX's it has. The amount of TRX's in a cell depends on the expected amount of traffic the particular cell must handle. (Eisenblätter & Koster, 2007)

Most of the research in the FAP has concentrated on the FFA. The reason for this is because FFA is a static technique, which allows it to come up with a better solution since it has more time for calculation. FFA is also easier to implement in practice and allows the network operators to cater for the worst case scenario - heavy traffic load on the network. The DFA is at the moment a very hard problem because the network frequency plan is constantly changing, which means as the traffic on the network increases the longer the DFA focused algorithm will take to allocate a frequency. This increase in processing time is because the algorithm has to take into account more constraints with a lower available frequency pool. DFA must do this process within seconds since a cell needs to serve clients. Most researchers have concentrated on solving the FFA using heuristic approaches like neural networks, local search techniques and more recently Meta heuristic approaches which include genetic algorithms, simulated annealing, ant colony optimization and particle swarm optimization (Zhang & O'Brien, 2005).

Fundamentally researchers have used two different approaches to evaluate frequency plans in the FAP:

a. **Call Orderings**: An old approach used in the beginning to try and solve the FAP. The main idea is to create an ordered list of all calls in the whole system which is then assigned frequencies based on a deterministic strategy. The number of frequencies needed to allocate a proper channel to a call depends significantly on the order of the calls in the generated call list. Some researchers have used heuristic measures to sort the ordered call list based on the difficulty of assigning a frequency to a call. Generally even using such a process of sorting the call list; call orderings do not lead to optimal frequency assignments (Hassan M., Hassan M., & Mina A., 2006).

b. **Minimization of Cost Functions**: A linear function is used to calculate to amount of interference that would be encountered due to violated constraints in the network with the current assigned frequencies. Researchers try to minimize this function since it is also a good metric to measure the quality of service that would be encountered in peak network traffic. An ideal solution would be if the evaluated cost is zero, which is unlikely to occur due to the problem domain being NP-complete, thus the objective is to get close to zero cost. The main drawback is that exact algorithms tend to get stuck in local minima. To overcome this problem authors turned towards meta-heuristic algorithms like simulated annealing and genetic algorithms. Consequently the Genetic Algorithm is a much more powerful solution than simulated annealing due to the algorithm use of randomization in creating populations (Hassan M., Hassan M., & Mina A., 2006). A more recent Meta heuristic called Particle Swarm Optimization uses inertia to break out of local minima.

The Meta heuristic field has seen in recent years a lot of growth in the research field with new variants of the algorithms appearing every year. Swarm Intelligence falls under Meta heuristic field. Swarm intelligence is the notion of entities working together in a group to solve a problem. Swarm intelligence borrows extensively from research conducted on swarm based life forms like bees, ants and fish. Consequently algorithms that have emerged from these studies are Ant Colony optimization and Particle Swarm Optimization.

Ant Colony Optimization (ACO) is an algorithm developed by (M. Dorgio et al. 1994) which based on a study conducted by (Deneubourg, Aron, Goss, & Pasteels, 1990). The algorithm is build around the notion of ants lying down pheromones as they move to allow fellow colony ants find better paths towards food. The more ants following a path the stronger the pheromone cent would be and more ants would be encouraged to follow the specific path. In the study by (Deneubourg, Aron, Goss, & Pasteels, 1990)it is noted that ants tend to choose the most cost efficient path toward a food source. Thus in the ACO algorithm the path chosen by the majority of the colony is considered the most optimum solution. Recent implementations of ACO on the FAP have achieved better results than most previous algorithms, see (Luna, et al., 2008) (Luna, Blum, & Alba, ACO vs EAs for Solving a Real-World Frequency Assignment PRoblem in GSM Networks, 2007).

The standard Particle Swarm Optimization (PSO) algorithm is based on the behavior of birds flying towards a nesting ground or food source. In a flock of birds any individual bird in the flock can influence the behavior and movement of the whole flock. In the algorithm, each particle (bird) knows its personal best position (personal best cost) that it has found as well as the globally best position found in the swarm. It uses its personal best and the globally best to adjust its velocity to fly/move towards a better position (Hassan M., Hassan M., & Mina A., 2006) (O'Niel & Brabazon, 2008) (Settles & Soule, 2005) (Vijay, Jung-Leng, & Eliot, 2009). With the global sharing taking place in the

	standard algorithm each particle can benefit from discoveries made by other individual particles. In the local version of the algorithm each particle does not know the global best found in the swarm rather is only knows the best solution found in its local neighborhood and its personal best position (O'Niel & Brabazon, 2008). With the conservative sharing in the local based algorithm, the swarm will not as easily converge to a solution as the global based one. Consequently the local version will search a larger search space. Currently the only PSO algorithms that have been used to solve the FAP use binary constraints. Binary constraints are similar to the call orderings approach, since list of calls are generated. Frequencies are assigned based on whether they violate a constraint (binary 0) and the call is blocked or whether the frequency doesn't conflict with the constraints (binary 1). The other variant uses binary constraints to indicate whether a frequency is available for assignment (binary 0) or busy being assigned (binary 1) (Hassan M., Hassan M., & Mina A., 2006) (Zhang & O'Brien, 2005). Utilizing the Call ordering approach the algorithms aim to achieve conflict free assignment. No PSO algorithm which follows the minimization of a cost function approach currently exists to our knowledge. We aim to either develop a new variant of the PSO or use an existing PSO following the minimization of a cost function approach. We will benchmark our final implementation with the COST259 instances found at (Andreas Eisenblätter, 2007).
Study methodology (techniques to be used, aspects to be investigated, etc.)	• Comprehensive literature study of current work in Particle Swarm, NP-Complete and Frequency Assignment fields. • An evaluation of the techniques discussed in the Literature study. • Identifying the strength and weaknesses of techniques utilized in the literature study • Define a new approach which improves upon the techniques evaluated. • Develop a prototype based on new approach • Evaluate prototype performance with domain specific benchmarks.
References (refer only to cited literature used in this proposal and provide at least three appropriate references to be referenced in full)	Aardal, I. K., van Hoesel, P. S., Koster, M. A., Mannino, C., & Sassano, A. (2007). Models and solution techniques for frequency assignment problems. *Annals of Operations Research* (153), 79-129. Deneubourg, J. L., Aron, S., Goss, S., & Pasteels, J. (1990). The self-organizing exploratory pattern of the Argentine Ant. *Journal of Insect Behavior* , 159-168. Dupont, A. L., Artigues, C., Feillet, D., Michelon, P., & Vasquez, M. (2009). The dynamic frequency assignment problem. *European Journal of Operational Research* (195).

	Eisenblätter, A., & Koster, A. (2007, 01 02). Retrieved 04 03, 2009, from FAP web - A website about Frequency Assignment Problems : http://fap.zib.de Hassan M., E., Hassan M., E., & Mina A., M. (2006). Channel Assignment for cellular radio using particle swarm optimization. *The 23rd National Radio Science Conference.* Egypt: Faculty of Electronic Engineering, Menoufiya University. Luna, F., Blum, C., & Alba, E. (2007). ACO vs EAs for Solving a Real-World Frequency Assignment PRoblem in GSM Networks. *GECCO'07* (pp. 94-101). London: ACM. Luna, F., Estebanez, C., Leon, C., Chavez-Gonzalez, M. J., Alba, E., Aler, R., et al. (2008). Metaheuristics for Solving a Real-World Frequency Assignment Problem in GSM Networks. *GECCO'08* (pp. 1579-1586). Atlanta, Georgia: ACM. O'Niel, M., & Brabazon, A. (2008). Self-organising swarm (SOSwarm). *Soft Computing* (12), 1073-1080. Settles, M., & Soule, T. (2005). Breeding Swarms: A GA?PSO Hybrid. *GECCO'05* (pp. 161-168). Washington DC: ACM. Vijay, K., Jung-Leng, F., & Eliot, W. (2009). Improving solution characteristics of particle swarm optimization using dgital pheromones. *Struct Multidisc Optim* (37), 415-427. Zhang, Y., & O'Brien, C. D. (2005). Fixed channel Assignment in Cellular radio Networks Using Particle Swarm Optimization. Dubrovnik, Croatia: IEEE ISIE. Colorni, A., M. Dorgio, V. Maniezzo and M. Turbian (1994). Ant System for Job Scheduling. Belgian Journal of Operations research, Statistics and Computer Science (Vol. 34) p36-53

- **Research Degrees: Master's** **To be submitted within <u>3 months</u> of registration date**

  Doctoral **To be submitted within <u>6 months</u> of registration date**
- **Tutored Degrees:** **To be submitted before the minor dissertation is commenced**

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Revised February 2008