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Optimizing the Timing of Background Transfers

(The Research Methodology Portfolio)

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Abstract

Telecommunications is one of the areas of technology which is considerably growing day by day. This technology can provide remarkable facilities for businesses and individuals to access information at electronic speed from almost anywhere in the world. It is very important not only because of its own right but also for the services that it can provide to the other areas of human life. However, telecoms which is supported by an ever-changing set of technologies and provides a huge number of services, presents a challenging range of hard designs, implementations and optimization problems. At present, Evolutionary Computation (EC) which is a subfield of artificial intelligence is one of the most efficient approaches for coping with these kinds of optimisation problems.The main objective of this research project which was offered us by Motorola company is to apply Genetic Algorithms as one of the most important and widely used EC techniques to the problem of the timing of background transfer as a new optimization problem in the field of telecommunication in order to optimize the parameters involved and investigate the possibility of creating a mobile phone which is able to delay initiating background transfers to times when the mobile is in an area of strong signal and or underloaded system resulting in using the radio resources as efficient as possible in the system and increasing capacity and also the quality of existing services. A simulator may be provided by Motorola Company for doing different experiments during the first stage of this project but in case of not receiving the simulator timely, we are aiming to create a simple form of that simulator by ourselves and finally a GA will be wrapped around this simulator in order to generate the optimized results. The main aim of presenting this portfolio was that it performs as the preparation phase of the MSc project and to put into practice the issues which were learned during the research methodology module. In this portfolio, some related works which also include the major part of the portfolio were reviewed and the main structure of the MSc dissertation was shown. Also some issues related to professional, ethical, social issues and risk assessment issues were addressed and at the end a conclusion containing the main issues associated with the project were presented.

1. Introduction

Telecommunications is one of the ever-expanding areas of technology and can be defined as the process of transmission of signals over a significant distance using electronic equipments. In modern times, telecoms typically involves the use of electronic transmitters such as the telephone, television, radio or computer. At present, telecoms industry delivers voice communications, data, graphics, television, and video at ever-increasing speeds and in an increasing number of methods. Whereas landline telephone communications were once the primary service of the industry, wireless communication services, Internet service, and satellite program distribution form an increasing share of the industry [2].

The vital role of telecommunications in the economic, social and political development of a country is now recognized throughout the world. The benefits derived from improved telecommunications not only contribute to strengthen the economy of a nation but also to reduce isolation and improve the effectiveness of social programs. The improvement in telecoms services is not straightforward because of the numerous complexities which are involved in this technology [3].

However, telecoms which is supported by an ever-changing set of technologies and provides a huge number of services, presents a challenging range of hard designs, implementations and optimization problems such as network design, call routing, signal processing, frequency assignment, wavelength allocation, capacity planning, admission control and network management etc. This means that for applying any improvement to the existing telecommunications industry, one of the most important issues is to cope with optimisation problems in this field as mentioned above [1].

At present, Evolutionary Computation (EC) which is a subfield of artificial intelligence is one of the most efficient approaches for coping with these kinds of optimisation problems. Evolutionary computation uses iterative progress, such as growth or development in a population. This population is then selected in a guided random search using parallel processing to achieve the desired end. Such processes are often inspired by biological mechanisms of evolution. Evolutionary techniques mostly include Evolutionary Algorithms (Genetic Algorithms, Evolutionary Programming, Evolution Strategy, Genetic Programming and Learning Classifier system) and Swarm Intelligence (Ant Colony optimization and Particle Swarm optimization) [6].

One type of random search algorithms based on the mechanics of ‘natural genetics’ and ‘natural selection’ is Genetic Algorithms (GAs) which are also one of the most important and widely used EC techniques [5]. In fact, GAs are founded upon the principle of the Darwin's ‘theory of evolution’ and in particular ‘the survival of the fittest’ [4]. A Genetic Algorithm creates a ‘population’ which is the collection of possible solutions and then allows them to evolve over multiple generations in order to discover better and better answers [4].

The earliest instances of GAs appeared in the early 1960s as a result of evolutionary biologists’ researches who were tried to model natural evolution. They were not aware that this methodology might be applicable to different type of problems. By 1962, researchers such as Friedman, Bledsoe, Box and Bremermann had developed some special kind of evolutionary algorithms independently for solving optimization and machine learning problems but their works did not attract other researchers. A more successful development in terms of evolutionary algorithms came in 1965 when Rechenberg introduced a new method called ‘evolution strategy’ at the Technical University of Berlin. There was no population and ‘crossover’ (one of the main operators of GAs operating as a method of change) in this method and all operations were based on the ‘mutation’ (another important operator of GAs operating as a change method) [5, 6, 7].

Another important development in this area came in 1966, when Walsh, Fogel and Owens introduced a new technique called ‘evolutionary programming’ which operated by randomly mutating like Rechenberg's evolution strategy and in this approach, possible solutions were described as simple finite-state machines. In both methodology mentioned, the lack of crossover was one of the characteristics [5, 6, 7].

Eventually, the seminal work in terms of GAs came in 1975. Holland introduced modern Genetic Algorithms with the publication of his famous book called ‘Adaptation in Natural and Artificial Systems’ at the University of Michigan. He was the first person who presented the concept of ‘adaptive digital systems’ and used ‘selection, crossover and mutation’ as the main operators simulating the process of natural evolution. At the same year, Jong pointed out the enormous potential of GAs by showing their considerable performance on a wide range of test functions such as ‘noisy, discontinuous, and multimodal search landscapes’ [5, 6, 7].

Since the mid of 1980s, GAs which are the result of the combination of genetic science, mathematic and computer science have been applied successfully to a wide variety of complex optimization problems related to different fields and subjects. Some samples of the applications of GAs in different fields are as follows [5, 6]:

- **Geophysics**

Sambridge and Gallagher (1993) used a genetic algorithm to locate earthquake hypocenters based on seismological data [7].

- **Astronomy and astrophysics**

Charbonneau (1995) suggests the usefulness of GAs for problems in astrophysics by applying them to three example problems: fitting the rotation curve of a galaxy based on observed rotational velocities of its components, determining the pulsation period of a variable star based on time-series data, and solving for the critical parameters in a magnetohydrodynamic model of the solar wind [7].

- **Electrical engineering**

Altshuler and Linden (1997) used a genetic algorithm to evolve wire antennas with pre-specified properties [7].

- **Mathematics and algorithmics**

Haupt and Haupt (1998) discuss the use of GAs to solve high-order nonlinear partial differential equations, typically by finding the values for which the equations equal zero, and give as an example a near-perfect GA solution for the coefficients of the fifth-order Super Korteweg-de Vries equation [7].

- **Aerospace engineering**

Williams, Crossley and Lang (2001) applied genetic algorithms to the task of spacing satellite orbits to minimize coverage blackouts [7].

- **Routing and scheduling**

Beasley, Sonander and Havelock (2001) used GAs for scheduling airport landings at London Heathrow, which is one of the busiest airports in the world [7].

- **Game playing**

One of the most novel and compelling demonstrations of the power of genetic algorithms was presented by Chellapilla and Fogel (2001), who used a GA to evolve neural networks that could play the game of checkers [7].

- **Acoustics**

Sato et al. (2002) used GAs for the design of a concert hall in order to maximize the sound quality [7].

- **Financial markets**

Andreou, Georgopoulos and Likothanassis (2002) used GAs to predict the exchange rates of different currencies one month ahead [7].

- **Systems engineering**

Benini and Toffolo (2002) used GAs to design new wind turbines for producing electric power [7].

- **Military and law enforcement**

Kewley and Embrechts (2002) used genetic algorithms to evolve tactical plans for military battles [7].

- **Materials engineering**

Robin et al. (2003) used GAs to design exposure patterns for an electron lithography beam, used to etch submicrometer-scale structures onto integrated circuits [7].

- **Pattern recognition and data mining**

Au, Chan and Yao (2003) applied genetic algorithms to this problem to generate a set of if-then rules that predict the churning probability of different groups of customers [7].

These instances are only a few applications of GAs in different fields of science and engineering and show their power and potential for dealing with different kind of problems. At present, this methodology is one of the best approaches for solving search, optimization and machine learning problems and also some complex problems for which there is no reasonable solution [4, 6]. A detailed discussion in terms of the vast applications of EC (particularly GAs) in telecommunications which is also the main theme of this research project will be appeared in the "related work" section. In the next section, the outline of the dissertation structure and layout is presented briefly.

2. Outline of the dissertation structure and layout

The dissertation has been divided into 9 main sections which are as follows:

- Section 1: introduction
- Section 2: outline of the dissertation structure and layout
- Section 3: Aims and objectives of the project
- Section 4: related work (literature review)
- Section 5: a detailed description of the problem of optimizing the timing of background transfer
- Section 6: a brief overview of the fundamentals of telecommunications (only with respect to the necessary aspects involved in this research)
- Section 7: a detailed description of the fundamentals of Genetic Algorithms
- Section 8: the process of solving the problem using GAs
- Section 9: the description of the developed computer program in brief
- Section 10: experiments, evaluation and results
- Section 11: conclusion
- Section 12: references and bibliography

The mentioned main sections may be divided into subsections as the project progresses and based on the requirements. In the next section, aims and objectives of the project is presented.

3. Aims and objectives of the project

The main objective of this research project which was offered us by Motorola company is to apply Genetic Algorithms as one of the most important and widely used EC techniques to the problem of the timing of background transfer as a new optimization problem in the field of telecommunication in order to optimize the parameters involved and investigate the possibility of creating a mobile phone which is able to delay initiating background transfers to times when the mobile is in an area of strong signal and or underloaded system resulting in using the radio resources as efficient as possible in the system and increasing capacity and also the quality of existing services. A simulator may be provided by Motorola Company for doing different experiments during the first stage of this project but in case of not receiving the simulator timely, we are aiming to create a simple form of that simulator by ourselves and finally a GA will be wrapped around this simulator in order to generate the optimized results. In the following section, some related works in terms of the application of EC in telecommunications is reviewed.

4. Related Work

There are a considerable number of the applications of evolutionary computation (EC) in telecommunications. In terms of the optimizing the timing of background transfers as the main theme of this research, there is almost no previous research exactly related to our research and for this reason, in this section, it is intended to classify and review the most important and relevant EC researches which have been conducted in the field of telecommunications since 1995.

4.1. Network design

4.1.1. Network architecture

At present, due to the significant growth in telecommunication services, the need for larger frequency bandwidth and the rapid progresses in media transmission, a remarkable attention is being allocated for designing new network architectures which involve a huge number of optimisation problems.

Celli, Costamagna and Fanni (1995) used a genetic algorithm for network design optimization. They simulated the problem using graph model and formalized it using basic assignments which are as follows [8]:

- The positions and the demands in terms of signalling rate of the N users in the geographical region.

- The possible position of the multiplexers.
- The set of existing connections between multiplexers and between multiplexers and users, and the set of possible links with respect to any provided constraint.
- The type of available tool and its cost.

The optimization problem called for the minimization of the overall cost of the network, determining [8]:

1) Site of the exchange.
2) Number and position of the multiplexers effectively activated.
3) Topology and size of the transport network (i.e. the set of links connecting exchange and Multiplexers, and their capacities).
4) Topology and sue of the distribution network (i.e. the set of links connecting any user to multiplexers or directly to the exchange).

Furthermore, hypotheses were introduced to obtain achievable solutions satisfying all the technical constraints [8]:

- Each user was connected to the closest multiplexer (the famous Dijkstra algorithm was used to build the distribution network).
- The positions of the multiplexers were assumed to coincide with some user locations, assuming a nil capacity demand, if required.
- The multiplexers were connected with a minimum length spanning tree.

The transport network was reconstructed resorting to the Dijkstra algorithm, in order to minimize its length which showed the main portion of the overall cost to be optimized [8].

For solving this problem, Celli et al. (1995) used a GA as mentioned before. They used binary strings as representation method for their designed network structure. As the second stage, they developed a suitable fitness function (FF) as shown below:

$$FF = - \log\left(\frac{OF}{OFstar}\right)$$

Their GA practices leaded to maximise the fitness function (FF), which was gained from the natural objective function (OF) of the network problem, i.e. minimize the total cost. In the mentioned fitness function OFstar is the cost of a pure star tree structure, in which no multiplexer is activated, and users are directly connected to the exchange. Since OFstar > OF, FF ranges from 0 to 1, corresponding to unachievable infinite and zero cost respectively [8].

The other steps that they considered to complete their algorithm are as follows [8]:

- Selection: starting from the FF figures obtained for the current population, the "remainder stochastic sampling without replacement" scheme was adopted.
- Crossover: the “uniform crossover" was used, by which each allele was swapped with the probability of 0.5.
- Mutation: all the string alleles were mutated according to a mutation probability equal to l/nm2, where nm is the strip length, i.e. the number of candidate multiplexer sites.

At the end, they concluded that the choice of parameters values in the GA implementation plays a key role in terms of the performance of the algorithm. They also did an extensive study of several networks and this allowed optimum value of these parameters to be determined, i.e., population size, crossover probability and mutation probability, together with the type of crossover strategy [8]. Furthermore, due to the large amount of computation time needed to evaluate each FF, compared to the data transmission time between processors, a parallel implementation of the algorithm was developed by them using a cluster of workstations. The results extracted from their research showed that the gain (in terms of computation time) obtained with the parallel algorithm increased with the number of network nodes, allowing to efficiently solving large problems that might be hard or inefficient to solve with serial implementation [8].

4.1.2. Protocol design

There are a considerable number of situations where a data network is needed in regions where there is no fixed networking infrastructure. The best examples of theses situations can be military operations and rescue operations. Ad hoc networking can respond to this need because it has the ability to form a network from scratch using wireless connections dynamically. The problem is that specific situations usually require that a network is optimized along certain characteristics such as delay, energy or overhead. In response to the different types of requirements and conditions, ad hoc networking protocols are designed with a considerable number of modifiable parameters. At present, due to the lack of efficient methodical ways, intuition and broad experience are usually used for the selection of the values of these parameters [13].

Montana and Redi (2005) used Genetic Algorithms for the automated selection of parameters in an ad hoc networking system. The parameters which they aimed to optimize using GAs were as follows [13]:

- **Heartbeat Interval** is how often to send neighbor discovery heartbeats (used for detecting new neighbors as well as a lost link to an existing neighbor).
- **Heartbeat Points** is the number of points to assign each received heartbeat from a neighbor node.
- **Score History Size** is the window of time to observe for making decisions about scores/points.
- **Up Score Threshold** is how high a score is needed within the history window to bring up a link to a new neighbor.
- **Down Score Threshold** is how low the score must go before the link to an existing neighbor is torn down.
- **Routing Algorithm** is either Hazy Sighted Link State or standard link state.
- **Routing Event Interrupt Period** is how often the routing module checks for link changes. If a link has changed, a new routing table is computed and a changed link state update packet is flooded through the network.
- **Routing Global Interrupt Period** is how often to send a new link state update (LSU) regardless of whether the state has recently changed or not. This is done for refreshing previous LSUs and insuring that previous LSUs are not lost.
- **Traffic Max Attempts** is the number of (re)transmission attempts to use at the radio layer for user traffic.

Some of the important factors of the GA that they used to optimize the parameters of the networking protocol were as follows [13]:

Representation – The chromosome was defined as a list of parameter values. This type of chromosome is usually called a real-valued chromosome. For each parameter, they selected a minimum value, maximum value and step size in order to define a discrete set of possible values for the parameter [13].

Generating new individuals – First the population was initialized with random individuals. Then uniform crossover and standard mutation were used as genetic operators with the probability of 0.5 for each. Also, an exponential parent selection scheme and a steady-state replacement policy were applied to the population. The mentioned strategies add a new individual into the population immediately after its generation and discard the worst population member [13].

Evaluation of an individual – According to their implementation, the evaluation of an individual is performed such that their algorithm runs a simulation with the networking parameters set as given in the individual and during the simulation, it collects information in terms of networking performance and then, it joins these together into a single score [13].

At the end, they drew three main and key conclusions from their research as follows [13]:
Firstly, the values selected for the different parameters of the networking algorithm could make a considerable difference in the performance of the network. Secondly, automated parameter optimization could generate remarkably better parameter values than hand tuning. Thirdly, for automated parameter optimization to perform best, the training data should represent the full range of operating conditions under which the parameters require to function.

4.2. Network management

4.2.1 Local area partitioning

Network management refers to the activities, methods, procedures, and tools which are related to the operation, administration, maintenance, and provisioning of networked systems and as the subscriber population increases and the network capabilities are improved, mobility management and resource management become significantly critical in cellular networks and may cause a considerable number of optimisation problems in this field [2, 9].

According to Gondim (1996), due to the continuous enlargement of coverage areas, the adoption of partitions to facilitate management activities is essential. He also adds that Location Areas form an important strategy of location management which can be used to reduce signaling traffic caused by location updating and paging messages in a cellular network and because of a huge state spaces which should be searched, the determination of optimal LA's (Location Areas) will result in a NP - hard combinatorial optimization problem. For solving the problem, he used Genetic Algorithms in order to group cells in an efficient way [9].

As it has been mentioned in [Gondim, 1996], each LA includes one or more adjacent cells which are managed by only one MSC (mobile switching centre) and a broadcast channel is used to inform which cells are composing each LA. It is also used to inform mobile terminals of the LA where they are grouped. The design of LA's aims to find a LA for each cell with respect to the minimization of the bandwidth consumption and the satisfaction of constraints such as cell adjacency and cell membership to only one LA [9].

He used a graph model for this problem and considered a cellular system with N cells shown by a graph G= (V, E) where V= set of cells and E= set of edges and defined an adjacency matrix B for G such that [9]:

$$\mathrm{b}_{ij} = \begin{cases} 1, \textit{if cells } i \textit{ and } j \textit{ are adjacent or } i = j \\ 0, \textit{otherwise} \end{cases}$$

The Local Area Partitioning Problem (LAPP) included the determination of the partitions in the graph G considering the minimization of an objective function. He used an objective function for this problem as indicated below [9]:

$$\sum_{k=1}^{N}\sum_{i=1}^{N}\sum_{j=1}^{N} C_U\, e_{ij} - C_P\,(p_i + p_j)\, g_{ik}\,(1 - g_{jk})........$$

Where:

C_u = location update cost

C_p = paging cost

e_{ij} = inter-cell traffic between cells i and j

p_i = number of pages / unit time in cell i

g_{ik} = 1 if cell i is assigned to LA k else 0

In the next step, he used an N-string of integer numbers in order to represent potential solutions such that its j^{th} position referred to the i^{th} cell and the value stored at this position referred to the LA which that cell belonged to. Thus an instance of location area partitioning was encoded by a chromosome whose length was the number of cells in the defined graph [9].

The objective function mentioned above was also used as evaluation function and the following relationship was considered to quantify the relative importance between C_p and C_u [9]:

$$C_p = 0.1\, C_u$$

The other parameters of the objective function were arbitrated in a common sense (for example, paging / cell was set as a proportion of the population of subscribers /cell). In terms of genetic operators, a special kind of crossover called edge-based crossover was used and the author concluded that the edge-based crossover used in this problem (and also in the other problems such as traveling salesman) could speed up the convergence time and the extracted results also showed that the performance of this type of crossover was considerably better than the other tested crossover operators which converge in the least number of iterations. At the end, he also emphasizes on the considerable capability of Genetic Algorithms for finding optimal or approximately optimal solutions to the LAPP in an acceptable computational time [9].

4.3. Admission Control

4.3.1 Call admission control

Admission control is one of the interesting issues in the field of telecommunication. When a cellular network is shared by customers with distinctive characteristics such as handoff rates or call holding times, the overall performance of the system can be enhanced by denying the service requests even if there is an excess capacity. Such selective denial of services based on the condition of the system is called admission control [2, 10].

According to Yener and Rose (1997), the allocation of the radio resources to the customers with minimum blocking of new calls and dropping of handoffs is a challenging issue in designing mobile communication systems. The allocation of channels to each user whenever the sources are available may not be an optimal strategy resulting in improving system performance. The performance can be enhanced if a state-based call admission policy is imposed on the system where there are different users with different service types and then the problem will become one of discovering the call admission policy providing optimal system performance [10].

Two types of cellular networks were investigated in their research: a 1-D ring-structured network with an even number of cells and a 2-D Manhattan model cellular network. They considered a system with two types of service requests which were new call set up request and handoff request. They also assumed a Markov model such that the new call arrival process to each cell was modelled as Poisson with rate λ [10]. Call holding times were exponential with average call completion rate μ. Another assumption that they made was that calls in progress were subject to handoff to either of the two (or four for the 2-D system) neighboring cells and the time that a mobile user spent in any cell was exponential with rate γ which was independent of the call arrival and call holding process [10].

For solving the problem, they used a two parent-two offspring Genetic Algorithm in order to discover near-optimal call admission policies for cellular networks to cope with the computational limits of the MDP (Markov decision process) approach. In their GA, each local policy represented a chromosome which was a collection of bits corresponding to admit (1) and reject (0) decisions for the new call setup and handoff requests at each local state of the system [10]. Also, a group of local policies or a community was selected randomly at first and each policy in the community was evaluated using Monte Carlo simulation with respect to a relationship shown below as the performance measure [10]:

$$T = P_b + w\,P_h$$

Where:

T = the cellular system performance

P_b = call blocking probability

P_h = handoff dropping probability

W = the relative penalty factor

In their approach, Policies with better performance are more likely to enter mating pool. Then the mentioned chromosomes performs crossover to exchange some bit information resulting in offspring policies and finally offspring policy bits performs mutation randomly. After mating, policies are selected to be deleted with the probability which is related to their fitness in reverse and then the offspring are placed in the population. They also tried to keep the population of the community constant from iteration to iteration and only delete as much policy as there are offspring. Their basic algorithm was repeated for a required number of generations or until policy improvement showed to stay unchanged [10].

At the end, they concluded that the performance of the best local policies was comparable with optima for small systems. In terms of large systems, they also added that the local policies which were discovered, outperformed the maximum packing and best handoff reservation policies for the systems that they considered and the local policies suggested by the Genetic Algorithm search in these situations were double threshold policies. After finding the best double threshold policies by comprehensive search for both 1-D and Manhattan model cellular networks, they indicated that they almost always outperformed the best trunk reservation policies for these systems [10].

4.4. Network planning

4.4.1 Radio coverage planning

Radio coverage planning is one of the crucial issues in network planning. One of the effective ways which can be used for radio coverage planning is to use network simulation tools. These tools allow the computation of the radio coverage provided by a given configuration of the base stations for instance. However, the radio coverage planning of the GSM (global system for mobile communications) cellular mobile telecommunication network can not be solved only using simulation tools because of facing hard optimization problems and for this reason the development of optimization tools for dealing with this issue is still under heavy investigation [11].

According to Lieska et al. (1998), the combination of simulation and optimization tools can be used as a very effective strategy to accomplish radio coverage planning automatically. The main aim of their research was to investigate the efficiency of GAs for optimizing the total radio coverage and for reaching this aim, they studied GAs with three different approaches in order to optimize the BS's (base stations) sites [11].

The problem which was considered in their research was to select the locations for a fixed number *K* of base stations (BS's) such that the criterion set for total radio coverage is fulfilled. Such a criterion could be to maximize the total radio coverage area for instance [11].

For solving the mentioned optimization problem, they used a simple genetic algorithm with three operators including reproduction, crossover and mutation. Three different approaches were also used to form chromosome's structures and fitness function [11].

In the first approach, a binary chromosome representation was used such that each chromosome consisted of a bit string with the length n and n was possible BS location. Those BS's which appeared in the solution were denoted by 1 and the others by 0. The fitness function presented had to be in such a manner to guide the algorithm in the direction where *k* BS's existed in the solution exactly and then for the fitness function $f(\mathrm{I})$, the chromosome (I) was defined as follows [11]:

$$f(\mathrm{I}) = \frac{c(I)}{|k - o(I)| + 1}$$

Where c (I) = total radio coverage area of chromosome I

K= the desired number of BS

o (I)= number of BS's in chromosome I

Due to the appearance of some problems with convergence in a run the following linear scaling was also used [11]:

$$f'(\mathrm{I}) = \mathrm{a} \cdot f(\mathrm{I}) + \mathrm{b}$$

In the second approach, a priori knowledge in terms of the desired number of BS's was used when they defined the chromosome structure. Because of the existence of only $\binom{n}{k}$ different possible solutions for examining, all the possible solutions were represented using l genes long chromosomes where l was defined as follows [11]:

$$2^{l-1} < \binom{n}{k} \leq 2^{l}$$

For computational reasons, each chromosome corresponded to exactly one possible solution and a linear scaling was used such that [11]:

$$\mathrm{M}(\mathrm{I}) = \mathrm{INT}\left(\mathrm{I}_{10} \cdot \frac{\binom{n}{k} - 1}{2^{l} - 1} \right)$$

Where:

I_{10} = the decimal value of chromosome I

INT = an operator which means rounding to the nearest integer

M = the index of possible solution

Considering the linear scaling the fitness function was defined as follows [11]:

$$f\big(M(I)\big) = a.c\big(M(I)\big) + b$$

Where: c (M(I)) = the total coverage area for the possible solution M

In the third approach, a different structure for chromosomes was used such that the chromosome was divided into k parts. K represented the desired number of BS's and every part corresponded to the index of BS which should be selected. With respect to the total number of BS's that was n, they represented each part of the chromosome by using a string of l bits length and l was defined as follows [11]:

$$2^{l-1} < n \leq 2^{l}$$

In this stage, the length of each chromosome was represented as (k . l) bits and the next step was to join each part of the chromosome to a exactly one BS location. Again, another linear scaling was used to reach this aim as follows [11]:

$$M^{P} = \mathrm{INT}\left(I_{10}^{p} \cdot \frac{n-1}{2^{l}-1} + 1 \right)$$

Where

P= the part index

M^{P} = the index of BS

(The fitness function which was used was similar to the fitness function in approach 2.)

At the end, they concluded that GA worked very well for solving their optimization problem and also approaches 2 and 3 were considerably more efficient than the random search method. Their researches showed that a-priori knowledge in terms of desired amount of BS's plays a key role when determining the structure of the chromosome and fitness function of the GA. Another important issue that they emphasized on was that their research was very brief and in the real situations, the optimization problem could be extremely larger and more complex than their case but this might be solved only by adjusting the fitness function [11].

4.4.2 Radio network planning

One of the most important challenges in telecommunication companies in terms of the deployment of a mobile phone network is to select a suitable set of sites among those which are possible for the installation of "base transceiver stations" (BTS). The problem will be appeared when the company aims to serve a maximum surface of a geographical area with a minimum number of base transceiver stations. The mentioned problem which is actually a mobile radio network planning problem, recalls minimum hitting set problem [12].

Calegari et al. (2001), were solved the problem by using greedy-like, Darwinism and genetic algorithms. They took the set of sites where BTSs might be installed, as an input and their aim was to discover a minimum subset of sites permitting good services [12].

For the purpose of this research the first two approaches namely greedy-like and Darwinism algorithms will not be reviewed in this paper and only the genetic algorithm approach will be mentioned briefly.

Calegari et al. (2001) used an island-based genetic algorithm for solving the problem. They selected binary string representation for encoding the potential solution to the problem. In their implementation, a chromosome represents the whole set of possible BTS sites and the selection of a location in a chromosome depends on the value of the corresponding entry in the bit string. A fitness value was also assigned to every chromosome such that [12]:

$$Fitness = (served\ area\ /\ total\ area)^{\alpha}\ /\ \text{number of BTSs used}\ (\alpha \text{ is a parameter})$$

Their experiments showed that if $\alpha = 4$, the solutions extracted from the algorithm will give approximately 90% of service ratio which is an acceptable result according to telecommunication experts. They also emphasized that the genetic algorithm introduced by Holland (modern Genetic Algorithms' creator) could be used to solve their problem but it had two important weaknesses [12]. Firstly, it was not fast enough to be able to be used for interactive use, as it is necessary for telecommunication operators. Secondly, rapid convergence of this algorithm might result in obtaining the solutions which are far from the optimum results. With respect to the reason mentioned, they tried to use a strategy to improve the quality of extracted results from GA. The algorithm that they used, called island-based Genetic algorithm. In this kind of GA, population is split into sub populations which are called islands that evolve independently and can cooperate in migrating chromosomes from an island to another [12].

In this method, a population must include a considerable number of chromosomes in order to generate satisfactory results although this can significantly increase computation load. In this case, the huge amount of independent processing which is needed for evolving islands suggests an ‘intrinsic parallelism’ and then the overall computational time could be decreased by distributing the islands on several processors [12].

In their implementation, the islands were placed virtually on an oriented ring and migrations were permitted only along that ring. Every time, a new generation was produced, a copy of the best chromosome (with the highest fitness value) ever met by each island was sent to the next island on the ring so each island received a new chromosome which replaced one of its chromosomes chosen randomly [12]. They selected this topology to minimize the amount of migrations and therefore to minimize the communication load because of the migrations between remote islands. At the end, they concluded that the results extracted from a greedy-like algorithm and an island-based genetic algorithm were satisfactory and the Genetic Algorithm could generate the best results with the least computational time after running a parallel version of program. Original Darwinism algorithm could not show an acceptable performance in comparison with the others but it indicated new perspectives for the ε-net theory [12].

There were 4 more papers that I reviewed but due to the lack of enough time, I could not write about them in this portfolio. I will include them in the second stage of this project.

5. The problem of optimizing the timing of background transfer

Telecommunications is one of the areas of technology which is considerably growing day by day and due to the ever-increasing number of subscribers, a significant number of overload scenarios can continuously occur in a cellular communication system. In these situations, some of the subscriber will not be able to receive a service immediately or quickly. This means that these transmissions must be deferred. Generally, it is better to defer those mobiles that need to perform background transmissions, such as periodic synchronization of emails or downloads of large files for instance. A slightly delayed email will harm customer’s satisfaction less than deferring a voice call on demand. In these overload conditions, the admittance of some fraction of those background service requests is usually feasible before the capacity threshold is reached. The selection of those mobiles that will receive a service can be performed by considering the level at which they receive the cellular signal. Those mobiles with stronger signals will be able to transfer the data faster than those with weaker signals and will impose less radio interference on the system. Furthermore, less demand will be placed on the batteries of those mobiles receiving stronger signals.

By creating a mobile phone which will delay the initiation of background transfers to the times when the mobile is in an area of strong signal and or underloaded system, the radio resources may be used more efficiently but if a considerable number of mobile phones suddenly perform this at the same time, the cellular network can be overloaded again. Generally, the mobile phone is able to recognize the signal strength for example the number of signal strength bars on the handset and it also can recognize how loaded the system is by monitoring the information that the cellular system broadcasts to all users.

This idea for having mobiles hold off performing access until the system advertises that it is sufficiently underloaded, is part of the 3GPP2 standards for 4G Ultra Mobile Broadband. The additional criteria of having the mobile hold off on performing access until it has a higher number of signal strength bars has not yet been accepted to the 3GPP2 standard.

With the advent of forth generation standards, mobile phones will be able to defer transmissions and sense their signal strength and also sense some data in terms of the overall load on the network but the main and most important question is that how best to select when and what to defer? This question is also the main research question of this MSc dissertation. The mentioned problem is important for Motorola Telecommunications Company in the next generation network systems and next generation mobile phones. Motorola's problem also involves the use of a simulator and for this reason it can be considered as a large-scale optimization because the simulation may need to be run thousands of times.

There are a remarkable number of issues involved in this problem that can be investigated but For the purpose of this research, we will mostly concentrate on optimizing the timing of background transfers in order to quantify the benefit that this approach can yield in terms of capacity increase and any effect on latency (delay). In the first phase of this project, we will simulate a mix of service users, spatial variations in channel conditions and temporal variation in traffic load. This will be used to measure how the capacity of the system and the typical delay for background classes varies with and without the proposed system to schedule deferrable data and in the second stage, the optimization of the parameters for the proposed system will be investigated by using Genetic Algorithms.

6. Professional, legal, ethical and social issues related to this project

Professionalism and avoiding plagiarism as key factors in every research project must be considered but the extremely important issue relating to this project is that there is an agreement between Motorola Company and us and according to this agreement, Motorola will provide confidential or proprietary information, data or algorithms or codes, project definitions, industrial supervision and training to us based on the requirements of this project and in consideration of the access given to Motorola facilities as mentioned above, we must carefully follow the agreed issues as it has been mentioned in the agreement. The most important issue in this agreement is that we must avoid disclosing any information owned by Motorola Company to the others.

7. Conclusion

At present, Telecommunications is being supported by an ever-changing set of technologies and provides a huge number of services. It also presents a challenging range of hard designs, implementations and optimization problems. Among different approaches, Evolutionary Computation (EC) which is a subfield of artificial intelligence is one of the most efficient methods for coping with these kinds of optimization problems.

The main objective of this research project which was offered us by Motorola Company is to apply Genetic Algorithms as one of the most important and widely used EC techniques to the problem of the timing of background transfer as a new optimization problem in the field of telecommunication in order to optimize the parameters involved and investigate the possibility of creating a mobile phone which is able to delay initiating background transfers to times when the mobile is in an area of strong signal and or underloaded system resulting in using the radio resources as efficient as possible in the system and increasing capacity and also the quality of existing services.

The main aim of presenting this portfolio was that it performs as the preparation phase of the MSc project and to put into practice the issues which were learned during the research methodology module. In this portfolio, some related works which also include the major part of the portfolio were reviewed and the main structure of the MSc dissertation was shown. Also some issues related to professional, ethical, social issues and risk assessment issues were addressed.

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MACS Risk Assessment Form (Project)

Student: ***Behrooz Koohestani***

Project Title: ***Optimizing the timing of background transfers***

Supervisor: ***Professor David Wolfe Corne***

Risks:

Risk	*Present (give details) (tick if present)*	*Control Measures and/or Protection*
Standard Office environment- includes purely software projects	Nothing important	Nothing
Unusual peripherals e.g. Robot, VR helmet, haptic device, etc.	Nothing	Nothing
Unusual Output e.g. Laser, loud noises, flashing lights etc.	Nothing	Nothing
Other risks	Nothing	Nothing