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MAXIMIZING POWER CONSUMPTION OF MIMO NETWORK USING A NOVEL QUANTUM GENETIC ALGORITHM

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Areeba Tabassum Shoaib

Summary

Quantum computing is one of the most promising approaches to addressing the problems of computational complexity, data storage, and power consumption because of its extremely fast performance. Applying the principles of quantum computing to the development of optimization algorithms is a rapidly growing field of study.

With its ability to provide improvements in area throughput and energy efficiency, the multiple-input multiple-output (MIMO) system offers significant potential for 5th generation (5G) wireless communication systems. The number of antennas used by the base station is increased in massive MIMO. This has several advantages, including an array gain that may be utilized to expand coverage, favorable propagation that makes user separation easier, and channel hardening that makes the system more robust and stable. Yet, the computational complexity of the embedded optimization techniques in MIMO systems remains a problem. Several techniques, such as the Nash equilibrium-based effective water-filling algorithm (WFA), have been developed in an effort to enhance the power allocation system for MIMO.

This thesis focuses on the question of how the power consumption of MIMO systems can be maximized by using a novel Quantum Genetic Algorithm.

In this research , we implemented a quantum optimization technique known as the Quantum Extreme Value Searching Algorithm (QEVSA) to Develop a new Unconstrained Quantum Genetic Algorithm (UQGA). Not Completed!!! DO AT THE END!!!

Sommaire

The text of a ½-1 page long summary goes here in a second language, different of English (German, French, Portuguese, Russian, Finnish, Korean, Chinese, Japanese, Hungarian, etc,). This summary is the translation of the summary in English and has to be also uploaded to the Thesis Portal separately.

Acknowledgement

To be Done!!

# Introduction

## Quantum Computing Overview

In classical computing, the smallest unit of information is referred to as a "bit" and can be represented by one of two states, "0" or "1"; these states are also known as classical states. The classical processor carries out a variety of transformations on classical states, i.e., information processing using classical gates. Comparable to classical computing, Quantum computing employs specific quantum elements that do not exist in traditional computation. It is important to note that there are four primary postulates that describe quantum computer, and they are as follows:

### Postulates of Quantum Computing

**First postulate (State-space)**

A qubit is the fundamental quantum systems unit in the quantum universe that can simultaneously contemplate both classical states, referred as superposition. Below is an illustration of a qubit:

(

where a and b are complex coefficients, and |0 > and |1 > are the so-called computational basis states , such that,

Two classical states can coexist in one qubit. The outcome of a coin flip can be thought of as an example of a qubit. If we toss a coin (and assume it's fair), we've got an equal chance of getting a head or a tail with a probability of 0.5 for either outcome.

It is important to stress that is a superposition of two states, and the precise formula of (1.1) can be stated as follows:

**Second postulate (Evolution)**

How a quantum state changes over time is described by the second postulate. For those unfamiliar, the quantum gate is just a unitary operator used in quantum computing.

A unitary operator satisfies the following formula:

Moreover, the unit norm of the quantum state is conserved by a unitary transformation. The relation between and is shown as in Figure 1.1, where between is an input quantum state and is the output quantum state after performing the unitary transform U.

Logic gates in digital circuits function similarly to quantum gates in quantum circuits. The manipulation and alteration of qubits is their primary goal. Contrary to logic gates, quantum gates support the idea of reversibility, which allows us to easily convert an input quantum state into an output quantum state and vice versa.

We list some well-known quantum gates here that work with just one qubit,

**Hadamard-gate**

All quantum algorithms rely heavily on this operator during their startup phase. It is well known that when the Hadamard gate is dominated by classical states, uniform probability distributions of all computational basis states are generated.

**Third postulate (Measurement)**

It is important to note that a quantum state cannot be observed; the only way to ascertain its state is to carryout a measurement. Notice that the measurement of a quantum system can be characterized by measurement operators , where m represents a potential measurement outcome. If the system is in state , then the probability of measuring the potential state m may very well be expressed as:

where the adjoint of is denoted by and the adjoint of is denoted by . The measurement apparatus is viewed as a connection between the classical and quantum worlds; hence, in order to validate the precision of the constructed measurement apparatus, the following completeness relationship needs to be satisfied.

**Fourth postulate (Composite systems)**

The postulate describes a quantum register. The term "quantum register" refers to the component that is created when numerous quantum states are grouped together using a mathematical technique called the "tensor product." Take, for instance, the case where there are three qubits available. In order to combine these three qubits into a single quantum register, we will make use of the tensor product.

The first qubit can be represented in the following manner:

While the second and third qubits are respectively described as,

It is possible to achieve the composite of these three qubits in the following manner:

### Quantum Entanglement

Quantum entanglement was first discovered in the 1960s and was named after John von Neumann, who discovered quantum mechanics. Quantum entanglement is a logical connection between quantum states in such a way that they are spatially separated but communicating with each other; in other words, there is a certain hidden relationship between the quantum states.. For instance, if two quantum states are separated by a significant distance, the measurement of one quantum state enables instantaneous estimations of the other quantum state. The capacity of quantum entanglement to communicate at speeds greater than the speed of light is perhaps its most crucial function, as it will greatly accelerate the rate at which human society expands.

The most well-known piece of mathematical equipment that can generate entangled states is called a CNOT-gate. One of the inputs of the CNOT gate is used for controlling the device, and the other input is used for feeding it data. One will be used for the output control, while the other will be used for the output data. When we input 0 into the control terminal, the value at the data terminal does not change, which is a crucial point to keep in mind. If we enter 1 into the control terminal, then the value at the data terminal will be averted. For example, if our control terminal is set to 1, and the data terminal is receiving input 1, then the output of the data terminal will be 0.

It is worth noting that the most well-known entangled states are termed Bell states, and they are stated as follows:



Both the Hadamard Gate and the CNOT Gate can be used to produce them. The circuit that produces a Bell state is illustrated in the figure below.

**H**

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The circuit depicted in Figure 1.2 is responsible for the generation of four distinct entangled pairs of "Bell states." The following is a list of them in order of precedence:

### No-cloning Theorem

According to the no-cloning theorem, it is not possible to clone unknown quantum states in the universe of quantum mechanics. However, it is possible to clone either recognized quantum states as well as orthogonal quantum states. Due to the fact that identical backups of quantum states cannot be created in advance in quantum computing, the "no-cloning theorem" rules out the use of conventional error correcting techniques on quantum states. Let's offer an example. Consider for a moment that there are two possible quantum states: |0> and |1>. It is not difficult to check whether or not the inner product of these two states is equal to zero. As a result, the quantum states 0 and 1 are orthogonal to one another. We are consequently able to clone them. Because of the no-cloning theorem, it is impossible to fix errors in quantum states by using the more conventional methods that were previously utilized. There is no way to build backup copies on the quantum states in the middle of the computation and check for mistakes in those copies.

The no-cloning theorem can be useful in a variety of situations. For example, quantum key distribution (QKD) is a method of communicating between two parties that is safer and more secure because it does not rely on cloning power (the generated key cannot be cloned by eavesdroppers). PROOF??

### Quantum Teleportation

The power of quantum entanglement is utilized in the process of quantum teleportation in order to swiftly transport an object from one location to another. The theory of quantum teleportation has been proven, but there are still a lot of obstacles to overcome before it can be used in practice. It is an interesting fact to note that the capabilities afforded by quantum teleportation have been employed as the primary concept for quantum repeaters and communication channels. There are several stages involved in quantum teleportation: the first step is to break the object to be conveyed into smaller pieces (electrons and photons) that are subject to the rules of quantum physics, Second, a classical or quantum channel could be used to send the electrons and photons through, Third, transporting the object across the space and reconstructing it in a different location (another cabin).

Let's say that Alice and Bob want to transport just one qubit between their two locations. They have to carry out a sequence of procedures. The first thing that needs to be done is for Alice and Bob to split their bell pair . After that, Alice needs to do a variety of operations on her qubits (CNOT and Hadamard, etc.). At long last, she is obligated to carry out a measurement. After that, the result that was produced is then transmitted to Bob through the traditional channel. Last but not least, Bob can retrieve the initial qubit (the qubit that was transmitted by Alice) by making use of either the I gate, the ZX gate, the X gate, or the Z gate.

Diagram

Description automatically generated

### Quantum Parallelism

The concept of quantum parallelism is regarded as the fundamental building block of any quantum computation. It permits the execution of activities that have a significantly lower computational complexity than the one that has traditionally been used. Let's say that we have a function that has n inputs but only one output. With the traditional approach, we need 2n-1 steps to get back the output result, while the quantum parallelism strategy just needs one step from us O(1).

A unique quantum gate, known as an f controlled CNOT gate, is responsible for carrying out the quantum parallelism. This gate is formulated as follows:

The following describes the output function obtained by applying the f-controlled CNOT gate:

As can be seen, the evaluation of each and every x is performed in a single step by the function f. The most significant shortcoming is that we are unable to verify the values of any f(x) due to the fact that the measurement equipment returns just a single value. Applying an amplification amplitude so that the probability of the desired outcome reaches one is the approach that needs to be taken in order to solve this challenge.

### Grover’s Algorithm

The Grover algorithm was first developed as an algorithm that could locate a certain item in a database which hadn't been ordered. This quantum tactic has a complexity of , which measures how difficult it is to compute. where N represents the entire size of the database before it was sorted.

I will explain the actions that need to be taken in order to perform a Grover operator as follows:

* The first step involves the use of a Hadamard operator on the upper wire to begin the process of initializing two quantum registers.
* The second phase involves applying the Oracle operator that reduces the probability amplitude of the requested item by a factor of -1 while keeping the original value for the remaining amplitudes.
* The third stage consists of applying the inversion about the the average method in order to increase the likelihood of achieving the desired outcome to 1.
* The fourth step is to use the Grover operator in a recursive manner until the sought-after value or item is located. Below is a breakdown of the required number of optimal evaluations:

A picture containing rectangle

Description automatically generated

## MIMO System

There has been a significant leap forward in communication technology ever since Marconi conducted his first experiments in the late 1800s, a fascination in the opportunities presented by wireless communications. Since then, wireless technology has progressed. The connections that once could only send data at a sluggish and irregular rate have evolved into the high-capacity networks that we see in use today. Numerous fields of application can be found: voice services have become so widespread that they can frequently take the place of fixed line services; wireless local area networks are up and running in many residential, office, municipal, or school buildings; and personal area networks, such as Bluetooth links form wireless connections between various consumer electronics devices. In spite of this, there is a seemingly incessant drive to enhance the capabilities of wireless communications in terms of throughput and/or reliability. Furthermore, there are a wide variety of novel applications and environments for which wireless technology is envisioned. But, despite the continually increasing number of wireless applications, bandwidth is still a very scarce resource, just as it was back in the days of Marconi. The limitation in available bandwidth has driven the development of unique transmission strategies. Out of these novel transmission techniques, MIMO systems have gained a lot of research interest in recent years.

MIMO is an abbreviation that stands for "Multiple Input Multiple Output." This abbreviation describes a method of wireless communication known as MIMO, which makes use of multiple antennas at both the transmitter and the receiver to increase the system's overall performance. For cellular networks of the fourth generation (4G) and the fifth generation (5G), the Multiple Input Multiple Output (MIMO) system is a technique that can boost the throughput and reach the radio channel capacity.

The basic purpose of Multiple Input Multiple Output systems is to improve the quality of communication while simultaneously expanding the capacity of wireless communication channels. MIMO systems include several antennas at both ends of the communication link. The rank of a MIMO system is defined by the total number of antennas. Two broadcast antennas and two receiver antennas are used in a 2x2 MIMO system. Multiple-input multiple-output (MIMO) systems allow the transmitter to convey numerous data streams at once by making use of multiple antennas. The numerous antennas at the receiving end pick up this information since it has been mixed with other streams before transmission. The original data is separated into its component streams and recovered by the receiver using signal processing techniques.

Multipaths are a defining feature of wireless communication channel propagation; they are the result of the signal being reflected and diffracted several times by various barriers along the path. Multiple-input multiple-output (MIMO) technology takes advantage of this by employing a network of antennas to broadcast multiple copies of the transmitter's signal. Signals in metropolitan areas may take multiple routes to reach their target due to obstacles like trees and buildings that might reflect or diffuse the signal. The multipath happens when duplicates of the signal arrive at the receiver at various times. This multiple input multiple output (MIMO) systems are able to receive all of these signals, combine them, and then reconstruct the information that was first conveyed. Due to the fact that an increase in the channel capacity is possible with an increase in the number of transmitting and receiving antennas, MIMO systems have been an important area of research.

Diagram

Description automatically generated

Multiple-input multiple-output (MIMO) link, in which the transmitting base station directs three separate spatial beams at the receiver.

MIMO technology can make a big difference in the system's speed, coverage area, and quality of service (QoS). Using MIMO, the best way to send data depends on how the antenna arrays in the sender and receiver are set up. In general, optimizing is a hard and expensive job. So, scientists and engineers have come up with effective ways to optimize MIMO projects so that they can be useful and affordable. In the Cellular Mobile System (CMS), algorithms based on artificial intelligence are used to optimize the way data is sent .

Moreover, there are many optimization strategies (heuristic and metaheuristic algorithms) which conserve the power consumtion in MIMO Network :

* **Genetic algorithm (GA):** Genetic Algorithm is a classic metaheuristic search method that is used to solve optimization problems. It is based on Charles Darwin's ideas about how things change over time. This strategy can be used as a simulation on a computer, and the new solution can be used in the next iteration of the algorithm. Here It's important to remember that every time natural selection is done, it's done on random sets.
* **Ant Colony Optimization (ANO):** They were inspired by a small species of ant that looks for food by walking around and leaving a trail back to its nest. At first, they follow the path that other ants have made until they find food. If some ants find a good path, most of the others will probably follow in their footsteps. We can see that all of the other ants are following the most recent route. The main idea is to keep going down this path, which helps solve the real problem and makes food cheaper. The problem with the ANO is that it doesn't guarantee coverage and relies mostly on the decision chain, which is pretty much random.
* **Particle Swarm Algorithm:** The particle swarm algorithm is a swarm intelligence algorithm that was made by simulating how a flock of birds hunts prey. In the search for load balance, particles share information to improve the search direction of each particle, so that the best solution can be found quickly.

## Organization Of The Dissertation

# Organization of The Dissertation

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* Update cross-references: select all the text first (Ctrl+A) and then press F9 to let the Word to update all cross-references. A check for “Error!..” at the places of references should be carried out.
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References

1. Levendovszky, J., Jereb, L., Elek, Zs., Vesztergombi, Gy.: Adaptive statistical algorithms in network reliability analysis, Performance Evaluation - Elsevier, Vol. 48, 2002, pp. 225-236
2. National Istruments: LabVIEW grafikus fejlesztői környezet leírása, <http://www.ni.com/> (2010. nov.)
3. Fowler, M.: UML Distilled, 3rd edition, ISBN 0-321-19368-7, Addison-Wesley, 2004
4. Wikipedia: Evaluation strategy, <http://en.wikipedia.org/wiki/Evaluation_strategy> (revision 18:11, 31 July 2012)

Annex