The Quantum Way Of Cloud Computing

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Abstract—Quantum Computing and Cloud Computing are the technologies which have the capability to shape the future of computing. Quantum computing focuses on creating super-fast computers using the concepts of quantum physics whereas Cloud computing allows the computing power to be provided as a service. This paper presents a theoretical approach towards the possibility of a Quantum-Cloud i.e. quantum computing as a service. This will combine the fields of quantum computing and cloud computing, resulting into an evolutionary technology. Also, this paper discusses the possible advantages of this in the near future.

Keywords— Quantum Computing, Cloud Computing, Qubit, Quantum Cloud

I. INTRODUCTION

Have you ever wondered that Quantum physics, which once considered as one of the weirdest part of physics, could become a cutting edge of computing technology? This is evident from the fact that a new revolution in computing is possible which would exploit the peculiarities of quantum phenomena to provide cloud computing. This revolution may be termed as the Quantum-Cloud.

Quantum Computing is a new field of computing which has the capability to revolutionize the field of computing. The basic idea of Quantum Computing is to create computers which would be million times more powerful than today's super computers. As we go deep into the functioning of quantum computers, we would be surrounded by more and more laws of quantum physics, the implementation of which would seem more of a fiction than reality. It has been therefore rightly said by the famous physicist Niels Bohr that "anyone who is not shocked by the quantum theory, has not actually understood it" [1] [2].

But, with astonishing research being carried out in this field, these laws have become as simple as ordinary guidelines. This is the power of technology which does not let us settle for anything less than the desired.

With incredible research going in this field, a Canadian company D-Wave was the first one to develop a functional quantum computer. Moreover, the company sold its quantum computer named as D-Wave One to United States defense contractor Lockheed Martin for 10 million dollars, marking the start of the revolutionary next generation computers. Though the development of this technology is in its early stage, but it will surely be practical in a few years of time.

As stated above, the quantum computers would be quite expensive in nature and would not be possible to be available to each and every one. So, the question arises that how this amazing technology would be accessed by the common people? Or will their use be limited to just a few companies like today's supercomputers. The best possible answer to this question is to incorporate this technology into a yet another remarkable field of computing i.e. Cloud Computing. The basic idea of cloud computing is to migrate the processing power from customer's computer to remote internet servers. In the case of Quantum-Cloud, this processing power would be the quantum computer.

This dual technology can provide quantum computing as a service to the customers. Therefore, everyone would be able to access the power of quantum computing without actually having it.

Before going deep into this dual Technology, we will first discuss about cloud computing, the security issue in cloud computing, how the quantum computing-cloud computing duo will help in overcoming this issue and various other advantages which would be offered by the Quantum-Cloud technology.

II. QUBIT

Qubit (or quantum bit) is the fundamental unit of quantum information. In comparison to classical computers which work by manipulating binary digits or bits, a quantum computer works by manipulation of qubits. A bit can take one of the values 0 or 1. A qubit on the other hand can be 1, 0 or superposition of both 1 and 0. This superposition of states occurs due to the ambiguity inherent in quantum mechanics [3].

The qubit can be visualized as a unit vector pointing from the origin to a point on the surface of bounding sphere [4]. The North Pole and South Pole are equivalent to 1 and 0 respectively. Rest of the locations is a quantum superposition of 1 and 0. Figure1 depicts a qubit under superposition of states

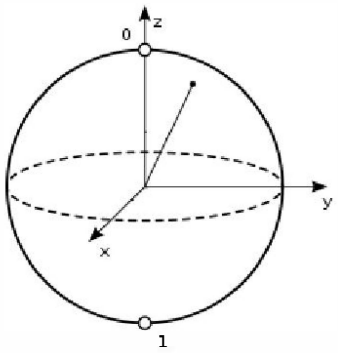

Figure 1. The Qubit

A quantum computer having more than one qubit exploits a

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concept of quantum mechanics called Quantum Entanglement. Albert Einstein had described entanglement as "spooky action occuring at a distance". It allows the state of a qubit to be linked to the state of some other, such that, setting the value of one qubit (with a 1 or a 0) will set the same value in the other.

Every time a qubit is added to the quantum computer, its computational power doubles. If a quantum computer is having 1000 qubits, it could test 2^{1000} combination of input at once. This is the incredible power of quantum computers which would shape the destiny of future technologies [5].

III. CLOUD COMPUTING

Cloud Computing is a field of computing wherein the computing power is provided as a utility [6]. This paves way for a shift in computing i.e. rather than computing being a product that is purchased; it would be delivered to the consumers over the internet from far off large scale data centers. The important point is that the customers will avail all these features without actually knowing how the cloud works. These data centers in which the data is actually stored and processed can be termed as the "clouds". This is how cloud computing gets its name [7]. The implementation of this technology allows the cost of computation, application hosting and data storage to be reduced significantly.

There are three service models in cloud computing. These are Software as a Service (Saas), Platform as a Service (Paas) and Infrastructure as a Service (Iaas).

In SaaS type of cloud computing, web applications are delivered through the browser to thousands of customers. In PaaS type of cloud computing, the development environment is delivered as a service. In IaaS type of cloud computing, the infrastructure such as storage is provided as a service to the customers through the internet.

Also, cloud computing contains four deployment models. These include public cloud, private cloud, hybrid cloud and community cloud. In a public cloud, the cloud service is provided to the public . In a private cloud, the cloud service is made available to a particular organization or a certain group of people. It cannot be used by the general public. The hybrid cloud combines multiple clouds (public, private or community). Here, the individual clouds retain their uniqueness, but are bounded together as a unit. In a community cloud, the cloud service is organized to serve a common function of one or more organizations [8]. With such applications of cloud computing, it can also be described as "sky computing", having numerous isolated clouds.

As the field of cloud computing grows even more, it faces a serious problem arising due to the very core of its success. This is the issue of security. Until this issue is completely eradicated, cloud computing would not be fully secure [9]. But, the question is how to secure the cloud using the current techniques in order to generate the trust of the organizations and the people towards the technology of cloud computing. The answer to this question lies in yet another field of computing which is about to make its journey from laboratories to practicality. This is the next generation technology of quantum computing. To remove the security problem, quantum computing may play an important role due to its inherent characteristics.

IV. THE CASE OF QUANTUM INTEGRATED CLOUD

The quantum cloud duo will be a technology of its own kind. It would add yet another functionality of "quantum computing as a service" to the field of cloud computing. It would offer so much technological advancement in the field of computing that today's computers will look like a thing of the past. This technological duo would provide many advantages in the near future. It would possess the key advantages of next generation of powerful quantum computing as well as the significant properties of cloud computing such as cost reduction, resource pooling, cloud storage cloud processing, easier maintenance, improved accessibility, flexibility and mobility. This technology would bring about unimaginable change in the technology around us which would be accessible through numerous touch points.

The most important advantage would be the eradication of security issue from cloud computing. This security would arise from the application of an inherent feature quantum computing called as Quantum Cryptography. Quantum Cryptography is a technology which aims at providing information security by applying the phenomena of quantum physics. The security of information is based on the inviolability of the laws of quantum mechanics.

Quantum computers would protect the data stored in the cloud using very strong encryption techniques which will take a hacker's computer millions of years to break [10]. This would help in building trust among the consumers towards the cloud technology.

Also, the quantum cloud duo would provide enormous processing power in the hands of the consumers. This means that consumers will access the super-fast technology of quantum computing from anywhere using the internet. Such a technology would pave way for next generation of computing which would make computing more portable and may lead to a tremendous growth in the field of smart phones. This is due to the fact that the application support infrastructure would be

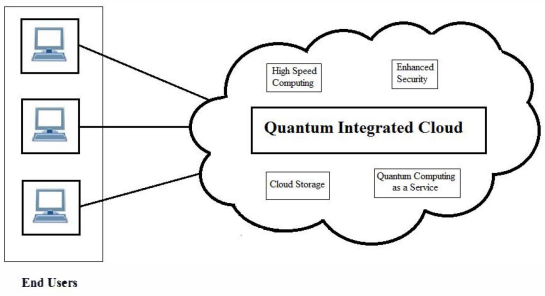

Figure 1. Quantum Integrated Cloud Technology

hosted on a highly advanced and shared cloud platform in accordance with the today's trend, but with more speed than ever before, paving way for high quality applications. It would also result in thinner and more powerful mobile devices.
Moreover, the aspect of quantum computing in cloud computing will provide a base for super-fast database operations in the

cloud. This feature of quantum technology was presented by Lov Grover. In 1996, Lov Grover devised a quantum algorithm to search an analogous quantum database having N terms in O(√ N) steps. In classical computation, this would require N/2 steps to find the required entry. It means that, for a database of 10,000 names, Grover's algorithm would require the use of √ 10,000 = 100 steps, rather than 5000. The algorithm operates by first creating a superposition of all the 10,000 entries where each entry has the same possibility of appearing in response to the measurement made on the system. By using Grover's algorithm, a quantum computer could reduce the search time from thousands of years to minutes [11] [12]. So, it would be extremely useful for providing fast database operations in the cloud storage. This would serve as a yet another advantage for this dual technology.

Moreover, such an extraordinary technology shall enable the organizations, whether large scale or small scale, to accept and implement the cloud technology. It would pave a way for wave of worldwide trust towards cloud computing and thus explore the world of computing in a new way. So, it cannot be neglected that the future of computing lies in the cloud and quantum computing. However, the integration of these technologies with each other will pave way for yet another revolutionary technology which would change the course of computing towards a new direction.

V. AN EXAMPLE OF QUANTUM-CLOUD PARTNERSHIP

A similar approach as visioned through quantum-cloud partnership would be demonstrated by a group of eminent scientists of Bristol University, United Kingdom. On 27 September 2013, the university would attach their quantum computer to the web to allow anyone to access and experiment the power of a quantum computing. This initiative has been named as Qcloud. The Qcloud quantum computer has been housed at the Centre for Quantum Photonics in the Bristol University. The idea is to demonstrate a practical aspect of quantum computing as a service, and let people understand the meaning of quantum computing. This quantum processor would be remotely accessed and controlled by anyone in the world. It would allow people to run an experiment, and test the real experimental data against their simulations. However, due to lack of quantum technology, the quantum computer used is of just two quantum bits or qubits [13] [14]. So, it would not be able to deliver all the peculiarities of quantum computing. But, this initiative would surely pave way for the proposed quantum way of cloud computing.

This shows a practical example of application of the quantum computing-cloud computing duo in recent time. However, such an application can be expanded to a much greater level resulting in the proposed quantum cloud functionality.

VI. FUTURE

With the expanding development of quantum computers in various laboratories across the world in the near future, the security of the cloud based on today's computing processes would become vulnerable to attacks by any quantum computer. The basis to this statement lies in the fact that the enormous power of quantum computers allows it to break today's strongest encryption methods. This has been proved using the Shor's quantum algorithm for factoring large numbers. This problem can be solved by implementation of quantum security which prevents any quantum system to access quantum information without it being disturbed. However, appropriate steps would be required to be carried out for it to be implemented in the quantum-cloud computing technology.

However, quantum computing is at the initial stage of development. Most of the quantum computing technology is limited to the research centers wherein scientists are applying their knowledge of quantum physics into developing revolutionary quantum computers. Though the intermixing of the quantum and cloud technologies may take time, but these two will surely work together in the quantum-cloud set up to form a powerful technology and put forward enormous advanced applications of the computing technology which today seem to be as fiction.

VII CONCLUSION

Through this paper, a new approach to cloud computing integrated with quantum computing has been proposed. This approach provides basis for yet another functionality of "quantum computing as a service" to the field of cloud computing. The prosed technological duo would provide many advantages in the near future. The most important advantage would be the eradication of security issue from cloud computing. Also, it would provide enormous processing power in the hands of the people. Moreover, such a technology would pave way for next generation of computing which would make computing more portable and may lead to a tremendous growth in the field of smart phones.

The pioneering work being carried out today is paving its way towards the era of Quantum-Cloud. In the near future, we may be using incredible technology which would tremendously affect our way of living. We can expect marvelous gadgets which could have never been thought of. Moreover, there would many new ways by which we will interact with technology and all these will be based on the concepts which today we term as fiction.

So, in the near future, this dual technology of quantum and cloud computing would be required to deliver its technological peculiarities and shape the field of future computing. The initial step has been taken and the goal has been set. Only the middle steps need to covered and these steps will result in the change we want

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