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ANALYSIS

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QUANTUM COMPUTING FOR BIG DATA ANALYSIS

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Abstract - Today the computing world is facing the problem of data storage and massively parallel processing because data on internet is getting bigger and bigger. We are living in a data world, While uploading image on Facebook, sending email through Gmail or writing messages on Twitter and many more , we are doing nothing other than playing with data. The data which is beyond storage capacity and processing capabilities of classical computer is called Big Data and getting some insight from large amount of data is very big challenge. So Big data analytics is very very important for business intelligence, looking for patterns, drawing inferences and making predictions. There are so many big data analytic tools available in the market, but there is still some problem at higher rank which could not be resolved in optimal time even by most advanced classical computers. To provide enormous processing capabilities to modern regular computer has given birth to the concept of quantum computing. The computer processing power depends on number of transistors used and according to Moore's law today this power doubles every two years. As of 2014 the commercially available processor processing highest number of transistors 15 core Xeon IvyBridge - EX with 4.2 billion transistors and in the case of graphic processors nvidia TESLA in which no of transistors exceeds 7 billion but high performance computing demands still more. Quantum computing is a whole new way of building computer using quantum mechanics. As we know that quantum mechanics is the physics of very very small. There is a world in an atom. The laws of physics that applies on microscopic world at the level of individual atoms, individual electrons, elementary particles where physics is qualitatively different from classical physics. By applying laws of quantum mechanics to computation has exponentially speeded up the processing capabilities over classical computing. Quantum computing is another set of tool for computer scientists, researchers, programmers to develop and enhance computation capabilities much better than we are able to do with classical computing. With each new discovery we are confronted with new questions and challenges. In this research paper we are going to discuss some potential benefits of quantum computing while dealing with big data and some issues in quantum computing environment.

Key Words **-** Atom, Big Data, Business Intelligence, Classical Computers, Moore's law, Quantum Mechanics, Quantum Computing.

1. INTRODUCTION

67 years ago when the first transistor was developed no one could have predict the role the computer will play in our society today through Internet. The web is not an overnight success. It had travelled journey of approx. 24 Years. In this short span of time it touches all most all aspect of life. We cannot imagine banking system, Railway reservation system, Airline data, Business data etc. without centralized data store on web. Due to rapid use of internet through social media, email services, web based communications tools, web conferencing etc. has rapidly increased the data size over web. The data which is beyond storage capacity and processing capabilities of classical computer is called Big Data and getting some insight from large amount of data is very big challenge. IT companies like Facebook, Google, Amazon, Salesforce etc. are managing their data at big rapid elastic data centres. These organizations also provide on demand various services like storage (SaaS), platform (PaaS), Applications (AaaS) etc. on rental basis called cloud computing. Cloud infrastructure is very good for small scale organizations and they are moving towards cloud vendors. Due to vast increase

of data on cloud, IT industries are facing a very big challenge of Big data analytics. Big data analytics is getting insight from vast set of data, getting business intelligence, looking for patterns, inferences and drawing some predictions. There are so many big data analytic tools available in the market, but there is still some problem at higher rank which could not be resolved in optimal time even by most advanced classical computers. For big data analytics we require system with tremendous processing capabilities. As we know that processing speed of a conventional computer depends on number of transistors we are using. By increasing transistors we can increase the processing capability or we can use HDFS and MapReduce for faster processing of data. When we are talking about high performance computing the term Quantum Computing has made a dramatic change in our mind set and provide processing capabilities to computation in order of 2^n for n qubit input. The promise of quantum computers is what computations conventional computers take hours to complete, the quantum computers can execute it in seconds.

Big Data: The data which is beyond storage capacity and processing capabilities of classical computer is called Big Data.

Data generating Sources: Social network data, Sensor network, internet search, genomics, astronomy, Airlines data etc.

Types of Data:

Structured Data: data that has pre-set format, Address book, product catalogues, banking transitions.

Unstructured data: Data that has no pre-set format. Movies, audios, text files, web pages, computer programs, social media.

Semi – structured data: Unstructured data that can be put into structure by available format descriptions.

Reasons of Big Data:

- **I.** Low cost storage to store data that was discarded earlier.
- **II.** Powerful multicore processors.
- **III.** Low latency possible by distributed computing: Computer cluster and grids connected via high speed network.
- **IV.** Virtualization: Partition, Aggregate, Isolate resources of any size and dynamically change it.
- **V.** Affordable storage and computing with minimal man power via clouds.
- **VI.** Better understanding of task distribution (map Reduce), computing architecture (Hadoop).
- **VII.** Advance analytical techniques (Machine learning).
- **VIII.** Managed big data platforms: Cloud service providers.
- **IX.** Open source software's: open stack,PostGresSQL.
- **X.** March 12, 2012 Obama announced $200 M for big data research to NSF, NIH, DOE, DoD, DARPA and USGS (geological survey).

Quantum Computing: Quantum computer is computer that uses laws of quantum mechanics to performing computations. It can solve faster than modern fastest computer. It promises more powerful processing capability than any conventional computer could ever be.

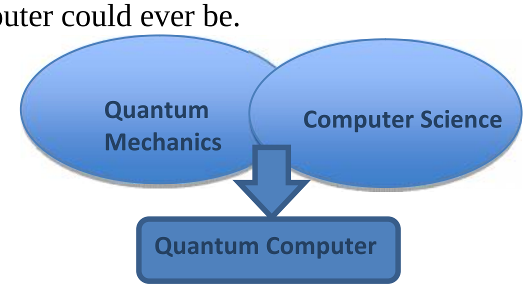

Fig. 1 Relationship of Quantum Computer with various fields

Qubit (Quantum Bit): In Quantum computer we use qubit (bit equivalent as in conventional computer) for storing data.

Generation of Qubit: Small particle like electrons, photons have spins and that spin can be measured by magnetic field. If we bring electron in a magnetic field, then it has spin in different directions and all at a same time, called quantum superposition. If we have n bits then due to superposition of them we will get 2^n Qubits.

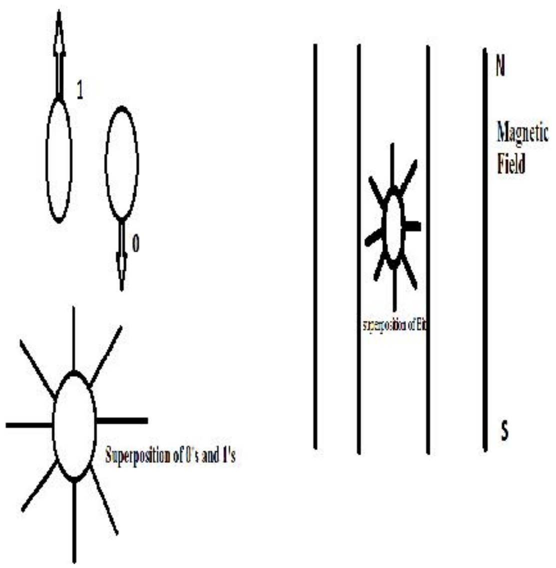

Fig. 1.1 Generation of qubit

A qubit is the analog of a bit for quantum computation. This means that the qubit can be represented as a linear combination of |0> and |1>:

$|\varphi\rangle = a|0\rangle + b|1\rangle$

Where **a** and **b** are probability amplitudes and are complex numbers. When we measure this qubit, the probability of outcome |0> is $|a|^2$ and the probability of outcome |1> is $|b|^2$. Because the absolute squares of the amplitudes equate to probabilities, it follows that a and b must be constrained by the equation

$$|a|^2+|b|^2=1.$$

That is we must measure either one state or the other.

Bloch Sphere: The qubit $|\varphi\rangle = a|0\rangle + b|1\rangle$ can be represented as a point (θ, φ) on a unit sphere called the Bloch sphere. Define the angles θ and ϕ by letting $a = \cos(\theta/2)$ and $b = e^{i\phi}\sin(\theta/2)$. Here, a is taken to be real, which can always be made real by multiplying $|\psi\rangle$ by an overall phase factor (that is unobservable). Then $|\psi\rangle$ is represented by the unit vector $(\cos\phi\sin\theta, \sin\phi\sin\theta, \cos\theta)$ called the Bloch vector.

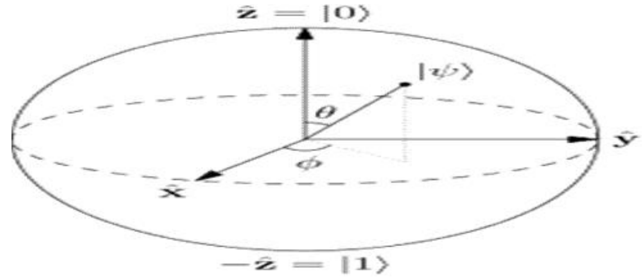

Fig. 1.2 Bloch sphere
(Image Source: http://en.wikipedia.org/)

Quantum Entanglement: Two objects if they quantum mechanically entangled then they are strongly related to each other even though they are vast distance apart. It means that superposition of bits and all at a same time. The electrons within an atom exist in quantized energy levels. Qualitatively these electronic orbits (or “orbitals” as we like to call them) can be thought of as resonating standing waves, in close analogy to the vibrating waves one observes on a tightly held piece of string. Two such individual levels can be isolated to configure the basis states for a qubit.

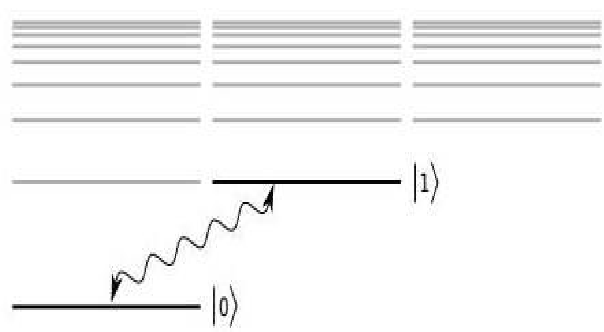

Fig. 1.3 Energy level diagram of an atom. Ground state and first excited state correspond to qubit levels |0> and |1>

Types of Quantum Computer:

I. Silicon quantum Computer- Using electron spin as a quantum bit or qubit.

Fig. 1.4 Silicon Quantum Computers

II. Optical quantum computer – It uses photon of light as a qubit.

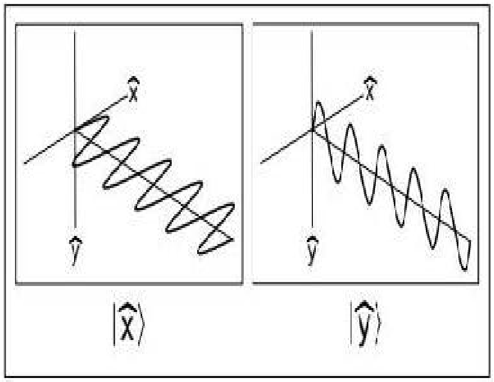

Fig. 1.5 using polarization state of light as qubit. Horizontal polarization corresponds to qubit state |x>, While vertical state corresponds to qubit state |y>.

The polarization of a photon can be measured by using a polaroid film or a calcite crystal. A suitably oriented polaroid sheet transmits x-polarized photons and absorbs y-polarized photons. Therefore a photon that is in a superposition $|\varphi\rangle = a|0\rangle + b|1\rangle$ is transmitted with probability $|a|^2$ If the photon now encounters another polaroid sheet with the same orientation, then it is transmitted with probability 1.

III. Secure Quantum Computer – Quantum Computer for secure communication.

Fig. 1.6 Secure Quantum Computer

IV. Gate model quantum computing – replicates digital gates which are the building blocks of today's computer and build quantum equivalence for those gates. Largest gate model quantum computing afford that is being done today factoring the no 21, 7 and 3 as we all know it is very small scale kind of experiment.

Ion trap quantum computing: It takes Ion as qubit. Wolfgang Paul got Nobel Prize Physics for his work in Ion trap quantum computing. Ions, or charged atomic particles, can be confined and suspended in free space using electromagnetic fields. Qubits are stored in stable electronic states of each ion, and quantum information can be processed and transferred through the collective quantized motion of the ions in the trap (interacting through the Coulomb force). Lasers are applied to induce coupling between the qubit states (for single qubit operations) or coupling between the internal qubit states and the external motional states (for entanglement between qubits).

V. D WAVE Quantum Computer: Joint project of Google and NASA.

Fig. 1.7 D WAVE Quantum Computer

On May 11, 2011, D-Wave Systems announced the D-Wave One, an integrated quantum computer system running on a 128-qubit processor. The processor used in the D-Wave One code-named "Rainier", performs a single mathematical operation, discrete optimization. Rainier uses quantum annealing to solve optimization problems. The D-Wave One is the world's first commercially available quantum computer system. The price will be approximately US$10,000,000.

2. Objectives of the Study:

The major objectives of our study are

I. To build ultra-fast quantum computation.
II. And ultra-secure quantum communication.

III. Applying quantum computing for business intelligence.

IV. To figure out scope of Quantum computing in various fields.

V. To figure out Quantum computing challenges.

3. Literature Review:

Need of Quantum computing and its potential benefits over conventional computer were studied by several authors (e.g. Kanamori [1], Devitt [2], Prantosh [3]). Chen and Chaiang (2012) have discussed in detail the process of business intelligence and how big data analytics is helpful for business decision making. Devitt and Munro (2011) have implemented a model of high performance quantum computer. Prantosh (2011) has discussed future of Quantum Science and its scope in various fields. Aaronson has discussed in his draft the limitations of quantum computation while implementing it in practical environment. He puts emphasis on why absolute zero temperature is required for quantum computer for measuring momentum of an atom. In the article D WAVE quantum computer tells about benefits and issues related with D WAVE quantum computer. It tells that how D WAVES can be utilized while solving travelling salesmen problem and other complex problems of decision making.

4. Research Findings:

In this qualitative research we are trying to figure out some potential benefits and challenges of Quantum computing. We are trying to make a new type of computer where the bits are not just normal transistor switching on or off but they are more complicated quantum mechanical system that can be on or off or both at the same time; that's what quantum mechanics allows us to do quantum superposition. Conventional computers are built with silicon chip having more than billions of transistors etched on them. With more transistors, computers are getting faster and faster. The quantum concept of qubit has changed the entire concept of computation. Conventional Computer uses 8 bit just to store single number between 0 and 256 where as in a quantum computer 8 qubits can store 256 numbers at once which dramatically speeds up the computation power. Let us consider all possible combinations of a 2 bit data system with 4 possible states 00, 01, 10 and 11. A 2 bit classic computer can at the most simultaneously perform one of these 4 possible functions. In order to check all of them the computer would have to repeat each operation separately whereas a 2 bit quantum computer due to phenomenon of superposition is able to analyse all of these possibilities simultaneously in one operation .This is due to the fact that 2 qubits contain information about 4 states whereas 2 bit contains information about one state:

2 Qubit	2 Bit
00	00
01	?
10	?
11	?

Thus a machine with n qubits can be in superposition of 2^n states at the same time. A 4 qubit computer could analyse 16 parallel states in a single operation; in comparison a 4 bit classical computer can only analyse one state. To achieve the same solution as the Quantum computer classic computer has to repeat this operation 16 times.

10 Qubits – Can store 1024 numbers.

11 Qubits –Can store 2048 numbers.

100 Qubits–Can store 1,267,650,600,228,229,401,496703205,376 numbers.

We can say Quantum computer can tackle problem on scale beyond any conventional computer. In this way we find that quantum computation can be utilized in a vast scale for analysing the problem of rapidly growing data on web called big data. It can be utilized by predicting weather in advance, forecasting natural disasters like tsunami, earthquake, for business intelligence and many more. Enemy of quantum computing is environment about near absolute zero, very clean environment. One of biggest problems faced by scientists working in quantum computing is the issue of de coherence (isolate system from outside environment), Optimization problem (choosing the shortest path) and quantum tunnelling (probability of disappearance of electron on other side).

5. Conclusion: In this research paper we had seen several benefits of quantum computing and their implementation challenges. The emphasis of today's computing is to design and manufacture such a computer which has enormous processing capabilities for analysing rapidly growing big data on web. Use of quantum computing enables us to predict statistical inferences, business decision making, and weather forecasting, pattern matching, web data mining and many more. Although the quantum computation is in initial stage but future of computing and big data analytics depends more on quantum computers. The use of quantum computing is very green in nature. It can save enormous heat consumption in data centres and reduce the power consumption from MW to KW. The Quantum computers that exists today let's say NASA's D WAVE quantum are domain specific and used for some complex applications and Universal Quantum Computer is still a dream for us. Centre of Quantum Computation and Communication technology, Australia is leading a global race to develop a quantum computer and quantum secure communications network and having visions to develop universal quantum computer. If we are able to build a universal quantum computer then high performance computation is not an issue for us. It is possible that a 500 qubit computer could one day analyse more data than there are atoms in the observable universe.

REFERENCES:

[1] Kanamori Y, Yoo SM, Pan WD, Sheldon FT (2006). A short survey on quantum computer, *International Journal of Computers and Applications*, Vol. 28, No. 3.

[2] Devitt JS , Munro JW , Nemoto Kae (2011). High performance quantum computing, *Special issue : Quantum information technology* , No. 8, pp.49-55.

[3] PK Prantosh. Quantum Information Science: Emerging basic science focused information science domain, *Abhinav : national monthly refereed journal of research in science and technology*, Vol 2 , No. 9, ISSN 2277-1174.

[4] Aaronson S (March 2008). The limits of quantum computer (Draft), *Issue of scientific American*.

[5] The D Wave quantum computer: http://www.dwavesys.com/sites/default/files /D-Wave-Overview-102013F-CA.pdf

[6] Chen H, Chaiang RHL, Storey VC (2012), Business intelligence and analytics : From big data to big impact, *MIS Quarterly, Special issue : Business intelligence research* , Vol. 36 No. 4.

[7] Big Data Fundamentals: http://www.cse.wustl.edu/~jain/cse570-13

[8] Quantum Artificial intelligence lab at NASA: www.nas.nasa.gov/quantum

[9] Image source (1.4, 1.6, and 1.7): http://www.cqc2t.org/

[10] Qubits and quantum measurements: http://www.inst.eecs.berkeley.edu/