2010 Second International Conference on Communication Software and Networks

LIMITATION OF SILICON BASED COMPUTATION AND FUTURE PROSPECTS

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***Abstract* ----- Conventional silicon based computing technology has reached to its upper physical limits of Design complexity, processing power, memory, energy consumption, density and heat dissipation. Therefore, there is need of searching for new alternative computing Medias, which can overcome all these conventional computation problems. The structure and type of these new alternative computing paradigms is a major challenge.**

Keywords: silicon based computing; Design complexity; energy consumption; heat dissipation; DNA computer; Molecular computation; Quantum Computer

I. INTRODUCTION

Moore's Law describes a long-term trend in the history of computing hardware, in which the number of transistors that can be placed inexpensively on an integrated circuit has doubled approximately every two years [1].

Conventional computer technology is based on silicon chips. Although silicon based computers have renovated the whole world from the start of computer age (1957 to till now). Since its invention, the whole advancement in silicon-based technology is according to the Moore’s Law and is achieved by doubling the processing speed and memory capacity at a very high rate. These tasks of high speed and memory capacity have achieved by reducing the size of components on chip and placing large number of transistors on IC chips. On the other hand, due to this continually doubling the numbers of transistors on these chips, also reducing the size of these chips and increasing density will cause some serious physical problems in stable computing, in the next few years. Moreover, this technology is going towards its decay.

Recurrently scientists observed that common silicon-based machinery has reached its higher confines while talking about speed, they have been working to develop alternative Medias which can solve conventional computational problems [2].

II. PHYSICAL LIMITATIONS OF SILICON-BASED COMPUTERS

Life of Silicon-based computational has going towards its end due to some of the following limitations:-

A. Speed and density

We know the phrase ‘processing power of a computer’ refers how fast a computer can execute an instruction that is given to a computer [3]. All conventional computers achieved high speed by reducing the distance between different IC chip components and shrinking the size of processing chip and transistors on it, so that instruction take less time to move from one component to another during execution. For this, designers have to package more and more transistors (closely with each other) on IC chip and making chip denser and denser. For example today on a frequently used Pentium IV processor chip, 55 million transistors are pack in the space of size of a ten cent coin or a diameter of 0.705 inches [4].

B. Design Complexity

As mentioned above, due to shrinking of IC chip size with doubling the transistors on it, chip manufacturing becomes more complex and if this trend of shrinking and doubling continues, design complexity of chip would get tremendous increase, it will not be feasible for designers to develop new Chips in the near future.

If chip size trimness continues at the similar pace, up till 2015 the chip size will reach to 10nm and number of transistors on that minute chip would reach 2018 [5], which is impossible? Further extension of Moore’s Law will face new more complex-design challenges.

C. Non- Recurring and High Cost

Investment over every new IC chip design will increase. As every new chip is more complex from the preceding one, therefore reducing size will not only add complexity to the

978-0-7695-3961-4/10 $26.00 © 2010 IEEE
DOI 10.1109/ICCSN.2010.81

design but it will also increase the overall cost per design from one chip to another.

D. Power Consumption and Heat Dissipation

Power consumption and heat dissipation is large obstacle for further advancement in silicon-based chips. Over the past few years Power density has the grown with the rate of rate $S^{0.7}$ for every generation [6]. This power consumption also inverts the rare positive effects of advancement in the number of transistors on silicon chip.

This large amount of power consumption boosts up the heat generation, increasing danger that transistors interfere with each other. As transistors are becoming small size and so small transistors consume small amount of power (voltage) but IC chip become denser and denser because of large number of transistors on it, therefore it uses large amount of power to driven all transistors and therefore generate more heat.

In November, 1971, Intel publicly introduced the world's first single chip microprocessor, the Intel 4004 with 2,300 Transistors at 10 µm, used tenths of watt while one of modern processor a 3.2 GHz Pentium IV extra edition consumes 135 watts [7]. Now in last few years increment in the number of transistors as 167 Million in dual core 2.8GHz Pentium D increased the power consumption to 244 watts.

Heat dissipation, Power consumption are major limitation with which traditional silicon-based computer are suffering. Therefore, there is need of searching for new alternative Medias, which can solve all computational problems cited before. Researchers have proposed a number of alternative technologies to silicon based computing. These computers are still in experimental stages and may take decade or more before they become commercially available.

III. FUTURE PROSPECTS

New proposed computation technologies include Biological (DNA), Optical, Molecular, and Quantum computing techniques. These new computational technologies can overcome limitations of conventional silicon-based chip computers. Some of these new alternatives of traditional computer are:

A. Optical Computer

These computers can overcome the speed barrier of the conventional silicon-based computation. Light pulses are used in optical computers as the replacement of conventional computer's electric signals. These light pulses will carry information from traditional silicon-based computers [4].

Processing speed of these new computers is equal to the speed of light (299 792 458 m/s) because of the light signals used in this technology for information processing. Like traditional computers, these computers also use binary values of '0' or '1' to represent information but at much faster speed. A table-top optical computer can process multiple operations at the same time with fast speed which is 100,000 times faster than a traditional conventional computer [8].

However, optical computers may require one or two decade to bring for commercial use in markets.

B. Quantum Computers

One another possibility to resolve the silicon chip limitations is usage of Quantum computing [Frank 2003]. Quantum computers are actually extensions of traditional classical computers.

However in quantum computing, the traditional transistors technology is replaced by usage of atoms, photons and molecules. Silicon-based computers used transistors to built logic gates but quantum computers use special quantum bits called qubits. Moreover, a group of qubits is called qubit register. Traditional computer bit have only two states either '0'or '1' but on the other hand a quantum computer can carry multiple values at the same time. In it qubit can be either '0' or '1' and some times both '0','1' at the same time and it is known as superposition of states.

Quantum computation can be implemented for simplifying variety of problems, such as Search, Cryptography number theory. Nevertheless, quantum computers cannot solve many other problems such as sorting [9], while practical implementation of these computers is also a big challenge

C. Molecular Computer

Molecular computing is massively parallel computing, by taking advantage of the computational power of molecules, usually biological molecules. It is another way to surmount certain limitations of traditional silicon-based computing. We can remove size problem of traditional computers by making the processors as small as a molecules. This technique makes circuits thousand times smaller than traditional silicon based computers.

The core gain of molecular computing is its potential to gathering vastly more circuitry onto a microchip than silicon based computing will ever be capable and in addition it will be done cost-effectively [10].

Molecular technology is based on forming circuits that are created by carbon monoxide molecular nano tubes embedded on a copper surface [4].This computer will reduce the size of processor to 10 nanometers. It means a small circuit can contain 10^{12} or more than trillion elements on the surface of per square centimeter. This would allow, for example, a computing system that contains approximately 10 billion switches to be made-up on the top of a particle of salt [11]. Molecular computers use binary values ('0' or '1') to process information like conventional computers.

D. DNA Computer

DNA has the two properties that are required to do computing: a way how to store information and a mean of manipulation information so in short any system having these two obligatory things can setup to do that computation. [Lloyd Smith 2000].

Cells (living parts) of organisms are ingredients for computation. These provide the basic idea of computing, as these tiny parts are complete machines and perform all the processing for the organisms activities. It can overcome on two major limitations of silicon-based traditional computers: storage capacity and processing speed. In this technique, enzymes and amino acids of DNA are use to solve particular problem.

In this approach of computing some specific Information is encoded on DNA and is then used to perform bio-molecular processes to attain intended computing [12]. DNA computing uses technique of parallel computing to speed up processing.

There are large amount of molecules and DNA present in small living organisms. It is quite obvious by modern research that a minute quantity of water can enclose 10^{22} molecules. That small molecule has extremely large memory capacity and can store such massive information that is hardly stored in one trillion Compact disks [13].

DNA computing can also solve energy dissipation problem of current technology. It consumes low energy and has proper heat swap over process. DNA computers have capability to perform 2 x 10^{19} group operations for each joule at the same time a traditional super computer can execute utmost 10^{9} operations for every joule [14].

IV. CONCLUSION

It has confirmed that silicon-based chip has now going toward its collapse and in the coming one-decade or two, this technology will reach a state where there is no further advancement in it is possible. This will definitively cause the death of computing if no alternatives of silicon-based computing are find. These alternatives should have the capacity to overcome all limitations of current technique. These alternatives are DNA, Molecular, Optical, and Quantum computing. All these new technologies are under processing and may available for commercial use in the coming one or two decade

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