ENERGY EFFICIENT GRID-COMPUTING USING SMARTPHONES

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Abstract - Smartphones are in general always connected to internet. A smart phone is idle at least 8 hours in a day on an average. A smartphone consumes less than 3-watt power when active. A novel idea of forming a grid with smartphones in their idle time is described.

Keywords - Supercomputers, parallel computing, grid-computing, energy efficient, smartphones.

I. INTRODUCTION

Integrated circuits were developed in the 1960s. They reduced the cost, size and power consumption of computers considerably. CDC 6600, built in 1964 by Control Data Corporation (CDC), Minneapolis, USA, is considered to be the first supercomputer in the history of supercomputing. In their design, instead of germanium based chips, Control Data Corporation switched to silicon based chips built by Fairchild Semiconductor. It consisted of 400000 transistors and more than 100 miles of wiring (done by hand). It had the fastest clock speed for its day (100 nanoseconds) and it outperformed all computers of its time. Control Data Corporation sold more than 100 units of these each at 6 to 10 million US dollars. The machine used a FORTRAN compiler and had a computing power of 500 kiloFLOPS reaching up to 3 megaFLOPS [1-4].

With the development of faster integrated circuits and VLSI, in 1970s and 1980s, fourth generation computers started to appear in market. Personal computers became a reality and were affordable while supercomputers increased their computing powers by many folds. In 1990s supercomputers crossed the limit of gigaFLOPS and it was possible to achieve up to teraflop computing power with ASCI Red[5-7].

Present day supercomputers can have thousands of processors and are capable of running around a hundred million billion floating-point operations per second.

II. ENERGY CONSUMPTION AND HEAT MANAGEMENT CHALLENGES

Supercomputers consume a lot of power. For example, the fastest supercomputer till today, Sunway TaihuLight[8], consumes 15 MW power as per Linpack[9] benchmark. The energy efficiency of these computers is measured in general in FLOPS per Watt and it lies in the range of several hundred MFLOPS/W to up to about 2100 MFLOPS/W for some greener machines [10-14]. Heat dissipation requires special attention in the designing of a supercomputer and hence designs for future supercomputers are somewhat power-limited.

III. USE AND COST OF SUPERCOMPUTERS

Supercomputers are mainly used by government, large organization, research facilities and academicians. Meteorological studies, Monte Carlo analyses, studying molecular dynamics, data mining are some of the areas that require supercomputers. A supercomputer capable of full weather modeling to cover a two-week time span would require a computing power of zettaFLOPS (10^{21} FLOPS) – about thousand times faster than the most powerful supercomputer of present time [15].

The supercomputing power does not come free of cost. They are very expensive. For example, Sunway TaihuLight, the fastest supercomputer to date, costs 273 million US dollars [8]. For their high cost (one need to keep in mind the operating cost in addition to the cost of the machine), it is not possible for individuals or small organisations to own a supercomputer. Most top ranked supercomputers are owned by government and large organisations in developed countries. Many developing countries do not own any supercomputer because they cannot afford it.

IV. GRID COMPUTING

Grid can be defined as a distributed system where the computers in the grid can share their resources. Although the term “Grid” was used much later, in late 1990’s[16], the idea of distributed computer network existed since 1960’s when J.C.R. Licklider, while working on ARPaNet in 1969, used the phrase "intergalactic computer network" [17]. Around the same time, it was visioned as a utility that would serve homes like electricity or telephones [18]. With the emergence of www, the potential for remote computing could be realised. Several projects viz. Charlotte [19], ParaWeb [20], Popcorn [21], and SuperWeb 74 [22], were initiated to make use of the distributed network of computers. Some of the very famous projects running at present are SETI@home (with over 5 million nodes, to look for extra-terrestrial intelligence) [23], Rosetta@home (with over 1.6 million nodes, for protein structure prediction) [24], Collatz Conjecture [25], GIMPS (Great Internet Mersenne Prime Search) [26]. Some of these projects are run by some organisations in their own network of distributed computers while many projects use the distributed network of computers from volunteers all over the world.

V. EMERGENCE OF SMART PHONES

Smart phones appeared in the market in mid 2000s and soon became very popular because of their cheap price and ability to perform numerous tasks. There are about 2 billion smartphone users all over the world at this moment. In addition, there are more than 2 billion tablet users and several 10s of millions of smartwatches, game consoles (ps, wii, xbox etc.) users. All these devices have processors with decent computing power. The smartphones are supposed to be always online. Other devices are online if there are suitable networks available. A smartphone should be idle at least 8 hours per day on an average (while the user is asleep). Other smart devices are also not active all the time and in general one can say most of the time these devices remain idle and their computing power is wasted. A grid can be built with these device utilising their unused computing power. Before we discuss the architecture of such grids, let us have a look at the computing power of some common devices.

VI. COMPARISON OF COMPUTING POWER

Apple iPhone 6 uses a 172 GFLOPS GPU whereas iPhone 7 is using an A10 processor with over 720 GFLOPS processing power. The processing power is more than that of the supercomputers in early 90's. The Samsung S6 uses an octa-core processor with more than 34 GFLOPS processing power. The newer generation Exynos Mali T880 GPU can reach around 260 GFLOPs whereas the Adreno GPU can output over 500 GFLOPS. These GPUs run on small 7-15 W-hr batteries and GFLOP per watt is very high compared to any supercomputer (over 100 GFLOPS per watt, compared to around 13 GFLOPS per wat for present day supercomputers). If one takes into consideration the number of transistors present in a processor, the A8 ARM processor has 2.00 billion transistors whereas the 8-core Core i7 Haswell-E has 2.60 billion transistors and the Apple A10 fusion processor has 3.30 billion transistors. Figure 1 shows the comparison among some well-known processors. Figures are not drawn to scale. GPU FLOPS are used for video game consoles since their performance relies more on GPU than CPU.

Table 1 shows a comparison of energy consumption of Sunway TaihuLight, the fastest supercomputer till today with an equivalent grid comprising of desktops and smartphones. Sunway TaihuLight has an average speed of 93 petaFLOPS whereas core i7 6700 processor has a speed of roughly 44 gegaFLOPS and Apple A10 fusion processor has a speed of over 720 gegaFLOPS. In the comparison, for the desktop PCs, only the power consumption of the processors is considered whereas for the smartphones, the power consumption of the phone as a whole (i.e. the CPU, GPU,

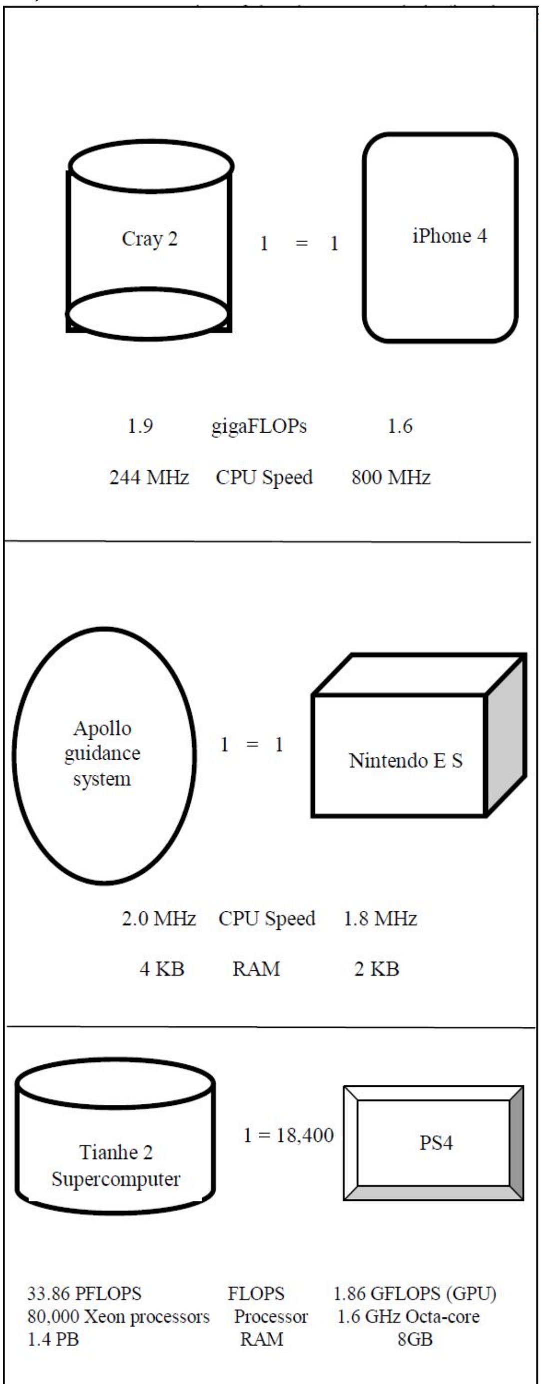

Fig 1: Comparison of computing power of some well-known devices.

screen and other hardware, power consumed for the GPRS and WiFi) is considered as it is practically impossible to form a grid with only the processors. Also, for smartphone based grid, the computing power of only the CPU is considered. The computing power of the GPU is ignored.

Table 1: Comparison of energy consumption of a traditional supercomputer with equivalent grids made with desktop PS's and smartphones.

	Sunway TaihuLight	Equivalent grid with core i7 6700 Desktop PCs	Equivalent grid with Apple iPhone 7 with A10 processor
Number of nodes	1	2.11 million	1,30,000
Total Power consumption	15.4 MW	137 MW	400 kW

In Table 2 we compare the cost of energy to crack a 64-bit encryption using brute force. A standard computer will need to check 2^{64} keys $=185 \times 10^{17}$ keys. We assumed, for simplicity, an optimistic case where one key can be checked in each floating-point operation. For practical purpose, we compared the performance of Sunway TaihuLight with the performance of a grid composed of 1000 desktop PCs with i7 6700 processor and a grid composed of 1000 iPhone 7. We assumed that the cost of electricity is $0.10 per kWhr.

Table 2: Comparison of cost of electrical energy to crack a 64-bit encryption using Sunway TaihuLight and grids composed of desktop PCs and smartphones.

	Sunway TaihuLight	Equivalent grid with 1000 core i7 6700 pc	Equivalent grid with 1000 iPhone 7
Required time	195 s	117 hrs	7.5 hrs
Cost of electricity	$83000	$7,40,000	$4

Even if we consider Landauer's principle[27], we know that the amount of energy required to erase 1 bit of information is $k_B T \ln(2)$ where k_B is the Boltzmann constant (approximately 1.38×10^{-23} J/K) and T is the temperature of the circuit in Kelvin. For smartphones, T is in general under 40^0C (313 K) and for desktops and supuercomputers above 60^0C (more often > 70^0C), making them more energy efficient.

VII. ARCHITECTURE

The schematic diagram of the architecture of the proposed grid using smartphones is shown in Figure 2. A server will distribute and manage the load wirelessly to the nodes in the grid. When a task is done, the phone/watch/tablet/node reports it to the server and the load is reassigned/redistributed.

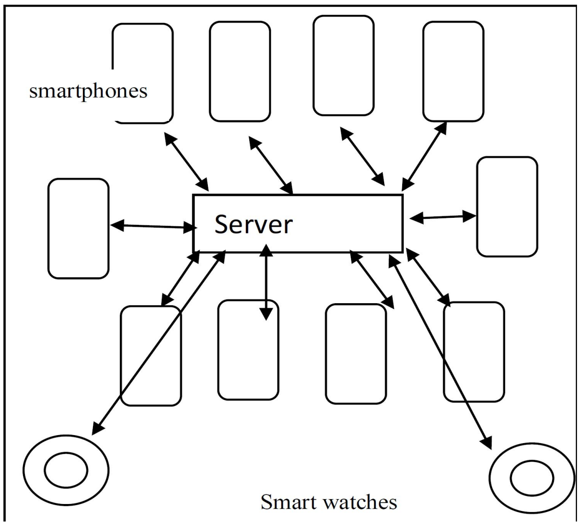

Fig 2: Schematic diagram of the proposed Smartphone based grid

VII. CHALLENGES

Like other grid computing scenarios, the major cost will be the cost of software. Although modern day processors have more than one core, not all operating systems are optimized to make use of multicore operation of a processor (for which reason single core performance for a smartphone processor is often more stressed upon). Cost of mobile data may also be another challenge.

CONCLUSION

In the present paper, when quoting the computing power of a smartphone, we used the CUP performance only and did not include the GPU power mostly because most OS are not optimised for massive parallel computing power offered by GPUs. If computing power of GPU is included, the performance of smatphone based grid will increase even further. The proposed smartphone based grid can be much energy efficient compared to supercomputers or traditional grids and can be seen as a greener approach in grid computing. Almost all the electrical energy used by a computer is converted to heat energy and hence heat management can be a crucial issue for any supercomputer. The proposed smartphone based grid is free from such problem. For developing countries or small organizations like universities, research labs etc., this approach can open up new scope.

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