CMPSCI 677 Operating Systems **Spring 2013**

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21.1 Green Computing

- Greening of Computing: Greening of Computing deals with Sustainable IT . It talks about developing energy efficient hardware/software systems.

- Computing for Greening: Physical Infrastructures like Homes , offices and building make use of lot of energy. Computing for Greening comes up with ways to make this energy usage more efficient.

21.2 Greening of Computing

In the past decade , a lot of research has been carried out aiming at providing better battery life to the mobile devices like PDAs , mobile phones and Laptops . However with the advent of data centers , Greening of Computing also deals with energy efficient designs for servers and to lower costs and carbon emissions produced by Data centers. A recent survey shows that quite a lot of power used in office buildings and colleges are spent on Computing.

21.2.1 Data Centers

A Data Center is a facility housing a large number of servers and data storage. The author shows statistics which show that the electricity bill for a data center is close to 6 million a month with about 20 percent of the power spent on cooling the data centers. A pie chart depicting the average costs has been provided. It shows that the average amount of money spent on buying the servers amortized over a period of three years is almost equal to the cost of powering the servers . These facts show that it is necessary to effectively utilize the electricity used by the Data centers

21.2.2 Power Usage Effectiveness

Power Usage Effectiveness = Total Facility Power/IT Equipment Power

The PUE is a ratio of the input power to the actual amount of power required by the servers at a Data Center . If the amount of power required to cool the system is 100 percent , then the PUE grows to 2 which is undesirable

21.3 Low PUE Design

21.3.1 Better Power Infrastructure

If there are multiple data centers in different locations then one way of making using of power infrastructure is to shift the load to the data center that has a low-price period. The power generally undergoes a conversion from AC-DC a number of times before it reaches the server , by reducing the number of conversion the conversion loss can be avoided . Multi phase power (use of a 3 phase AC) can help provide efficient power usage.

21.3.2 Better air conditioning

Cold air is allowed to pass through the servers . On passing through the servers the cold air turns hot and this is cooled and then reused. Balancing load across the data center helps eliminating hot spots Another means of cooling is to use the outside air to cool the machines . Iceland being a cold country and being a good source of Geothermal energy hosts a few data centers. Microsoft conducted an experiment by placing the servers outside and using the outside air to cool the systems . The servers worked fine even with temperatures in the late 90s.However the faced issues with filtering the outside air which contained leaves and other dust particles

21.3.3 Better server and IT equipment

A survey shows that the servers consume 65% of the power. A server is not to be energy proportional if the power usage scales linearly with the workload intensity . However in practice , the servers are not energy proportional and consume close to half the power even when they are in the idle state . This is attributed to various components like Disk , RAM , motehrboard and network card which consume power even in the idle state. In practice it is observed that the servers are around 10-30% utilized all the time.

The amount of work done by the server for each joule of energy used is defined as the efficiency . The servers are not efficient either. This is due to the unused CPU features like the Large caches , complex architecture. If the CPU is not the bottleneck for the application then the use of a CPU with limited features can solve the problem and also make the server more efficient.

The server is most efficient when its utilization is 100% . The efficiency of a server is also linked with the software flexibility. By using Virtualization,the CPU/memory usage can be controlled. Migrating virtual machines to a subset of the physical machines and switching the other machines off also helps in efficient usage.

21.3.4 Common Approachs

One common approach is to make the Ensembles energy proportional . This is achieved by distributing the workload and with the decrease in utilization the components are turned off and the wordload is migrated to active components . If there is an increase in the utilization the components are turned on and the load is migrated to the newly active components. However , this method does have problems. Moving the workload might take a long time and turning on/off of the components takes a long time. It also does not work if hte workload intensity changes faster than the data transfer and if the workload is not distributed.

Some of the other IT components like the switches and the routers are much inefficient when compared to the servers. They are at 100% Utilization all the time. Turning off RAM memory banks is rarely done . Mechanical disks are not energy proportional. Flash disk use no energy but they are expensive

21.3.5 Renewables

The Main reasons behind using renewables is due to the Bad press for using many fossil fuels, electricity costs and also to reduce carbon emissions. However with renewables the wordload and the available power are now changing and there is a need to match supply and demand since storage of power brings in additional overhead.

21.4 Computing for Greening

Information technology can be used to make the building more green using sensors , smart softwares , smart appliances and smart meters

21.4.1 Smart Buildings

In order to make the building smart , there is a need to monitor the energy usage . The user must be able to control electrivity usage by automatically turning devices on and off. The environment must be monitored . Computing for Greening comes up with means to satisfy these needs cheaply and reliably.

The *Building Management Systems* are existing systems that monitor the energy usage . However they are not fine-grained and do not provide pervasive load control mechanisms

21.4.2 Monitoring Energy Usage

Energy usage can be monitored at multiple levels of the wiring tree right from the electricity ingress level to the outlet level. But transfering the data in real time is an issue. This transfer can be done using Wireless networking techniques like Zigbee and Wifi or using powerline networking techniques like X10 , Insteon and HomePlug

It is a Challenging task to place sensors at every load since its expensive , it may not look good and its unreliable due to the bandwidth constraints .

Some Alternatives include collecting high bandwidth data at the ingress , disaggregating data into seperate loads by using well placed sensors.

21.4.3 Controlling Energy Usage

Programming load control switches are needed to control the energy usage . Generally the control involves switching a device on/off . The switching mechanism may be external or internal.An example of a wifi enabled washer and dryer has been provided. The control is provided by means of a mobile application.

21.4.4 Environment Monitoring

It has similar issues as energy monitoring . It include monitoring weather , thermostats , doors and tracking motion.

Energy usage can be implemented using recommendations via smart phones , enabling remote but manual control , automated scheduling policies . The main aim of the computing for greening is to optimize for lower costs , lower energy usage , lower peaks and aligning consumption with renewable generation.