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Integrated approach for efficient mobile application development using Cloud Computing and Green SDLC: A Study

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Abstract: The power of cloud computing by virtualization makes it possible to have energy efficient, cost effective and resource optimization modalities. For optimal use of resources, data centre, hardware, application platform and application, there is a need to pay much more attention on aspects like energy consumption at various stages of mobile application development. Approaches in SDLC stages related to energy issue are recognized and make helpful to develop more friendly platforms for the software applications in general and mobile application in particular by exploiting cloud deployment framework and its versatility. Green computing can be achieved by either product longitivity resource allocation, virtualization or optimum power management. This study concentrates on various approaches which are there in literature formulate a base towards new developmental framework for mobile application using cloud computing and Green SDLC. The study puts more consensuses on various aspects to make broader prospects to achieve greener software products that are able to sustain the environment and also future generation and to design a way that will lead transmission of green software products through mobile devices is energy efficient.

INTRODUCTION

IT technologies are becoming increasingly common because the internet usage increasing day by day and the cost of computer hardware is decreasing. It becomes necessary to explore a new paradigm for the energy efficient computing called Green Computing [5].The most important part of cloud is internet. As the internet has penetrated into our daily lives cloud computing has emerged as a new kind of "utility" that gets delivered through wired or wireless networks. If you have access to internet you can access your service from anywhere. It makes you to view and use your services even after moving physically. It reduces the cost and energy consumption. Green and cloud computing, these two concepts are the back bone of this study as these help to design an application architecture that is most energy efficient in a cloud setup.

Overindulgent energy consumption causes over emission of green house gas, which according to experts consensus, is a root cause for the current global warming. It is therefore, vital for mankind to seek green technologies i.e., technologies that can reduce energy consumption.

The main purpose of the green computing is to investigate new computer systems, computing model and applications with the low cost and low power consumption and promote the sustainable development of economy and society. The amount of energy consumption and carbon dioxide emission in one Google search is presented below in fig1: [4].

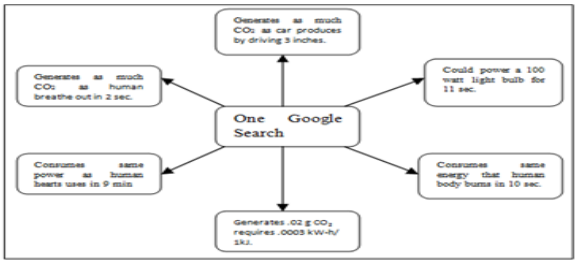

Fig 1: **Energy consumption in one Google Search[4].**

Green cloud computing is defined as the practice of designing, manufacturing, using and disposing of computer servers and associated sub-systems such as monitors, printers , storage devices and networking and communications system efficiently and effectively with minimal or no impact on the environment. The goal of Green computing is to reduce the use of hazardous materials, maximizes energy efficiency during the products lifetime and promote the recyclability of outdated product and factory waste. In fig 2; Software and cloud structure are two main parts; where the software part and cloud service includes system software and application software. Developers should design energy efficient operating system and application. The cloud structure service provider data centers need many types of processing cpu's, hardware, storage and network devices to run a cloud setup.

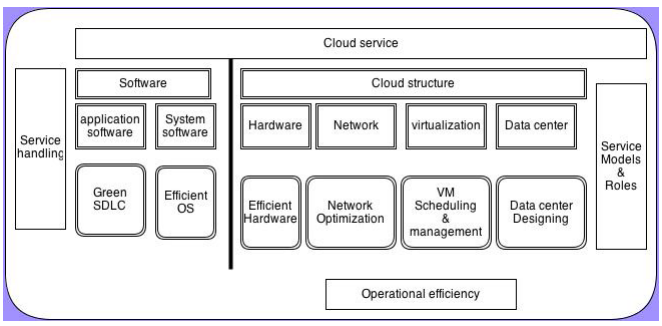

Fig:2Energy Efficient Cloud Structure[13]

Mobile cloud computing is a computing of mobile application through cloud with the growing demand of smart phone the demand for fast computation is also growing. Mobile cloud computation addresses the intensive processing and storage demand of real- time and high end applications. Mobile cloud computing (MCC) refers to an infrastructure where both data storage and the data processing happen outside of the mobile device. Mobile cloud applications move the computing power and the data storage away from mobile phones into the cloud. Mobile

cloud computing (MCC) has three components Mobile device, Wireless communication channel and cloud. Mobile devices have resource constraint in terms of battery power, memory, processing power and have multivariate hardware, operating system and input output interface. In this study we highlighted that the energy related issues should be discussed and considered as early as possible in the development of an application makes the application more energy efficient and expenses regarding energy consumption can be minimized. We need to explore more opportunities to reduce carbon footprints in the cloud environment; evaluating the cloud's ability to save energy through both technology and process related changes. The typical SDLC has a vital role to play in building efficient software applications in a systematic way.

RELATED RESEARCH

As previously researchers tell that by using virtualization CC (cloud computing) is itself energy efficient technology. The key driver technology in clouds for energy efficiency is the "Virtualization" [1]. In past A.J. Younge and his colleagues proposed a green cloud framework a few years ago, but it covered only virtualization and data center operations [2]. Here in this paper the proposed structure covers green computing in an application development perspective, which can improve energy efficiency in cloud environments significantly in the very early stages of development process. 40% of people in IT departments believe energy efficiency and equipment recycling are important factors to consider and about 65% believe that reduction of energy related operating costs is the driving factor for implementing green IT.To reduce the power consumption on cloud the CPU power should be reduced. One approach for developing energy efficient servers is innovative inter connect technology. One such interconnect technology is Three dimensional stacking technology [5]. Li et al [3]has proposed an optimized cost model for calculating total utilization cost of cloud. Many ideas have been proposed in literature to reduce power consumption. Due to high number of internet users storage requirement of cloud is raising, face book alone needs peta byte (PB) storage these days. Power is required for this storage, for networking peripherals, for data processing software and hardware and for data transmission [4].

There are five phases in software development life cycle (Requirements, Design, Implementation, Testing, and Maintenance). However, from Green perspective, several important steps need to be added into the process of life cycle. In the Requirement phase, sustainability should be added as one of the nonfunctional requirements(Chauhan & Saxena, 2013; Afzal et al., 2013)[6]. Besides, Design phase should include energy consumption issue,such as to reduce highly dependent modules which could result in high energy consumption (Chauhan & Saxena, 2013)[8]. Moreover, due to increasing popularity of smart gadgets (with limited battery power), GUI design should optimize user interfaces in order to save energy (Vallerio et al., 2006). Data structure and algorithms design should also prevent redundancy and uncontrolled dataflow (Potlapally et al., 2003)[10]. In Implementation phase, Kocak (2013) [7]suggested that efficient code can reduce cost overheads and energy depletion. Afzal et al. (2013) [6]recommended that programming language used can affect energy consumption, which particular of the languages will effectively practice multithreading and garbage collection methods in CPU and memory. Hence, this issue should be thought wisely. On the other hand, testing procedure should be well- organized, which includes scope, objectives, approach, number of people and amount of equipment assigned for the planning of energy consumption testing. Lastly, Chauhan and Saxena (2013)[8] suggested that software maintenance unit and users should keep an eye on carbon footprint of the software patches and fixes from time to time. Shenoy and Eeratta (2011) [9]proposed a model which to improve effectiveness of the phases of software development lifecycle by giving recommendations about green activities and practices that can be implemented in the lifecycle. Moreover, in the model proposed by Shenoy and Eeratta (2011)[9], environment-friendly infrastructure such as meeting rooms, hardware, power equipment etc., is crucial in developing software. Besides, a number of quality processes and standards which targeted to achieve sustainability need to be focused in the software development lifecyle. According to Chauhan and Saxena (2013)[8], and Penzenstadler and Femmer (2013)[11], concept of GSD life cycle should be propagated in the early stage to create environmental awareness.

ENERGY SAVING TECHNIQUES:

The following techniques to minimize the power consumption of cloud.

A. Resource Virtualization, Enabling Energy

Virtualization is a foundational technology for deploying cloud-based infrastructure that allows a single physical server to run multiple operating system images concurrently. As an enabler of consolidation, server virtualization reduces the total physical server footprint, which has inherent green benefits [15].

B. Resource Efficiencies

From a resource-efficiency perspective, less equipment is needed to run workloads, which proactively reduces data center space and the eventual e-waste footprint. From an energy efficiency perspective, with less physical equipment plugged in, a data center will consume less electricity [15].

C. Automation Software, Maximizing Consolidation

The presence of virtualization alone doesn't maximize energy and resource efficiencies. To rapidly provision, move, and scale workloads, cloud-based infrastructure relies on automation software. Combined with the right skills and operational and architectural standards, automation allows IT professionals to make the most of their cloud-based infrastructure investment by pushing the limits of traditional consolidation and utilization ratios [15].

D. Pay-Per-Use and Self-Service, Encouraging More Efficient Behavior and Life-Cycle Management

The pay-as-you-go nature of cloud-based infrastructure encourages users to only consume what they need and nothing more. Combined with self-service, life-cycle management will improve, since users can consume infrastructure resources only when they need it and "turn off" these resources with set expiration times. In concert, the pay-per-use and self-service capabilities of cloud-based infrastructure drive energy and resource efficiencies

simultaneously, since users only consume the computing resources they need when they need it[15].

E. Multitenancy, Delivering Efficiencies Of Scale To Benefit Many Organizations Or Business Units

Multitenancy allows many different organizations (public cloud) or many different business units within the same organization (private cloud) to benefit from a common cloud-based infrastructure. By combining demand patterns across many organizations and business units, the peaks and troughs of compute requirements flatten out. Combined with automation, the ratio between peak and average loads becomes smaller, which in turn reduces the need for extra infrastructure. The result: massive efficiencies and economies of scale in energy use and infrastructure resources. If cloud providers are truly going to position their services as green, they must invest in renewable energy sources. The reality is that even the most energy-efficient data center can have a significant carbon footprint because they are typically getting 70 percent of their electricity from greenhouse-gas-emitting fossil fuels, like coal. Ideally, centralized cloud data centers would be powered by renewable sources of energy, like wind, solar, or hydroelectricity. To date, however, cloud providers have prioritized other factors in designing and locating their data centers, including the cost of land, cost of power, property taxes, data privacy regulations, and access to power, bandwidth, local skills, and customers[15].

F. By Reducing CPU Power Dissipation Processor consumes electrical energy in form of charging (direct supply) for its operation, for the switching devices contained in it, for cooling of transistors and numerous chips. It dissipates this energy in surroundings. Processor dissipates heats but the processors of different mobile devices, embedded system consume less power than the processor of palmtop, net book, notebook, desktop, laptop, so they dissipates less energy in surrounding. By adapting free cooling this power dissipation can be reduced [14].

G. By Using Advance Clock Gating

Clock gater is a hardware switch that is responsible for activating and deactivating the clock. The clock of a logic block must be activated only when the logic block is doing some work and clock must be turned off when logic block is not performing any task. This technique is very popular and it has been used in many synchronous circuits but it can also be used in globally asynchronous locally synchronous circuits for reducing dynamic power dissipation [14].

H. By Using Split Plane Power

Splitting means division but in processor terminology splitting means division across horizontal axis. Here processor will not share power plane with North Bridge (These are the microchips developed by Intel that makes communication [14].

EFFICIENCY MODEL

When it comes to deploying cloud for business software there are a numerous factors which come to consideration. Also these factors are interdependent and have a cumulative effect on the energy use. Here the cycle shows the nodes at which the energy is wasted at independent companies who are not using cloud[12].

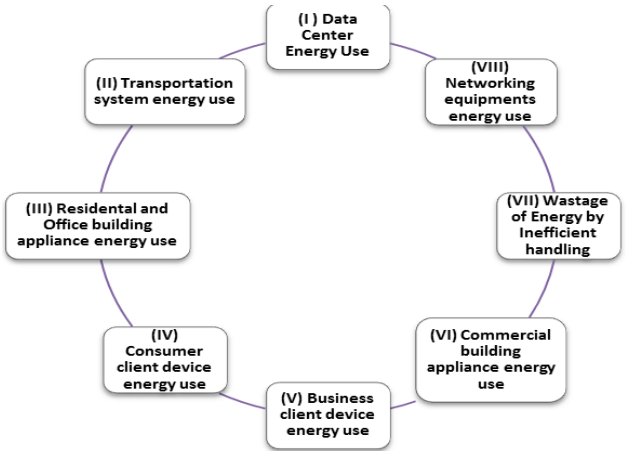

Figure 3: Cloud Efficiency Model[12]

In this model all the factors are interdependent. These are explained as follows:

1)Data Center Energy Use: When companies use their dedicated data centers they need to have a lot of resources which primarily involves:

a) Air Conditioning unit.
b) Dedicated Hardware.
c) Resource Person
d) Power Backup
e) Security

2)These all resources are used by all individual data centers in all corporations. This leads to energy wastage. Where as when the cloud is implemented there is only one server at one data center which is maintained by the datacenter and this server is used by many corporations which leads to a lot of energy saving as there is only nodes at the client side.

3)Transportation System Energy Use: This involves the data transfer from client system to main server and back to the client. Moreover if data transfer needs to take place between the nodes itself, there is separate data transfer Whereas in case of cloud there is direct transfer from client to server thus saving energy that was wasted in transport.

4)Residential and Office Building appliance energy use: The individual electrical appliances further used leads to wastage of energy which is all together no use of any extra appliances on the client side.

5)Consumer Client device Energy Use: This is related to the fact that if data transfer needs to be done from client to any other device the entire data is transferred. Whereas in cloud the data can be easily accessed thorough any device.

6)Business Client Device Energy Use: In corporations there is a lot of redundancy of data which leads to memory and energy wastage. The cloud architecture takes care of it and energy efficiency is maintained.

7)Commercial Building & Appliance Energy use: The large cooling systems that are used for maintaining the server is not needed in cloud systems thus leading to energy efficiency as only small node computers are required to access the data.

8)Network Equipment Energy Use: There is a lot of networking components involved when there is a network of computers in a building. As we see in Fig 3, we find that all these resources are interdependent on each other. Thus a network equipment is dependent on all other factors as well such as commercial building appliance energy use and also to the wastage of energy due to inefficient

handling. Instead if we go for internet connection and cloud architecture the energy can be saved.
9)Energy wastage by inefficient handling: The cost involved in maintaining the servers and also the inefficient use of resources by individuals. This could be reduced by cloud architecture as all the maintenance is done by datacenters with efficient resources.

CLOUD SERVICE MODELS

Mobile devices are connected to the mobile networks via base stations that establish and control the connections and functional interfaces between the network and mobile devices. The requests made by mobile clients are transmitted to central processing unit connected to server providing mobile network server. The subscriber's requests are delivered to a cloud through the internet. In the cloud, cloud controllers process the requests to provide mobile users with the corresponding cloud services. Mobile cloud computing is computing of mobile application through cloud. With the growing demand of Smartphone the demand for fast computation is also growing. Mobile cloud computation is an answer to intensive processing and storage demand of real time and high end application. Mobile cloud computing has 3 components: mobile devices, wireless communication channel and cloud. Mobile devices have resource constraint in terms of battery power, memory, processing power and have different types of hardware, operating system and input output interface. Wireless communication channel has different radio access technologies such as GPRS, 3G, WLAN and Wimax with variable network conditions in terms of limited and unstable bandwidth. In cloud computing there are 3 service models:

a) Software as a Service(SaaS): In SaaS users access the cloud application through interface like web browser as per requirement and play for use. In SaaS it's the responsibility of cloud provider to maintain the hardware, operating system and application maintenance. Cloud provider provides the security to client as per service level agreement. Multiple clients can access the application at the same time with their respective subscription. Example of SaaS are Salesforce, Customer Relationship Services, Google Apps, Gmail andGoogleDocs.

b) Platform as a Service(PaaS): PaaS provide o/s and other tools for software development and allow client to deploy its application or the cloud client need not maintain the cloud infrastructure like storage , servers, operating system, programming tool kit, network and software license. Client only maintain its software or application and its environment configuration deployed on cloud. Examples of PaaS are Microsoft Windows Azure, Google App Engine and Amazon web servers.

c) Infrastructure as a service(IaaS): In IaaS client has direct access to cpu processing , servers, network and storage device. Client can install and use operating system, software's of their choice on their virtual machines accessed through IP address. Cloud provider maintains the underlying infrastructure and provides virtualized Ip address to the clients for direct access to hardware resources. Example of IaaS are Amazon EC2, IBM computing on demand, GoGrind and Rack space cloud.

Table 1 Summary of Cloud Services[16]

	Software as a Service	Storage as a Service	Processing as a Service
Location of Processing	Cloud	Client	Short tasks at client, large tasks in cloud
Location of Storage	Cloud	Cloud	Client
Function of Transport	Transmit commands and receive results	All files/documents	Files for large tasks

GREEN SDLC:

In general green software is defined as software which offers direct and indirect positive effects to economy, society and environment. Green software is that kind of software which focuses more in environmental requirements. Software development is about concerning of theories, practices, methods and tools that are essential to develop and maintain the software products. G-SDLC(Green software development life cycle) is an organized process that is being used by many organization for the development of software applications. Energy efficient SDLC for mobile cloud applications can be described in two concepts Green computing and cloud computing.
To make software development life cycle energy efficient SDLC is divided into different phases [17]:

1. Green software requirement specification: For greener approach into the software requirements means that there is an addition of sustainability into the specification of software in order to check is there any need of additional software requirement e.g., some additional security and communication requirements in cloud environment? Is there any need to measure the energy consumption of the application in a cloud.
2. Green Software design: Most of the developers while designing software focuses on modules, abstraction levels, data structures, software architectures but a good design should also include energy efficiency e.g., if the modules are dependent there will be consumed more energy because of overhead of communication, unnecessary loops, controls, switch statements in algorithms require additional computation and results in extra energy consumed. In cloud scenario encryption is a key functionality for security related challenges and generally Advanced Encryption Standard(AES) encryption algorithm consumes less energy than Data Encryption Standard(DES).
3. Green Software Implementation: An efficient code in the cloud scenario reduces both costs and energy consumption. More use of existing programming techniques those can help to reduce an application CPU consumption, the number of parameters should be controlled to enhance the energy consumption in a network during information transmission.
4. Green Software Testing: The testing term should create and execute well defined test cases related to energy consumption. They should also find out the number of people and amount of equipment allocated for testing to measure energy use.
5. Green Software Maintenance: It depends on model which is being used in cloud service. An efficient model will keep equipment operating at optimal efficiency. This model should perform regular maintenance tasks that will keep data transmission at optimal efficiency.

CONCLUSION

In this paper we carry out the discussion to prove that mobile cloud computing can save energy as well as time to Smartphone by offloading its tasks to the cloud using high speed stable internet connections. We also conclude that in mobile cloud computing framework energy and time is directly proportional to the speed of the internet connection and its stability. The mobile device itself consumes the main memory, processor as well as the energy of the Smartphone; computational offloading is a better alternative to it. Mobile cloud computing and Green computing is combined and a green cloud structure has been proposed. The introduction of concepts of energy efficiency early in the SDLC ensures it will be propagate through SDLC phases in order to reduce energy related expenses for later. Future work of the research needs to make computation, networks, storage, energy efficient as much as possible. Energy efficiency currently has a low priority but with the increase in adaptation of cloud requires that cloud should be green as well. Green cloud Computing is the future technology that supports environment, reuse consumed power and energy, and optimize the resources efficiently. Green computing focuses on reduction of CO2 emission in environment and thus makes IT industry environment friendly. As we are moving towards cloud and using its application in every field such as disaster management, service provisioning, online data storage, data retrieval from any place at any time etc we must ensure it to be environment friendly otherwise the day will not be far when pros of cloud becomes cons for environment.

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