Energy Aware Mobile Cloud Computing

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Abstract—In today's modern world, mobile cloud computing (MCC) is a hot topic, because mobile has become an essential part of our lives. It has become a primary computing platform to many users, they want to perform every task on their mobile devices which they perform on desktop computers. The reason for this is that mobile computing is able to provide a tool to the user when and where it is needed regardless of user movement. It enables the user to perform tasks which require high performance computation, but these tasks consume a high amount of mobile battery. Latency issue and energy consumption are the major issues of mobile clients in cloud computing. This paper presents the challenges of MCC but the main focus of this paper is energy consumption in mobile devices. Then, this paper reviews the different techniques, their weaknesses and strengths. Finally, the paper discusses about the future of MCC and the need for future research.

Keywords - Mobile cloud computing; energy saving; latency issue; energy consumption.

I. INTRODUCTION

Advancement of the modern world has made mobile phones an important part of our life as it provides the simplest way of communication irrespective of place and time [13]. The typical characteristics of cloud computing are no up-front cost, cheap cost operating systems, highly scalable and easy to access but still there are many difficulties involved when applying cloud computing to mobile environment such as security, privacy, energy efficiency, mobility, availability of service but limited power supply is the biggest constraint [12]. Execution of many applications which are too computation intensive is not easy on a mobile system. Computation of these applications can only be performed in the cloud [11]. Offloading is a technique used in mobile cloud computing which helps to prevent battery drainage in mobile devices which are faced with problems of memory space, battery and computation power. The method of Offloading (in which procedures execute in mobile devices to the adjacent servers is done by the system) should be completedonly when the cost of communication of mobile device with the cloud is less than the cost of computation in mobile device. Offloading allows some of the tasks to be executed in the cloud. Mobile development and cloud computing are combined together to build mobile applications which can be hosted on cloud. MCC has explosive growth, but still deals with some problems that bound its performance in some areas. MCC architecture contains three technologies i.e. mobile internet, mobile computing and cloud computing, these technologies allow mobile users to offload data storage and computation into the cloud through wireless networks and mobile devices [10]. Thus, the main concept of MCC is power management of mobile devices. In this paper some of the challenges faced by mobile cloud computing and methods to solve them are discussed.

II. CHALLENGES OF MCC

Mobile cloud computing is a method for applications which can be hosted in the cloud. MCC is a combination of cloud computing and mobile computing. MCC started to grow due to its advantages, as it can be accessed from anywhere, is multiplatform supported, is cost efficient etc. MCC provides a way to store data and do processing outside of the mobile devices which gives the user benefit to avoid storage and computation limitations in mobile devices. It also helps to allow data access easily and the load is reduced. But besides having advantages, MCC also face some challenges, one of the major problem MCC faces is the energy consumption. Almost all mobile devices are battery powered. MCC increases battery usage of mobile devices. Many methods have been tested to decrease energy consumption; one of them being reducing usage in high power. The cause of energy drainage is a lot which includes screen brightness, Wi-Fi connectivity, screen timeout, heating etc. The process of offloading costs time and energy which should be considered too.

Low bandwidth is another big problem faced in MCC [18]. As bandwidth is limited and the wavelength available is distributed in different devices cause in slowing of speed. Data access becomes slower, as there is increased amount of mobile traffic due to increase in population. As compared to wired devices, performance of MCC should be efficient and it should be compatible to all devices running on different platforms. MCC also deals with security concern as all kinds of data are provided. There is a lack of resources in mobile devices as compared to personal computers, which makes it difficult to adopt services of MCC in general. Many techniques are being used to overcome these challenges. Energy saving techniques are discussed further.

TABLE 1. CHALLENGES OF MOBILE CLOUD COMPUTING

List of Challenges	Description	Contribution
Limited Energy source	Energy consumption is one of the major issuesof mobile computing. Mobile users want to perform heavy computational tasks on mobile devices which cause battery drainage.	[1][2][3][4][5] [6][7][8][9][10] [11][12][13][14][15] [16][17][18]
Privacy and security issue	It is difficult to handle threats on mobile devices as compared to desktop devices because in a wireless network there are more chances of loss of the information from the network.	[7][8][18]
Low bandwidth	Radio waves, used in Mobile cloud, are limited as compare to wired network.	[18]
Service Availability	Another major threat in cloud computing is connection. Users often face problems like breakdown of network and transportation crowding.	[18]

III. ENERGY EFFICIENT MCC

Most users prefer mobile devices to perform their task which they perform on desktop computers. These tasks need heavy computation which causes battery drainage. A study conducted in 15 different countries in 2005 concluded that users prefer longer battery life in mobile devices than other features like camera or storage. Therefore, effective green techniques are important to extent the battery life. In this research study we discussed some energy saving techniques which are widely used in MCC.

IV. ENERGY EFFICIENT MCC TECHNIQUES

Dynamic Backlight Scaling [15] support reduces the backlight of a device for every time frame without affecting any application. This allows device to lessen the power consumption. Screen brightness is usually the reason of power drainage in programs. Mostly a technology or method is used to decrease the screen brightness regularly to make sure the end users are not suffering. Another scheme is also offers to check internet connection regularly if it's not used which also refreshes itself after sometime for any new notifications.

EEMSS [17], Energy Efficient Mobile Sensing for Automatic User State recognition is a framework proposed that provides and manage energy saving sensors that detect user's states. User's daily activities like background environment is quiet or loud, user is moving or not etc. are recorded by it automatically. This state descriptor in XML-Format is used as input in a functional block that assigns sensors to control sensors. The users are sorted according to their application necessities. It also invokes new sensors and assigns minimum sensors. It performs sensor working and provide the data to higher layer application, and acting as a medium between them. EEMSS uses Wi-Fi locator, GPS accelerometer and amplifier mostly found in mobile phone sensors. The output of this framework distinguishes and sort user states as idle, moving, outside, at a noisy place, at home, in vehicle etc. with the help of information through sensors. This system is said to increase battery life by 75%.

In 2015 Benkhelifa, Elhadj and their group members introduced this technique for energy consumption known as Green MCC [4]. After studied the energy consumption in MCC they proposed a system in which a user's profile is generated through their interaction and component's usage. The general objective of this system is to estimate the energy consumption for applications by each user in mobile device. This technique gathers the data of several application usages and saves this information in historical database. Then this data generates a profile of user for every application that estimates the information i.e. how much energy and resources of each application will be consumed in the future. To attain the estimation profiling uses statistical methods. If a mobile device needs an extension of resources, it will be delivered by CSPs (Cloud Service Providers). This system is beneficial for both users and cloud service providers.

The major strength of this approach includes the estimation of energy consumption by all users in mobile devices and also an estimation of resource usage in future and the limitation of Green MCC includes that it is used only for mobile applications [4].

In 2011 N. Vallina-Rodriguez and J. Crowcrof proposed the technique ErdOS [2] [14]. It is the extension of Android OS, which extends the battery life ofmobile devices through two methods given below:

A. A user-centered proactive resource management system

This method predicts the demands of users for resources through their usage of applications, habits, action, work, and charging the phone.

B. Opportunistic access to resources

In this method a mobile device can access resources from other nearer mobile devices through wireless networks. But the authors suggested that Bluetooth is the most appropriate wireless interface because of its low energy consumption.

ErdOS consist of three key components: Activity Manager, Access Control Manager and ErdOS Manager. Observing and profiling of user activities and usage of Android resources and its framework at run time is done by Activity Manager. Access Control Manager holds essential data i.e. profile of users, strategies, public keys and IPC (Inter Process Communication) mechanisms. ErdOS is responsible for detection of close devices, handling local resources and determining access patterns based on forecasting algorithms.

The most important strength of ErdOS lies in improving the usability of handsets and also extending the battery life and the major limitation of this technique include that it is used only for handsets and android operating systems [3].

Clone Cloud is an energy efficient technique in MCC. It transfers a part of mobile applications on cloud and executes there. The speed of running mobile applications has been increased by Clone Cloud which uses different data centers. The main objective is to clone the whole data from mobile phone to the cloud and execute some of the applications on the clone and display the results on the mobile phone. More than one clones can be applied to a single device. A unique clone cloud is combined to every mobile device which boosts mobile device efficiency. An application's partitioner partitions application-level run on VM, and the execution runtime controller smoothly off-load the executions, which were partitioned, from mobile device to the clone cloud. A crucial goal for Clone Cloud is that it provides easy to decide which operation should execute where, another design goal is to provide partitioning of applications smoothly [5].

Clone cloud helps to increase computation power, enhance memory, and saving mobile device energy. The execution of an individual machine application is transmitted into executions with shared applications.

Mobile cloud has been introduced by cloud computing in order to improve the usage of mobile phones and also to reduce the power consumption. In MCC, the applications that runs on mobile devices are transformed to cloud data centers to save the energy consumption, computation and mobile device storage.

Mobile devices face the challenge of battery life and processing time. The solution of energy consumption is to off-load some part of computation to a suitable place [6]. Clone cloud have some limitations in a way that is not capable of migrating native state and to export unique native resources remotely. Another limitation is that Clone Cloud doesn't have access to virtualize native resources which are not virtualized earlier as well as not available on Clone Cloud [5].

One of the main reasons behind energy drainage in mobile devices is executing heavy computational task on mobile. There are many techniques use to increase the mobile battery life. [7] Offloading is one of energy saving technique which minimizes the battery consumption of mobile devices by transferring computation intensive tasks on cloud. In this approach the computation is not performed on mobile rather it is performed someplace else. There are two challenges to address when using these approaches which are listed below:

- When to offload computation from the mobile to the cloud?
- What are the main considerations while offloading to the cloud?

There is an address these issues based on the study of the battery usage for a computation task on mobile versus on the cloud. In [8] following formula is used to calculate the amount of energy saved while offloading any task:

$$P_c \times \frac{C}{M} - P_i \times \frac{C}{S} - P_{tr} \times \frac{D}{B} \qquad (1)$$

Where, M is the speed of mobile (instructions/second),

C is the number of instructions to be offloaded for computation,

S is the speed of cloud server,

Pc is the energy consumption of mobile device (watts),

Pi is the energy consumption of mobile device in idle condition (watts),

Ptr is the transmission power consumption of mobile device (watts),

B is the network bandwidth,

D is the bytes of data to be exchanged

$P_c \times \frac{C}{M}$ is the energy consumption if the computation is performed on the mobile and if computation is performed on server then energy consumption is $P_i \times \frac{C}{S} + P_{tr} \times \frac{D}{B}$.

Assume that the server is F times faster—that is, S = F × M. Then the formula will be:

$$\frac{C}{M} \times \left(P_c - \frac{P_i}{F}\right) - P_{tr} \times \frac{D}{B} \qquad (2)$$

Consider Pc, Pi, Ptr are constant, if the answer of this formula is a positive number, offloading decrease energy consumption, otherwise not. The formula will produce positive number if D/B is adequately small compared with C/M and F is large enough.

Due To The Increase In Demands Of Computation And Online Storage The Scales Of Data Centers In The Backhaul Of Mobile Networks Are Growing Faster Than Any Other Information And Communication Technologies [9]. Meanwhile, Data Centers Are Also Producing Huge Amount Of Energy From Transmitting, Storing And Computing. Many Energy Saving Techniques Are Used To Minimize The Energy Usage, Most Of Them Use On/Off Resource Allocation And The Virtualization Techniques. Due To The Overprovisioning Of Data Centers, Most Of The Time Their Computational Power Is Much Below Than The Peak Value. Hence, There Are Many Approaches Which Are Used To Schedule The Turning Off The Software-Level Functions And Hardware Level Devices According To The User Requests And Traffic Load. These Techniques Decrease Energy Consumption By Shutting Down Unnecessary Links And Idle Network Devices. Elastictree Discovers Minimum-Power Network Subsets Across An Extent Of Traffic Patterns, And Also Scales Up And Down The Functionalities Of A Network. Virtualization Techniques Are Also Used In Many Designs To Virtualize Physical Machines Into Many Operating Systems Called Virtual Machines. The Approaches We Discussed In This Paper Are Vm Migration In Green Cloud And Live Vm Migration. Vm Migration In Green Cloud Provides Mobility User Can Work On Different Virtual Machines On Different Time. Live Vm Migration Enables Data Centers To Adjust Resources Dynamically By Transferring The Workload Of Virtual Machine From One Physical Machine To Another Without Terminating The Services To Meet The Elastic Demands.

TABLE 2. ENERGY EFFICIENT TECHNIQUES IN MOBILE CLOUD COMPUTING

Techniques	Description	Contribution
Dynamic Backlight Scaling	Decreases power consumption of mobile devices by reducing backlight of device per frame.	[15][16]
EEMSS	A framework that detect user's daily activities and state through energy saving sensors, saves about 75% of energy.	[15][17]
Green MCC	Estimate energy consumption for applications by each user in mobile device.	[4]
ErdOS	Handset can share their local resources with close devices.	[1][2][3]
Offloading	Offloading minimizes the battery consumption of mobile devices by transferring computation intensive tasks on cloud.	[7][8]
Clone Cloud	To clone the whole data from mobile phone to the cloud and execute some of the applications on the clone and display the results on the mobile phone.	[5][6]

V. COMPARISON OF ENERGY EFFICIENT TECHNIQUES

Mobile Cloud Computing is an emerging promising technology which merge cloud computing with mobile devices. Through MCC mobile users are capable of utilizing cloud services using mobile devices. It enables users to perform computation intensive task on their mobile devices. These tasks need increasing amount of computational power, storage and energy. The limited battery life time is one of the major issue in mobile devices. MCC provides solutions of this problem by using different approaches which are discussed in this paper. In this section we highlighted weaknesses and strength of these approaches [4].

Dynamic backlight scaling has its own strengths and weaknesses. It is applicable on LCD displays and has minor color distortion. In order to recompense the image quality degradation, it enhance the brightness and contrast of image by adjusting its color. Dynamic backlight has its limitations too; a video has continuous series of image frames at constant rate. The intensity of luminance depends on the backlight level and pixel luminance [16]. The backlight level is decreased to save energy as it is more energy consuming than pixel luminance. The backlight level is treated as a scaling constraint which is applied per frame. The constant change in backlight level in most videos causes a flickering effect which affects user's experience, so the change in backlight level must be limited. Also, a light source is required to illuminate display panel. Usually light source adjusts the backlight level but may not be able to adjust it immediately because hardware takes time. Different algorithms have been implemented in order to overcome mentioned problems.

EEMSS characterizes state of the user by monitoring user's time, location and activities. The user state update is real-time. It also detects the situation of user's surrounding automatically. A study has shown that EEMSS technique reduces battery drainage effectively. However, in EEMSS, the detection of the state is not always accurate as for accurate results sensors should be monitored continuously which can cause decrease in

device's battery life. Due to the classification algorithm constraints, the state recognition accuracy is not 100% either [17].

Green MCC is a technique which estimate energy consumption and utilization of resources in future by gathering data from several applications [4]. The major strength of this approach is that it estimates resource usage and energy consumption of each application.

Clone cloud is another energy saving technique which transfers a part of application into cloud and performs computation. After computation only the result is displayed on the user mobile. Clone cloud have some limitations in a way that is not capable of migrating native state and to export unique native resources remotely. Another limitation is that Clone Cloud doesn't have access to virtualize native resources which are not virtualized earlier as well as not available on clone cloud [5].

ErdOS [1] [2] [3] technique which is extension of Android OS which increases the mobile devices battery life through two methods are discussed above. The main objective of this technique is to predict future utilization of resources and energy. This technique has some limitations such as its energy and computational overhead (mainly caused by profiling and predicting resources utilization and state), fairness, scalability and security issues [14].

In offloading battery consumption of mobile devices is reduced by transferring computation intensive tasks on cloud. It enables mobile devices to perform task which required heavy computational power and energy. Privacy and security is the main issue in this approach as the user's data is uploaded into cloud and the location of the cloud is unknown. Other limitations of this techniques are mobility, fault tolerance, inter-operability and context awareness.

TABLE 3. COMPARISON OF STRENGTHS AND LIMITATIONS OF TECHNIQUES IN MOBILE CLOUD COMPUTING

Contribution	Techniques	Strengths	Limitations
[15][16]	Dynamic Backlight Scaling	Applicable on LCDs, minor color distortion, enhance brightness and contrast.	Causes flickering effect if backlight change is not maintained, hardware limitation.
[15][17]	EEMSS	Detect state in real-time, detect situation automatically.	Results are not always accurate.
[4]	Green MCC	Estimate energy consumption and usage of resources in future.	Only for mobile applications.
[1][2][3][14]	ErdOS	Improve handset usability. Extend battery life.	Only for Android OS, energy and computational overhead (mainly caused by profiling and predicting resources utilization and state)
[7][8]	Offloading	Enable mobile devices to perform heavy computation. Extend battery life.	Context awareness, Privacy and security.
[5][6]	Clone Cloud	It provides easy to decide which operation should execute where and provide partitioning of applications smoothly.	It is not capable of migrating native state and to export unique native resources remotely.
[9]	Data centers in backhaul	Provide storage to perform heavy computational tasks.	Latency issue, produce huge amount of energy.

VI. CONCLUSION

Mobile Cloud Computing is a hot topic nowadays, because Mobile phones are crucial part of our daily routine. Users like to perform all their tasks with a handheld device rather than desktop, which demands heavy energy consumption, memory, and storage. There is a need of such technology which deals with power management and heavy computations in hand. Still MCC is facing many issues which have been discussed in this paper and appropriate techniques are suggested to resolve these problems. Mobile Cloud Computing is a boundless subject for research. Future work must focus to enhance the cloud computing field and to develop new energy-saving infrastructures as it is a vast research topic and need more work to be done on it.

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