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Predictive Approach for Energy Efficient Computation Offloading In Mobile Cloud Computing

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***Abstract*—** Mobile Cloud is providing facilities of storage and remote application hosting. Several mobile applications are too computation intensive so power consumption issue is critical problem in mobile devices. Offloading feature in mobile cloud computing reduced power consumption issues of mobile devices. Existing research works have either used fixed mobile device speed or does not consider mobile device speed in estimation of local execution energy. Speed of mobile device plays a significant role in determination of local execution energy and it is affected by parallel running applications and clock frequency of mobile device. Because when there are applications running in parallel, execution speed of mobile is not fixed. In order to counter these issues, this work exploits Exponential Weighted Mean Moving Average to predict device speed according to load on mobile device. We have compared proposed work with two types of systems: Fixed CPU Speed system where CPU speed of mobile device is fixed throughout all offloading decisions, and Oracle which assumes to know exact speed of mobile device in advance. Evaluation of all systems is carried by using synthetic workloads.

***Keywords*—** Mobile cloud computing, Offloading, Network Bandwidth, Energy saving, Execution speed

I. INTRODUCTION

Cloud computing provides service over networks, which may be public or private. Cloud is available at a remote location. It may be utilized in wide area network, local area network or in virtual private network. There are a lot of applications like email & web dependent applications. Cloud computing [1] has offered platform independency. Thus, there is no need to setup a particular software on computer. It could be said that today's business software are mobile & collaborative. This is because of cloud computing. Here are several services which have made cloud computing most feasible. They are also making data access easy to the user. The services offered by cloud computing are shown in Figure 1 Cloud computing is a mechanism that is providing many types of facilities. Cloud computing is delivering the computing services. These services are virtual machine services, storage services, database services, software services, and networking services. The companies are offering these computing services which are called cloud providers. These service providers charge the users on the basis of usage, similar to billing of electricity at home. Cloud computing is more suitable & comfortable for any system & network connection.

Figure 1: Cloud Computing

Cloud computing is more suitable & comfortable for any system & network connection.

If we use online service to send email, edit documents, watch movies, and listen music, play games & store pictures, cloud computing is making it all possible behind the scenes. Cloud computing could be used in the following terms: -

1. Create new app & services: - When we want to create any new application & any other service, we can use cloud computing. Cloud computing makes it easy & execute it with a required data.
2. Host websites & blogs: - With cloud computing we can easily create host websites & blogs. The maintenance of these websites & blogs is getting simpler with the support of cloud computing.
3. Stream audio & video: - By using cloud computing, we can process the audio & video files & can produce the

required data. Cloud computing makes it more understandable and capable to flow in a continuous manner.
4. Deliver software on demand: - By using cloud computing, we could deliver the software on demand. It could be delivered within a time period, which is selected by clients. So, cloud computing is playing an important role in the delivery of software services.
5. Storage, backup & data: recovery - Cloud computing offers the services like storage, backup & recovery of data. These services are very necessary for us. Cloud computing facilitates these types of services. It makes the work easier.
6. Analyze data for patterns & make a prediction: - Since Cloud computing can provide vast amount of hardware resources, therefore, analyses of the raw data are very easy. It also facilitates in making predictions from the actual raw data.

Motivators for Mobile Cloud Computing

Mobile equipment has got popularity in many areas as enterprises, government organizations, and social facility providers like education, health care, and engineering organizations. Figure 2 represents how bandwidth, processing power, local storage, and energy resources influence the mobile cloud computing [2]. However, in spite of important improvement in the abilities of mobile computing, still computing needs mobile operators which are mainly enterprise operators. Many limitations of mobile devices hinder reliability of concentrated computing of mobile & motivate augmentations which are listed below are Low bandwidth, Processing power, Energy resources, Local storage, Visualization capabilities.

Advantages of Mobile Cloud Computing

Mobile cloud computing is providing us a software system. Benefits [4] of mobile cloud computing has been given as follows:
1.It is giving power to operators to cast their mobile network. It supports billings by giving a full commercial solution.

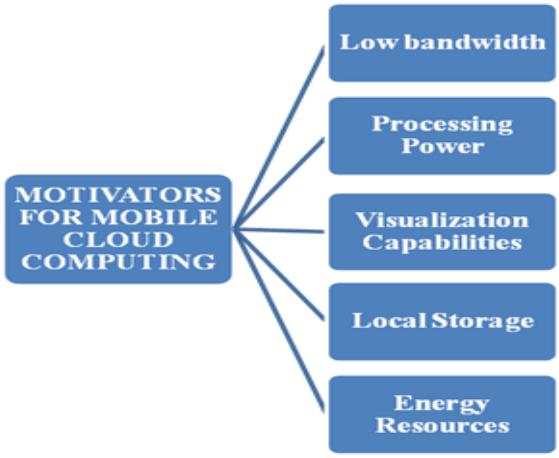

Figure 2: Motivators for Mobile Cloud Computing

2. It is provided on demand services. It has added mobile network enablers & brilliant commerce services. It has given power to make recent business to business solutions.
3. Such solutions are supporting organizations as well as enterprise.
4. MCC is enabling website & mobile developers. It comprehends applications with the support of mobile networks.

Challenges in Mobile Cloud Computing

There are many challenges [5] related to cloud computing as well as network communication.

A. Challenges at Mobile Side

- **Less Bandwidth:** Bandwidth becomes a major issue in mobile cloud computing. There is always limited bandwidth over a network. This could be overcome with the help of the Peer to Peer Media Stream. It is sharing limited bandwidth. It is shared among users. These users are situated in nearby area.
- **Availability:** The network failures are a big issue for the user who is connected to the cloud.
- **Heterogeneity:** There are networks that could be used as WIMAX, GPRS, CDMA, WCDMA and WLAN. It is hard to handle such heterogeneity in various networks.

B. Challenges in Cloud Side

Main issues [5] during computations are as below:

- **Computing Offloading:** Offloading is one of the main features of Mobile cloud computing. It is for improvement of battery life time. It is to increase performance of application using cloud computing. The computation offloading [6] technique works with the purpose of migrating very large computations. It also performs complex processing.
- **Security:** Security has been considered a major issue in mobile computing. It is gaining more importance. This is because hackers and intruders are increasing continuously in the cloud. Cloud security is must for user privacy & secrecy of the data. Users face security issues with mobile devices.
- **Authentication:** Application developer & mobile users should be very careful during dealing with data. It occurs when the user stores & process large amount of data on a cloud.
- **Data Access:** Accessing has become very challenging with increment in the number of data resources. The problem has arisen due to various cloud services. It occurs while dealing with data resources.

Moreover, the offloading feature in mobile cloud computing has reduced the power consumption issues of mobile devices. A lot of research works have been carried out on computation offloading in mobile cloud computing. However, these works have either used fixed mobile device speed or does not consider the mobile device speed. This research is based on when and in which circumstances the offloading should take place. An analysis has been made for

considering the influencing factors such as bandwidth, speed of central processing unit and performance of the device.
The remainder of the section is organized as follows: Section II described the related work. Section III presented the proposed work. Section IV describes the results and other discussion. The paper concludes in Section V.

II. RELATED WORK

There are several researches in the field of mobile cloud computing. Here discussion has been made regarding existing research on mobile cloud computing. Some of the researches have discussed saving of energy in cloud computing. Some researchers have considered the concept of off loading. Offloading in Smartphone has been also discussed in some researches.

Kumar et al. [1] focused on the reliability & data communication before offloading. Analysis during research concluded that cloud computing is capable to save energy for mobile users. It has been found, there is a lack of energy efficiency in the case of cloud migration. According to research, Mobile cloud computing services are found different from cloud services.

Cuervo et al. [2] proposed MAUI to minimize the burden on programmers. It has handled the program partitioning. The system enabled fine-grained as well as energy aware offloading of mobile code. Such type of offloading of mobile code has been made in infrastructure. MAUI uses the advantages of a managed code environment.

Kosta et al. [4] discussed that Think Air is a framework for computation of mobile offloading to the cloud. Think Air needs only simple changes to an application's source code. It is coupled with the use of the tool - chain of our Think Air.
Barbera et al. [7] presented that mobile cloud computing are sustained by continuous updating of software clones. The updates are done in the cloud with a reasonable overhead in terms of bandwidth. In this study, the authors have assumed an architecture where real device is associated to a software clone in case of cloud. They considered two different types of clones. One of them is off-clone. The objective of this type of clone is to help in computation offloading. The second one is back-clone that gets utilized when restoration of user's information and application is required. The feasibility and expenses in case of off-clones and back-clones are discussed.

III. METHODOLOGY

The local execution energy can be estimated as

$$E_{local} = t_{local} * (P_{cpu} + P_{display}) \quad (1)$$

Here, E_{local}, t_{local}, P_{cpu} and $P_{display}$ are local energy, local execution time, power consumed during CPU working and power consumed by display of the mobile device.
Similarly, the cloud execution energy can be estimated as

$$E_{cloud} = T_{tr} * (P_{3G} + P_{display} + P_{idle}) + t_{cloud} * (P_{idle} + P_{display}) \quad (2)$$

Here, T_{tr}, t_{local}, P_{3G}, $P_{display}$ and P_{idle}, are transmission time, cloud execution time, power consumed during data transfer using 3G, idle power and display power of the mobile device.

Table 1 Power consumed by different components of mobile devices [8]

Power consuming part of the mobile device	Power consumption (in mW/sec)
Display	900
CPU working	400
Data transfer using 3G	750
CPU idle	50

However, the existing research works have either used fixed mobile device speed or does not consider the mobile device speed in the estimation of local execution energy. But when there are different applications running in parallel, the execution speed of the mobile does not remains fixed.
Here is an example by considering the factors which have significant impact of the offloading.

- At a time the execution speed of mobile device as 500 mips & workload as 5000 MI,
  Then the local execution time will be $E_{local} < E_{cloud}$ ==>execute locally …….. by using eq. (1) & (2)

- If there are many applications running in the background, then the speed of mobile device becomes slow. Suppose speed=200 mips
  Then 5000/200=25 Sec.
  $E_{local} > E_{cloud}$===>Offload
- That's why we are using predictor, to predict the speed for better decisions.
- Then in order to verify our result compare it with oracle speed decisions.
- Proposed work would produce results as offloading decisions for Oracle, Predicted & Fixed cases.

However, instead of using fixed device speed, this work exploits Exponential Weighted Mean Moving Average (EWMA) to predict the device speed according to the load on the device.

$$S_P^t = \alpha\, S_{ob}^{t-1} + (1-\alpha)\, S_P^{t-1}$$

Where S_P^t = speed of mobile device

S_{ob}^{t-1} = observed speed of mobile device in previous clock interval

S_P^{t-1} = predicted speed of previous clock interval

$\alpha =$ a constant that determines the weightage of observed value & predicted value,

IV. RESULTS AND DISCUSSION

The evaluation of proposed work has been carried out using the following input variables: transmitted data, CPU power, display power, 3G power, & idle power. For the evaluation of the work proposed in this dissertation, we developed a customized simulation application using Java. This simulation helps in deciding whether to offload or not. We have compared the proposed work with two types of systems:

1. Fixed CPU Speed system: The CPU speed of mobile device in such systems is assumed to remain fixed throughout all the offloading decisions.
2. Oracle: It assumes to know the exact speed of the mobile device in advance.

The evaluation of all the systems is carried by using synthetic workloads.

V. RESULT

The Mean Square Error (MSE) is estimated to determine the optimal value of "α". The calculated Mean Square Error's for different values of "α" as 0.1, 0.2 & 0.3 is 3.8187, 3.9637 & 4.05928, respectively and are depicted in Table 2.

Table 2: Different Mean Square Error Estimation for α

A	Mean Square Error
0.1	3.818762
0.2	3.963781
0.3	4.059289

Mean Square Error Estimation of α is represented. The Mean Square Error value for "α" is minimum in case of 0.1 as compared to 0.2 & 0.3. So, we take "α" as 0.1 for further work.

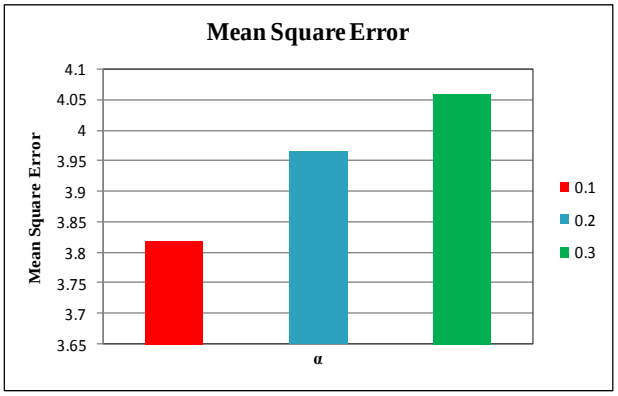

Figure 3: Mean Square Error Estimation of "α"

Table 3 shows the offloading decisions in oracle, predicted and fixed cases to decide to execute locally or remotely.

Table 3: Offloading Decisions

Case	Offloading Decision (%)
Oracle	85.71429
Predicted	78.57143
Fixed	42.85714

Figure 4 represents the offloading decisions in case of oracle, predicted & fixed case. The result shows that the offloading decisions are higher for oracle than that of predicted & offloading decisions in case of predicted is more than fixed.

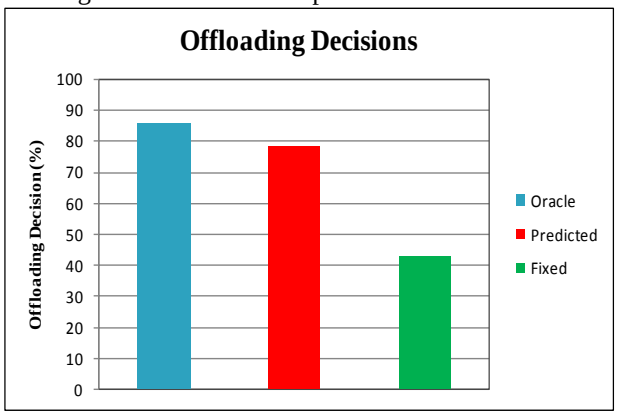

Figure 4: Offloading Decisions

Table 4 shows the energy saving (%) in case of oracle, predicted & fixed on the basis of their remote execution.

Table 4: Energy Savings

Case	Energy Saving (%)
Oracle	11.71569
Predicted	10.62688
Fixed	4.21123

Figure 5 represents the energy savings in case of oracle, predicted & fixed cases. It shows that 6.42% energy is saved by proposed methodology as compared to fixed.

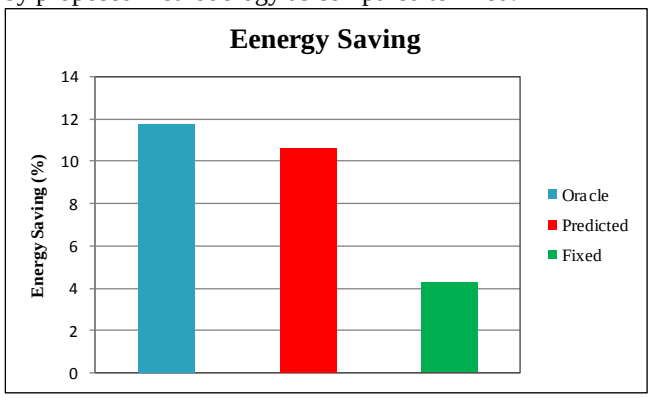

Figure 5: Energy Saving Graph

VI. CONCLUSION AND FUTURE SCOPE

A lot of research work has been carried out in mobile cloud computing. However these works have either considered fixed mobile device speed or does not consider the mobile device speed. The speed of mobile device plays a significant role in the determination of local execution energy and it is affected by various issues such as parallel running applications and clock frequency of the mobile device. In order to counter these issues, this work exploits exponential weighted mean moving average (EWMA) to predict the device speed according to the load on the mobile device. We have evaluated the proposed work by using synthetic workloads. The results of evaluation show that our proposed solution enhances the energy savings of the mobile device by 6.42%.

This work can be extended to the organization of data centres in the geographical regions. This would require the knowledge base user's location. Furthermore, this work can also be extended to balance the load within the data centres. It would require change in the VM initialization policies of the server.

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