Activity recognition and resource optimization in mobile cloud through MapReduce

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***Abstract*—Mobile cloud computing aims at improving user experience through enhancing the ability of mobile applications by doing intensive tasks in the cloud. In this paper we consider an environment similar to a hybrid cloud in which the mobile device works as a private cloud. Given that the mobile phone has both limited processing resources and battery time, the proposed mobile application architecture has been designed with the capability of sending specified data/parameters to the cloud. This data is subsequently used for further processing/mining and visualization to assist in inferring further information through mapreduce. This information gives details about resource and battery consumption which will help in optimizing the relationship between the mobile device and cloud. It will also be beneficial to the optimization of the mobile application through the trends visualized in the cloud. In this paper we created an activity recognition health application as an example and helped the user about his health along with giving an insight into abnormal behavior and lifestyle trends.**

I. Introduction

Cloud computing has opened many opportunities in collaborating with unique and different fields which range from health informatics, parallel batch processing, computationally intensive applications, analytics and mobile applications [1] . The notion of mobile cloud computing leverages the elastic resources of cloud computing due in part to the limited resources on the mobile device and as such can be viewed as a mix of mobile computing, cloud computing and networking [2] .

Cloud computing has recently become a popular paradigm for leveraging mobile phone applications. As a result, Cloud computing based services are more frequently being used as part of mobile phone based applications. Moving data and processing from mobile devices to large data centers makes sense as it enables users to obtain a better experience from a range of perspectives, most notably being the increase of service performance [3] [1]. The latest trend is to build mobile applications in which the data is transferred and seamlessly available to laptops and computers in addition to applications such as dropbox, skydrive and icloud. According to latest research the market for cloud based mobile applications will reach $9.5 billion by 2014 [3] . Cloud computing services are becoming integrated into many diverse types of mobile applications varying from games and social networking to health and social care applications. There are still, however, many point of views related to mobile cloud computing. One viewpoint is that both data storage and data processing for mobile applications should be performed outside of the mobile device [4] . An alternative viewpoint is to connect the network of mobile devices in a peer to peer network for resource sharing [5] . In our current work we follow the former point of view mainly due to the fact that mobile cloud computing is an extension of cloud computing and is termed as an ad-hoc infrastructure [6] .

Although mobile cloud computing can offer a number of advantage as previously outlined it also brings a set of problems and challenges with it. Many problems occur related to the diversity of network conditions like low bandwidth, disconnection and limited power‘[7] . Mobile cloud computing must therefore address the challenges associated with mobility in an effort to support a range of different user scenarios. One of the major challenges is to encapsulate the heterogeneous nature of the underlying technology [8] where the operating system and storage model can significantly influence the performance of the overall system.

This paper helps in resource optimization of the mobile application through data mining and visualization and user trends being done on the cloud. Through the information in cloud mobile application can be more energy efficient.

The remainder of the paper is organized as follows. Section II briefly reviews related work in the area of mobile cloud computing. Section III proposes a framework for mobile cloud service. Section IV explains the simulation platform. Conclusions and Future Work are presented in Section IV.

II. Related Work

Research in mobile cloud computing has ranged from topics considering energy saving, data management and migration, social networks and healthcare. The potential of applying mobile cloud computing for purposes of monitoring healthcare has the potential of minimizing costs of traditional health care treatment. Monitoring patients and accessing medical records

easily at all times is a clear advantage. In addition, taking action with some intelligent emergency management system when the patient has been identified as being in distress is a further advantage. The concept of the Health cloud [9] , is a prototype which utilizes the public Amazon cloud to manage patient records and relevant medical images. The project has developed an android application for viewing JPEG2000 standard images with image annotation exploiting the multi-touch functions of the Android OS

Nike + iPod [10] , initiated by Nike, logs user well-being activities such as running, jogging and gym activities via the Nike+ hardware device paired with Apples iPhone or iPod. Activity data is subsequently published over Nikes portal [11] , which provides data visualization services and data persistence services. MapMyRun [12] , is a similar application that keeps track of users workout activities and nutrition intake with intuitive visualizations and track mapping services. Activity data gathered from a smartphone can be stored over the MapMyRun Portal [13] or exported as log files to be synced with cloud storage services like dropbox [14] .

Most of the available life-logging applications are focused on wellbeing and workout tracking. Life-log data recorded by the smartphones [10] [11] [12] [13] provide improved activity tacking by utilizing the built-in sensors and GPS capabilities of the phone. These applications utilize the cloud and the web for the persistence of activity data. This data is used as the basis for improved visualization over the web and smartphone, and can also be used for expert analysis such as physicians and trainers. In [15] architecture is proposed which creates a smartphone clone on the cloud infrastructure. The computationally expensive processes are executed in the clone and the clone can also be used as a backup if the smartphone is lost. In [16] a system MUAI (Making Smartphones Last Longer with Code Offload) has been proposed which enables fine grain energy aware offloading of mobile code to the cloud instead of whole image migration or making a clone. MUAI can offload main application computation working as a thin client as well as background computation which usually does not need the user interaction. MUAI in both cases significantly boosts the battery time as computation is passed upon to the cloud and less battery is consumed. A similar approach is taken in [17] where an elastic application model is created that seamlessly use the resources of cloud storage. They breakdown one application into small components called weblets which is then migrated into cloud. For an optimal weblet they use naive-Bayes classifier. Another approach proposes an objective function i.e. latency, data transferred, cost etc. and plot the consumption graph with respect to this function to optimize the distribution of application modules.

III. Proposed Framework

In this section we discuss the proposed system and its components in detail. It consists of two main parts i.e. the mobile application and the cloud computing storage and processing module as shown in figure 1. The proposed system in the current work benefits from the potential advantages of Cloud computing in general. Storing the data in the public cloud will help reduce costs that are usually incurred to store data on local servers and replicate this data on backup servers. There will be very low costs for using the cloud storage on a pay-per-use basis with very little or no technical knowledge. There will be no special considerations required for security and privacy of data in the cloud due to the intelligent cloud based anonymization service. Ubiquitous access of data from the public cloud will allow multiple devices (including smart phones, laptops and personal computers) to access the data and services instantaneously over the Internet.

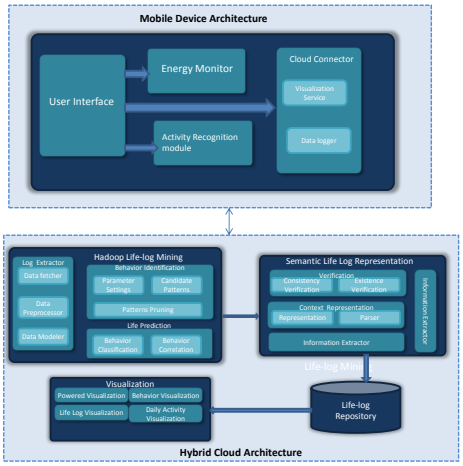

Fig. 1. Hybrid Cloud Architecture

A. Mobile application and architecture

In our current implementation, we store the data on the device and the system generates as an activity model from the collected training dataset and stores the results.

1) Energy Monitor: The energy module in the application monitors the battery consumption of the device while the application is running. Based on the readings it decides whether a task will be executed on the mobile phone or not.

2) Activity Recognition module: The main function of our mobile application is activity recognition during different time of the day during a users life. In total 9 contexts (3 different activities for 3 different locations) are recognized with over 90% accuracy. Other activities such as running, driving a car, bicycling, riding a train, going up/down stairs etc. are also planned to be included in the application [18] . Recognizable activities are walking, standing and sitting at different locations namely home, office and outdoors. The activities are the same; however, the meaning of the activity in a specific location is different. For instance, if the system recognizes sitting at the office, it means the user is working. Or if user is undertaking the same activity at home, it would be considered as taking a rest.

B. Cloud System Architecture

1) visualization : The visualization component within the architecture will provide users with understandable visualiza-

tion of the activity data and user behavior based on data relayed from the mobile device. The visualization component has the potential to help in identifying anything abnormal relating to the users health. The activity data and behavior visualization will present graphs relating to the users behavior in relation to a certain time period. The daily activity component will present the heart rate activity of users during different activities for each day as the timestamp will also be sent to the cloud. Resource management is one of the influencing factors in the mobile cloud computing due to constraints in the mobile device. The visualization of power usage of the mobile device will relate to the information about the battery status of the mobile device. To track the consumption of the mobile application we also show the battery consumption graph of the mobile device. This can help optimize the application and also indicate on which phase of execution, more battery was consumed. Moreover this information will also give the heads up about the battery depletion time when combined with the timestamp.

2) Hadoop Life Log Mining: Hadoop is a cloud computing platform and an open source implementation of MapReduce programming model [19] . In a MapReduce job there are three phases i.e. map, copy and reduce. In Map Phase we individualize the activities and the times with respect to their locations. The log extractor is done in the map phase and the logs are structured and preprocessed in it. These activities are then co related with the timestamps, spatial-temporal activity information in order to map users life events and obtain a timeline and their frequency of occurrence in reduce phase. This will help in identifying the behavior identification. The Behavior identification identifies the frequent and regular behavior of users from their previously recorded profiles. Life prediction will classify the user behavior for future predictions and long term recommendations. The parameters needed for Hadoop are the number of mappers and reducers, file size, patterns that are needed for pruning of unnecessary information as well as the different classifiers that were used in detecting the activity. The life log module will be capable of mining life-logs and hence be able to evaluate a user's behavior based on life conditions and constraints. This component will analyze the users behavior relating to a set of daily activities to assist them in daily lives according to their interests. The Log Extractor will aggregate spatial-temporal activity information in order to map users life events and obtain a timeline. The Behavior identification identifies the frequent and regular behavior of users from their previously recorded profiles. Life prediction will classify the user behavior for future predictions and long term recommendations.

3) Semantic Life log Representation: The Context Extractor will extract relevant activity information and then the context information is logged in the Life Log Repository compliance with the Context Representation Model. Context Verification will verify the consistency of the represented information for both consistency and existence and following verification the parser will parse the incoming information and then save it based on the format specified in the life log repository. It will provide analysis and recommendation applications over the life log as a computation will be required for data mining on the cloud. It will provide a visualization Service and provide intuitive graphs and statistics for better user understanding of the life log and user behavior The approach will achieve accurate life analysis pattern, improved behavior extraction and improved recommendations based on behavior analysis and life analysis pattern.

IV. IMPLEMENTATION AND RESULTS

We developed an android app with smart multimodal sensors. We used GPS and accelerometer, gyroscope, proximity sensors. We used Samsung galaxy S3 for experiments We had 3 different activities i.e. standing, walking and sitting for 3 different locations i.e. home, office and standing.

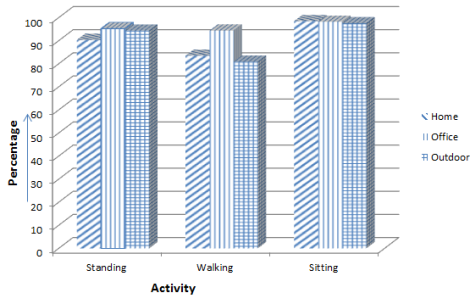

Fig. 2. Accuracy of the activities in different places

For the home location the accuracy was 90.74% and around 9.26% error for the activities i.e. standing, walking and sitting.

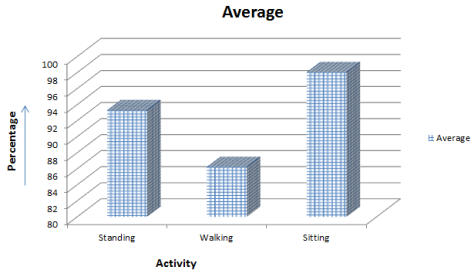

Fig. 3. Average accuracy of all activites

The average for recognizing standing was 93.28% whereas the average for walking and sitting was 86.22% and 98% respectively as shown in figure above. We have simulated the synthetic data to ascertain the feasibility of the overall framework. We used a private cloud and a virtual machine was used with a Dual Core with 4 GB ram and 2 GHz processor. There are two main web services one of which connect to the android application and retrieve the parameters such as heartbeat, timestamp, activity label and the battery status of the mobile phone. This web service saves these parameters in the cloud's repository. The second web service is mainly responsible for the visualization of the different parameters according to the activities undertaken. These graphs provide

a clear idea about the status and trends of the heartbeats according to the labeled activity.

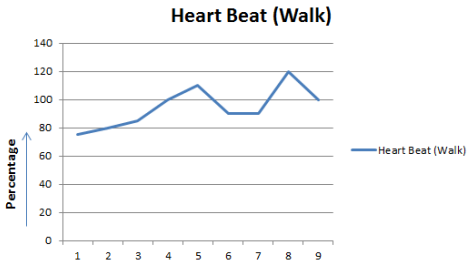

Fig. 4. Heart Beat during walk activity

In figure 4 graph the heartbeat during the activity walking has been plotted. Here we can see a spike in the graph where the heart rate is around 120 in one case. This is very high in case of walking. It means that this should be investigated why the users heartbeat was so high when walking. The battery consumption is also presented in a graphical form. This will provide an indication of how much battery is being consumed with one push of the data in the cloud. It will also be indicative of whether some tweaking is required in the mobile application if the consumption is too high or maybe requires a change in the settings of the mobile device.

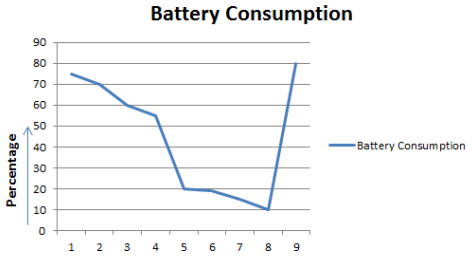

Fig. 5. Battery Consumption chart

In figure 5 a graph has been plotted with battery remaining in the mobile device when it sends the parameters. Here the mobile phone battery is constantly dropping. But there is sharp drop from around 55% of the battery to around 20%. This indicates that the resource consumption was very high at that point. As all the messages have been time stamped we could check in the mobile application logs what operation was done at that time. This could help optimize the mobile application in terms of resource usage. The later jump to high battery time indicates that the mobile device has been charged The graphical views will provide an idea in relation to the recommendations for a particular user. Furthermore, the saved data will be mined to obtain the behavior of the users, i.e. how much walking they undertake, sitting time etc. This could help in deducing an improved healthcare plan.

V. CONCLUSION AND FUTURE WORK

Mobile cloud computing is very beneficial when used for health care given that it has the potential to revolutionize the patient management process and the subsequent recommendations for care giving. The ability to reduce costs is a huge advantage. This paper presents an exemplar involving healthcare monitoring and the visualization of data collected. This framework enables us to obtain the user's health and deduce the behavior patterns and subsequently provide recommendations. Further future work will include deploying the concept into the public cloud to measure the advantages with a private cloud in addition to making the system more energy aware with respect to the consumption of the mobile application. We will develop an algorithm and fully evaluate it later for optimal decision making regarding the mobile application.

VI. CONCLUSION

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