Towards a Framework for Enhanced Mobile Computing Using Cloud Resources

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***Abstract*—As mobile devices become both computing tools as well as communications devices, mobile cloud computing provides a means to enhance the computational capabilities of these devices. As an initial step in the development of this technology, this paper proposes a framework that identifies and defines various important aspects of mobile cloud computing. These aspects include computational and communication requirements, mobile network impact, energy considerations, information security, system reliability and application usability.**

I. Introduction

Mobile Internet Devices (MIDs) such as smartphones and tablet computers are becoming increasingly prevalent. However, these devices are still limited in terms of computational capacity due to the requirements for mobility. Through the investigation of current trends, Section II explains the motivation for augmenting the computing capabilities of mobile devices.

It has been proposed that the emerging cloud computing paradigm, which involves the use of remote high-capacity elastic computing resources, could be used to enhance the computational capabilities of mobile devices [1]. Using this paradigm, MIDs can connect to remote cloud resources via the internet. For this analysis it is sufficient to represent cloud resources as a combination of data processing and storage capability which is significantly greater than that of a mobile device. This distributed computing relationship is known as *mobile cloud computing*.

The aim of this work is to develop an analysis framework for mobile cloud computing. The framework identifies and defines various aspects of mobile cloud computing which can be used to analyse different mobile application domains and implementation approaches. These aspects are explained in Section III and examples of their applicability presented in Section IV. In the overall scope of this research, the analysis framework will be used to analyse and compare several important mobile application domains as well as various implementation approaches to mobile cloud computing.

II. Motivation for Enhanced Mobile Computing

The global percentage of mobile broadband users has exceeded the percentage of fixed broadband users since 2008 and, in 2010, there were 12.6 mobile broadband connections per 100 inhabitants worldwide [2]. In the period 2008-2010, over 300,000 different mobile applications were developed [3]. This wide range of functionality indicates that MIDs are increasingly being used as computing tools as well as communications devices. Despite this trend, the computational capabilities of mobile devices are still more limited than those of traditional PCs.

Two primary considerations of mobile device design are physical size and battery capacity. The energy density of batteries is limited by current technology and so any increase in battery capacity results in an increase in physical size. Whilst it is possible to enhance the computational capabilities of a mobile device by using more advanced hardware, this results in higher power requirements and costs.

As new applications are developed, it is increasingly likely that their requirements will exceed the capabilities of mobile devices. In order to meet this demand, it will be necessary to augment and enhance the computational capabilities of mobile devices through the use of mobile cloud computing.

III. Aspects of the Framework

Based on recent literature, this framework identifies various important aspects of mobile cloud computing which must be considered when evaluating systems based on this technology. Each aspect is a logical grouping of considerations and metrics. Although each is important individually, this framework also identifies a number of interdependencies between these aspects.

A. Computational Requirements

The quantity and complexity of the computations performed and the data stored by a mobile application constitute its computational requirements. There is a broad range in these requirements as some applications do not use the full capability of the mobile device whilst others would be infeasible without augmented capabilities [4]. By evaluating the computational requirements of a specific application and comparing these to the capabilities of both the mobile device and cloud resource, it will be possible to estimate the performance benefit to the application. Under this aspect, the degree of parallelism of the application must also be evaluated. Since this is effectively a parallel computing architecture, Amdahl's law could potentially enforce an upper bound on the performance increase.

B. Communication Requirements

Since the communication between the application and the cloud takes place over a mobile network, it is critical that bandwidth and latency characteristics be taken into account [5]. It is also important to analyse the communication between the application and other internet end-points such as web-services which are external to both the application and the cloud resource. It may be possible to design the application such that data is transferred directly between the cloud and the external end-point. In this way, the overall efficiency of the application can be increased by using the cloud as a communications proxy.

C. Mobile Network Impact

The network impact aspect is a comparison between the communication requirements of the mobile application and the current and future capabilities of mobile communication networks. The dynamic characteristics of these networks must be considered when evaluating mobile cloud computing systems. Analysis of the network impact is important to ensure that the mobile network technology is able to support an application's Quality of Service (QoS) requirements [5].

D. Energy Considerations

It has been shown that mobile cloud computing can be evaluated in terms of energy considerations [6]. Due to its optimised computing architecture, the cloud uses significantly less energy per computation compared to a mobile device. However, additional energy is required for communication between the device and cloud. In the energy domain, this interdependency between computing and communication leads to a dynamic optimum balance between performing computations on-device or offloading them to the cloud [6].

E. Information Security

Security is an important aspect of mobile cloud computing because of the transfer of data over a non-private network. For applications involving sensitive information, the appropriate security services must be used during both the data transfer as well as the processing and/or storage in the cloud [7]. The use of existing cryptographic techniques increases the computational and energy requirements of the system.

F. System Reliability

The overall reliability of this technology is limited by the reliability characteristics of the constituent subsystems. In applications with strict reliability specifications, any mobile cloud computing system can only utilise network and cloud services which provide sufficient reliability guarantees.

G. Application Usability

Due to physical size constraints, the user interface of the mobile device could become a limiting factor. Depending on the application, the input and output capabilities could be limited by the device's small keypad and screen size [8]. It would not be beneficial to increase the computational capabilities beyond this user interface performance ceiling. However, the use of peripherals such as sensors or external displays could remove these limitations.

IV. Enhanced Mobile Application Domains

From initial investigation, it is proposed that various application domains could benefit from mobile cloud computing. These include scientific computing, multimedia processing, eHealth, entertainment and gaming. Two such domains are briefly analysed to demonstrate the use of this framework.

A. Mobile eHealth Applications

Certain mobile eHealth applications involve the connection of physiological sensors to a mobile device [7]. The computational requirements of these applications are high due to the processing of a relatively large amount of sensor data. However, the results are not highly time-sensitive and so will not be affected by the latency of the mobile network. If a remote cloud resource were to be used, additional security measures would be required since the data contains sensitive medical information [7]. Depending on the exact application, reliability concerns may also have to be addressed. Even though the cloud-device communication and additional security measures would consume some energy, it is likely that the use of mobile cloud computing would still reduce the overall energy consumption and increase the performance of this type of computationally intensive application.

B. Mobile Entertainment and Gaming

Graphically intensive mobile games also demonstrate high computational requirements which can very often be parallelised [4]. Although data security is not critical in this application, communication requirements become important because the network must be capable of supporting the high speed transfer of graphical data. However, the size and resolution of the mobile device's screen will limit the maximum graphical quality of the game. Significant energy reductions could also be achieved in this domain.

V. Conclusion

Mobile devices are becoming both computing tools as well as communications devices. In order to support this user requirement, the computational capabilities of mobile devices can be enhanced through the use of mobile cloud computing. An analysis framework for the development of this technology is proposed. This framework identifies and defines seven important aspects which must be considered in the analysis of applications and implementation approaches of mobile cloud computing. These aspects include computational and communication requirements, mobile network impact, energy considerations, information security, system reliability and application usability. Mobile eHealth and gaming examples demonstrate the use of this analysis framework in analysing applications of mobile cloud computing.

References

[1] Q. Liu, X. Jian, J. Hu, H. Zhao, and S. Zhang, "An Optimized Solution for Mobile Environment Using Mobile Cloud Computing," in *Wireless Communications, Networking and Mobile Computing, 2009. WiCom '09. 5th International Conference on*, 2009, pp. 1–5.

[2] ITU World Telecommunication/ICT Indicators Database, "Global ICT developments, 2000-2010." [Online] Available: http://www.itu.int/ITU-D/ict/statistics/

[3] IDC, "Worldwide and U.S. Mobile Applications, Storefronts, and Developer 20102014 Forecast and Year-End 2010 Vendor Shares: The Appification of Everything," Dec. 2010. [Online] Available: http://www.idc.com/getdoc.jsp?containerId=225668

[4] X. Luo, "From Augmented Reality to Augmented Computing: A Look at Cloud-Mobile Convergence," in *Ubiquitous Virtual Reality, 2009. ISUVR '09. International Symposium on*, 2009, pp. 29–32.

[5] M. Satyanarayanan, P. Bahl, R. Cáceres, and N. Davies, "The Case for VM-Based Cloudlets in Mobile Computing," *IEEE Pervasive Computing*, vol. 8, no. 4, pp. 14–23, Oct. 2009.

[6] K. Kumar and Y.-H. Lu, "Cloud Computing for Mobile Users: Can Offloading Computation Save Energy?" *Computer*, vol. 43, no. 4, pp. 51–56, Apr. 2010.

[7] M. Nkosi and F. Mekuria, "Cloud Computing for Enhanced Mobile Health Applications," in *Cloud Computing Technology and Science (CloudCom), 2010 IEEE Second International Conference on*, Dec. 2010, pp. 629–633.

[8] L. Chittaro, "Visualizing Information on Mobile Devices," *Computer*, vol. 39, no. 3, pp. 40–45, Mar. 2006.

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