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A Survey of Adaptation Techniques in Computation Offloading

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Abstract

Computation offloading is a method of saving energy and time on resource-constrained mobile devices by executing some tasks on the cloud. A computation offloading mechanism determines portions of the application that can be offloaded for remote execution. The offloading decision problem depends on various parameters, like application characteristics, network conditions, hardware features, that influence the operating environment of an offloading system. Variations in these parameter values make it challenging to design effective offloading solutions that can adapt gracefully to all the changes. Hence a number of work has focused on offloading solutions that can adapt to changes in the parameter values. In this paper, we survey adaptation techniques used by offloading systems. We provide a panoptic view of the task offloading problem by identifying the variable parameters in the offloading ecosystem, present offloading solutions that adapt to these parameters, and point out the associated improvements in Quality of Experience of users.

Keywords: Mobile Cloud Computing, Application Offloading, Distributed Systems, Smartphones, Adaptive offloading

1. Introduction

Computation offloading involves partitioning power-hungry mobile applications to utilize remote cloud resources. An offloading framework identifies portions of code that are profiled to be computation and energy intensive to execute on cloud servers. The benefits of offloading to save energy on mobile devices has been demonstrated in several prototype systems [31, 29, 60]. However, computation offloading is yet to be in mainstream use on mobile devices [14] [44].

One of the challenges towards practical use of computation offloading is the unpredictable operating environment. There are several sources of variation due to application characteristics, network conditions and platform differences. The unstable bandwidth of wireless networks can hurt the gains derived from using offloading. Similarly, diversity in application workload on the device, or on the cloud servers can diminish the potential gains from offloading.

At the core of it, the problem lies in how the task offloading mechanism selects the tasks for remote execution. If the offloading decision cannot factor in variations in the operating environment, it can lead to poor performance. Several recent works have explored offloading techniques that can adapt at run-time to changes in the operating parameters. Adaptive offloading solutions are complex given the presence of several parameters and their unpredictable variations. Hence the solutions have explored techniques that range from adapting to single parameter to multiple parameters.

In this paper, we survey the state-of-the-art adaptive algorithms used for computation offloading. In order to define the

sources of variation in the operating environment, we describe the entities in a practical mobile-cloud ecosystem. We use this ecosystem to define the parameters that can vary at runtime, and its effect on user experience. We classify the solutions for adaptive offloading based on the parameters that the solution can adapt to. We also present the effect of the parameters on the Quality of Experience metrics suitable for offloading environment, like energy saved, application completion time, monetary cost, and security features.

A number of surveys have studied offloading frameworks from various viewpoints (Table 1). For example, Dinh et al. [34] summarize the overall idea of computation offloading, and discuss its different applications. Shiraz et al. [100] and Sharifi et al. [95] discuss different methods of implementing offloading from smartphones. Abolfazli et al. [2] study the impact of types of cloud resources used on computation offloading. A more recent survey, Sanaei et al. [88], provides a taxonomy of the environment in which offloading is used. Liu et al. [75] focus on the offloading algorithm used by different offloading frameworks. Finally, Shaukat et al. [96] provide a taxonomy of solutions that use cloudlets, which are defined as resource-rich computers in proximity to mobile devices. However, these surveys do not study the adaptation of offloading algorithms to different environmental conditions. Since offloading is known to improve performance of mobile applications, an important factor behind its adoption lies in the way it works in the real environment. Thus, we focus on adaptive offloading techniques aimed at handling changes in the operating environment.

The contributions of this paper are summarized as follows:

- We identify parameters that are prone to variation in a practical mobile cloud ecosystem.
- We discuss adaptation techniques used by offloading frame-

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