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Will Mobile Cloud Gaming Work? Findings on Latency, Energy, and Cost

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***Abstract*—Mobile cloud gaming is a new and promising concept for the cloud-based delivery of video games to mobile devices in a platform-independent manner. In our ongoing work, we examine potential challenges of this service model concerning latency, energy consumption, and cost. The paper outlines our approach and presents initial results, which indicate that mobile cloud gaming could work well in wireless networks, specifically on modern smartphones, but may suffer from latency and cost issues in cellular networks.**

***Keywords*-mobile; cloud; gaming; latency; energy; cost**

I. Introduction

Mobile cloud gaming is situated at the intersection of three major trends in IT: The rapid spread of mobile devices, i. e., smartphones and tablet computers, the increasing delivery of services through the cloud, i. e., large centralized data centers, and the growing interest in interactive entertainment through video games. The essential idea of (mobile) cloud gaming is that video games are centrally executed on high-end servers in a cloud data center and delivered to (mobile) clients as a video stream via the Internet, with the clients serving as simplistic input and playback devices [1].

This new service model offers multiple potential advantages: It reduces the risk for copyright infringement, eliminates the need to adapt games for multiple platforms, and reduces hardware expenditures. However, mobile cloud gaming also poses new challenges:

- *Latency*: Due to the introduction of wireless and cellular networks as delivery medium, mobile cloud gaming could suffer from high latency, which may impair the subjective gaming experience.
- *Energy*: Mobile cloud gaming may reduce battery drain by shifting computational load to the cloud, but also requires constant data transfer, which can be energetically expensive.
- *Cost*: Given that cellular data transfer can be financially expensive, mobile cloud gaming may impose significant cost on the user.

In our ongoing work, we aim to empirically and analytically examine above issue. This work-in-progress paper presents our methodology and first results.

II. Research Approach and Initial Results

A. Latency

In the context of mobile cloud gaming, latency refers to the timespan that passes between a user action, e. g., pressing a button, and the corresponding reaction, e. g., the game character moving. It is a major determinant of the subjective Quality of Experience (QoE) of a video game [1], [2]. Latency comprises of different components, e. g., the latency of the game pipeline, the time required for video stream encoding and decoding, and network latency. With our first experiment, we aimed to quantify the latter with respect to common cellular and wireless networks.

Specifically, we conducted measurements of latencies using three different network connections: ADSL that is accessed via cable-bound LAN, the identical ADSL line being accessed via wireless LAN (WLAN), and cellular UMTS. For the experiments, we launched VM instances in three Amazon EC2 data centers in Ireland, the eastern United States, and Japan. Subsequently, we measured the round-trip times using the tool `TCPing`[1] between these VMs and a client based in Darmstadt, Germany.

The results of our experiments are given in Figure 1. In accordance with expectations, the observed latencies significantly increase with geographical distance, which explains the tendency of cloud gaming providers to construct dedicated data centers close to their potential customers. Between the cable-bound and wireless connection, we found statistically significant, yet small differences in latency around 5 ms. For UMTS, the difference compared to both other connection types is significantly higher and corresponds to about 150 ms. Given that tolerable *overall* latencies in video games have been empirically found to lie in the range between 100 and 150 ms [2], we conclude that the latency of contemporary cellular networks can indeed be problematic for the QoE, and thus acceptance, of mobile cloud gaming.

B. Energy

Given the limitations of today's battery technology, energy consumption is a challenging issue on mobile devices. Mobile cloud gaming promises to shift computational load to cloud data centers, which potentially reduces CPU and GPU battery drain. However, it also requires constant data transmission, which can be costly from the standpoint of energy. Thus, we aimed to assess the energy demands of local and cloud-based mobile gaming in our second experiment.

For this purpose, we measured the mean battery drain of a *Nokia E71i*, *Motorola Backflip*, and *Samsung I9250*

[1]http://www.elifulkerson.com/projects/tcping.php

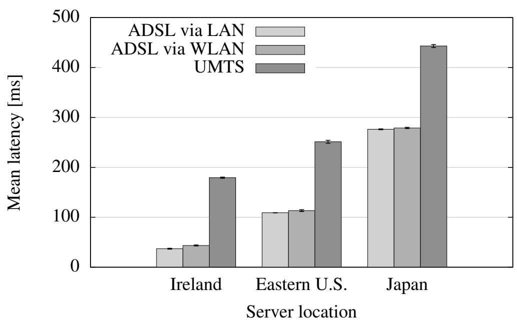

Figure 1: Results for latency (sample size $n = 250$).

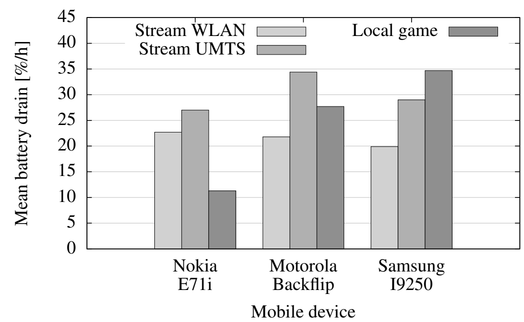

Figure 2: Results for energy consumption.

smartphone in three different application scenarios: Local game execution, WLAN-based video streaming, and UMTS-based video streaming. Because video streaming features two similar energy-intensive tasks, i. e., data transfer and video decoding, it should provide a good approximation for actual mobile cloud gaming. Since all measurements are based on the phones' reported battery levels, they should be seen as a first indication only.

Figure 2 illustrates the results. On the Nokia E71i, both streaming scenarios result in comparable battery drain and consume sizable more energy than a local game execution. In contrast, on the Samsung I9250, we find reversed results, with both streaming scenarios having advantages over a local game execution. On the Motorala Backflip, only the WLAN-based streaming permits reduced energy consumption compared to a local game, whereas UMTS-based streaming results in more battery drain. This indicates that mobile cloud gaming may most likely facilitate energy *savings* on contemporary smartphones (such as the Samsung I9250), where the battery drain of CPU and GPU potentially exceeds that of the wireless or cellular radio modules.

C. Cost

Despite increasing competition and recent regulatory efforts, the cost of cellular data transfer is still comparatively high in many countries, specifically compared to fixed subscriber lines. Mobile cloud gaming requires the constant transmission of a video stream from the provider to the mobile client; thus, we provide a brief analytical assessment of user-side costs in the following.

Assume that the game video stream is encoded using the popular H.264 codec at level 1.3, which allows a resolution of 352×288 pixels at 30 frames per second[2]. Such stream has a bit-rate of to 0.75 Mbit/s in the baseline profile, which corresponds to 337.5 MB of data transfer per hour. Further assuming that the cost of domestic data transfer is 1% of the maximum charge that has been imposed by the European Commission for roaming connections as of 2012[3], i. e., 0.7 cents per MB, the stream incurs cost of approximately 2.36 Euros per hour.

Thus, in comparison to the average sales price of a mobile game in popular app stores, the cost of data transfer is certainly non-negligible. Furthermore, actual cloud gaming offers will most likely come at an additional usage fee, which covers the operational cost of the provider as well.

III. Conclusions and Outlook

Our initial results indicate that mobile cloud gaming may indeed "work" technically and economically if WLAN is used as network connection. It exhibits similar latency as a cable-bound connection, which is an important condition for acceptable QoE in cloud-based gaming. In addition, energy consumption is reasonable in such an application scenario, and data transfer costs are usually negligible due to the prevalence of flat rates.

In contrast, third-generation UMTS cellular networks, which are widely deployed today, exhibit high absolute latencies even for geographically close target hosts. In addition, data transfer fees may easily mitigate the potential advantages of mobile cloud gaming, such as platform independence. With respect to energy consumption, mobile cloud gaming based on UMTS may have slight advantages over a local game execution, at least on contemporary smartphones with powerful hardware.

Our future work will aim at the substantial extension of the experiments. Specifically, we will consider additional mobile devices (e. g., tablet computers) and networks (e. g., LTE), further application scenarios, and examine actual data transfer costs in cellular networks worldwide.

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