

Enabling Mobile Multimedia with the Cloud

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1. Introduction

Mobile Cloud Computing refers to mobile services that use the computing resources and data on the cloud to provide a requested service. A request from a mobile client leads to a process in the cloud that operates on the data in the cloud and the result of this processing is returned to the mobile client. The main reasons for using the cloud to deliver mobile services are lack of sufficient computing and data resources on the mobile client. This cloud computing model works especially well for mobile devices and enables services that are not otherwise possible because of limited computing and communication resources. Cloud computing can also improve the energy performance of mobile applications when computationally intensive tasks are off loaded to the cloud [1].

2. Mobile Cloud Computing

Multimedia applications require significantly more computing, storage, and bandwidth resources and the resource constraints on mobile devices are the main reason for the lack of resource intensive multimedia services on mobile devices

2.1 Computing Constraints

Computing resources increase the cost of the devices and lower-end devices are characterized by limited computing resources. Mobiles with computing constraints can use the cloud for computing needs and available bandwidth affects the types of services offered. Applications such as remote rendering and remote gaming fall into this category.

2.2 Bandwidth Constraints

Bandwidth availability varies with network service availability and costs increase with bandwidth usage. Cloud based services can be used to reduce the bandwidth usage (e.g., video transcoding to lower bitrates) or a mobile device's computing resources can be used to pre-process the data and reduce the outgoing bandwidth needs (e.g, compact feature set instead of an image for a query).

2.3 Latencies

A key factor that affects the services offered is latency. Cloud based services can have higher latencies because of the distributed architecture and the higher latencies impact the services offered. For example, conversational services such as video conferencing are highly sensitive to latencies and hence are not suitable for cloud platforms. Services such as video on demand and broadcasting can hide latencies and can benefit from cloud computing [2].

2.4 Cloudlets

Problems such as high latencies can be addressed using a local cloud that uses the computing available in physical proximity [3]. A typical home environment has high bandwidth wireless connectivity and significant computing resources available in home devices such as PCs, game consoles, TVs, and entertainment units. These resources in the immediate proximity can be exploited to provide rich services to mobile users.

3. Mobile Cloud Computing Applications

Cloud based services are usually offered to enhance the mobile user experience and enable services that are otherwise not possible on mobile devices. In this section we present mobile cloud computing problems we have been working on and discuss the key problems and solutions.

3.1 Remote Gaming

Games are one of the most common applications on mobile devices. Complex games require powerful CPUs and dedicated graphics processing unit (GPU) to accelerate 3D graphics rendering. Resource constrained nature of mobile devices limits mobile devices from playing sophisticated games on such platforms. Gaming can be enabled on resource constrained mobile devices by offloading the computing tasks to the cloud.

We have developed a remote gaming platform where games are rendered on a server and the graphics updated by the game play are encoded as a video stream and streamed to a mobile device. The mobile device only needs computing resources to play the video and capture user interactions and sufficient bandwidth to enable game play without interruptions. Figure 1 shows the architecture of the proposed remote gaming platform. The user interactions are captured at the receiver/mobile device and

transmitted to the server where the game play is advanced and graphics updated. High bandwidth and low latency is critical to uninterrupted game play. We studied the impact of latency and developed solutions to hide part of the latencies by controlling the gaming environment [4]. Lower bandwidth is not as a big a problem as high latencies. Bandwidth usage can be decreased by reducing the video bitrate and using content aware encoding solutions.

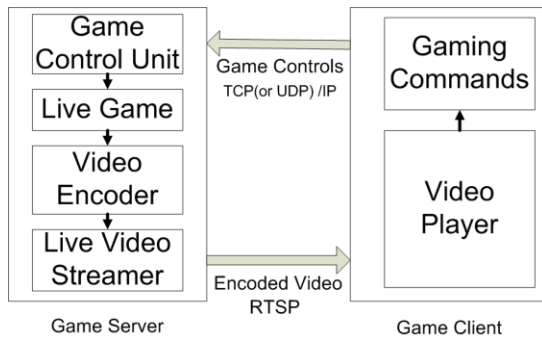


Figure 1. Remote gaming platform

3.2 Remote Rendering

Remote rendering, as in the case of remote gaming, uses cloud based rendering along with video streaming to enable compute intensive visualization applications. This instance of the cloud computing problem is compute constrained as scientific visualization has large data and compute requirements.

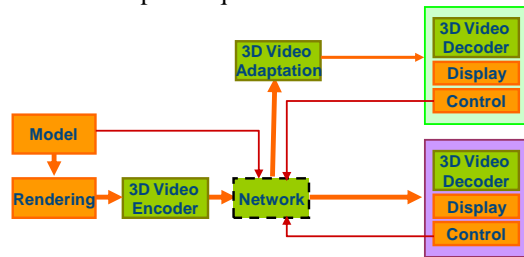


Figure 2. Remote rendering for data visualization

To enable this application on mobile devices, the rendering task is offloaded to a cloud and rendering is done on nodes that are close to the data storage. The rendered views are encoded as a video stream and streamed to the mobile device. A video stream is used to show continuous response to user interaction. Since the application is interactive data visualization, latency is not a significant problem as response times in visualization are much slower than the case of gaming. In our proposed solution, left and right views of rendered 3D volumes are encoded as a 3D video stream and streamed to

the receiver [5]. Figure 2 shows the key components of the proposed solution. The bitrates of the coded video are kept at 500 Kbps and give very good quality due to low frame rate necessary to view the rendered models.

3.3 Distributed Transcoding in the Cloud

When available bandwidth is a constraint that needs to be addressed, cloud computing can play a key role in repurposing content to fit the available bandwidth for the mobile device. Distributed processing frameworks such as Hadoop can be used to quickly develop services on the cloud. We evaluated the performance of Hadoop based distributed systems for video transcoding. The goal is to transcode video to meet the bandwidth availability of a mobile device. This solution works well for on-demand services as a video can be segmented into chunks that are transcoded independently. A set of chunks can be assigned for processing on each node of the Hadoop cluster for a faster turnaround. Recent developments such as adaptive streaming over HTTP are based on the principle of segment videos into independent chunks that are adapted for mobile needs. We show that a Hadoop solution can increase the performance of video delivery services [2].

3.4 Cloud-based Mobile Visual Search

Visual search and augmented reality applications are becoming prevalent on mobile platforms [6]. These augmented reality services search and overlay information over images and video captured by the mobile phone camera. A typical scenario is a tourist using his/her mobile phone to point, click and identify names and history of buildings around him/her.

Applications of mobile visual search have received significant industry interest and this has resulted in a recent MPEG standards activity called the Compact Descriptor Visual Search (CDVS) [7]. CDVS aims to ensure interoperability of visual search applications and databases, among others. The Call-for-Proposals (CfP) has been issued during the 97th MPEG meeting in Turin, Italy in July 2011 with planned evaluation of proposals to start in November, 2011.

Visual search on mobile platform imposes certain requirements on latency, processing, bandwidth and robust performance. Mobile devices have limited memory, processing power and battery life so the retrieval framework has to adapt to these stringent mobile system requirements. The computation on the mobile device has to be fast to achieve low power consumption. The descriptor size has to be small and compact to reduce transmission latency. The

algorithms should be robust to allow objects to be recognized accurately under various conditions such as different viewing angles, lighting conditions, or when there are partial occlusions or blurred motion.

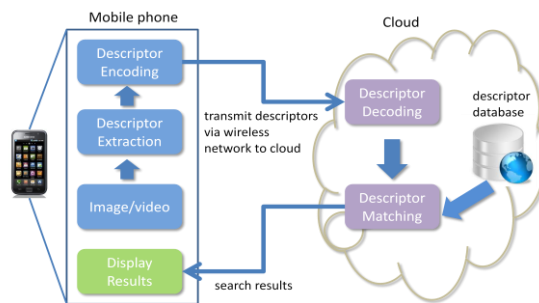


Figure 3. Cloud-based Mobile Visual Search

By deploying mobile visual search at the cloud, a few of these challenges can be alleviated. Figure 3 shows one of the possible client-server architecture supporting mobile visual search in the cloud. The process involves first extracting descriptors of images/video captured by the mobile phone camera. The descriptors are features used to uniquely identify the visual content. These query descriptors are then compressed/encoded and transmitted to the cloud where they are compared against descriptors of images/video stored in the cloud database during the descriptor matching process. The image/video of the closest matching descriptor in the database is then selected.

As shown in the diagram, the computation involved in matching query descriptors of images/video with the candidate descriptors in the reference database is offloaded to the cloud by leveraging the relatively higher power and processing resource at the cloud. However, feature extraction, especially of query image/video still has to be performed at the mobile device and the challenges of achieving a good tradeoff between compact descriptor size (to reduce bitrate and latency) and accuracy of object recognition and robust performance remains. Alternatively, when bandwidth is available, the captured image or video clip can be sent to the cloud for feature extraction and search.

4. Conclusion

We presented an overview of mobile cloud

computing. Cloud computing is expected to become integral part of mobile services; especially for resource intensive multimedia services. Offloading computing to the cloud allows service providers to offer services that do not heavily rely on the receiver resources. Cloud computing can be used to address the computing and/or bandwidth constraints on mobile devices. Examples from our recent and ongoing research activities are presented. The remote rendering ideas presented enable multimedia services on resource constrained devices and have many applications. This solution works well when there is bandwidth availability and computing is the main constraint. Migrating mobile visual search to a cloud-based environment may alleviate resource issues for intensive search and matching operations, however many challenges still remain. It is anticipated that the emerging standardization efforts of CDVS will encourage development and standardization of the best possible solution and further increase both the research community's and the industry's interest in this area.

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