DESIGN ISSUES FOR MULTIMEDIA INFORMATION SERVERS IN MOBILE COMPUTING ENVIRONMENT

Jinsung Cho and Heonshik Shin
Department of Computer Engineering
Seoul National University
Seoul 151-742, Korea
Email: {cjs,shinhs}@comp.snu.ac.kr Fax: +82-2-874-3104

Abstract

In the near future a large number of clients carrying portable multimedia terminal will access multimedia information over wireless links. The realization of such services requires the development of multimedia information servers that provide multimedia streams for mobile clients. In this paper, we identify the new requirements of multimedia information servers in mobile computing environment. For the purpose of satisfying the requirements, a novel multi-resolution stream layout is proposed in our disk array model. Our scheme effectively adapts to the low and fluctuant network bandwidth of mobile computing environment. We also present a logical architecture of mobile multimedia information server suitable for the proposed scheme and other considerations in mobile computing environment.

1 Introduction

Recent advances in computer technology and demands of video, audio, and text integration services have provided driving forces behind the emergence of various multimedia information services. The realization of such services requires the development of *multimedia information servers* that support efficient mechanisms for storing and delivering multimedia streams. The fundamental problem in developing multimedia servers[1] is that the delivery and playback of multimedia streams must be performed at real-time rates[1]. Recent researches on multimedia servers are focused on guaranteed retrieval and delivery of continuous media such as video and audio[2], data distribution and disk scheduling for high throughput of storage subsystem[3], efficient buffer management[4], admission control and QoS management for deterministic service guarantee[5], and scalable server architecture and scheduling in parallel or distributed environment[6, 7]. However, they assume that clients are connected to the server by fixed high-speed network capable of delivering the required bandwidth of multimedia streams.

[1]In this paper, the terms multimedia information server and multimedia server are used interchangeably.

Another advances in personal computer hardware and wireless communication technologies have introduced a new computing environment, or *mobile computing environment*[8, 9]. In the future mobile computing environment, a large number of clients carrying low-power palm-top machine will access multimedia information over wireless links anywhere and at any time[10]. The anticipated applications and services in mobile computing environment will include personalized information, travel information, electronic magazines, shopping, and electronic mail services[11]. It is taken for granted that an important and challenging area of mobile computing is the design of the server for providing mobile clients with multimedia information services.

In this paper, we aim to design a mobile multimedia information server based on the characteristics of mobile computing environment. First, its new requirements are described. In order to fulfill the requirements, a novel multi-resolution stream layout is proposed in our disk array model. Our scheme well adapts to the low and fluctuant network bandwidth of mobile computing environment. We also present a logical architecture of mobile multimedia information server suitable for the proposed scheme and other considerations in mobile computing environment.

The remainder of this paper is organized as follows: Section 2 describes the characteristics of mobile computing environment and specifies the impact of its characteristics on multimedia servers. In Section 3, we design a mobile multimedia information server by presenting a multi-resolution stream layout and a logical architecture, and Section 4 concludes this paper.

2 Impact of mobility on multimedia information servers

Characteristics of mobile computing environment are due to the wireless medium and mobile hosts. The former is characterized by low bandwidth, frequent disconnections, and high bandwidth variability and the latter by limited computing power, small screen and size, and limited battery life[8, 9]. Considering these characteristics given above, we must cope with many challenging

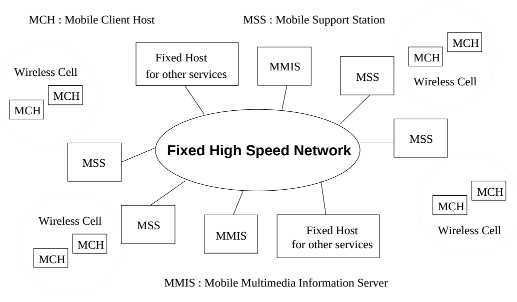


Figure 1: System model of typical mobile information services

problems when we attempt to design multimedia servers in mobile computing environment. Since most existing multimedia servers have been designed for fixed clients, providing multimedia services for mobile clients involves modifying the server architecture to accommodate the constraints induced by mobile clients.

First, we begin by introducing a system model of typical mobile information services (see Figure 1). In Figure 1, *mobile support stations* (MSSs) are fixed hosts and equipped with wireless interface. A MSS serves as a gateway between wired and wireless medium and covers the designated *wireless cell* area. A *mobile client host* (MCH) is a portable multimedia terminal that can move while retaining its network connections through wireless communication. Via MSSs, MCHs access services from *mobile multimedia information server* (MMIS) over the high-speed communications backbone. MMIS can be distributed or duplicated geographically. In addition, MMISs will provide application software, so that a mobile client can download the software via a MSS which covers the area where the mobile client exists and run it on MCH. While data delivery over wired and wireless network and location management of mobile clients are in charge of the underlying communications system, we will focus on the design of MMIS in this paper.

In multimedia information systems, continuous media (especially video) is probably the most demanding data type because of its large data size and strict timing constraints. Although network bandwidth is relatively low in mobile computing environment, multimedia streams must be continuously presented and synchronized. Besides continuous and synchronized playback of multimedia streams, we identify the following requirements that should be met in designing a MMIS:

- *QoS management of multimedia streams.* Each MCH is connected to the system with available network bandwidth, depending on whether it is plugged in or using wireless access and on the type of connection at its current cell. In addition, MCHs have different capabilities in manipulating video streams, such as color depth, window size, and frame rate. Hence, clients are likely to request various qualities even for the same video stream. MMIS should effectively manage the variable QoS level of multimedia streams.

- *Adaptability to high bandwidth variability.* Fluctuation in network bandwidth is one of the most fundamental problems in the field of mobile computing. Furthermore, wireless networks have higher error rates and are prone to frequent disconnections which result from communication failure, battery limitations, and voluntary disconnections. MMIS should detect the variation of bandwidth and be able to adapt to currently available resources, providing clients with gracefully degraded quality.

- *Support for interactive operations.* In mobile information services, interactive operations (e.g., pause, resume, reverse, rewind, and fastforward) are far more important than static services like VOD. Clients are likely to pause or rewind for more detailed information and to search streams for required information via fastforward. MMIS should support these operations without additional cost such as disk and network bandwidth.

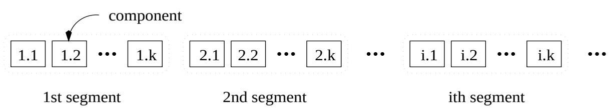


Figure 2: k-level multi-resolution video stream model

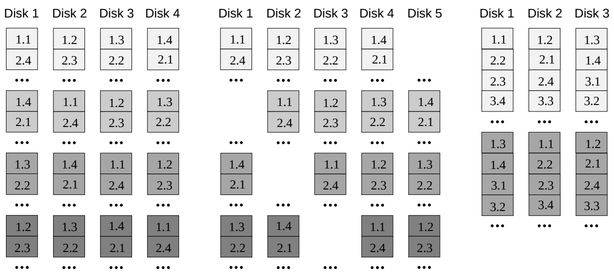
3 Design of MMIS

The most demanding resources in traditional multimedia servers are I/O (disk and network) bandwidth and memory. Most existing works on multimedia servers distribute video streams across multiple disks for high degree of parallelism and consider the effective management of disk bandwidth. This is because the bandwidth of disk subsystem is relatively smaller than that of network in static environment. In mobile computing environment, however, a network subsystem has far lower bandwidth; so, the design issues of MMIS should be focused on the requirements described in Section 2 rather than the effective management of disk bandwidth.

In [12, 13], the concept of multi-resolution coding of video streams is introduced. They integrated the multi-resolution data with high bandwidth storage provided by disk arrays to support high I/O rate and small waiting time. Based on the notion of multi-resolution video, we propose a video layout scheme to satisfy the requirements of MMIS in the next subsection.

3.1 Multi-resolution video layout

In the literature the notion of video resolution is defined in three dimensions: chroma, spatial, and temporal. In these dimensions, video streams can be compressed into multi-resolution format. We consider multi-resolution video streams created by a scalable compres-



(a) $k = d$ (b) $k < d$ (c) $k > d$

Figure 3: Multi-resolution video layout

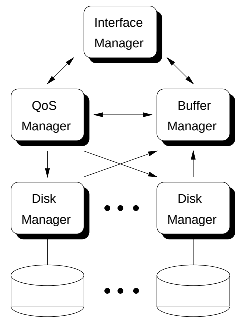


Figure 4: Logical architecture for the proposed MMIS

sion algorithm but do not assume the specific compression algorithm. Figure 2 depicts a k-level multi-resolution video stream we consider, where a segment consists of k components and can be one or more frames. The jth level resolution can be obtained by integrating j components from the lowest one. In our multi-resolution stream model, each video stream can be provided in k-level of quality and the QoS parameter is represented by the number of components in a segment. All the components constitute the full resolution quality.

Multi-resolution video streams given in Figure 2 are striped across disk arrays as shown in Figure 3, where d denotes the number of disks. While the striping unit is a component, successive components of a stream are placed on consecutive disks in a zig-zag pattern, as shown in Figure 3. When video streams are allocated to multiple disks, we must consider the load balance among disks. Our zig-zag multi-resolution video layout allows deterministic access to disks, which is the most important characteristic for the continuity requirement of video streams, and achieves the disk load balance while providing a variable level of QoS. For the service of the first stream (the least shaded one) in Figure 3(a) with the second level resolution, for example, the first segment is retrieved from disk 1 and 2 (components 1.1 and 1.2, respectively) and the second from disk 3 and 4 (components 2.1 and 2.2). In addition, we distribute the starting point of each stream (distinguished by the shade in Figure 3) for the disk load balancing when multiple streams are requested concurrently.

If the number of disks is equal to the QoS level, or $k = d$, as in the case in Figure 3(a), our layout scheme is straightforward. When $k < d$, a video stream is allocated to only k disks as shown in Figure 3(b). Figure 3(c) presents the case that is expected to be rare, that is, $k > d$. However, all the cases have the same properties described above. On the other hand, considering the scale of the system, our disk array model can be implemented either in a single computer equipped with multiple disks or in parallel or distributed environment which consists of multiple nodes.

We now describe how our layout scheme fulfills the requirements of MMIS identified in Section 2.

- *QoS management of multimedia streams.* Our scheme handles a various level of QoS for each video stream. For each QoS request of video streams, our MMIS is only to calculate the required QoS parameter in our multi-resolution video model. Based on the value, the requested resolution of services proceed.

- *Adaptability to high bandwidth variability.* First of all, MMIS should be able to detect changes in bandwidth of connections with MCHs. Furthermore, if necessary, MMIS notifies the changed information to MCH. Our MMIS can adapt to the network bandwidth variability by recalculating QoS parameters. QoS changes from the negotiation with clients also can be accomplished without any overhead.

- *Support for interactive operations.* We are not concerned with operations like pause and resume because they do not require additional disk and network bandwidth. MMIS should be able to support rewind and fastforward operations within the given bandwidth. In our layout scheme, by degrading QoS of the requested stream, fastforward and rewind can be accomplished. For example, let us assume that a fastforward operation is requested to a video stream with the forth level resolution. If we lower the QoS level to the second level, two times fastforward is possible without any additional disk and network bandwidth. For the case of low level QoS where it is impossible to degrade the level, a segment skipping scheme similar to [14] can be integrated with our scheme.

3.2 Logical architecture of MMIS

In general, mobile applications have the following properties that we should contemplate in designing MMIS: (1) short period of connections and (2) shared medium for broadcast. Unlike static services such as VOD, in mobile information services, multimedia streams are expected to have relatively short durations and thus small data sizes. It is possible to handle the whole data in main memory rather than in secondary storage. MMIS needs to keep track of the access frequency of multimedia streams, employing an effective buffer management scheme. In addition, by broadcasting frequently accessed streams periodically over wireless network, we can save disk and network bandwidth.

In Figure 4, we propose the logical architecture of our MMIS considered for the multi-resolution video layout and the properties of mobile applications given above. As shown in Figure 4, our MMIS consists of 4 managers with different functions, which are as follows:

- *Interface manager.* The main function of the interface manager is to communicate with MCH. It handles requests from MCHs and delivers the requested data to MCHs. Another function is to keep track of the available network bandwidth between MMIS and MCHs.

- *QoS manager.* Requests analyzed by the interface manager are passed to the QoS manager. It calculates QoS parameters for the desired resolution and adjusts them to the proper values when changes in QoS occur. It also creates schedules for each disk manager unless the requested data exist in buffer cache. Another important function of the QoS manager is an admission control in terms of disk and network bandwidth.

- *Buffer manager.* It allocates available buffers to disk managers. An efficient replacement scheme similar to LRU is required for frequently accessed streams.

- *Disk manager.* From the schedule generated by the QoS manager, the disk manager retrieves data blocks from the disk. Its performance can be improved by disk head scheduling. A disk manager exists per disk in our disk array model.

4 Conclusions

In this paper, we have specified the new requirements of multimedia information servers in mobile computing environment and presented a multi-resolution stream layout scheme under our disk array model. The proposed scheme fulfills the specified requirements. We also suggested a logical architecture of mobile multimedia information server to be considered for our layout scheme and other properties of mobile applications.

The following problems remain to be addressed in the future: (1) formal proof of optimality of the proposed scheme in terms of the load balance of disks including analytic studies, (2) buffer management to improve the system throughput, and (3) experiment on the performance.

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