International Journal of Mathematical Archive-2(11), 2011, Page: 2456-2461
Available online through www.ijma.info ISSN 2229 – 5046

P2P MEDIA STREAMING IN MOBILE ENVIRONMENT

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(Received on: 25-10-11; Accepted on: 09-11-11)

ABSTRACT

Multimedia information services in mobile environments are becoming more and more important with the proliferation of 3G technologies. Media streaming, in particular, is a promising technology for providing services such as news clips, live sports, and hot movies on the fly. To avoid service interruption when the users keep moving, proper data management strategies must be employed. We propose a new headlight prefetching technique for the streaming access points to deal with the uncertainty of client movement and the requirement of seamless service hand-off. For each mobile client, we maintain a virtual fan-shaped prefetching zone along the direction of movement similar to the headlight of a moving vehicle. The overlapping area and the accumulated virtual illuminance of the headlight zone on a particular cell determine the degree and volume of prefetching to be made by the streaming access point of that cell. Headlight prefetching solves the issues of identifying the streaming access points responsible for prefetching, the timing and the amount of data to prefetch in a single mechanism which is simple and effective. Simulation results demonstrate that our techniques can significantly decrease streaming disruptions, reduce bandwidth consumption, increase cache utilization and improve service response time.

Keywords - *Media streaming, prefetching, mobile data management.*

1. INTRODUCTION:

Media streaming is a promising technology for providing multimedia information services such as news clips, live sports, and hot movies in mobile environments. Effective data management for media streaming is naturally the key to the successfulness of such services. Since many users may request the same media (hot media), traditional client-server model can easily result in server bottleneck, bandwidth waste, poor cache utilization and longer delay.

Furthermore, the mobility of mobile users raise the issue of seamless service hand-off. To avoid service interruption, proper data management strategies must be employed. In this paper, we propose a new technique named *headlight prefetching* for media streaming in mobile environments. The technique is designed for the streaming access points to deal with the uncertainty of client movement, the unpredictability of request pattern and the requirement of seamless service hand-off. For each mobile client, we maintain a virtual fan-shaped prefetching zone along the direction of movement similar to the headlight of a moving vehicle. The overlapping area and the accumulated virtual illuminance of the headlight zone on a particular cell determines the degree and volume of prefetching to be made by the streaming access point of that cell. When a mobile user makes an unexpected sharp turn, the *headlight shifting* technique is used such that all the previously prefetched media segments can be easily shifted to accommodate the new direction of movement. For users requesting the same media at around the same time, the *headlight sharing* technique is developed for sharing the headlight zones to avoid repeated prefetching.

The set of techniques solve the issues of identifying the streaming access points responsible for prefetching, the timing and the amount of data to prefetch in a single mechanism which is simple, intuitively appealing and effective. To evaluate the effectiveness of our techniques, we construct a Java-based simulation environment and compare the performance of different combinations of our schemes with on-demand techniques.

Simulation results demonstrate that, for streaming media services in mobile environments, headlight prefetching, shifting and sharing are simple and effective techniques which can significantly decrease streaming disruptions, reduce bandwidth consumption, increase cache utilization and improve service response time.

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The rest of the paper is organized as follows. Section 2 provides a survey of related issues and research work. Section 3 presents the media streaming system infrastructure we assume and characterize the challenges of dynamic data management in such environments. Section 4 introduces the idea of headlight prefetching and the associated data management techniques. In Section 5, we outline the simulation environment for experimenting with our ideas and present the results of performance evaluation on different aspects of the prefetching techniques. Section 6 concludes the paper.

2. RELATED WORK:

With the proliferation of 3G technologies, the integration of cellular and broadcast networks, and the rapid advances of the capabilities of handheld devices, mobile multimedia services such as live news, sports events, hot movies or even TV broadcast to mobile phones and PDAs are becoming more and more feasible and attractive to an estimated over 2 billion customers worldwide. New services and standards such as MBMS [2], DVB family(DVB-H in particular) [3, 13], BCMCS [13] and MediaFLO [5], etc., are all striving to satisfy the ever stronger demand of mobile users on up to date multimedia contents and entertainment. Seamless media streaming in mobile environments plays the key role in such services since most of them are provided in the form of streaming media.

Traditional media streaming are mostly focused on wired networks such as Internet [7, 8, 11, 14]. Media streaming in mobile environments has been attracting much attention lately. Fitzek and Reisslein propose a real-time continuous media streaming protocol with special emphasis on dynamic transmission capacity allocation and prefetching [4]. Li and Wang develop NonStop [10] which is a set of middleware-based run-time algorithms with partition prediction and service replication for continuous media streaming in mobile and ad hoc networks. Anastasi et al. look further into the problem of energy efficiency when providing streaming media services to mobile clients [1]. Xue et al. explore group mobility to predict the future availability of wireless links for increasing total streaming capacity with P2P streaming [15]. Qin et al. propose an iterative algorithm to predict continuous link availability between two mobile peers [12]. The V3 architecture proposed by Guo et al. for live video streaming is essentially a P2P streaming architecture for moving vehicles [6]. Kyriakidou et al. discuss streaming architecture, content distribution and rate adaptation algorithms for video streaming to fast moving users in 3G networks [9]. Zhai et al. propose buffer management methods that employ statistical analysis to predict the trend of user movement among cells [16]. The problem we face is challenging in that we must deal with the uncertainty of client movement, the unpredictability of request pattern and the requirement of seamless service hand-off with a simple and unified mechanism. The set of headlight prefetching techniques we proposed can effectively cope with the dynamics of mobile environments to provide effective streaming media services.

3. STREAMING MEDIA SERVICE ARCHITECTURE:

For media streaming services in mobile environments, we assume system architecture as depicted in Figure 1. The multimedia information are provided by *streaming media servers* (SMSs). All cells have corresponding *streaming access points* (SAPs) connected with each other through traditional fixed link networks. Each SAP provides wireless media services for *mobile users* within that cell. Users not reachable from any SAP are *disconnected*.

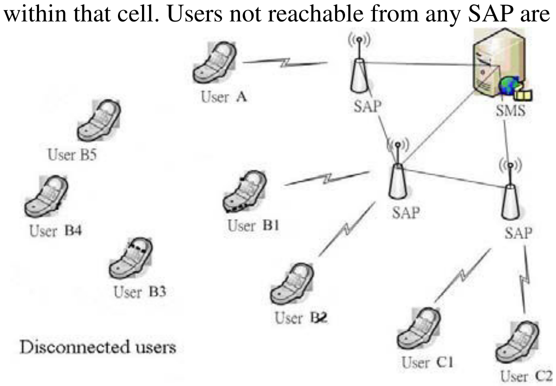

Figure 1: System architecture for mobile streaming service.

In general, let the local wireless access cost between a mobile user and an SAP be L, and the remote access cost of requesting the unit from an SMS be R. Then, based on the nature of the architecture and service charge, we assume that L is larger than R since wireless access cost is usually larger than that of fixed link. However, if a media segment is available locally on an SAP, then it only takes a local access cost of L to service the segment. If the segment is not available on the SAP cache, then a remote access cost of R must be added in addition to the local access cost. Therefore, a remote access is always more expensive than a local access. Since intermittent disconnection is unavoidable in mobile environments, effective data management strategies must be employed to conserve access cost and reduce play interruption.

A streaming media is usually considered as a sequence of media segments. Because of the streaming nature, it is not necessary to provide the entire media all at once. A media request from a mobile client can therefore be treated as the starting request of a sequence of media segments. There are several data management challenges for streaming media services in mobile environments:

- A mobile user can request any media from any location at any time. On a request, the SAP of the cell where the user resides must locate and send the first segment as soon as possible to reduce service delay.

- Once started, the SAP must fetch and transmit the subsequent segments fast enough to catch up with the playing speed. Good prefetching and buffering techniques are required to avoid possible interruption.

- A mobile user can move and change direction at any time. Such a dynamism can only be handled by close coordination of neighboring SAPs to provide seamless streaming media services across cell boundaries.

- To reduce cost, the media segments should be served on a proximity basis. In other words, it is best to use the local SAP or to locate a nearby SAP with the requested segments to provide the service. The remote access to the SMS should only be used as a last resort.

Our goal is to develop effective dynamic data management techniques to answer the challenges of streaming media services in mobile environments. In particular, the headlight prefetching and associated techniques are designed to solve the problems of identifying responsible SAPs, determining prefetching segment assignment and handling the dynamic data management issues in a simple and unified framework. Our schemes are unique in several respects:

- The idea of virtual fan-shaped headlight prefetching zone is simple, intuitive appealing and efficient. We can use the headlight coverage area to identify the prefetching SAPs and the virtual illuminance to determine the lookahead window for each SAP. Both are straightforward and easy to compute.

- Headlight prefetching is flexible and dynamic adjustable. We can use the shape and size of the virtual fan to control the range and degree of prefetching. For mostly straight and fast moving users (eg. vehicles on a freeway, passengers on a train ...), we can have a smaller central angle and longer radius.

- For slow moving clients that tend to wonder around, a larger central angle and smaller radius allow more neighboring SAPs to be prepared for serving the clients.

- Should a mobile user make an unexpected sharp turn, we provide the *headlight shifting* technique such that all the previously prefetched segments can be easily shifted to the SAPs along the new direction.

- To efficiently reuse prefetched segments, the *headlight sharing* technique is developed to coordinate neighboring SAPs on media services and to avoid repeated segment prefetching.

As a summary, streaming media services in mobile environments entail significant challenges on highly dynamic and efficient data management. The mobile and streaming characteristics of the services also provide a window of opportunity for information system designers. We take on this opportunity to provide simple and effective dynamic data management techniques that adhere closely to the movement patterns of mobile users. It turns out that high quality streaming media services in mobile environments can indeed be achieved with proper coordinations of SAPs and right strategies for data management.

4. HEADLIGHT PREFETCHING:

As stated earlier, an important characteristic of streaming media is the continuous playing requirement. Once a media is started, the requesting user expects a smooth and seamless viewing experience. Fetching a segment upon its request is not likely to catch up with the playing speed. Prefetching and buffering are almost a must in such case. Traditional prefetching is simply done by maintaining a sliding window immediately ahead of the current segment by the SAP in charge of the media service. This is only satisfactory when the user is moving in a straight ahead pattern. For irregular moving patterns, the traditional approach may fail miserably. The problem is that if the user changes direction and moves toward a new SAP, the later may not have anything prepared for the user. The uncertainty of user movement can easily result in frequent disruption and unpleasant viewing experience. To have all surrounding SAPs prefetch the needed segments for the user is clearly not cost effective.

We therefore need a good mechanism to continuously identify the proper set of prefetching SAPs for a moving client. Those SAPs that are more likely to be visited next should be selected with higher probability. Even if the set of prefetching SAPs is successfully identified, we still have another important problem of determining the right media segments for each SAP to prefetch. The simplest approach of having all selected SAPs prefetch the same set of media segments is certainly not satisfactory. To save processing and communication costs, the ideal case is to prefetch just the segments needed to keep the media viewing smooth. Similar to the previous issue, we need to cope with the uncertainty of user's moving speed and pattern by dynamically determining the prefetching segments assignment. Those SAPs that are more likely to be visited next should be assigned more segments to prefetch. In addition to the prefetching SAPs identification and segment assignment problems, we also need to determine the right timing for the SAPs to start or stop prefetching. Otherwise the prefetched segments may either arrive too early or too late. The idea of headlight prefetching is to have a simple and unified mechanism for solving the issues discussed above. A *headlight prefetching zone* as depicted in Figure 2 is a virtual fan-shaped area along the direction of user movement similar to the headlight of a moving vehicle. All SAPs of the cells touched by the headlight zone are selected as the prefetching SAPs for the user. The overlapping area and the accumulated virtual illuminance of the head light zone on a particular cell determines the degree and volume of prefetching to be made by the SAP of the cell. Headlight prefetching solves the issues of prefetching SAPs identification, segment assignment and the prefetch timing in a single mechanism which is simple and intuitive appealing. The headlight prefetching zone is modeled by two parameters as illustrated in Figure 3. The radius *r* determines the extent of look ahead for prefetching. The angle θ is used to control the span of coverage. Both are dynamically adjustable. In general, faster moving users need longer radiuses. Users that tend to wonder around need larger θs to have more SAPs ready to carry on the services when a user changes direction unexpectedly. The headlight zone serves as a prediction of possible future interaction of the user with neighboring cells. By using such a simple and intuitive appealing metaphor, we can easily identify the set of SAPs that need to prefetch media segments for the user.

Once the prefetching SAPs identification problem is solved, we still need to take on the segment assignment problem. The headlight metaphor gives us yet another simple way to handle this problem. A basic characteristic of a vehicle headlight is that the farther away from the vehicle the lower the illuminance. The area immediately in front of the vehicle has the highest brightness. This characteristic matches exactly the requirement of the segment assignment problem. Since a user can change direction at any time, the media segments prefetched by the SAPs farther away from the user are less likely to be actually used. They should be assigned fewer segments to save the cost. On the other hand, the SAPs closer to the user are more likely to be responsible for providing the media services. They should be allocated more segments to prevent undesirable disruption. Due to such a close resemblance, we use the accumulated virtual illuminance of the cell area covered by the headlight zone as the weight for segment assignment. In this way, we solve both problems in a unified framework.

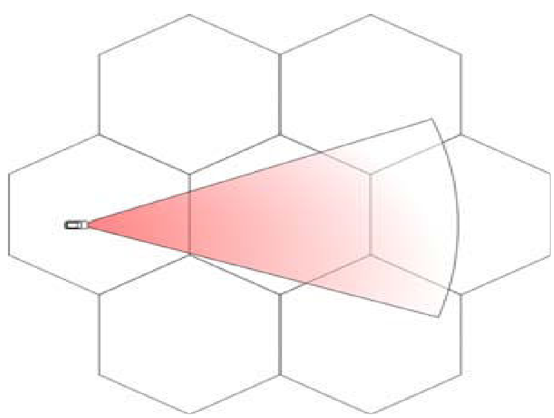

Figure 2: The headlight prefetching zone.

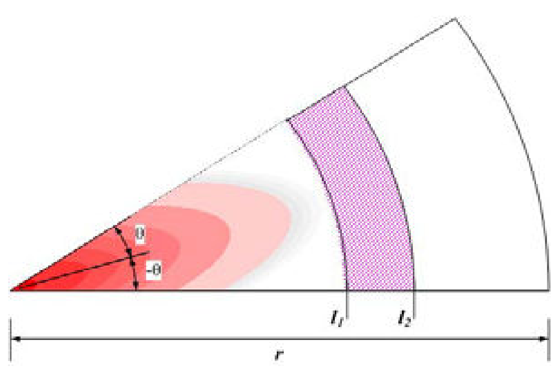

Figure 3: The headlight model.

5. CONCLUSIONS:

We have proposed a new set of techniques to facilitate data management for media streaming in mobile environments. The headlight prefetching techniques provide good performance in comparison with traditional on-demand or simple prefetching techniques. To offer even better data management in response to the changes in user behavior such as access and moving patterns, we are developing an adaptive headlight prefetching technique such that the shape and size of the headlight zone can be dynamically adjusted to accommodate the changes in speed or direction. We are also developing a P2P dynamic chaining method for the sharing of information among peers to maximize cache utilization and streaming benefit.

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