Video-on-Demand Broadcasting to Mobile Wireless Users

Duc A. Tran, University of Massachusetts, Boston, MA
duc.tran@umb.edu

1. Introduction

Today's wireless technologies such as IEEE 802.16 (a.k.a., WiMAX) for long-haul communications and IEEE 802.11 (e.g., WiFi) and Bluetooth for short distances are widely deployed. As beneficiaries, users can move freely without disconnection from the network and can enjoy ubiquitous entertainment services. This paper briefly discusses technologies that enable mobile video-on-demand (VOD) services. Unlike other video services such as pay-per-view (PPV) and video in demand (VID), individual VOD clients in an area are able to watch different programs whenever they wish to, not just in time as in VID or pre-scheduled as in PPV.

2. VoD on the Internet

VOD services are already available on the Internet. News video clips can be rendered on demand on most Web media outlets (e.g., cnn.com, espn.com). Video commercials in business areas ranging from automotive to real estate to health and travel can also be played on demand via a product of Comcast called ComcastSpotlight [1]. The major server providers for VOD deployment include Motorola On-Demand Solutions [2], SeaChange International [3], and Concurrent Corp. [4]. Informa Telecom (http://www.informatm.com) predicted a revenue of more than 10.7 billion US dollars from VOD services offered to more than 350 million households by 2010.

The designs for current VOD systems can be categorized into three main approaches: client/server, peer-to-peer, and periodic broadcast. These approaches are like "apple and orange" when it comes to comparison because each approach is effective for a certain subset of VOD applications. Video popularity is known to practically follow an 80/20-like rule of thumb; that is, most clients would be interested in only a few popular videos. As such, periodic broadcast should be best used for transmitting popular videos to a large number of clients, while client/server and P2P techniques are better suitable for non-popular videos or for videos requested by not too many clients.

3. VoD for Mobile Wireless Users

When deployed to a wireless environment, the success of existing VOD designs may not apply. Because the most popular form of wireless communications in a local area is by IEEE 802.11 technologies, the network bandwidth shared by all the users covered by an access point is typically limited, putting a cap on the number of video streams that can be delivered simultaneously. Taking into account signal inference, the effective number of such streams would actually be much fewer. Also, an 802.11-enabled host can only reach other devices within 100m of its radius, while that radius is 10m for Bluetooth; if a user is too far away from any access point, how can it get the video service?

Fortunately, today's wireless hosts are able to concurrently participate in multiple connections: with the access point in the infrastructure-based mode and with a nearby host in the ad hoc mode. Therefore, it is possible that a distant user could get the video service from the access point via several intermediate hosts. The problem is that significant amounts of bandwidth and energy of the intermediate mobile hosts are consumed. We do not have this problem with the typical Internet.

So arise two questions: 1) what should be the architecture for a mobile wireless VOD system? and 2) what should be the communication protocol for a client to download a video from the video server?

To cope with the limited wireless bandwidth, as each wireless transmission is a broadcast where every host can hear, it is natural to think that it would be more efficient if we adopt the broadcast approach. It would be best if we apply the broadcast approach to the most popular videos and the client/server approach only for ad hoc unpopular video requests.

To cope with the limited wireless coverage, we should allow sharing of video contents among the users. For instance, instead of playing a video through multiple hops from an access point, we hope to play the video or part of it in some existing users nearby. In other words, we should adopt the P2P approach for this kind of users.

4. MobiVOD

Despite many periodic broadcast designs for the Internet, they may not be directly applicable to a

wireless network due to requirements on client bandwidth and caching space (see Table 1).

Table 1. Client Resource Requirement for Representative Periodic Broadcast (PB) Techniques

Technique	Caching Space (% video size)	Bandwidth (times playback rate)
Staggered [5]	0	1
Skyscraper [6]	10	2
Pyramid [7]	75	>=4
Permutation [8]	20	>=2
Pagoda [9]	45	>=5
Harmonic [10]	40	>=5
Fast [11]	50	>=6

None of these periodic broadcast techniques can provide true VOD because their service delay is the duration of the first segment. MobiVOD [12] is a mobile wireless near-true-VOD solution based on Staggered Broadcasting (SB). SB is chosen because of its modest resource requirement on the client side, thus suitable for clients of mobile wireless networks. MobiVOD erases SB's service delay by leveraging video content sharing between the wireless clients in a P2P manner

The system architecture for MobiVOD consists of three components: video server, clients, and local forwarders. Because it is not possible for the server to wirelessly transmit a video to clients located in a too-wide geographic area, local forwarders are deployed to relay the video broadcast (using SB) from the server to clients in their corresponding service area. The communication between local forwarders and the server is via wired broadband or wireless like WiMAX. A local forwarder broadcasts video content to its local coverage using a short-range wireless technology, for example, IEEE 802.11.

When a new client starts the video request and the first segment is not yet available on any broadcast channel, the new client can get this segment instantly from a nearby client who has a cache of it. Obviously, if the cache is several hops away, it is helpless because there is no efficient way for the new client to download the segment in a multi-hop manner. A key property of MobiVOD is its attempt to make the cache available within one hop (i.e., from a direct neighbor), without asking too many nodes to cache. The idea for MobiVOD to do this is to require only the clients that belong to a dominating set of the clients to cache the first segment. Simulation results are provided in [12], showing a service delay nine times better than that of SB in most scenarios.

Although originally designed to work with SB, MobiVOD can be modified to work with most other PB techniques. Also, in real-world implementation, we actually have to deal with different types of clients, especially those having bandwidth less than the video consumption rate. For this purpose, one can employ a multi-resolution or layered video coding approach [13, 14]. Each video can be encoded into several "layers", including a base layer and one or more enhancement layers. The base layer provides the version of least quality, while its combination with enhancement layers provides incrementally better quality. These layers are broadcast on separate channels. A new client selects a combination of layers that best match its resource constraints and only tunes in the corresponding channels to download such layers. As for the initial segment that the client misses from the current broadcasts, it searches for a nearby client who caches a "version" of the first segment (a version is a combination of the base layer and one or more enhancement layers). If more than one such client are found, the client with the highest-quality version is selected.

5. Conclusions

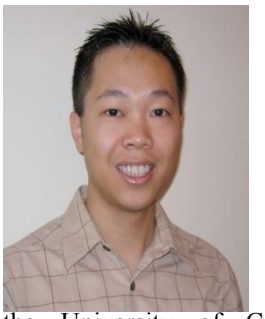
While broadcasting is the nature of wireless communications, VOD broadcasting is not trivial to be implemented in a wireless network. This is because, unlike the Internet where one-to-one communication does not affect nodes that do not involve in the communication, wireless transmission between two nodes may interfere with transmissions by other nodes. MobiVoD is a feasible VOD technique for wireless environments, offering much better VOD feel when combined with a periodic broadcasting technique. Using today's technologies, clients can communicate wirelessly through access points, base stations, or one-to-one in an ad hoc manner with each other. The key idea of MobiVoD is to leverage client collaboration.

The future of VOD is bright. A VOD system of the future will be realization of the video rental shop brought into the home, and wherever the client goes. Airlines could provide VOD services in airport lounges to entertain passengers on their own PDA while they are waiting for a flight; a museum

could provide video information on the exhibits on demand over the wireless network; in education, a university could also install such a system on campus to allow students to watch video recorded earlier from lectures they were not able to attend. Despite all these potential demands, research and development on mobile wireless VOD remain sparse and it will be interesting (and rewarding) to investigate further into this problem.

References

[1] Comcast spotlight: Video advertising on demand. http://www.comcastspotlight.com.
[2] Motorola on-demand solutions. http://broadband.motorola.com/business/ondemand/VideoOnDemand.html.
[3] Seachange international: The global leader in video on demand. http://www.schange.com/.
[4] Concurrent. On-demand and real-time linux solutions. http://www.ccur.com/.
[5] J. B. Kwon and H. Y. Heom. Providing vcr functionality in staggered video broadcasting. IEEE Transactions on Consumer Electronics}, 48(1):41--48, 2002.
[6] K. A. Hua and S. Sheu. Skyscraper broadcasting: A new broadcasting scheme for metropolitan video-on-demand systems. In Proc. of the ACM SIGCOMM'97, pages 89--100, Cannes, France, Sepetember 1997.
[7] S. Viswanathan and T. Imielinski. Metropolitan area video-on-demand service using pyramid broadcasting. ACM Multimedia systems Journal}, 4(4):179--208, August 1996.
[8] C. C. Aggarwal, J. L. Wolf, and P. S. Yu. A permutation-based pyramid broadcasting scheme for video-on-demand systems. In Proc. of the IEEE Int'l Conf. on Multimedia Systems '96, pages 118--126, Hiroshima, Japan, June 1996.
[9] J. F. Paris, S. W. Carter, and D. D. E. Long. A hybrid broadcasting protocol for video on demand. In ACM/SPIE Conference on Multimedia Computing and Networking , 1999.
[10] L. Juhn and L. Tseng. Harmonic broadcasting for video-on-demand service. IEEE Transactions on Broadcasting, 43(3):268--271, 1997.
[11] L. Juhn and L. Tseng. Fast data broadcasting and receiving scheme for popular video service. IEEE Transactions on Broadcasting}, 44(1):100--105, 1998.
[12] D. A. Tran, K. A. Hua, and M. Le. MobiVOD: A video-on-demand system design for mobile ad hoc networks. In Proceedings of IEEE International Conference on Mobile Data Management (MDM 2004), Berkeley, CA, USA, January 19-22 2004.
[13] S. Bajaj, L. Breslau, and S. Shenker. Uniform versus priority dropping for layered video. In ACM SIGCOMM, pages 131--143, 1998.
[14] V. N. Padmanabhan, H. J. Wang, P. A. Chou, and K. Sripanidkulchai. Distributing streaming media content using cooperative networking. In ACM/IEEE NOSSDAV, pages 177--186, Miami, FL, USA, May 12-14, 2002.



Duc A. Tran is an Assistant Professor in the Department of Computer Science at the University of Massachusetts at Boston, where he leads the Network Information Systems Laboratory. He received a PhD degree in Computer Science from the University of Central Florida (Orlando, Florida). Dr. Tran's general interests are in the areas of networking and distributed systems, particularly in support of information systems that can scale with both network size and data size.. The results of his work have led to research grants from the National Science Foundation (NSF) and two Best Papers (ICCCN 2008, DaWak 1999). Also, his contribution on P2P streaming is widely-cited in this area (to date approaching 600 citations according to Google Scholar). Dr. Tran has engaged in many professional activities, serving as a Review Panelist for the NSF, Editorial Board member for the Journal on Parallel, Emergent, and Distributed Systems (2010-date) and ISRN Communications Journal (2010-date), Guest-Editor for the Journal on Pervasive Computing and Communications (2009), TPC Co-Chair for CCNet 2010, GridPeer (2009, 2010, 2011), and IRSN 2009, TPC Vice-Chair for AINA 2007, and TPC member for 40+ international conferences. He is a member of the ACM and the IEEE.