An Adaptive Video-on-Demand Resource Sharing Scheme for Next-Generation Heterogeneous Networks

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Abstract

In network-aware concept, applications are aware of network conditions and are adaptable to the varying environment to achieve acceptable and predictable performance. Two basic aspects of network-aware applications, network awareness and network adaptation, have been widely addressed in the literature. In this work, a solution for video on demand service in heterogeneous networks that integrate wireless and wirelined networks by using the network aware concepts including the integration of a heuristic multicast algorithm (DDVMA) and service oriented architecture (SOA) is proposed. Meanwhile, a link connectivity enhancement mechanism based on mobility model is presented to lower the defection probability, average latency and delay jitter. The experimental results demonstrated that effectiveness and practicability of the proposed work.

Keywords: network-aware, video on demand, heterogeneous network, service oriented architecture (SOA), mobility model

1. Introduction

In network-aware concept, applications are aware of network conditions and are adaptable to the varying environment to achieve acceptable and predictable performance. Recent advances in communication and computer technology have made increased the speed of transmission across the Internet. Next-generation networks will support transmission rates that are higher than current rates. Therefore, the explosive increase in commercial usage of the Internet has resulted in a rapid growth in demand for video delivery technologies. In such a system implemented with client-server architecture, viewers have the flexibility of specifying both the video they want as well as the time at which they wish to watch the video.

A video-on-demand (VoD) system comprises a video server with a video archive and several client machines linked via a local area network. Users request their desired videos using client software. The server delivers the requested video to the user in an isochronous data stream in response to a service request. Bar-Noy [1] found two major bottlenecks in current VoD system architecture:

- The limited number of broadcasting channels available on the access network.
- The number of movies that a server can send concurrently.

Many schemes have been proposed to enhance the efficiency of the VoD system, including resource sharing and scheduling [2], admission control [3], disk striping [4], data replication [5], disk head scheduling [6] and data block allocation and rearrangement [7]. This work concentrates on resource sharing and scheduling schemes as described below.

With the proliferation of high bandwidth networks, Video-on-Demand system has recently gained intensive consideration due to its promising usage in a rich set of Internet-based services such as distance learning, rich media news distribution, and entertainment video distribution, etc. The conventional design of VoD systems follows the Client-Server model, in which a set of centralized servers store all the video files. Clients directly contact servers and request streaming content from servers. Obviously, this architecture is not scalable since servers become bottleneck as the requests increase. To alleviate servers' traffic load, several proxy-based architectures have been proposed, in which a set of proxies are deployed in the network. Clients can request the cached portion of videos from the proxies.

However, in both server-based and proxy-based architectures, servers and proxies are expected to deliver high-quality streaming service to a large number of clients. Therefore, servers and proxies should be very powerful in terms of computing power, outbound bandwidth, storage, etc., which makes the deployment and maintenance cost highly expensive. On the other hand, recent research and experiments reveal that current Internet has enough resources to support large-scale media streaming in a peer-to-peer fashion [16][7]. Moreover, as this kind of application applies in the heterogeneous network environments due to the different network characteristic such as dynamic topology and less bandwidth in mobile ad hoc network (MANET), the traditional video on demand service architecture needs to modify to address the heterogeneous characteristic. This motivates us to exploit the often underutilized peers' resources with network-aware concepts to support large-scale VoD services in this work.

The basic idea of our proposed architecture is to split published videos into segments and distribute them to different peers through service oriented architecture (SOA). When watching a video, requesting peer (or receiver) first searches the corresponding segments, then aggregates bandwidths from multiple peers to stream the video. To deploy this architecture in a dynamic heterogeneous peer-to-peer network, four problems need to be addressed: (1) How to distribute and cache segments, taking into consideration that peers offer different resources and may leave at any time. (2) How to efficiently find the desired segments. (3) How to aggregate bandwidths from multiple peers and coordinate them to serve one streaming request. (4) How to ensure the link connectivity on wireless network side should be considered. In this paper, we present our approaches to address the above four problems, with the emphasis on the third and the last ones.

The remainder of this paper is organized as follows. Section 2 gives a brief overview of the resource sharing schemes proposed in the literature. Section 3 presents the proposed resource sharing scheme that embeds the integration of SOA, and the link connectivity enhancement mechanism based on mobility model. The simulation result is given in Section 4. Conclusion is made in section 5.

2. Related works

A majority of existing VoD systems follows Client-Server model. However, this architecture is not scalable since servers will become the bottleneck as the requests increase. To alleviate servers' traffic load, multicast has been applied and different solutions have been proposed. Batching [4] aggregates multiple client requests into one multicast session. Patching [6] allows a client to catch up with an on-going multicast session and patch the missing starting portion through server unicast. In merging [1], a client can repeatedly merge into a larger and larger multicast session. In periodic broadcasting [14], server separates a media stream into segments and periodically broadcasts them through different multicast channels, from which a client can choose to join in.

Another major category of VoD systems employs cooperative proxy caching technique. Existing work in this area include prefix-based caching [13] and segment-based caching [12][17]. In prefix-based caching, proxies store the initial frames of popular clips. Upon receiving a request, proxy initiates transmission to the client and simultaneously requests the remaining frames from the server. In segment based caching, parts of media content are cached on different proxies in the network and the stream is coordinated playback from these independent caches.

Unlike all of the solutions mentioned above, the proposed architecture in this work exploits often-underutilized peers' resources to support large-scale video streaming in heterogeneous network environment, which distinguishes itself as a network-aware sensitive approach.

3. The proposed VoD resource sharing system

Fig. 1 illustrates the proposed VoD resource sharing system architecture employed in this work. There is an edge QoS guarder residing at each edge of different network sides. The functionality of edge QoS guarder is monitoring on the network status and adapting the application specification while delivering media content through different network environment. The edge QoS guarder also collects information from different network sides. When a client requests a video from wireless network, the edge QoS guarder first checks whether it contains this clip and fetch this clip in case it doesn't have. Once it catches the video clip, it executes a wireless-wired data transformation protocol to transform the video data to a specific size which is suitable for the network bandwidth. As comparing to wirelined networks, the network bandwidth over wireless network is not stable and limited due to high packet loss rate. Kazuo [19] proposed a rate control mechanism to determine the transmission rate of compressed video packets from server to client and minimize the required network bandwidth and optimize the network I/O buffers. In this work, we assume the edge QoS guarders transmitting packets through such a dynamic transmission rate algorithm to optimize the rate control for video stream transmission and the client buffer utilization of the video transmission under unstable network environment over wireless network and wirelined network. Moreover, the QoS edge guarder uses caching strategy that caches some parts of server information at some of the nodes distributed across the network to effectively reduce the access latency in such a communication environment. As for multicasting scheme, we use the work presented in [22], name delay and delay variation multicast algorithm (DDVMA) which is suitable for the proposed multiple ad hoc networks and heterogeneous network environments since this scheme can find a multicast tree to satisfy the end-to-end delay constraints and minimum delay variation while transmitting a video.

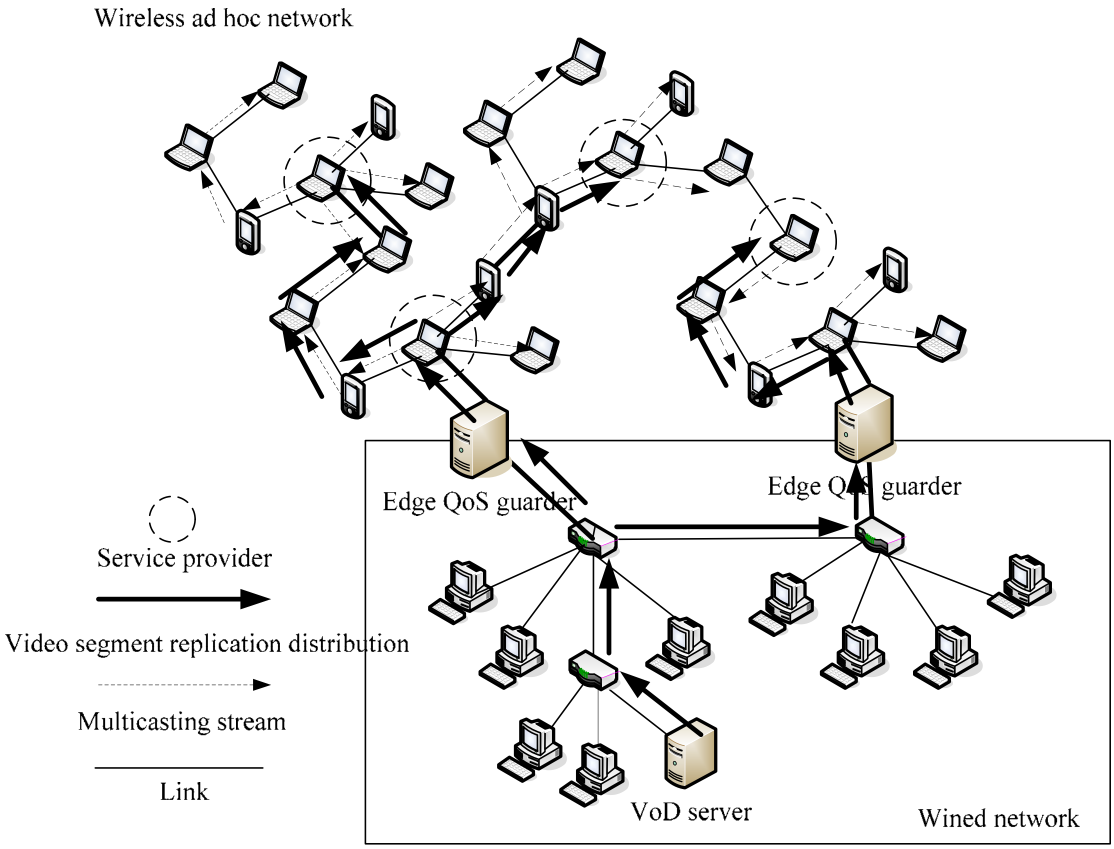

Fig. 1. The proposed VoD resource sharing system architecture.

3.1. Integration of DDVMA and SOA

In a heterogeneous network comprising multiple mobile ad hoc networks (MANET), each MANET is attached to the backbone internet through a QoS guarder, which is a fixed node in the intersection between wireless and wirelined network. A QoS guarder forwards data packets and relays them between MANETs and the Internet. When a MANET is connected to the Internet, it is important for the mobile hosts (MH) to detect available QoS guarder, especially in the VoD resource sharing system. The DDVMA [22] constructs a QoS multicast tree over the backbone wirelined network to transmit multicast messages from the QoS guarder to all the destination nodes. The DDVMA calculates the delay values of the collected wireless routes constructed by routing protocol and finds out the shortest path tree (SPT). The DDVMA uses optimization procedure that finds a better path to optimize the QoS of the SPT. The objective of the optimization procedure is to achieve a smaller delay variation under an end-to-end delay constraint.

Recently, Service Oriented Architecture (SOA) [18] is getting popular in the software design for distributed systems such as peer-to-peer applications. The characteristics of the services defined in SOA can be enumerated as follows: [18]

- Services are self contained and modular
- Services are discoverable and dynamically bound
- Services stress interoperability
- Services are loosely coupled, reduction of artificial dependencies to their minimum
- Services have a network-addressable interface
- Services have coarse-grained interfaces in comparison to finer-grained interfaces of software components and objects
- Services are composable

The above characteristics indicate that the SOA architecture should make the distributed system as simple as possible. More precisely, the SOA is an architectural style to achieve flexible coupling among interacting software agents. In SOA, it defines three components, Service-Requestor (R), Service-Provider (P), and Service-Broker (B) as shown in Fig. 2.

In the SOA architecture, the Service-Providers publish their services to a service registry. There might be more than one Service-Broker in the service environments that replicate their service registries. The Service-Requestors then employ the Service-Broker to search for services and integrate them by accessing the service description. In this work, the SOA architecture is applied to the edge QoS guarder connected between wireless and wirelined networks to enable scalability in the VoD services on the wireless access network side. Moreover, this hierarchical service architecture is also used in caching management, link enhancement and congestion avoidance in wireless network side to enhance the robustness of VoD services.

Caching may result in a considerable overhead cost; for example, it will bring additional energy consumption as well as bandwidth burden while disseminating additional information over the environment. In Fig. 1, the DDVMA and SOA are integrated by means of incorporating the SOA architecture in the edge QoS guarder and the video segments in the QoS guarder are cached to share the network resource. While a client requests video, it firstly sends a request message to its neighboring node asking whether the QoS guarder has cached for the requested video. Since the wireless systems are suffered from limited energy and bandwidth constraint due to its natural characteristics, we first apply the cache placement algorithm proposed in [20] on wireless network side to find the best placement of the video segment to distribute the video data over the whole network based on the detected network status. Then the QoS guarder disseminates the video segments to the downstream service providers after it prefetches the requested video data. Once there is a request from a client, the client could get request video from the disseminated service providers through the multicasting tree, which consists of the nearest service provider that contains requested video cache segment as shown in Fig. 1. Besides, we also address the issues of the link connectivity enhancement and congestion avoidance in the wireless ad hoc networks in this work because they are the crucial factors that affect the performance of the VoD services. In this work, the integration of DDVMA and the SOA is proposed to promote the scalability of the VoD system in optimizing both minimum tolerable delay latency and resource sharing among the heterogeneous network, and incorporating link connectivity enhancement to ensure the link state in transmitting video data.

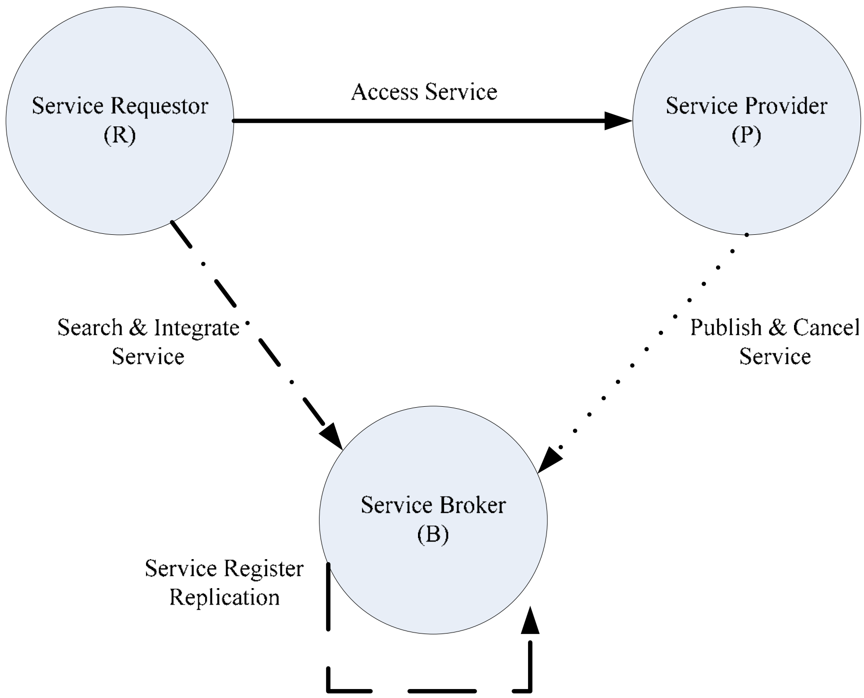

Fig. 2. SOA structure.

3.2. Link connectivity enhancement for wireless mobile ad hoc network

In wireless mobile ad hoc networks, the robust connectivity can be established by offering alternative routing paths whenever a broken link event occurs on the routing path. In this work, we propose a probability model of a mobile node that moves away from the radio range of other neighboring nodes. The derived probability is then used to determine whether the backup route path should be activated.

As report in [23][24], the distribution of the link duration and path duration in routing protocols for mobile ad hoc networks appears to be exponentially distributed. We thus assume the moving patterns of the mobile nodes are also exponentially distributed as follows,

$$p_t(r) = c_t e^{-\frac{u}{t}r} \quad .(1)$$

Here $p_t(r)$ represents the probability density function of a node moving for the distance of r after a duration of t, and u is a user-defined constant.

Since

$$\int_0^\infty 2\pi r p_t(r) dr = 1 \quad , \qquad (2)$$

we have

$$c_t = \frac{1}{2\pi \int_0^\infty r e^{-\frac{ur}{t}} dr} = \frac{\left(\frac{u}{t}\right)^2}{2\pi} \quad , \qquad (3)$$

and

$$p_t(r) = \frac{\left(\frac{u}{t}\right)^2}{2\pi} e^{-\frac{u}{t}r} \quad . \qquad (4)$$

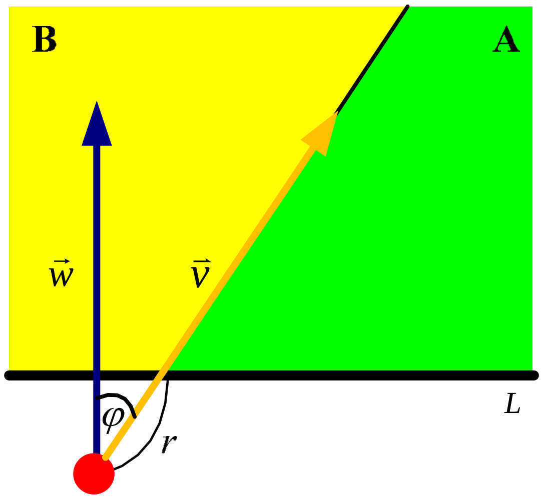

Fig. 3. Zones **A** and **B** separated by $\vec{v}$.

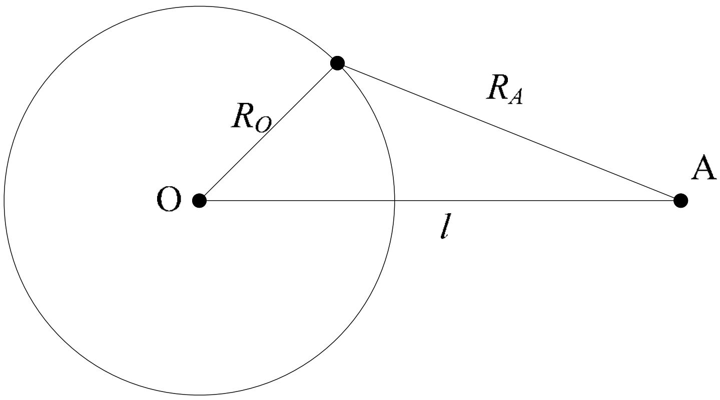

Fig. 4. The distance and communication range between a fixed communication device **O** and a mobile device **A**.

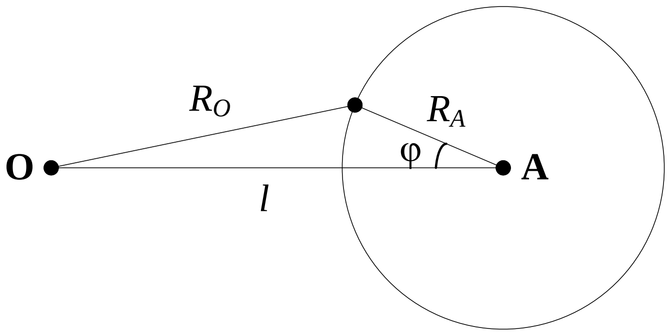

Fig. 5. The distance and communication range of two mobile communication devices **O** and **A**.

The probability of a node moving into zones **A** and **B** separated by $\vec{v}$ as shown in Fig. 3 can be respectively obtained by,

$$A_t(L,\vec{v}) = \frac{1}{2\pi}\int_{-\frac{\pi}{2}}^{\varphi(L,\vec{v})} O_t(r\sec\theta)d\theta, \quad (5)$$

and

$$B_t(L,\vec{v}) = \frac{1}{2\pi}\int_{\varphi(L,\vec{v})}^{\frac{\pi}{2}} O_t(r\sec\theta)d\theta, \quad (6)$$

where

$$\varphi(L,\vec{v}) = \arcsin\frac{\vec{w}\times\vec{v}}{|\vec{w}||\vec{v}|}. \tag{7}$$

Here $\vec{w}$ denotes the vector perpendicular to L as shown in Fig. 3.

Now assume a mobile node is located at location **A** and another mobile node is located at fixed location **O** as shown in Fig. 4. The distance between the two mobile nodes, l, is larger than the communication range of mobile node, R_O. The probability of mobile node **A** moving to communicatable position of node **O** is,

$$\begin{aligned} I(l) &= \int_{l-R_O}^{l+R_O}\left(2R_A\cos^{-1}\frac{R_A{}^2+l^2-R_O{}^2}{2R_A l}\right)\left(\frac{c^2}{2\pi}e^{-cR_A}\right)dR_A \\ &= \frac{c^2}{\pi}\int_{l-R_O}^{l+R_O}\left(R_A e^{-cR_A}\cos^{-1}\frac{R_A{}^2+l^2-R_O{}^2}{2R_A l}\right)dR_A \end{aligned}. \tag{8}$$

On the other hand, if the distance between the two mobile nodes is within the communication range of them, the communicatable probability is

$$\begin{aligned} J(l) &= \int_0^{R_O-l}\left(2\pi R_A\frac{c^2}{2\pi}e^{-uR_A}\right)dR_A + \int_{R_O-l}^{R_O+l}\left(2R_A\cos^{-1}\frac{R_A{}^2+l^2+R_O{}^2}{2R_A l}\right)\left(\frac{c^2}{2\pi}e^{-cR_A}\right)dR_A \cdot \\ &= 1-\left(1+c\left(R_O-l\right)\right)e^{-c(R_O-l)} + \frac{c^2}{\pi}\int_{R_O-l}^{R_O+l}\left(R_A e^{-cR_A}\cos^{-1}\frac{R_A{}^2+l^2+R_O{}^2}{2R_A l}\right)dR_A \end{aligned} \tag{9}$$

Next we estimate the probability of two mobile nodes with distance, l, that can communicate with each other as shown in Fig. 5. The probability of mobile node **O** with communication range R_O moving to the communication range of node **A** becomes,

$$\begin{aligned} Q(R_A) &= \int_0^{2\pi}\left(\frac{c^2}{2\pi}e^{-c\sqrt{l^2+R_A{}^2-2R_A l\cos\varphi}}\right)d(R_A\varphi) \\ &= \frac{c^2}{\pi}R_A\int_0^{\pi}e^{-c\sqrt{l^2+R_A{}^2-2R_A l\cos\varphi}}d\varphi \end{aligned}. \tag{10}$$

Based on Eqs. (8), (9), and (10), the probability of two mobile communication devices with distance, l, that can communicate with each other can be obtained by,

$$K(l) = \int_0^{R_O} I(l)Q(R_A)dR_A + \int_{R_O}^{\infty} J(l)Q(R_A)dR_A, \tag{11}$$

where

$$\begin{aligned} I(l) &= \frac{c^2}{\pi}\int_{l-R_O}^{l+R_O}\left(R_A e^{-cR_A}\cos^{-1}\frac{R_A{}^2+l^2-R_O{}^2}{2R_A l}\right)dR_A \\ J(l) &= 1-\left(1+c\left(R_O-l\right)\right)e^{-c(R_O-l)} + \frac{c^2}{\pi}\int_{R_O-l}^{R_O+l}\left(R_A e^{-cR_A}\cos^{-1}\frac{R_A{}^2+l^2+R_O{}^2}{2R_A l}\right)dR_A \\ Q(R_A) &= \frac{c^2}{\pi}R_A\int_0^{\pi}e^{-c\sqrt{l^2+R_A{}^2-2R_A l\cos\varphi}}d\varphi \end{aligned}. \tag{12}$$

4. Simulation

A series of simulations were run in this work to evaluate the performance of the proposed video resource sharing systems. Here DS-LVoD represents the one embedded with the integration of DDVMA and SOA and the link connectivity enhancement mechanism, DS-VoD the one with the integration of DDVMA and SOA scheme, D-LVoD the DDVMA scheme with link enhancement mechanism, and D-VoD pure DDVMA scheme. We assumed that the system contains 20 videos; each is 120 minutes long and the relative frequency of the individual video is *Zipf-like* distribution.

4.1. Performance metrics

In the analysis of our video resource sharing systems, the following performance measures are used:

- Blocking probability: This is the probability that an arriving client leaves the system without being serviced due to the lack of server stream.
- Defection probability: This is the probability that an arriving client leaves the system without being served due to the waiting time exceeding the viewer's tolerance. Obviously, the defection probabilities may vary across different videos. Let r_i denote the defection probability for video i, then the mean defection probability can be expressed by,

$$\bar{r} = \sum_{i=1}^{N} r_i / N. \tag{36}$$

  Meanwhile, the user defection behavior is modeled using normal distribution with a mean value of five minutes and standard deviation of one.
- Average latency time: The latency of a client is the period which elapses between the arrival of the video request and the time when the service to the display device is actually initiated. Only non-defecting clients are considered in the latency time measure.
- Average delay-jitter: The delay jitter is the variance of the delay latency for every service. Like average latency time, only non-defecting clients are considered in the delay-jitter measure.

4.2. Simulation result

We first ran a series of experiments wherein arrival rate was varied from 5-25 requests per minute with network bandwidth fixed at 54 Mbps. Then we varied network bandwidth from 11-108 Mbps while fixing arrival rate at 5 requests per minute.

Fig. 6 compares the blocking probability of the three proposed schemes and that of pure DDVMA. The proposed video resource sharing system with integration of DDVMA and SOA, and link connectivity enhancement mechanism (DS-LVoD) achieves better performance than the other two proposed schemes (DS-VoD, D-LVoD) and pure DDVMA multicasting scheme (D-VoD). The pure DDVMA multicasting scheme performs poorest because whenever a client requests a video it simply transmits the requested video without using the caching mechanism to share the network resource. Besides, the proposed DS-LVoD that consists of a scalable SOA and link connectivity enhancement can evenly distribute the video segments in the network and establish robust connectivity to effectively reduces the blocking probability. Fig. 7 illustrate the comparison of defection probability of the proposed schemes. As expected, the DS-LVoD achieves the best performance among the four. Notably, lacking of the link connectivity enhancement mechanism in DS-VoD and D-VoD resulted in an additional delay latency caused by re-constructing link path and the defection probability was thus increased.

Fig. 8 andFig. 9 show the average latency time and delay jitter comparison. It can be observed that the proposed DS-LVoD has less delay latency and delay jitter than the other three schemes. Since the pure DDVMA multicasting scheme needs to rebuild the multicast tree in case there is a link break among the multicast tree, the pure DDVMA multicasting scheme performs the worst among these schemes because the overhead caused by the rebuilding process. On the other hand, DS-LVoD and D-LVoD employ the link connectivity enhancement mechanism to effectively maintain the link state and activate alternate link path mechanism in case an unstable link state is detected.

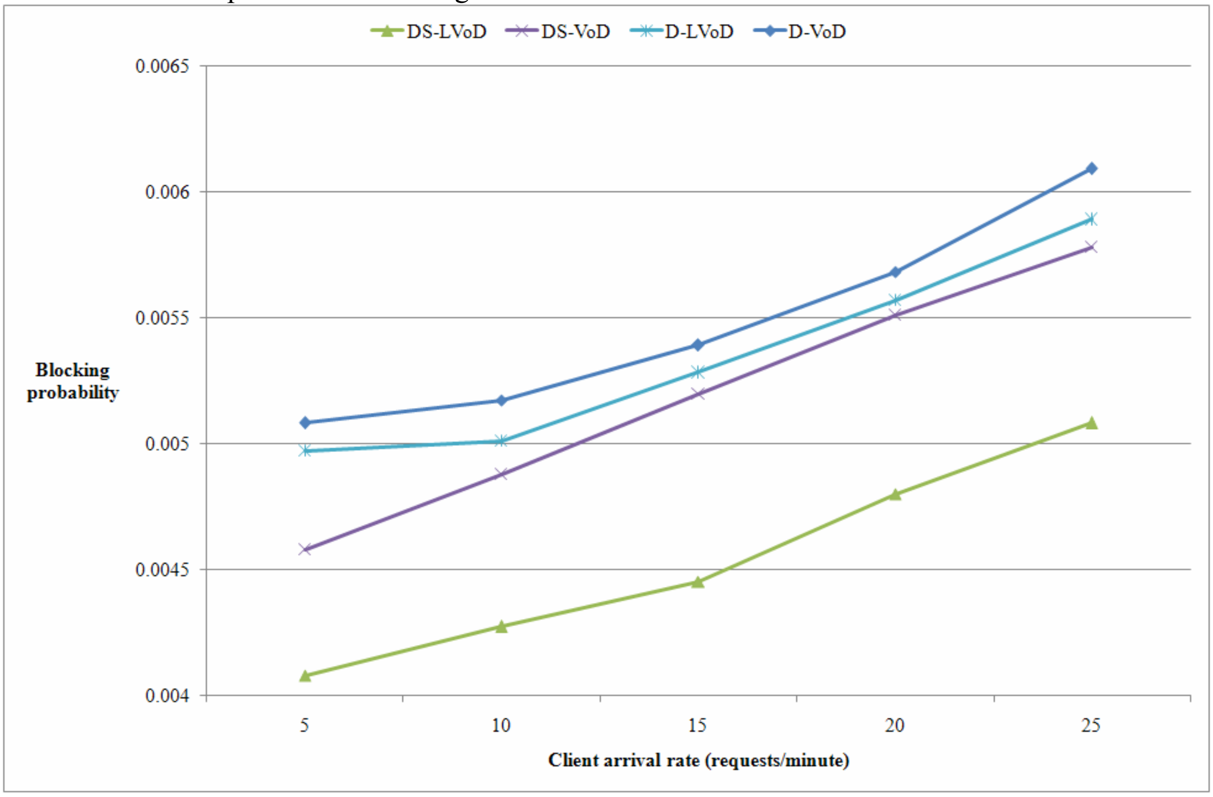

Fig. 6 Blocking probability at varied client arrival rates.

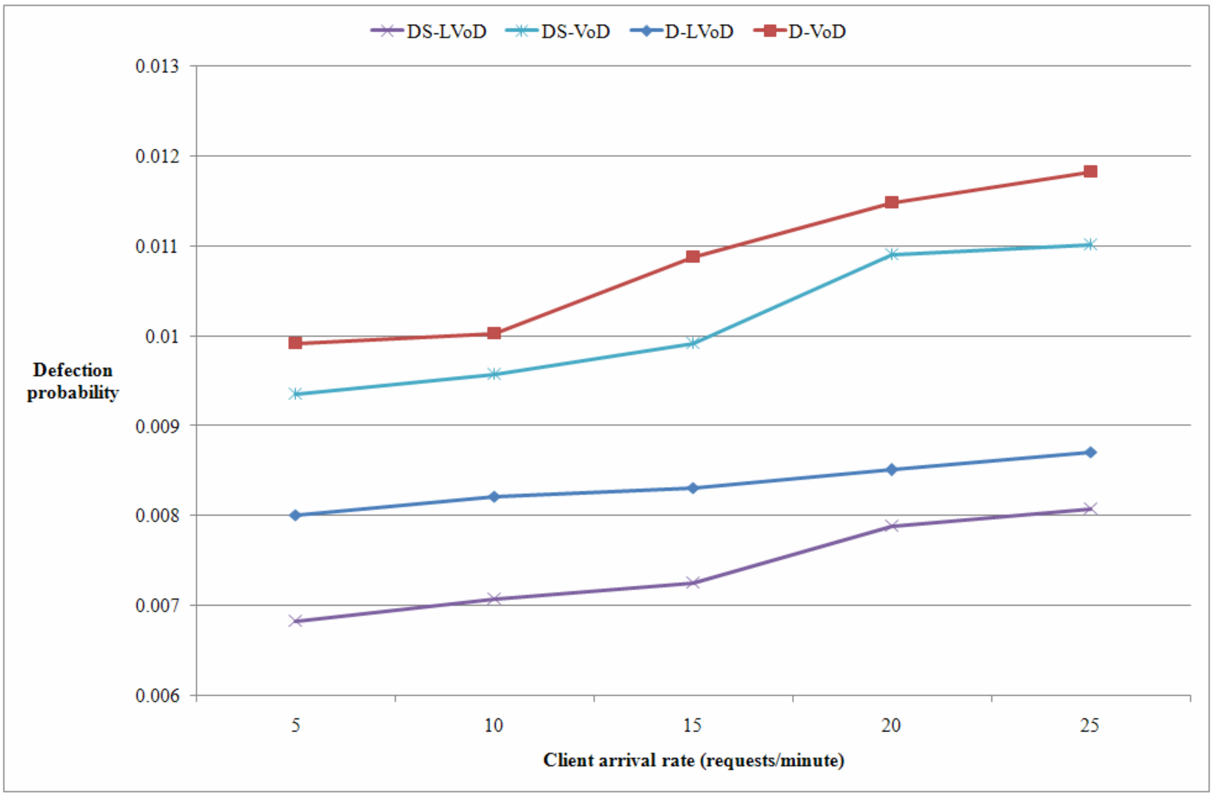

Fig. 7 Defection probability at varied client arrival rates.

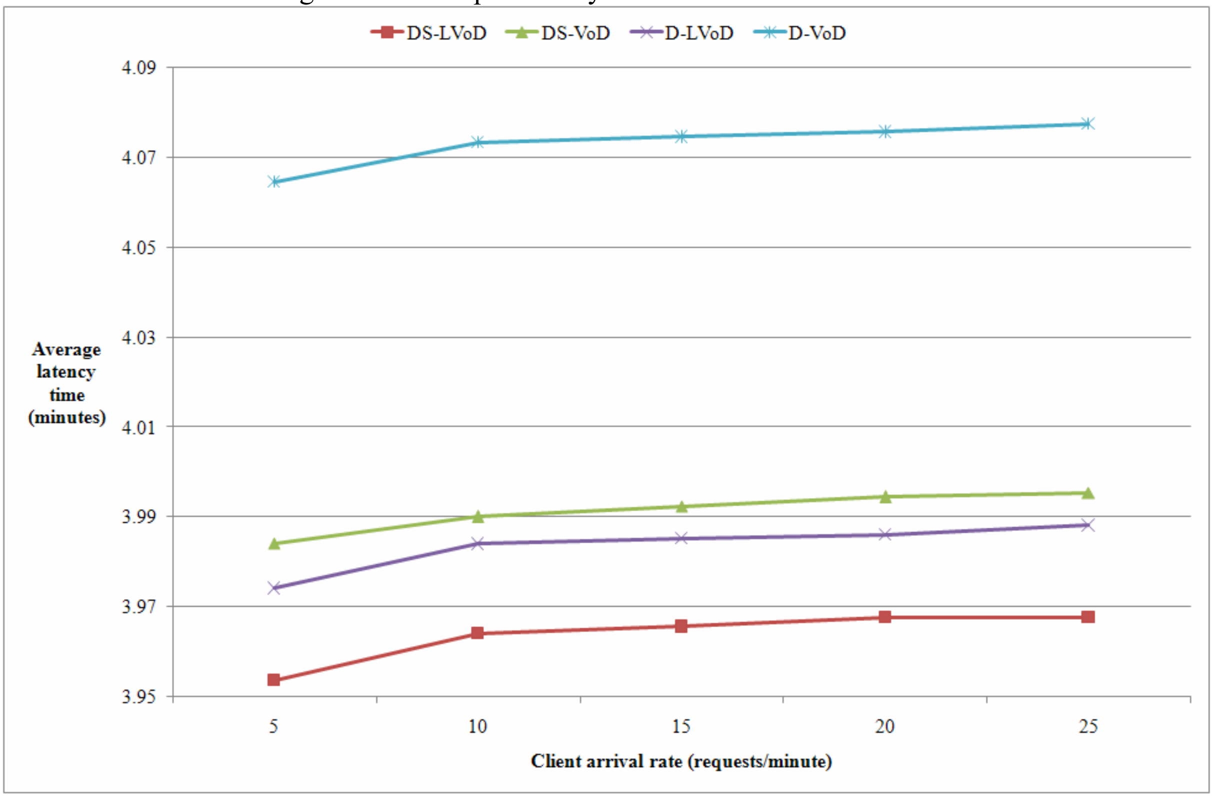

Fig. 8 Delay latency at varied client arrival rates.

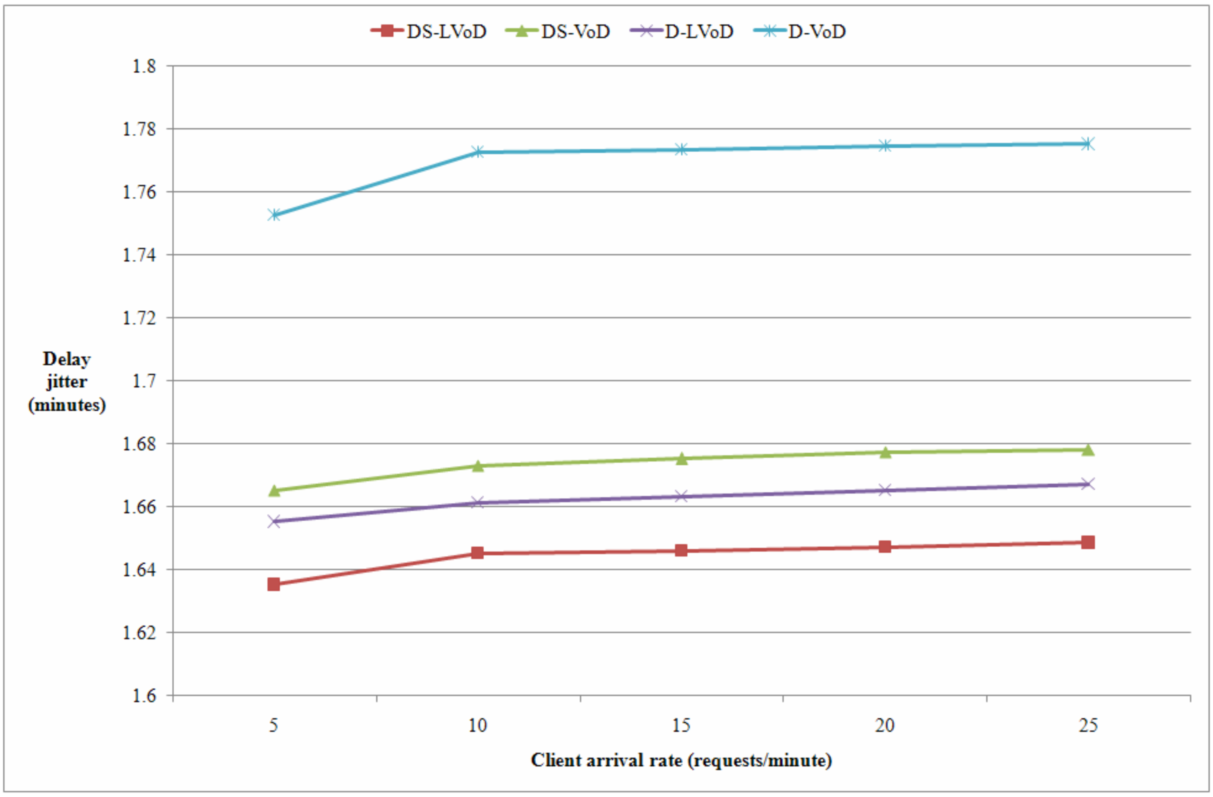

Fig. 9 Delay jitter at varied client arrival rates.

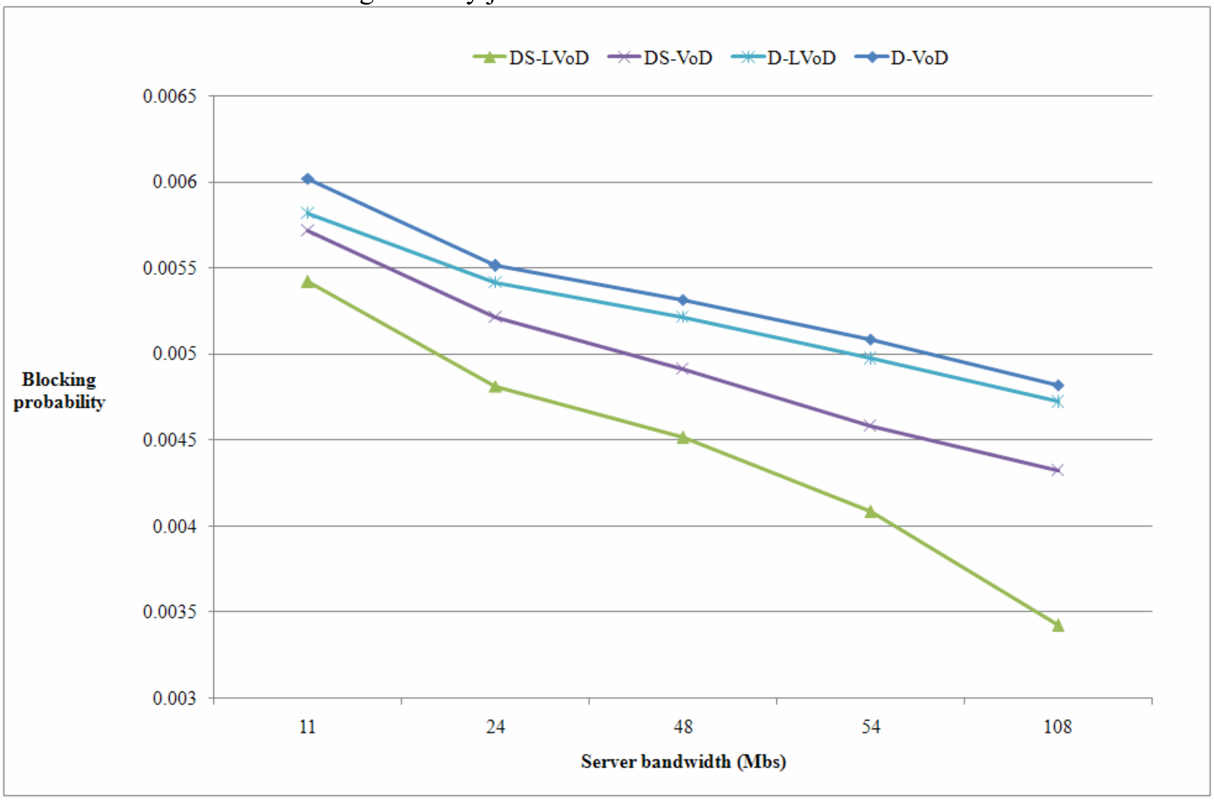

Fig. 10 Blocking probability at varied server capacity.

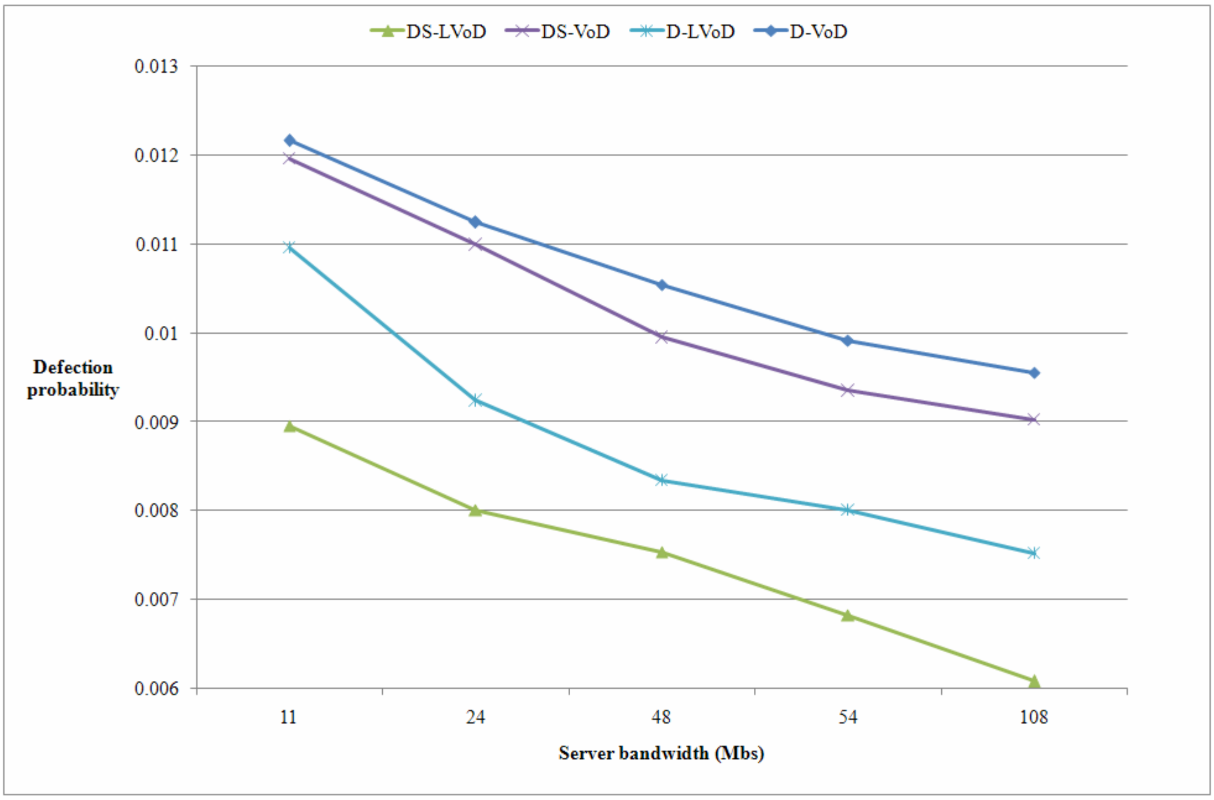

Fig. 11 defection probability at varied server capacity.

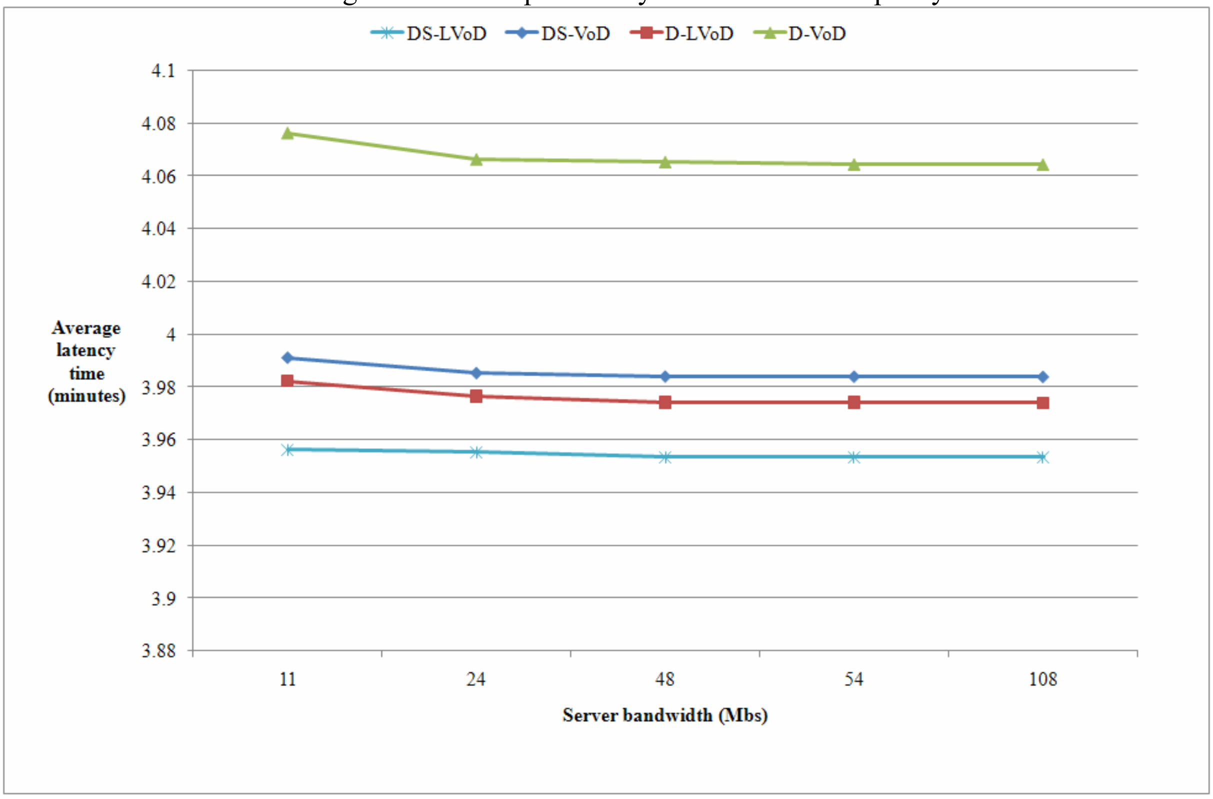

Fig. 12 Average latency time at varied server capacity.

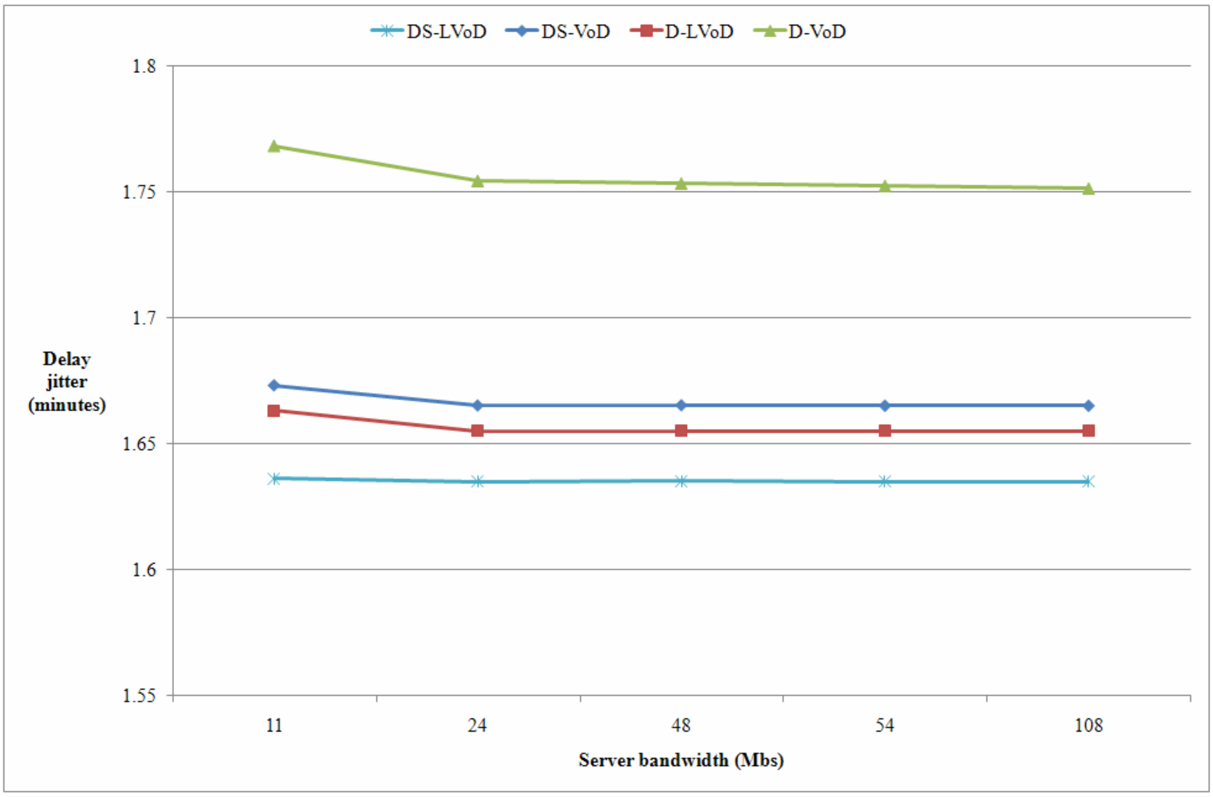

Fig. 13 Delay jitter at varied server capacity.

Fig. 10-Fig. 13 give the simulation results of the four schemes with network bandwidth varied from 11 - 108 Mbps. As shown in Fig. 10, the blocking probability of DS-LVoD and DS-VoD still outperform the other two schemes owing to the efficient SOA structure, whereas DS-LVoD, D-LVoD have lower defection probability, less latency time and delay jitter in Fig. 11 - Fig. 13 due to the effectiveness of link connectivity enhancement mechanism.

5. Conclusion

This work presents a video resource sharing system that consists of link connectivity enhancement mechanism and the integration of DDVMA and SOA. The proposed scheme can effectively promote the scalability of the VoD system in both minimum tolerable delay latency and resource sharing among the heterogeneous network owing to the effectiveness of the DDVMA and SOA, respectively. Meanwhile, the link connectivity enhancement based on mobility model is also proposed to dynamically monitor the link connectivity and maintain the multicast tree. A series of simulation results showed that integration of DDVMA and SOA can effectively reduce the blocking probability, while the link connectivity enhancement mechanism can greatly lower the defection probability, average latency and delay jitter.

Reference

[1] A. Bar-Noy, J. A. Garay and A. Herzberg, “Sharing video on demand,” *Discrete Applied Mathematics*, 129(1), 2003, 3-30.

[2] L. Juhn and L. Tseng, “Harmonic Broadcasting for Video-on-Demand Service,” IEEE Trans. on Broadcasting, 43(3), 1997, 268-271.

[3] B. Qazzaz, J. Moreno, J. Xiao, P. Hernandez, R. Suppi and E Luque, “Admission control policies for video on demand brokers,” *International Conference on Multimedia and Expo*, 2, 2003, 529-32.

[4] P. Sumari, A. Samsudin and H. Kamarulhaili, “Data storage and retrieval for video-on-demand servers,” *Fourth International Symposium on Multimedia Software Engineering*, 2002, 240 – 245.

[5] T.K. Ho and J.Y.B. Lee, “A row-permutated data reorganization algorithm for growing server-less video-on-demand systems,” *3rd IEEE/ACM International Symposium on Cluster Computing and the Grid*, 2003, 44 –

51.

[6] J. Kim, Y. Lho and K. Chung, “An effective video block placement scheme on VOD server based on multi-zone recording disks,” *IEEE International Conference on Multimedia Computing and Systems*, 1997, 29 – 36.

[7] W.K.S. Tang, E.W.M. Wong, S. Chan and K.-T. Ko, “Optimal video placement scheme for batching VOD services,” *IEEE Transactions on Broadcasting*, 50(1), 2004, 16 – 25.

[8] S.-H.G. Chan and F. Tobagi, “Tradeoff between system profit and user delay/loss in providing near video-on-demand service,” *IEEE Transactions on Circuits and Systems for Video Technology*, 11(8), 2001, 916 – 927.

[9] W.-F. Poon, K.-T. Lo and J. Feng, “Determination of efficient transmission scheme for video-on-demand (VoD) services,” *IEEE Transactions on Circuits and Systems for Video Technology*, 13(2), 2003, 188 – 192.

[10] W.-F. Poon, K.-T. Lo and J. Feng, “Provision of continuous VCR functions in interactive broadcast VoD systems,” *IEEE Transactions on Broadcasting*, 51(4), 2005, 460 – 472.

[11] J.B Kwon and H.Y. Yeom, “VCR-oriented video broadcasting for near video-on-demand services,” *IEEE Transactions on Consumer Electronics*, 49(4), 2003, 1106 – 1113.

[12] S.A. Azad, M. Murshed and L.S. Dooley, “Bandwidth borrowing schemes for instantaneous video-on-demand systems,” *IEEE International Conference on Multimedia and Expo*, 3, 2004, 2011 – 2014.

[13] L. Gao and D. Twosly, “Supplying instantaneous video-on-demand services using controlled multicast” *Proceedings of IEEE International Conf. on Multimedia Computing and Systems*, 1999, 117-121.

[14] A. Dan, D. Sitaram, and P. Shahabuddin, “Scheduling Policies for an On-Demand Video Server with Batching” *Proceedings of the ACM Conf. on Multimedia*, 1994, 391-398.

[15] C. C. Aggarwal, J. L.Wolf, and P. S. Yu, “The Maximum Factor Queue Length Batching Scheme for Video-on-Demand Systems” *IEEE Trans. on Computers*, 50(2), 2001, 97-110.

[16] P. K. Jana and B. P. Sinha, “Fast Parallel Algorithms for Forecasting,” *Computer Math. Applic*. 34(9), 1997, 33-49.

[17] M.-Y. Wu, S. Ma and W. Shu, “Scheduled video delivery-a scalable on-demand video delivery scheme,” *IEEE Trans. on Multimedia*, vol.8, no.1, pp. 179 – 187, 2006

[18] G. Gehlen, L. Pham, “Mobile Web services for peer-to-peer applications,” *Proceedings* of *IEEE International Conf. on Consumer Communications and Networking*, pp. 427-433, 3-6 Jan. 2005

[19] K. Takahata, N. Uchida, and Y. Shibata, “Dynamic packet video rate control over wireless network,” *Proceedings of the 11th IEEE International Conf. on Parallel and Distributed Systems*, vol.1, pp. 606- 612, 20-22 July 2005

[20] P. Nuggehalli, V. Srinivasan, C.-F. Chiasserini, and R. R. Rao, “Efficient Cache Placement in Multi-Hop Wireless Networks,” *IEEE/ACM Trans .on Networking*, vol.14, no.5, pp. 1045- 1055, Oct. 2006

[21] M.-Y. Wu, S. Ma and W. Shu, “Scheduled video delivery-a scalable on-demand video delivery scheme,” *IEEE Trans. on Multimedia*, vol.8, no.1, pp. 179 – 187, 2006

[22] H. Cheng, J. Cao and X. Wang, “A heuristic multicast algorithm to support QoS group communications in heterogeneous network,” *IEEE Trans. on Vehicular Technology*, vol.55, no.3, pp. 831 – 838, May 2006

[23] F. Bai, N. Sadagopan, B. Krishnamachari and A. Helmy, “Modeling path duration distributions in MANETs and their impact on reactive routing protocols,” *IEEE Journal on Selected Areas in Communications*, vol.22, no.7, pp. 1357- 1373, Sept. 2004

[24] A. Nasipuri, R. Castaneda, and S. R. Das, “Performance of multipath routing for on-demand protocols in ad hoc networks,” *Mobile Networks Applicat.* (*MONET*) *J.*, vol. 6, no. 4, pp. 339–349, 2001.