SAMP: Supporting Multi-source Heterogeneity in Mobile P2P IPTV System

Weizhan Zhang, *Member*, IEEE, Zhenyan Li, and Qinghua Zheng, *Member*, IEEE

**Abstract — ***Peer-to-Peer (P2P) streaming provides an effective method to deploy large-scale internet protocol television (IPTV) application over today's Internet. A major challenge in designing such an application is how to deal with content delivery among heterogeneous clients. Especially, with the development of the mobile internet and smart phones, how to provide an effective multi-source heterogeneous P2P IPTV solution becomes of great importance. Due to the special requirement of supporting differentiated multiple video streaming for different users, already existing P2P live video streaming techniques are inappropriate to be adopted directly. Therefore, this paper proposes a source-aware mobile P2P IPTV solution (SAMP) to provide multi-source live streaming for heterogeneous clients. In detail, SAMP includes a source-aware P2P topology construction algorithm to deduce the bandwidth occupation and the control overhead among the P2P clients, and contains a source-aware P2P streaming scheduling algorithm to further enhance the delay performance of the P2P IPTV system. The evaluation results show that the proposed SAMP scheme can provide a differentiated multi-source live streaming for heterogeneous clients with reduced bandwidth consumption, control overhead, and delivery delay*[1].

Index Terms — Multi-source heterogeneity, peer-to-peer, IPTV, live streaming.

I. Introduction

In many multimedia applications, there is often a requirement for supporting live streaming to a large number of receivers simultaneously. IP multicast is a natural solution for such group-oriented applications. However, it cannot be well deployed over today's Internet, which suffers from various issues such as group management, congestion control, and security [1]. For the past decade, Peer-to-Peer (P2P) streaming has been intensively studied as an alternative technology for IP multicast. Many approaches have been designed and implemented [2]. These P2P approaches utilize clients to construct tree-based or mesh-based overlay networks, and provide flexible and scalable solutions for video streaming applications [3]-[11]. Some successful internet protocol television (IPTV) systems based on P2P streaming have already been deployed over today's Internet.

However, with the development of mobile network and smart phones, designing a P2P IPTV streaming system must take the heterogeneous clients into account. Besides the traditional PC, laptop, and set-top box clients, numerous users may join the P2P streaming sessions by tablets and smart phones. Therefore, P2P IPTV systems must address some new challenges, such as the mobility of P2P users, the heterogeneous network condition, and the heterogeneous service requirements. Although some researchers have addressed some aspects of the mobile P2P solutions [12]-[15], the solution for the multi-source heterogeneous of P2P streaming remains intact. However, there is a requirement to support differentiated multiple related streams to different users due to the different resolutions and screen sizes of the client devices. In particular, the motivation for this research comes from integrating multi-source P2P live streaming in a mobile P2P IPTV system. The system is designed to deliver multiple time-related views of a live spot, and is supposed to provide differentiated response schemes for heterogeneous clients. For a PC user, the system reconstructs the vivid scenario of the live scene through providing multi-source P2P live streaming. While, For a mobile user, due to limited screen and constrained computing and networking condition, the system provides a single scenario of the spot. Therefore, how to provide an effective multi-source heterogeneous P2P solution becomes of great importance for the mobile P2P IPTV systems.

To handle the challenge mentioned above, this paper proposes a Source-Aware Mobile P2P (SAMP) IPTV scheme to provide multi-source live streaming for heterogeneous clients. Firstly, SAMP proposes a source-aware topology construction algorithm of P2P network. The algorithm takes the data source requests from users into consideration in the process of neighbor selection, and divides the nodes into different overlay units. In this way, it reduces the bandwidth occupation and the control overhead among the P2P clients. Secondly, SAMP proposes a source-aware streaming scheduling algorithm based on the SAMP topology construction algorithm. It introduces a source-aware scheduling strategy. The streaming scheduling algorithm further decreases the delivery delay of the P2P IPTV system.

The remainder of this paper is organized as follows. Section 2 summarizes related work. Section 3 describes the

[1] This work was supported in part by National Science Foundation of China under Grant Nos. 61103239, 61221063; National High Technology Research and Development Program 863 of China under Grant No. 2012AA011003; Cheung Kong Scholar's Program; the Fundamental Research Funds for the Central Universities; Ministry of Education of China Humanities and Social Sciences Project under Grant No.12YJC880117; Key Projects in the National Science and Technology Pillar Program under Grant Nos. 2013BAK09B01.

Weizhan Zhang, Zhenyan Li, and Qinghua Zheng are with the MOEKLINNS Lab, Department of Computer Science and Technology, Xi'an Jiaotong University, Xi'an, 710049, China (e-mail: {zhangwzh@mail, lzy1500604@stu, qhzheng@mail}.xjtu.edu.cn).

Contributed Paper
Manuscript received 09/26/13
Current version published 12/24/13
Electronic version published 12/24/13.

architecture of the SAMP IPTV system. Section 4 and 5 present the proposed SAMP scheme, including the source-aware P2P topology construction algorithm and the source-aware P2P streaming scheduling algorithm. Section 6 evaluates the performance of the proposal. Finally, Section 7 concludes the paper and discusses potential future works.

II. Related Work

There has been a great amount of work in the area of P2P streaming. For single-source P2P live streaming, the existing P2P live streaming approaches can be categorized as either tree-based P2P multicasts [5], [7], [10], or mesh-based P2P overlays [8], [9], [11]. The tree-based P2P approaches organize peers into explicit data delivery trees. Meanwhile, the mesh-based P2P approaches maintain a set of partners for each peer, and exchange the data availability information without an explicit structure support. Generally speaking, mesh-based P2P overlays outperform the tree-based P2P approaches in many ways, such as reliability and maintenance overhead [16], [17]. To learn from each other, the researchers also employ push-pull methods for data scheduling in mesh-based P2P overlays [18]. These methods overcome the inherit delay drawback with the implicit delivery tree structures. However, in the above solutions for single-source P2P live streaming, multi-source live media delivery is not an issue, and the multi-source heterogeneity is not concerned.

For multi-source P2P live streaming, on one hand, many multi-channel P2P IPTV systems have recently been proposed in data-driven P2P network. Firstly, there is a number of researches focusing on the strategies of handling the conflict in coexisting overlays [19]-[21]. However, these multi-channel P2P streaming solutions deal with multiple sessions, but not time-related multiple sources in a P2P session. Secondly, some P2P approaches also utilize multi-channel structure for single media source [22], [23]. In these cases, the multiple diverse distribution trees or mesh overlays are built not for multiple sources, but for issues like heterogeneity and redundancy. On the other hand, for multi-source live streaming, there are also some researches that study the multi-view P2P streaming. This kind of researches mainly focuses on providing 3D entertainment applications by P2P streaming [24], or tries to provide the ability that a user can simultaneously watch multiple channels on screen [25]. However, these researches still deal with multiple sessions on a screen, but not tightly contain time-related multiple sources in a P2P session. And what is more, content delivery among heterogeneous clients with differentiated sources is not addressed.

Recently, some mobile P2P streaming studies have begun to consider some aspects of mobile features. RaptorStream [12] proposes to increase the upload throughput of mobile P2P applications by the use of Raptor codes. LocalTree [13] studies how to achieve broadcasting minimizing of broadcast energy consumption in the network while meeting a certain stream quality requirement. Kim *et al* [14] propose an energy-efficient two-layer overlay network architecture for mobile IPTV systems. Mobile peers can reduce the number of data packets and control messages by receiving video data from stationary peers only in a push manner. Xie *et al* [15] discuss how to support a receiver peer with enough QoS (Quality of Service) of the multimedia streaming by multiple source peers. However, these researches mainly concentrate on the heterogeneity about the stability and mobility of clients, the source heterogeneity is not concerned.

In brief, the existing P2P streaming mainly focuses on the single source streaming applications. For multi-source P2P streaming, solutions are provided to support multi-view 3D streaming or picture-in-picture multi-channel streaming for a client. However, these solutions have not taken the source heterogeneity into account. Meanwhile, the problem incurred by heterogeneous P2P clients has only been mentioned in several Mobile P2P IPTV researches. Nonetheless, multi-source delivery is not an issue for those structures, and is not mentioned in these cases. Comparably, SAMP differs from them in that it proposes a method that tightly associates with the source heterogeneity, and embodies the tight correlation among different sources.

III. Architecture of the SAMP IPTV System

The overview of the SAMP IPTV system is illustrated in Fig. 1.

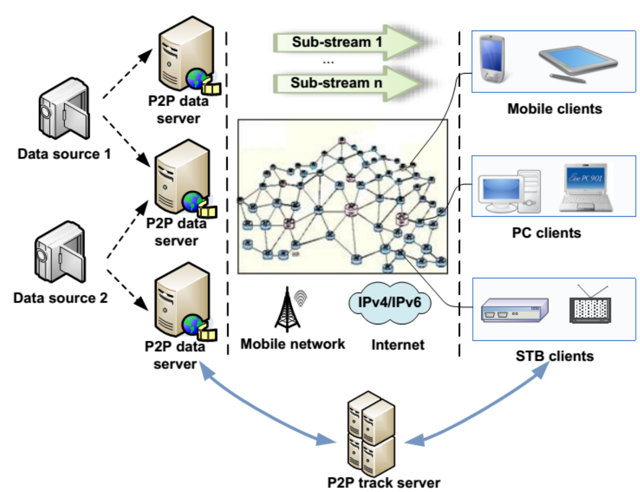

Fig.1. Architecture of the SAMP IPTV system.

As shown in Fig. 1, the proposed SAMP IPTV system consists of P2P track server, P2P data servers, and P2P nodes. Specifically, the P2P track server is the rendezvous of the whole system. It maintains global information of the running system. The P2P data server is in charge of data acquisition, coding, substream division, packaging, and initial substream pushing. In the SAMP IPTV system, multimedia data received from different data sources are divided into multiple substreams, and these substreams are distributed among different peer nodes based on the proposed scheme.

The proposed SAMP scheme embodies its special features in two aspects. Firstly, it provides a source-aware P2P topology construction algorithm to deduce the bandwidth occupation and the control overhead among the P2P clients. Secondly, it introduces a source-aware P2P streaming scheduling algorithm to further enhance the delay performance, which is based on push-pull data scheduling scheme.

IV. Source-aware P2P Topology Construction Algorithm of SAMP

The proposed SAMP P2P topology construction algorithm separates the whole P2P overlay network into different subsets by considering the multi-source heterogeneity of different peers. In detail, the subsets of the P2P overlay network are formed by the peers with a source-specific manner. Since the topology of a push-pull P2P streaming system is gradually constructed by neighbor selection of each peer, the P2P overlay network partition strategy is embodied and really implemented by the neighbor selection.

A. P2P Overlay Network Partition Strategy

The subset partition of the P2P overlay network depends on the source requirement information. In a multi-source P2P live streaming system, a client will send its source requirement to the track server, and the track server will return an appropriate candidate neighbor list by the neighbor selection method. Therefore, the proposed topology construction algorithm defines SOU (Sub-Overlay Unit) as a subset of the whole overlay network, which is formed by the peers according to a specific data source. That is, the SOU and the media source is a one-to-one mapping relationship. Each SOU represents an overlay subset according to a data source. If there are clients with multiple source requirements, there will be intersection between the different SOUs. A simple example of the P2P overlay network partition is shown in Fig. 2, in which there are three nodes requesting for the two data sources simultaneously.

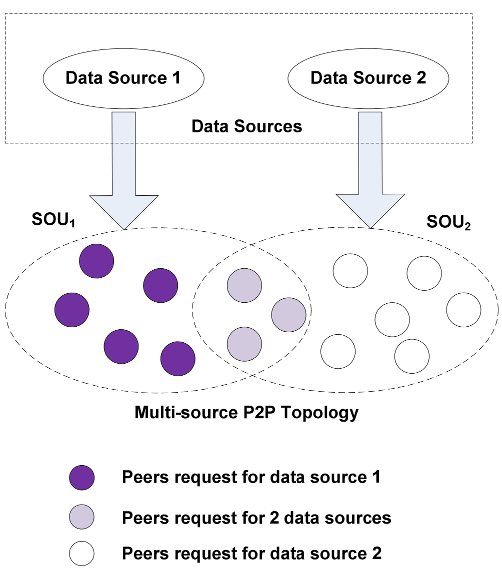

Fig. 2. An example of the sub overlay unit division.

In other cases, if the different SOU subsets are completely the same, then the multi-source P2P IPTV system can be converted into a traditional single-source P2P streaming system by merging different data sources into a single stream. On the contrary, if the intersection of different SOUs is empty, that is, different SOUs are independent of each other, the multi-source P2P IPTV system can be treated as a multi-channel P2P live streaming system.

B. Source-aware Neighbor Selection

The objective of the source-aware neighbor selection is to make sure that the gradually constructed P2P overlay network is in accordance with the P2P overlay network partition strategy. The basic idea of the neighbor selection is to select the nodes with exactly the same source requirement. In a further step, among these candidate neighbors, the nodes with longer online duration, shorter network distance, and bigger redundant bandwidth are preferred to be selected as the neighbors. Only if the candidate neighbors with the same source requirement cannot satisfy the minimum number of the neighbors, the nodes with parts of the source requirement are selected as the neighbors. Notice that, in reality, these parameters, such as the online duration, the network distance, and the available bandwidth, can be gotten in a simplified manner through the heat beat and control messages. For example, the online duration of a node can be achieved through the periodic increment of the heartbeat connections. The uplink bandwidth of a candidate neighbor node can be evaluated by the number of nodes it serves.

In brief, the source-aware neighbor selection partitions the whole P2P overlay network into multiple source-specific SOU subsets, and selects the nodes with the highest similarity in the source requirement as neighbors. In this manner, together with the P2P streaming scheduling algorithm of SAMP, it is possible to obtain better synchronization performance among multiple sources, and to deduce the control overhead by packaging the messages from multiple sources together.

V. Source-aware P2P Streaming Scheduling Algorithm of SAMP

This section discusses how to implement streaming scheduling to further support the multi-source heterogeneity based on the constructed source-aware topology. The detailed streaming scheduling algorithm is based on substream, which is the fundamental logic unit of push-pull P2P live streaming. Since the data streaming in a push-pull P2P IPTV system mainly depends on pushing mechanism. The SAMP scheduling focuses on the pushing method of the substreams, whereas the pulling mechanism adopts the traditional data-driven pull-based scheduling strategy. In detail, SAMP concentrates on two aspects of the pushing mechanism to deduce the streaming delivery latency. On one hand, the proposal defines a method for the substream reservation, that is, the source request manner from the side of the requestor. On the other hand, the algorithm considers that how to feedback the source reservation requests from the side of the responder. The detail strategies are illustrated in the following subsections, respectively.

A. Multi-source Substream Reservation

The SAMP P2P streaming scheduling algorithm splits each source stream into several substreams, and each substream has its own buffer map. In this manner, a multi-source P2P IPTV system is quite similar to a single-source P2P system, since both of them need to schedule several substreams. However, compared with the common single-source P2P streaming system, the special feature of the SAMP scheduling algorithm is that the relation among different streaming sources must be considered. Otherwise, poor synchronization performance among different media sources may increase the multi-source playback latency.

The pushing relation among peers in a push-pull P2P IPTV system is determined by the substream reservation. The substream reservation is performed from the side of the requestor. The detailed multi-source substream reservation mechanism is illustrated as follows. In accordance with the source-aware neighbor selection strategy, the requestor prefers to turn to the neighbor nodes with the same source requirement for help in the process of substream reservation or data requests. If the condition of these neighbors for the substream reservation is satisfied, the requestor verifies its substream reservation.

Otherwise, if the neighbors selected by the above mechanism cannot satisfy the condition for substream reservation, the P2P streaming scheduling algorithm acts as a common single-source P2P live streaming scheduling scheme, without distinguishing the node types of the substreams. If the condition for the substream reservation is still hard to satisfy, the P2P streaming scheduling algorithm degrades to the traditional data-driven pull-based scheduling.

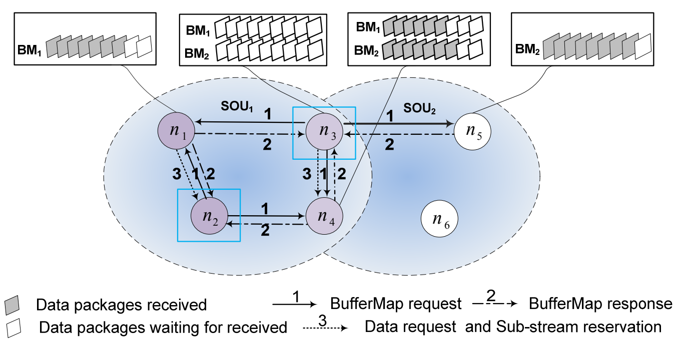

Fig. 3. Data request and substream reservation for multi-source node.

As an example shown in Fig. 3, suppose that there are two data sources, and the corresponding buffer maps are BM_1 and BM_2, respectively. The corresponding SOUs are SOU_1 and SOU_2, respectively. Then, the substream reservation process for multi-source node n_3 is executed as follows. Firstly, node n_3 sends the buffer map request messages to all of its neighbors, including n_1, n_4, and n_5. Secondly, node n_1 and n_5 response the buffer map request by sending back their buffer map directly. Differently, node n_4 merges two buffer maps together at first, and then sends it back to node n_3. Finally, node n_3 chooses node n_4 as the candidate for the data request, since they have exactly the same source requirement. In detail, node n_3 puts the data request information for the two media sources together in a message, and sends the substream reservation message to node n_4.

As also shown in Fig. 3, the substream reservation process for single-source node n_2 is executed as follows. Since node n_2 and its neighbor node n_1 are with the same source requirement, node n_2 will choose node n_1 as the data request candidate, rather than the other neighbors.

The advantages of the multi-source substream reservation mechanism lie in two aspects. On one hand, for multi-source clients, the requests and responses for the multiple substreams from different media sources can be packaged together. In this way, the mechanism can enhance the concurrent scheduling performance of multiple data sources by reducing the control overhead. On the other hand, this mechanism can reduce the playback latency caused by multi-source asynchronous situation. If a multi-source node turns to different SOUs for different media sources, it is prone to incur larger delay for waiting time-related media sources.

B. *Multi-source Data Pushing*

In the former section, the SAMP P2P streaming scheduling algorithm defines the method for the substream reservation from the aspect of the requestor. In this section, the algorithm proposes the data pushing method from the side of the responder, and decides how to feedback the source reservation requirements. In a P2P streaming system, the peers generally provide best-effort service, and will not take the initiative to reject other nodes for their buffer map requests. Therefore, there exists a case, that is, a data block owned by one node is requested by several neighbors simultaneously. Since the limitation of the node upload bandwidth, the node with the desired data block must make its decision to identify the nodes that it will serve at first.

The detailed multi-source data pushing mechanism is illustrated as follows. A single-source node who acts as a responder prefers to accept the substream reservation or data requests from multi-source neighbors. Similarly, a multi-source node who acts as a responder prefers to respond to the requirement from single-source neighbors in handling concurrent data requests or substream reservations.

Notice that the multi-source data push mechanism is quite the opposite of the multi-source substream reservation mechanism. The reason can be explained as follows. According to the SAMP P2P topology construction algorithm and the multi-source substream reservation mechanism, a multi-source node who acts as a requester prefers to send its request to the multi-source neighbors. Only if these multi-source neighbors cannot satisfy its data or substream reservation requests, the requester turns to single-source neighbors for help. Therefore, the single-source neighbors who act as responders prefer to accept the substream reservation or data requests from multi-source neighbors.

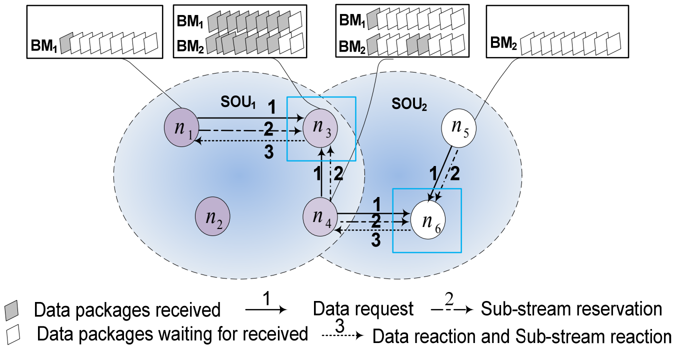

Fig. 4. Data pushing for single-source nodes.

As shown in Fig. 4, if node n_3 receives substream reservation or data requests from n_1 and n_4 simultaneously, according to the multi-source data push mechanism, the multi-source node n_3 will accept the substream reservation or data requests from the single-source neighbor n_1, rather than the multi-source neighbor n_4.

For the same reason, a multi-source node who acts as a responder prefers to response the requirement from single-source neighbors. As also shown in Fig. 4, if node n_6 receives substream reservation or data requests from n_4 and n_5 simultaneously, according to the multi-source data pushing mechanism, the single-source node n_6 will accept the substream reservation or data requests from the multi-source neighbor n_4, rather than the single-source neighbor n_5.

In general, the SAMP P2P streaming scheduling algorithm has the following advantages in supporting multi-source heterogeneity. On one hand, according to the SAMP P2P topology construction algorithm and the multi-source substream reservation mechanism, the data scheduling mainly occurs within the nodes with the same source requirement. In this manner, it reduces the heterogeneity among neighbors, and improves the efficiency of the data scheduling, with respect to the control overhead and the delivery delay. On the other hand, according to the multi-source data pushing mechanism, when a node cannot be served by the neighbors with the same source requirement, it obtains the service from the nodes in the intersection. In this manner, from an overall point of view, the strategy ensures the connectivity of the overlay network, avoiding the segmentation among the different overlay subsets.

Finally, besides the scheduling scheme among peers, the SAMP P2P streaming scheduling algorithm also considers how to assign the initial peer nodes to receive the media streaming from the multiple sources. Since the multiple media sources are time-related, the delay caused by data loss from any one of them will influence the general performance, the algorithm prefers to select the multi-source nodes as the initial seeds, and makes sure to push all of the substreams to the initial seeds. In this manner, the integrated multi-source substream reservation ensures that the implicit trees constructed by the substream data pushing will follow the similar delivery manner, so as to improve the delay performance and facilitate the synchronization of multiple data sources.

VI. Evaluation and Simulation

This section evaluates the performance of the proposed SAMP scheme. Since no researches directly match this proposal using P2P streaming to support multi-source heterogeneity, to show the effectiveness of the proposed algorithm, the traditional push-pull P2P streaming protocol GridMedia is adopted as a benchmark for quantitative comparisons [18]. In the evaluations, the benchmark multi-source P2P streaming is implemented by delivering independent multi-channel streaming for all of the sources by Gridmedia. In this manner, the multi-source heterogeneity is simply imitated by ignoring unwanted data sources. This multi-channel version of Gridmedia is named as Gridmedia*.

In detail, the constructed P2P system has two media sources in the simulation. Then all of the peers can be categorized as three kinds. The first kind of nodes is the peers which only require the first data source, the second kind of nodes is the peers which only require the second data source, and the last kind of nodes is the peers which require the two sources simultaneously. The number of neighbors for peers is set to 15. Due to the limitation of the compute and bandwidth capacity, the maximum number for a node to be neighbors of the other nodes is set to 20.

A. *Evaluation Result of the Bandwidth Optimization*

This section demonstrates the efficiency of the bandwidth optimization. For the benchmark Gridmedia*, the multi-source live streaming with heterogeneity is implemented by multi-channel live streaming that ignores unwanted media streams, and those ignored streams incur the bandwidth redundancy of Gridmedia*. The bandwidth redundancy result is determined by the ignorance ratio for all of the nodes. Obviously, the smaller the number of multi-source nodes is, the larger the bandwidth redundancy is. The advantage of the bandwidth utilization of the proposal is straightforward and can be evaluated directly by comparing the bandwidth redundancy with its benchmark Gridmedia*.

For example, suppose that there are two data sources in a multi-source P2P IPTV system, and the bit rates for the two sources are the same. Then, the bandwidth redundancy of Gridmedia* is shown in TABLE I, with different ratios of the multi-source nodes which request the two sources simultaneously. Since the data scheduling of the proposal handles the multi-source streaming by considering the source requirement. This kind of bandwidth redundancy for Gridmedia* does not exist, and equals to zero.

TABLE I
BANDWIDTH REDUNDANCY BY SINGLE-SOURCE STREAMING

Ratio of the Multi-source Nodes (%)	Bandwidth Redundancy of GRIDMEDIA* (%)
0	50
10	45
20	40
30	35
40	30
50	25
60	20
70	15
80	10
90	5
100	0

Considering the fact that the theoretical analysis is simple and straightforward, the simulation will not carry out further experiments for the bandwidth optimization. The following simulation will focus on the performance improvement of the control overhead and the delivery delay by the proposal.

B. Simulation Result of the Control Overhead

This section demonstrates the effectiveness of the SAMP P2P topology construction algorithm in reducing average control overhead.

The simulation constructs the multi-source P2P live streaming system with two solutions, and compares the average control overhead with each other. That is, one set of the simulation results is obtained by the source-aware neighbor selection of SAMP, which means that the neighbors are selected based on their required data sources. Correspondingly, the other set of the simulation results is obtained by Gridmedia*, which indicates that the peers select their neighbors randomly if they require the data sources. The simulation results of the average control overhead with 1800 node topology are shown in the Fig. 5.

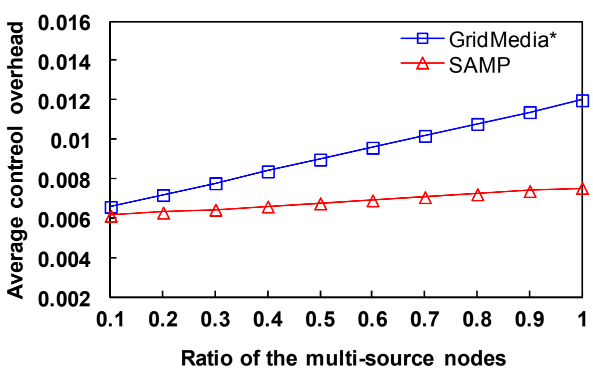

Fig. 5. Average control overhead of P2P overlay network.

In Fig. 5, the average control overhead increases along with the increasing ratio of the multi-source nodes. It can be explained as the multi-source nodes need more control messages for scheduling multiple sources. Especially, compared with the common random selection method by Gridmedia*, the proposed source-aware neighbor selection scheme has a lower average control overhead, and a more stable result about the increasing tendency of the control overhead. It can be explained as follows. The proposed source-aware neighbor selection segments the overlay network into multiple subsets. This approach makes multi-source nodes cluster together, and the data requests for multi-source nodes are handled within these multi-source nodes. In this manner, the requests for multiple sources can be packaged together, which establishes an effective and stable data scheduling relationship.

C. Simulation Result of the Delivery Latency

This section demonstrates the effectiveness of the proposal in reducing the average delivery latency of the media streaming.

The same as the former subsection, the simulation constructs the multi-source P2P live streaming system with the two solutions. The average delay results of the entire P2P network with 1800 node topology are shown in Fig. 6.

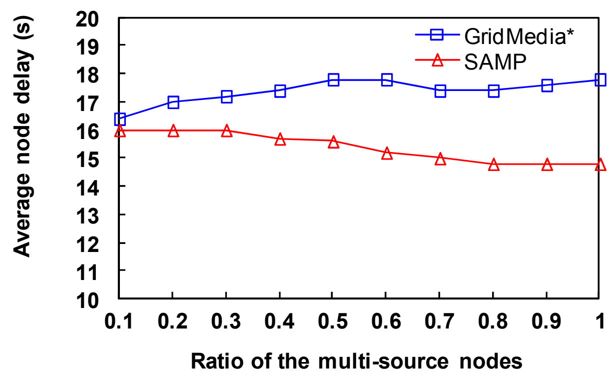

Fig. 6. Average delay result of P2P overlay network.

From the simulation results in Fig. 6, the proposed SAMP scheme cuts down the average delay performance compared with the common multi-channel P2P streaming approach Gridmedia*. The reason can be explained as follows. Since there exists waiting latency for supporting time-related multi-source P2P streaming by Gridmedia*, the delay result of Gridmedia* is larger than the delay result of SAMP, especially with the increasing ratio of the multi-source nodes. Meanwhile, since the proposed SAMP scheme decreases the heterogeneity among the neighbors by a source-aware strategy, the delay caused by time synchronization for multiple sources is reduced.

VII. CONCLUSION AND FUTURE WORK

This paper discusses the challenge of supporting multi-source heterogeneity in a mobile P2P IPTV system, which is a common requirement in many media streaming applications. The proposal utilizes a source-aware P2P topology construction algorithm and a data scheduling algorithm to support multi-source heterogeneity. Firstly, the topology construction algorithm of the proposal forms source-specific subsets of overlay network to reduce the bandwidth occupation and the control overhead. Secondly, the scheduling algorithm of the approach schedules the streaming from both sides of the requestor and the responder, so as to further enhance the delay performance. The simulation results show that the approach can provide a differentiated multi - source live streaming for heterogeneous clients. And what is more, with the increasing ratio of multi-source nodes, the proposal outperforms the traditional multi-channel approach in reducing bandwidth consumption, control overhead, and delivery delay.

In this paper, the priorities of the multiple sessions for different media sources are not considered. The future work will try to introduce a differentiated distribution solution based on session priorities, considering the factors such as dynamic popularity, stream quality, and other QoS requirements. Furthermore, besides the simulations of the proposal, the future work will include evaluating the efficiency of the proposal in a real P2P IPTV environment, obtaining subjective judgments from users.

REFERENCES

[1] C. Diot, B. N. Levine, B. Lyles, H. Kassem, and D. Balensiefen, "Deployment issues for the IP multicast service and architecture," *IEEE Network*, vol. 14, no. 1, pp. 78–88, Jan/Feb. 2000.

[2] B. Li, and H. Yin, "Peer-to-peer live video streaming on the internet: issues, existing approaches, and challenges," *IEEE Commun. Magazine,* vol. 45, no. 6, pp. 94-99, Jun. 2007.

[3] Z. Chen, C. Lin, and X. Wei, "Enabling on-demand internet video streaming services to multi-terminal users in large scale," *IEEE Trans. Consumer Electron.,* vol. 55, no. 4, pp. 1988-1996, Nov. 2009.

[4] X. Wang, C. Zheng, Z. Zhang, H. Lu, and X. Xue, "The Design of Video Segmentation-aided VCR Support for P2P VoD Systems," *IEEE Trans. Consumer Electron.,* vol. 54, no. 2, pp. 531-537, May 2008.

[5] D. Guo, Y. Liu, and X. Li, "BAKE: A balanced Kautz tree structure for peer-to-peer networks," *in Proc. IEEE Conference on Computer and Communications,* Phoenix, USA, pp. 2450-2457, Apr. 2008.

[6] C. Lee, E. Hwang, and D. Pyeon, "A popularity-aware prefetching scheme to support interactive P2P streaming," *IEEE Trans. Consumer Electron.,* vol. 58, no. 2, pp. 382-388, May 2012.

[7] W. Zhang, Q. Zheng, and Y. Lian, "Tree-Aware Selective Frame Discard for P2P IPTV System on Set-top Boxes," *IEEE Trans. Consumer Electron.,* vol. 55, no. 4, pp. 1982-1987, Nov. 2009.

[8] N. Magharei, and R. Rejaie, "PRIME: Peer-to-Peer Receiver-driven Mesh-based Streaming," *IEEE/ACM Trans. Network.*, vol. 17, no. 4, pp. 1052-1065, Aug. 2008.

[9] D. Ren, Y. Li, and S. Chan, "On reducing mesh delay for peer-to-peer live streaming," *in Proc. IEEE Conference on Computer and Communications,* Phoenix, USA, pp. 1732-1740, Apr.2008.

[10] K. Vik, P. Halvorsen, and C. Griwodz, "Multicast Tree Diameter for Dynamic Distributed Interactive Applications," *in Proc. IEEE Conference on Computer and Communications,* Phoenix, USA, pp. 2270-2278, Apr.2008.

[11] L. Yu, L. Gao, J. Zhao, and X. Wang, "SonicVoD: A VCR-supported P2P-VoD system with network coding," *IEEE Trans. Consumer Electron.,* vol. 55, no. 2, pp. 576-582, May 2009.

[12] P. M. Eittenberger, "RaptorStream: boosting mobile peer-to-peer streaming with rapor codes," *in Proc. ACM SIGCOMM annual Conference,* Helsinki, Finland, pp. 291-292, Aug. 2012.

[13] B. Zhang, S. -H. G. Chan, G. Cheung, and E. Y. Chang, "LocalTree: An Efficient Algorithm for Mobile Peer-to-Peer Live Streaming," *in Proc. IEEE International Conference on Communications,* Kyoto, Japan, pp. 1-5, Jun. 2011.

[14] D. Kim, E. Kim, and C. Lee, "Efficient peer-to-peer overlay networks for mobile IPTV services," *IEEE Trans. Consumer Electron.,* vol. 56, no. 4, pp. 2303-2309, Nov. 2010.

[15] M. Xie, G. Wei, Y. Ge, and Y. Ling, "Receiving-peer-driven multi-video-source scheduling algorithms in mobile p2p overlay networks," *Comput. & Electr. Eng.,* Vol. 38, no. 1, pp. 116-127, Jan. 2012.

[16] N. Magharei, R. Rejaie, and Y. Guo, "Mesh or Multiple-Tree: A Comparative Study of Live P2P Streaming Approaches," *in Proc. IEEE Conference on Computer and Communications*, Anchorage, USA, pp. 1424-1432, May 2007.

[17] J. Seibert, D. Zage, S. Fahmy, and C. Nita-Rotaru, "Experimental comparison of peer-to-peer streaming overlays: An application perspective," *in Proc. IEEE Conference on Local Computer Networks,* Montreal, Canada, pp. 20-27, Oct. 2008.

[18] M. Zhang, Q. Zhang, L. Sun, S. Yang, "Understanding the power of Pull-based Streaming Protocol: Can We Do Better?" *IEEE J. selected Areas common.*, vol. 25, no. 9, pp. 1678-1694, Dec. 2007.

[19] C. Wu, B. Li, and S. Zhao, "Multi-Channel Live P2P Streaming: Refocusing on Servers," *in Proc. IEEE Conference on Computer and Communications,* Phoenix, USA, pp. 2029-2027, Apr. 2008.

[20] C. Wu, and B. Li, "Strategies of Conflict in Coexisting Streaming Overlays," *in Proc. IEEE Conference on Computer and Communications,* Anchorage, USA, pp. 481-489, May 2007.

[21] C. Wu, and B. Li, "Diverse: application-layer service differentiation in peer-to-peer communications," *IEEE J. Selected Areas Commun.,* vol. 25, no. 1, pp. 222-234, Jan. 2007.

[22] G. Dan, V. Fodor, and I. Chatzidrossos, "On the Performance of Multiple-Tree-Based Peer-to-Peer Live Streaming," *in Proc. IEEE Conference on Computer and Communications,* Anchorage, USA, pp. 2556-2560, May 2007.

[23] V. Venkataraman, K. Yoshida, and P. Francis, "Chunkyspread: Heterogeneous Unstructured Tree-Based Peer-to-Peer Multicast," *in Proc. IEEE International Conference on Network Protocol,* Santa Barbara, USA, pp. 2-11, Nov. 2006.

[24] E. Kurutepe, and T. Sikora, "Multi-view video streaming over p2p networks with low start-up delay," *in Proc. IEEE International Conference on Image Processing,* San Diego, USA, pp. 3088-3091, Oct. 2008.

[25] M. Wang, L. Xu, and B. Ramamurthy, "Channel-Aware Peer Selection in Multi-View Peer-to-Peer Multimedia Streaming," *in Proc. IEEE International Conference on Computer Communications and Networks*, St. Thomas, US Virgin Islands, pp. 1-6, Aug. 2008.

BIOGRAPHIES

Weizhan Zhang (S'08-M'10) received the BS degree in electronics engineering in 1999 from Zhejiang University, China, and the PhD degree in computer science in 2010 from Xi'an Jiaotong University, China. He served as a software engineer in Datang Telecom Corporation from 1999 to 2002. Now he is an assistant professor in the department of computer science and technology in Xi'an Jiaotong University, China. His research interests include multimedia systems for e-learning, peer-to-peer streaming, and mobile computing.

Zhenyan Li received the BS degree from the school of software engineering, Zhengzhou University in 2012. Now she is a master candidate in the department of computer science and technology in Xi'an Jiaotong University, China. Her research interests include multimedia systems for e-learning and peer-to-peer streaming.

Qinghua Zheng (M'05) received the BS degree in computer software in 1990, the MS degree in computer organization and architecture in 1993, and the PhD degree in system engineering in 1997 from Xi'an Jiaotong University, China. He is a professor in the Department of Computer Science and Technology in Xi'an Jiaotong University. He serves as the dean of the Department of Computer Science and Technology, and vice dean of E-Learning School of Xi'an Jiaotong University. His research areas include multimedia distance education, computer network security, intelligent e-learning theory and algorithm. He did postdoctoral research in Harvard University from February 2002 to October 2002 and Visiting Professor Research in HongKong University from November 2004 to January 2005. He got the First Prize for National Teaching Achievement, State Education Ministry in 2005, and the First Prize for Scientific and Technological Development of Shanghai City and Shaanxi Province in 2004 and 2003 respectively.