Proceedings of the 15th Asia-Pacific Conference on Communications (APCC 2009)-206

Performance Evaluation of AS-friendly Peer Selection Algorithms for P2P Live Streaming

Yukinobu Fukushima, Kazuya Inada, Yin Tao, Yasuyuki Fujiwara and Tokumi Yokohira
Graduate School of Natural Science and Technology, Okayama University,
3-1-1 Tsushima-naka, Kita-ku, Okayama-city, Okayama 700-8530, Japan
Email: fukusima@cne.okayama-u.ac.jp

***Abstract*—In this paper, we evaluate the performance of peer selection algorithms: MLH (Minimum Logical Hop) and MPH (Minimum Physical Hop) to increase the number of joining peers and to decrease inter-AS traffic volume in P2P live streaming, where we assume that every peer's logical hop count (the number of providing peers between an origin streaming server and the peer) is limited by a predetermined value in order to keep real-time property of live streaming. In MLH, a newly joining peer selects such providing peers that the logical hop count is minimum to increase the number of joining peers. And then if there are several such providing peers, the newly joining peer selects such providing peers that the number (physical hop count) of ASs between the newly joining peer and each of the providing peers is minimum to decrease the inter-AS traffic volume. In MPH, a newly joining peer selects providing peers in the reverse order of MLH. Simulation results show that MLH achieves about from 20% to 60% more maximum joining peers than MPH, and MPH shows smaller inter-AS traffic volume than MLH when the number of joining peers is small while MLH shows smaller inter-AS traffic volume when the number of joining peers is large.**

I. INTRODUCTION

In recent years, streaming systems to view video have been widely used as the bandwidth of access networks becomes larger. In particular, live streaming systems to view sports games and music concerts are said to become one of killer applications in the Internet. Most live streaming systems are based on the traditional client-server paradigm. This type of systems is very useful in the environment with a small number of viewers. However, when the number of viewers increases, the systems can not afford to accept all the viewers due to the limitations in server processing power and the capacity of links connecting to servers. In order to get over such limitations, a new kind of live streaming system using peer-to-peer (P2P) technologies is currently emerging [1]–[3]. In these P2P live streaming systems, because peers can become a provider of live streaming video, a peer can retrieve live streaming video from many peers in a multihop manner, and consequently the limitation described above can be resolved.

One of important measures in P2P live streaming systems is the number of peers that join the system to view the corresponding live streaming video, because the income of the system is proportional to the number. Another important measure is the traffic volume between ASs (autonomous systems), because the system operation cost (i.e., transit cost of provider ASs) becomes larger as the inter-AS traffic volume increases. The two measures are influenced by the performance of peer selection algorithms that are adopted in P2P live streaming systems.

In this paper, we evaluate the performance of peer selection algorithms: minimum logical hop (MLH) peer selection algorithm and minimum physical hop (MPH) peer selection algorithm. The former aims at increasing the number of joining peers first and then decreasing the inter-AS traffic volume secondly while the latter aims at them in the reverse order, where we assume that the number (logical hop count) of relaying peers to obtain streaming video is limited by a predetermined value in order to keep real-time property of live streaming.

In MLH, a newly joining peer selects such providing peers that the number (logical hop count) of providing peers between an origin streaming server and the peer is minimum to increase the number of joining peers. And then if there are several such providing peers, the joining peer selects such providing peers that the number (physical hop count) of ASs between the joining peer and each of the providing peers is minimum to decrease the inter-AS traffic volume. In MPH, a newly joining peer selects providing peers in the reverse order of MLH.

The rest of this paper is organized as follows. Section II describes P2P live streaming systems that we assume in this paper and describes the peer selection methods in detail. Section III describes our simulation model and evaluation results. We conclude this paper in Section IV.

II. PEER SELECTION ALGORITHMS

A. Overview of assumed P2P live streaming systems

Figure 1 depicts the P2P live streaming system that we assume in this paper. It consists of origin streaming servers (OSSs) that provide live streaming videos and peers that want to view the video. A newly joining peer first requests a list of peers that are viewing the video from the system. Then, the peer selects a subset of the peers as providing peers and retrieves the video from them. The peer can also select OSSs as providing peers. We call a physical network that represents physical interconnections between peers and routers *an underlay network* and a logical network that represents logical interconnections between peers *an overlay network*, respectively.

We assume that a minimum unit of streaming between peers and OSSs is a Mbps and the bit-rate (A) of a live streaming video is $A = N \times a$ Mbps, where N is a constant determined

978-1-4244-4785-5/09/$25.00

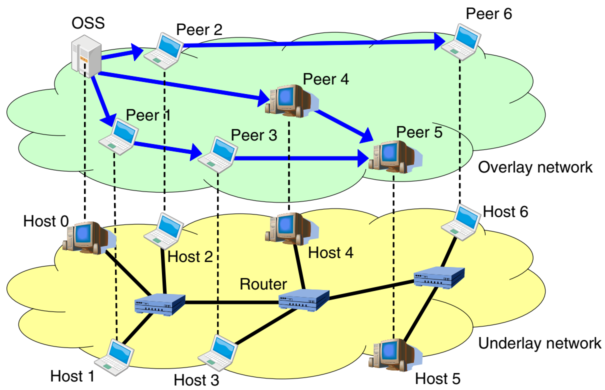

Fig. 1. P2P live streaming system.

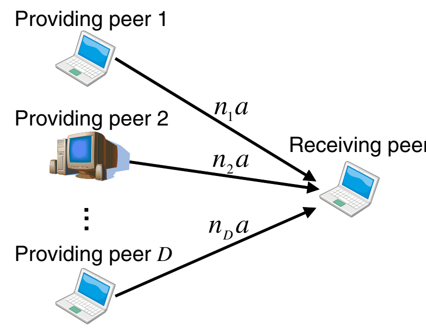

Fig. 2. Peer viewing the live streaming video.

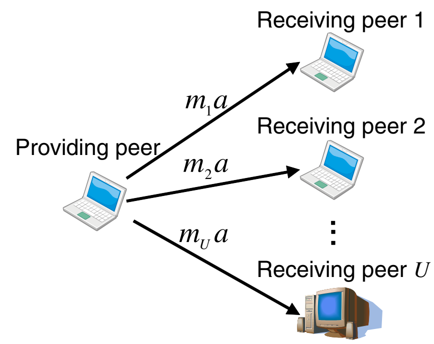

Fig. 3. Peer providing the live streaming video.

in each video. Each peer can view the video if the sum of the received streaming rates reaches the video bit-rate. Figure 2 shows an example of a peer that can view the video. For such peers, following equation is satisfied:

$$N = n_1 + n_2 + \ldots + n_D \quad (1)$$

$$1 \leq D \leq N \quad (2)$$

where D is the number of providing peers and n_i is the number of minimum units which are sent by providing peer i. Each peer has the ability to provide the streaming rate of $M \times a$. We call M as *the providing capacity*. Figure 3 shows an example of a peer that provides its streaming video to other peers. For such peers, following equation is satisfied:

$$M \geq m_1 + m_2 + \ldots + m_U \quad (3)$$

$$1 \leq U \leq M \quad (4)$$

where U is the number of receiving peers and m_i is the number of minimum units which are retrieved by receiving peer i.

In order to keep the real time property of live streaming, our P2P live streaming system introduces the constraint on logical hop counts from OSSs with the assumption that each single logical hop imposes a constant delay. We express the maximum logical hop count as H and the logical hop count from OSSs to peer x as h_x, respectively. In Figure 1, peers 1, 2 and 4 directly retrieve the video from the OSS, thus their logical hop counts are 1 ($h_1 = h_2 = h_4 = 1$). Peers 3 and 6 are two hops away from an OSS, thus $h_3 = h_6 = 2$. On the other hand, peer 5 retrieves the video from providing peers with different logical hops. In this case, the logical hop of peer 5 is calculated as 3, that is, the maximum ($h_3 = 2$) of logical hop counts of the providing peers plus one. This is because peer 5 can begin to provide its streaming video after it is ready to view the video. If the maximum logical hop count is limited to three, peer 5 can no longer provide the video.

As explained above, we can keep the real time property of the live streaming video by introducing the upper bound on logical hop counts. However, this results in limiting the number of joining peers. Thus, it is important to accommodate as many peers as possible under the constraint on logical hop counts.

Another important measure in P2P live streaming systems is inter-AS traffic volume. If peers select their providing peers without any consideration of the underlay network, the constructed overlay network may result in an inefficient structure for the underlay network and generate large inter-AS traffic volume. Because larger inter-AS traffic for provider ASs leads to higher transit cost, Internet Service Providers (ISPs) hope to decrease inter-AS traffic volume. In order to decrease inter-AS traffic volume, we need to take account of the structure of an underlay network in a peer selecting algorithm and have each peer select their providing peers so that the physical hop count is minimized.

B. Minimum logical hop (MLH) peer selection algorithm

In order to maximize the number of joining peers, we should avoid the situation where a peer selects multiple providing peers with different logical hop counts because of *logical hop waste problem*. The problem means that when a peer selects multiple providing peers with different logical hop counts, the logical hop count can increase by more than one, and consequently the number of joining peers decreases.

An example of the logical hop waste problem is described in Figure 4. In this example, we set the maximum logical hop count (H) to 5 and the bit-rate (A) of live streaming video to $2a$. Peers 1, 2, 3 and 4 have already joined the system and peer 5 newly joins the system. Assume that peer 5 selects an

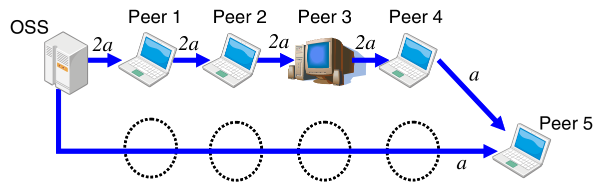

Fig. 4. Logical hop waste problem (H = 5).

OSS and peer 4 as its providing peers with the providing bit-rate a. As a result, the logical hop count of peer 5 reaches the upper bound and can no longer provide its video. Note that the streaming video from an OSS to peer 5 could be provided for four more peers in addition to peer 5 if it had not been provided for peer 5 directly. Thus, to increase the number of joining peers, we must avoid the occurrence of the logical hop waste problem.

The first peer selection algorithm called MLH tries to avoid the logical hop waste problem by selecting such providing peers that the logical hop count between an OSS and them is minimum (i.e., minimum logical hop peer selection). And then if there are several such providing peers, the joining peer selects such providing peers that the number (physical hop count) of ASs between the joining peer and each of the providing peers is minimum to decrease the inter-AS traffic volume.

The algorithm is described as follows.

(1) A newly joining peer (P_{new}) obtains a list L_1 of candidates for providing peers (i.e., peers with providing bit-rates greater than or equal to a and logical hop count smaller than H) from the system.

(2) P_{new} repeats the following steps (2.1) and (2.2) as long as L_1 includes at least one peer.

(2.1) From L_1, P_{new} selects the providing peers with the minimum logical hop count, adds them to a list L_2, and removes them from L_1.

(2.2) P_{new} repeats the following steps (2.2.1) and (2.2.2) as long as L_2 includes at least one providing peer.

(2.2.1) P_{new} selects a providing peer ($P_{selected}$) with the minimum physical hop count from L_2. If there are multiple such providing peers, it randomly selects one peer as $P_{selected}$. Then, P_{new} removes $P_{selected}$ from L_2.

(2.2.2) Assume that the remaining bit-rate requested by P_{new} is $q \times a$ and the remaining providing bit-rate of $P_{selected}$ is $p \times a$. If $q \times a$ is larger than $p \times a$, then P_{new} retrieves $p \times a$ bit-rate from $P_{selected}$. Otherwise, P_{new} retrieves $q \times a$ bit-rate from $P_{selected}$ and P_{new} successfully finishes the algorithm.

(3) P_{new} fails to join the system and the algorithm is finished.

Figure 5 shows an example of peer selection by MLH. The underlay network consists of three ASs. In the overlay network, there are five peers: peer 1 in AS1, peers 2 and 3 in AS2 and peers 4 and 5 in AS3. Assume that the OSS has no remaining capacity while every peer has some providing capacities. When peer 6 newly joins to the system in AS1, it selects peers 2 and 5 (i.e., peers with the minimum logical hop count) as a candidate for a providing peer. Because the physical hop between peers 6 and 2 is smaller than that between peers 6 and 5, peer 6 selects peer 2 as a providing peer. If peer 6 needs additional providing peer, it further selects peer 5 as a providing peer.

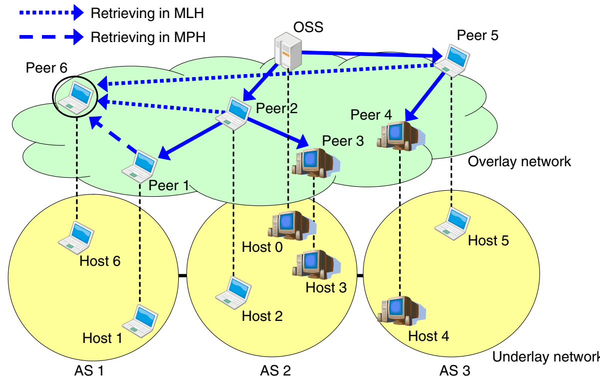

Fig. 5. Example of peer selection with MLH and MPH.

C. Minimum physical hop (MPH) peer selection algorithm

The second peer selection algorithm called MPH tries to decrease inter-AS traffic volume by selecting such peers that the physical hop count between the newly joining peer and each of the providing peers is minimum (i.e., minimum physical hop count peer selection). And if there are several such providing peers, the joining peer selects such providing peers that the logical hop count is minimum to increase the number of peers accommodated in the system.

The algorithm of MPH is realized by replacing "the minimum logical hop count" in (2.1) of MLH to "the minimum physical hop count" and "the minimum physical hop count" in (2.2.1) of MLH to "the minimum logical hop count".

For example, newly joining peer 6 in Figure 5 selects peer 1 (i.e., a peer with the minimum physical hop count) as a candidate for a providing peer. If peer 6 needs additional providing peer, it further selects peers 2 and 3 as a providing peer.

III. Performance Evaluation

A. Simulation model

In simulation, we use an AS topology with 500 nodes (ASs) and 1000 links between ASs, which has a scale-free structure [4], as an underlay network model. The topology is generated with BRITE [5]. Table I summarizes the parameter settings in our simulation. We assume there are peers with different providing capacities (e.g., ADSL users and FTTH users) and set the providing capacity of each peer except OSSs to an integer randomly selected between 1 to M_{max}, where M_{max} is the maximum providing capacity. We adopt two OSS

TABLE I
PARAMETER SETTINGS

Parameter	value
topology	BA model (node:500, link:1000)
bit-rate of live streaming video (A)	1 [Mbps]
minimum bit-rate (a)	256 [kbps]
maximum providing capacity (M_{max})	min:20, max:40
number of OSSs	10
providing capacity of OSS	400
placement of OSSs	random placement, large-degree first placement

placement methods: random placement and large-degree first placement that deploys one OSS to one AS in an decreasing order of node-degrees.

In addition to MLH and MPH, we use MLH' and a random peer selection algorithm. MLH' is a modified version of MLH. MLH' assumes that complete AS topology information is not available (i.e., each peer cannot obtain physical hop count from its providing peers) but only each peer's belonging AS is available. Thus, when there are several providing peers with the minimum logical hop count in MLH', a newly joining peer selects the peers within the same AS instead of peers with the minimum physical hop count. If there is no such providing peer, the newly joining peer randomly selects its providing peers from the peers with the minimum logical hop count. In a random peer selection algorithm, a newly joining peer randomly selects its providing peers without any consideration of logical and physical hop count.

We use the maximum number of joining peers and *congestion degree* (relative inter-AS traffic volume) as performance measures. The congestion degree (C) is calculated as follows:

$$C = \frac{\sum_{0 \le i \le k} \sum_{0 \le j \le k} \lambda_{ij} h_{ij}}{\sum_{0 \le i \le k} \sum_{0 \le j \le k} \lambda_{ij}} \qquad (5)$$

where i, j is an index of peers or OSSs (indexes between 0 and 9 corresponds to OSSs), λ_{ij} is bit-rate of streaming from i to j, h_{ij} is a physical hop count from i to j, and k is the sum of the number of OSSs and the maximum number of joining peers.

The numerator is the total traffic volume weighted by physical hop counts and the denominator is the total traffic volume. Thus, the congestion degree (C) means the relative total traffic volume to the ideal traffic volume where all traffic are transmitted with a single physical hop.

In terms of the maximum number of joining peers and congestion degree, we evaluate the performance of the peer selection algorithms under the assumption that a peer which tries to join P2P live streaming is generated in a randomly selected AS one by one. In the evaluation, we assume that every peer does not leave the system and the reconstruction of the overlay network is not performed.

B. Maximum number of joining peers

Figure 6 shows the maximum number of joining peers in MLH, MPH, MLH' and a random peer selection algorithm as

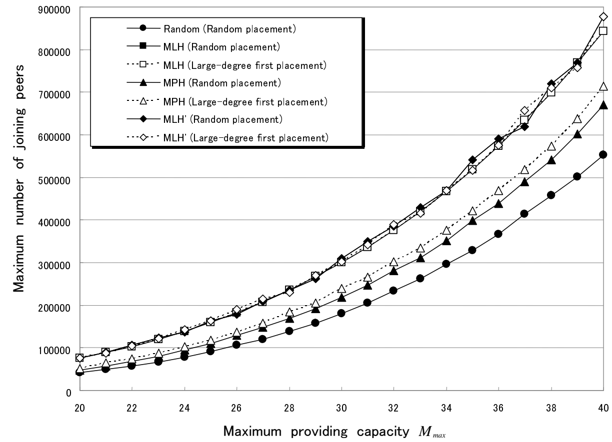

Fig. 6. Maximum number of joining peers as a function of the maximum providing capacity ($H = 5$).

a function of the maximum providing capacity of peers. The maximum logical hop count (H) is 5.

MLH shows about 60% more maximum joining peers than MPH for random deployment and $M_{max} = 20$, and about 20% more maximum joining peers than MPH for large-degree first deployment and $M_{max} = 40$, respectively. Thus, we can say that MLH decreases the frequency of the occurrence of logical hop waste and accommodates more peers than MPH. MLH' shows almost the same maximum joining peers as MLH. The random peer selection shows the smallest maximum joining peers because it does not consider the logical hop counts of each providing peers and does not try to avoid the logical hop waste problem.

MPH shows more maximum joining peers for large-degree first deployment than that for random deployment. This is because physical hop count between peers and OSSs becomes smaller for large-degree first deployment and each peer has more chance to select providing peers with small logical hop counts in ASs located near OSSs.

C. Congestion degree

We next show the change in congestion degree when the number of joining peer increases in Figure 7. Here we set H to 5 and M_{max} to 40, respectively. Note that newly joining peers are uniformly distributed to every AS.

When the number of joining peers is smaller than about 45000, MPH achieves smaller congestion degree than MLH. This is because newly joining peers can find its providing peer that are physically located close to them in MPH, while newly joining peers select OSSs or peers with small logical hop count as its providing peer even if OSSs or those peers are located away from them in MLH during initial state. Figure 8 depicts an example of overlay networks of MLH and MPH during initial state. Assume that an OSS can provide the video for five peers and each peer can provide the video for four peers. Also assume that fifteen peers from P_1 to P_{15} join to AS $\{(i-1) \bmod 5+1\}$ in turn and H is set to 2. The five peers retrieve the video from the OSS in MLH, which results in

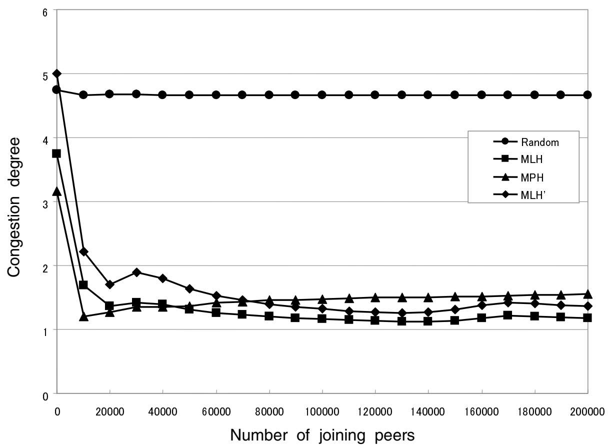

Fig. 7. Congestion degree as a function of the number of joining peers ($H = 5$, $M_{max} = 40$)

increased inter-AS traffic volume, while peers in ASs 4 and 5 retrieve it from the providing peers in ASs 2 and 3 in MPH.

However, when the number of joining peers is larger than about 45000, MLH outperforms MPH. This can be explained as follows. MLH succeeds in distributing providing peers with small logical hop to each AS during initial state. Thus, the forthcoming peers in each AS can find its providing peers within the same AS, which leads to small congestion degree during final state. MLH achieves almost as low congestion degree as the ideal value (1.0). On the other hand, in MPH, the distribution is not realized because it does not give the first priority to minimum logical hop selection. The peers with small logical hop tends to intensively locate in ASs that have an OSS. Thus, the forthcoming peers in ASs located away from OSSs tend to fail to find their providing peers within the same AS and retrieve the streaming video from the providing peers in different ASs, which leads to the increased inter-AS traffic volume. In the example in Figure 9, all the forthcoming peers in each AS successfully find its providing peer within the same AS in MLH, while the forthcoming peers in ASs 4 and 5 (i.e., ASs located away from the OSS) need to retrieve the video from providing peers in different ASs in MPH.

MLH' shows larger congestion degree than MLH because newly joining peers cannot select providing peers with shorter physical hop count outside their belonging ASs. However, because MLH' also succeeds in distributing providing peers with small logical hop to each AS during initial state, it achieves smaller congestion degree than MPH when the number of joining peers is larger than about 70000.

In the view point of congestion degree, we can say that we should use MLH for popular live streaming videos while we should use MPH for such live streaming videos that have a small number of viewers.

IV. Conclusion

In this paper, we evaluated the performance of peer selection algorithms by simulation. Simulation results show that 1) MLH achieves about from 20% to 60% more maximum joining peers than MPH, 2) MLH', which uses each peer's belonging AS information instead of the complete AS topology information, achieves almost the same maximum joining peers as MLH, and 3) MPH shows smaller inter-AS traffic volume than MLH and MLH' when the number of joining peers is small while MLH and MLH' show smaller inter-AS traffic volume than MPH when the number of joining peers is large.

One of our future work is to evaluate the performance of the peer selection algorithms on more realistic AS topologies such as "The CAIDA AS Relationships Dataset (09/06/2008)" [6].

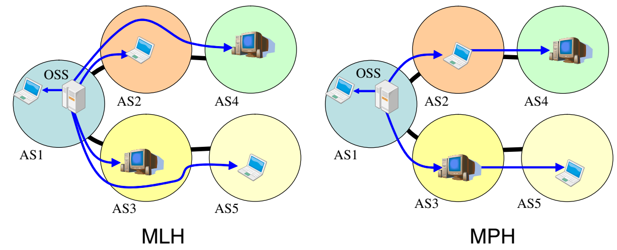

Fig. 8. Overlay network during initial state ($H = 2$)

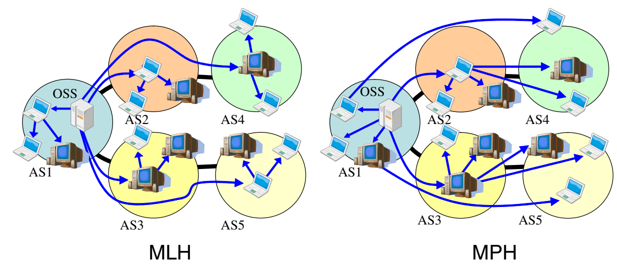

Fig. 9. Overlay network during final state ($H = 2$)

References

[1] X. Hei, Y. Liu, and K. W. Ross, "IPTV over P2P streaming networks: the mesh-pull approach," *IEEE Communications Magazine*, pp. 86–92, Feb. 2008.

[2] "PPLive." http://www.pplive.com/.

[3] "BBbroadcast." http://bbbroadcast.tv-bank.com/.

[4] B. Zhang, R. Liu, D. Massey, and L. Zhang, "Collecting the Internet AS-level topology," *SIGCOMM Computer Communication review*, pp. 53–61, Jan. 2005.

[5] A. Medina, A. Lakhina, I. Matta, and J. Byers, "BRITE: Universal topology generation from a user's perspective," *Technical Report, Boston University*, 2001.

[6] "The CAIDA AS Relationships Dataset (09/06/2008)." http://www.caida.org/data/active/as-relationships/.