Utilization Based Hybrid Overlay Approach for P2P live Streaming: A Comparative Analysis

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Abstract – Some of the characteristics of the Peer to Peer (P2P) approach such as its cost effectiveness and scalability have contributed to the growth of its popularity over the last few years. Thus, a significant amount of traffic over the internet uses the P2P approach for live video streaming. P2P is a decentralized media communication method. The traditional P2P network suffers from some limitations that overshadow its advantages and, one of these limitations is Overlay Construction. Some of the unstructured overlay approaches like tree and mesh overlays have already been discussed. The two prime considerations while overlay creation is upload bandwidth of peer and peer utilization. These two parameters play a crucial role in P2P network. So, in this paper, a comparative analysis of utilization-based hybrid overlay (Which combined these two crucial parameters for overlay creation) for the P2P network is done with traditional and famous overlay approaches available in the P2P network. Through the theoretical and simulation results it is provided that the crucial delay factors in P2P live streaming like startup delay, end to end delay and playback delay is improved in utilization based overlay as compare to other traditional and famous overlays.

Keywords: Peer to Peer network, Resource utilization, Live video streaming.

1 Introduction

An exponential growth has been witnessed in the number of Internet users for live video streaming in the past few years. IPTV [1], YouTube [2], and NetTv [3] etc. are some of the most popular media platforms. According to a study conducted by Cisco, 90% of the traffic over the Internet till 2019 will be due to media transmission [4]. Also the popularity of media streaming websites is increasing rapidly and according to Alexa ranking system [5] the second most popular site over the Internet is YouTube. This huge increase in demand also increases the cost and complexity of video streaming at the server side in the traditional client server architecture [6]. Such problems related to the client server architecture with respect to live video streaming can be solved using a distributed system like the Peer to Peer (P2P) network. P2P is a distributed architecture which distributes the task and workload between the peers in the network. Instead of only downloading the content in the network peer can also upload the content to other peer so upload bandwidth of the peers can also be used for the benefit of the network. One of the landmark work in the field of live video streaming with P2P network is CoolStreaming [7]. Bit torrent also uses the same approach for content mechanism as is used in CoolStreaming. Swarm based and gossiping approaches are used in CoolStreaming for content distribution and overlay construction respectively. Some of the design and implementation issues related to CoolStreaming are discussed in detail by SusuXie et al. [8]. An improvement of CoolStreaming and its design and theory is discussed by B. Li et al [9]. P2P network solves the problem of cost and complexity upto some extent but it also adds some new issues such as, overlay construction, data scheduling, flash crowd and selfish peer etc. In this paper, we focused on the overlay construction approach and have discussed different possible overlay approaches in the P2P network.

2 Related Work

A network that is built on an already existing network is known as an overlay network. Through the virtual or logical links the peers are connected to each other in the overlay. The unstructured overlay can further be classified into tree and mesh overlay.

2.1 Tree Overlay

The basic unstructured overlay is tree overlay as it is less complex and easy to handle as compared to the other overlay approaches. The server is a source peer located at level 0 that works as a parent peer to all other peers. As the number of peer increases the height of the tree increases and the level of peer also increase. The peers at level 1 work as a parent for the peers at level 2 and as child for the level 0 peers. So it is the responsibility of the immediate parent to transfer the media content to its child peers. Tree overlay is fragile in nature and the child peer fully depends on the parent peer to receive the data. Because of this parent-child relationship between the peers the startup delay in the tree overlay is minimized as compared to the other approaches such as mesh overlay. The type of data scheduling scheme generally preferred in tree based overlay is a push based scheduling scheme. Every parent peer pushes the media content to all its dependent child peers, so that the media content is delivered from source to destination. But the utilization of resources in case of tree overlay is limited as the upload bandwidth of leaf peers can't be used. Leaf peers can only download the content from the parent peers thus, the upload bandwidth of the leaf peer is not used and thus the overall utilization of the resources degrades that also affects the overall performance of the P2P network. ESM and NICE are some of the examples of the tree based overlay [10].

2.2 Mesh Overlay

Another overlay approach that is quiet popular in P2P network and can provide a solution to the issues in tree overlay is mesh overlay. Each peer in mesh overlay follows the property of complete mesh as it is connected to each and every other peer in the network. Content and bandwidth bottleneck are some of the basic problems in P2P live streaming. PRIME describes the mesh based P2P live video streaming in detail [11]. A solution to both the problems discussed above is achieved in PRIME using the swarming based content delivery mechanism. Efficient pattern delivery and bandwidth degree condition mechanism is used for providing a solution to content bottleneck and bandwidth bottleneck respectively [12]. For scheduling, the pull based scheduling scheme is generally used in mesh based overlay because push based scheduling scheme generates redundant packets in the P2P network. Pull based scheduling scheme provides a near to optimal solution for bandwidth utilization and throughput in mesh based overlay [13]. Some of the examples of mesh based overlay are CoolStreaming ,Bullet, Chainsaw, and Anysee [14].

2.3 Hybrid Overlay

Both the approaches i.e. tree and mesh overlays discussed till now have their pros and cons. Some authors tried to combine both the approaches into a hybrid overlay that leverages the characteristics of both the overlays. A hybrid overlay approach defined by Q. Huang [15], the approaches uses different overlays for transferring different kind of packets in the network like tree overlay is used for transferring the control packets and mesh overlay is used for transferring the data packets in the network. The geographical location of each peer is used for calculating the tree overlay and further peer selection mechanism is applied to create the mesh overlay. This approach only uses the geographical location of each peer and other crucial factors like upload bandwidth and stability of peer are not used, this is the biggest drawback of this approach. Another approach which considers stability as a prime consideration for overlay construction is mTrrebone [16]. The backbone of the overlay is tree and creation of the tree is done using the stability of peer. So peers that are more stable are connected to form a stable structure and further these stable peers are connected with unstable peer to form a mesh overlay. Other crucial parameters like bandwidth and delay between the peers are not considered in this approach.

Another approach, Hybrid Live P2P Streaming Protocol (HLPSP) discussed by C. Hammami, et al. can be used to solve the problem of overlay construction. One of the prime considerations for the overlay creation in the approach is upload bandwidth of the peer. Peers having high upload bandwidth should be near to the source peer. So the peer that is higher in the hierarchy has more upload bandwidth as compared to peers lower in the hierarchy and the source peer is at level 0. A simulation analysis of the approach is done with the Denacast approach (an enhanced version of CoolStreaming). The simulation results show that HLPSP provides less control overhead, better data flexibility, and less start-up delay as compared to Denacast approach. All the crucial factors for overlay creation like geographical location, upload bandwidth and stability of peers are considered together in the new hybrid overlay approach [17]. The hybrid overlay approach is a combination of both the tree and mesh overlays. Through the simulation analysis of the approach it can be concluded that end to end delay, playback delay and start up delay are minimum for the approach as compared to Denacast [18].

3 Utilization Based Overlay

From the above discussion it is clear that upload bandwidth of the peer plays a key role in P2P overlay network. A major role is also played by the upload bandwidth of peer however if connectivity to other peers is not good and sufficient amount of data is not uploaded by peer then upload bandwidth of the peers is not considered as a sufficient parameter. So instead of upload bandwidth, utilization of upload bandwidth is considered as a crucial parameter and plays a significant role in the P2P network. Utilization based overlay approach is discussed in this paper. The peers that utilize their resources are given more priority during overlay creation instead of peers that have a high bandwidth but are not ready to share their bandwidth in the network. The overlay is hybrid in nature and leverages the property of both tree and mesh overlays.

The procedure followed by the new peer j is discussed in Algorithm 1 in detail.

Algorithm 1[A1]:

1. REQ_j^T <G_j, C_{id}, B_{TU}^j >
2. Check the request if new goto 3 else 4.
3. Search position P_j (G_j, B_{TU}^j)[A2]
4. Neighbour List (L_j)
5. $RES_T^i < L_j >$
6. Periodically checks for updates
7. $CREQ_j^i$ Where ($i \subseteq L_j$)
8. $CREQ_j^i$
9. if($CREQ_j^i$) goto 10 else 7 for ∀ k L_j
10. Find best peer according to RTT
11. If continue goto 12 else peer leave network
12. Each peer updates information periodically and goto 2.

Algorithm 1 shows the procedure for new peer j. Peer j sends the request to tracker peer. This request is in the form of a tuple and contains crucial information regarding the new peer j. G_j is the geographical location of peer j, C_{id} is the content id of media that peer j wants to view and B^j_{TU} is the total upload bandwidth of peer j. After receiving the request tracker calculates the level of the new peer in the network. For calculating the level different parameters given by the new peer are used. If the peer is old and is coming for a new session then average utilization of its previous transaction is used otherwise initial threshold value is applied to that peer. Algorithm 2 is used for finding the level of the peer in the overlay.

Algorithm 2[A2]: Find Level (G_i, B^i_{TU})

1. Find Server Upload Bandwidth B^S_{TU}
2. Use Range R of network
3. Find location (G_j, C_{id})
4. $level_j$ = Ceil[{ $B^S_{TU} - B^j_{TU}$ } / R] ;
5. Return $level_j$

The level of the new peer j is calculated using Algorithm 2 by using the upload bandwidth of peer j and its geographical location. After calculating the level of the new peer j, tracker calculates the available list of neighbor peers that can fulfill the demand of peer j. Neighbor list L_j is created using Algorithm 3.

Algorithm 3: Neighbor Creation [A3]:

```
1.  Check for server (S) free slot if yes goto 2 else 3
2.  L_j.insert (S)
3.  level_k = 1;
4.  While(level_j >= level_k && list is not full )
5.  {  for ( each peer at same layer)
6.      {  P^j_U > Th_2 &&  P^j_o != P_active^j_max)
7.              L_j.insert( P^j_U)       }
8.  If(L_j<Th_1)
9.  {           For(y=0; y<n; y++)
10.     {       If( P^j_U > Th_2 and at lower level there is one
        peer than level_k and p_j has space in L_j)
11. L_j.insert( P^j_U)       }
12.  level_k ++;
13. } }
14. Pos_k =1;
15. While Pos_k <=Pos_j && list is not full)
16. {           For( k=0; k<n; k++)
17.     {       If( P^j_U has at least one place remain left)
18. L_j.insert( P^j_U)       }
19. If(L_j<Th_3)
20.   {         For(y=0; y<n; y++)
21.     {       If( P^j_U has at least one place less than level_k
        and  P^j_U has one place remain left )
22. L_j.insert( P^j_U)       }
23. level_k ++;
24. } }
```

The list of neighbor peers is used by the tracker peer and is created according to the utilization of each peer available in the network. The highest level is given to the server peer and if the server has sufficient capacity then server is added to the list of new peer j (line number 1-2, Algorithm 3). But this updation is also done if the peer is lower in the hierarchy (line 11-20, Algorithm 3). While creating this list only those peers are considered that are at an equal or lower level to the level of the new peer j. So the peers that have more or equal upload bandwidth are given priority to be chosen as a parent or neighbor peer. This list contains the lower level peers and as the hierarchy increases the level also increases (the server is at the lowest i.e. at level 0). Before inserting the peer into the list tracker checks the utilization of the peer. If the peer has more utilization factor as compare to threshold (Th2) then only the peer is inserted into the list. Tracker also checks the size of the list and adds the new peer in the list if there is sufficient space (Th2) and if the level of the peer is less than the level of new peer (line 4-13, Algorithm 4). For old peers utilization of each peer is calculated using the last three transactions while for the new peer utilization is initialized as an average of all peers. So the overlay is created in such a way that the peers that have more bandwidth and are interested in sharing the resources are placed above in hierarchy and near to the source peers. These peers also get priority for being considered as a parent peer. So that the new peer can retrieve the media content smoothly and with minimum startup delay.

Tracker sends the list of neighbor peer to the new peer j after creating the complete list L_j (line number 5 algorithm 1). Peer j sends the connection request to all the peers available in the list. Peer j can send the connection request to more than one peer and according to the response time (RTT) the peer chooses the parent peer (line 5-10, Algorithm 1). Tracker provides the list according to the geographical location, upload bandwidth and utilization; however RTT time gives the idea of real time congestion in the network.

Further in this paper, we provide a comparative analysis of utilization based overlay approach with some of the popular overlay approaches like Denacast, Stability based overlay and bandwidth aware overlay approaches. For simplicity, further in this paper, we will refer to Denacast (Mesh Based Overlay) as Approach 1, Stable peer hybrid overlay as Approach 2, Bandwidth, geographical location based hybrid overlay approach as Approach 3 and utilization based overlay approach as Approach 4.

4 Analysis of Utilization based Overlay Scheme

Theoretical and simulation analysis of different characteristics of utilization-based overlay is given below:

4.1 Simulation Setup:

All the four overlay approaches are implemented using the Oversim simulator. Oversim provides an open source overlay for OMNET++ simulation environment OS) in P2P network. For processing and message passing Discrete Event Simulation (DES) is used. Different modules are created in

Oversim and inter-module communication takes place using C++ language and topology descriptive language is used for creating the modules [19]. Table 1, shows the different simulation parameters used for simulation of different overlay approaches.

Table 1: Simulation Parameters and Values.

S. No	Parameter	Value
1.	Simulation Duration	200s
2.	Chunk Size	5 Frames
3.	Average Chunk Length	130Kb
4.	Average Video Bit Rate	512 Kbps
5.	Neighbour Notification Period	2s
6.	Buffer Map Exchange period	1 s
7.	Maximum Number of levels	6
8.	Source Number	3
9.	Video Codec	SVC
10.	Number of Runs	10

4.2 Theoretical Analysis:

Bandwidth Utilization and Scalability: Bandwidth utilization in distributed network plays a significant role and utilization based overlay considers this point. In this approach, the peers that have more upload bandwidth and are willing to share their resources get priority in hierarchy. The overlay is a hybrid overlay which is a combination of both the tree and mesh overlays so the utilization of the leaf peers is also high as compared to tree overlay. In the hybrid overlay, the utilized peers are selected as a parent peer so the overall resource utilization of the network is increased that also has a positive effect on the scalability of the P2P network.

Reliability and Network Congestion: Parent selection mechanism and mobility of peer directly affects the reliability of the network. Tree overlay is less reliable as compared to mesh overlay due to the fact that it has more than one peer as a parent peer. Data transfer can take place from the other peer if the actual parent peer leaves the network or if the peer looses connectivity with its actual parent. While in such a situation of loss of connectivity in tree overlay, the peer has to start the parent selection mechanism again and find a new parent peer. Hybrid overlay solves this issue as in a hybrid overlay the peer is connected to more than one peer and in case the parent peer leaves or if connectivity is lost, the child peer can retrieve the media content from the other connected peers. This improves the overall reliability of P2P network.

Maintenance of mesh overlay network is more as compared to that of tree overlay because control packets in mesh overlay are more as compared to that in tree overlay. Utilization based overlay is a hybrid overlay and not complete mesh overlay so number of control packets in hybrid overlay are less as compare to that in mesh overlay. Also the packet which misses the deadline in the network are useless in live streaming and only increase the congestion over the network. So if the packets are delivered before its deadline then congestion over the network is less. In utilization based overlay, peers with high bandwidth and utilization are above in hierarchy and are preferred for being selected as parents so a peer can receive the packets without any delay in the network and that decreases the congestion over the network.

4.3 Simulation Analysis:

Start-up Delay: Utilization based overlay directly affects the performance of the network. Start-up delay is directly affected by the overlay construction approach. A comparative analysis of the approach is done with the Denacast approach and the other two previous approaches. In the utilization based overlay, peers form overlay according to their upload bandwidth and utilization of each peer. So peer with more upload bandwidth are above in hierarchy and have more chances of being selected as a parent peer. So parent peer have more upload bandwidth and are more willing to share their resources. This directly affects the start-up delay in the network as compared to Denacast, stability based hybrid overlay and bandwidth aware overlay approach also shown in the figure 1. Initially start-up delay of approach 1 and approach 4 is approximately same as the number of peer are less but as the number of peer increases the start-up delay of utilization based overlay is less as compared to the other approaches. Approach 3 has the maximum start-up delay as compared to the other approaches, the reason is that the stability of peer without bandwidth and utilization is not as crucial as it should be in P2P live streaming.

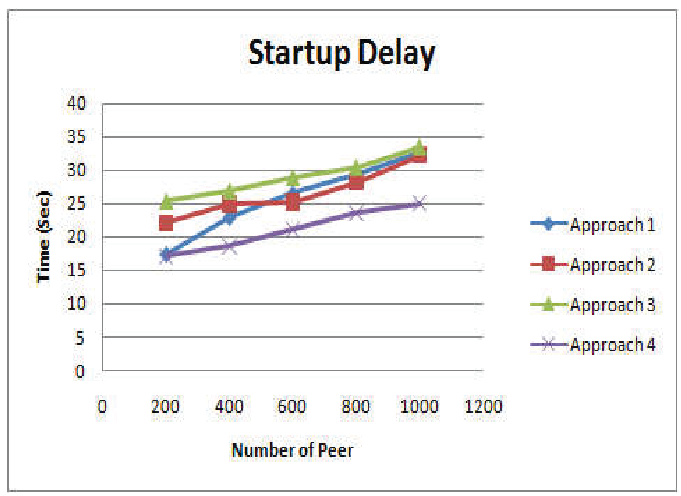

Figure 1: Average Startup Delay.

End to End Delay: End to end delay between the peer directly depends on the upload capacity and congestion in the network. If parent peer is not uploading the content or doesn't have sufficient upload bandwidth the end to end delay increases. In utilization based overlay, peer that have a high upload bandwidth and share more are above in the hierarchy and are preferred as a parents peer. So the peers that are active, have more upload bandwidth and are willing to share their upload bandwidth are chosen and that's why the end to end delay in utilization based overlay is minimize as compared to the other approaches as shown in Figure 2. Initially, when the number of peers is less in the network the congestion is less and all the overlay approaches behave same in terms of end to end delay. But as the number of peers increases end to end delay of all other approaches is more as compared to that of Approach 4.

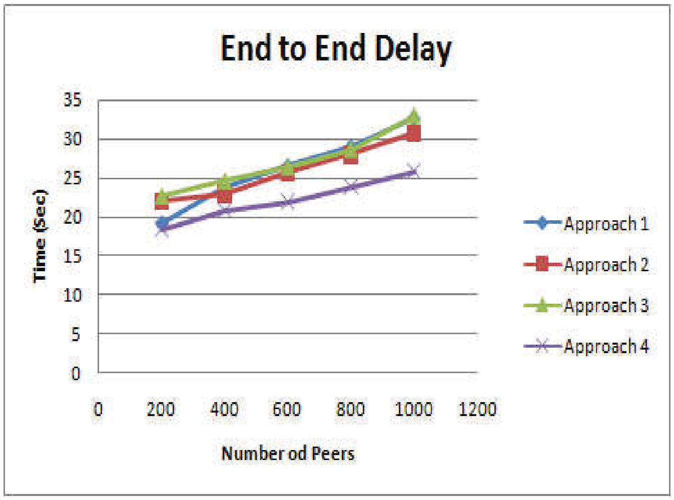

Figure 2: Average End to End Delay.

Playback Delay: Playback delay of utilization-based approach is a bit more as compared to that of DenaCast approach. As the number of peers in the network increases it comes to be approximately same for both the approaches as depicted in Figure. 3. So the overall QoS due to utilization based hybrid overlay increases and the overall performance of the network also increases.

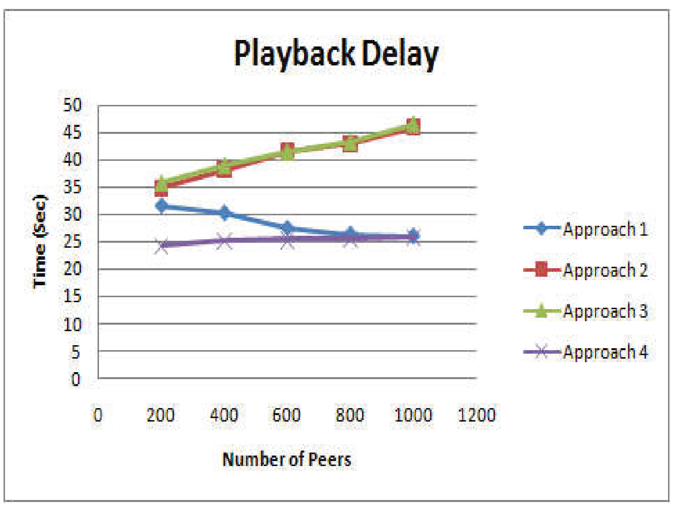

Figure 3: Average Playback Delay.

5 Conclusion and Future Work

The Peer to peer approach is gaining popularity in live video streaming transmission because of its scalable and cost effective nature. However, the traditional P2P network approach also suffers from some limitations and one of them is overlay creation. In this paper, we have given a comparative analysis of the utilization-based overlay construction approach in the P2P overlay. Here, parameters like upload bandwidth and peer utilization are used for overlay creation, both these parameters are very useful for overlay creation. If the highly used peer with maximum upload bandwidth is near to the source, then it can provide better quality media to other peers as well. Different levels consisting of highly used peers are created for mesh overlay. Through the simulation results it can be verified that the crucial delay factors in P2P live streaming like startup delay, end to end delay and playback delay are improved in utilization based overlay as compared to the other overlays.

6 References

[1] "IPTV." [Online]. Available: https://www.iptvonline.ca/. [Accessed: 11-Jan-2017].

[2] "YouTube." [Online]. Available: https://www.youtube.com/. [Accessed: 11-Jan-2017].

[3] "NetTv." [Online]. Available: http://nettv.com.np/nettv/. [Accessed: 11-Jan-2017].

[4] E. Summary, "Cisco Visual Networking Index: Forecast and Methodology, 2014-2019 White Paper - white_paper_c11-481360.pdf," 2015.

[5] "Alexa." [Online]. Available: http://www.alexa.com/topsites. [Accessed: 10-Jan-2017].

[6] V. Venkataraman, P. Francis, and J. Calandrino, "Chunkyspread: Multi-tree Unstructured Peer-to-Peer Multicast," *Proc. 14th IEEE Int. Conf. Netw. Protoc. - ICNP'06*, pp. 2–11, 2006.

[7] X. Zhang, J. Liu, B. Li, and T. S. P. Yum, "CoolStreaming/DONet: A data-driven overlay network for efficient live media streaming," *Proc. IEEE Infocom*, vol. 3, no. C, pp. 13–17, 2005.

[8] S. Xie, B. Li, S. Member, G. Y. Keung, X. Zhang, and S. Member, "Coolstreaming : Design , Theory , and Practice," *IEEE Trans. Multimed.*, vol. 9, no. 8, pp. 1661–1671, 2007.

[9] B. Li *et al.*, "An empirical study of the coolstreaming plus system," *IEEE J. Sel. Areas Commun.*, vol. 25, no. 9, pp. 1627–1639, 2007.

[10] S. Awiphan, Z. Su, and J. Katto, "ToMo: A two-layer mesh/tree structure for live streaming in P2P overlay network," in *2010 7th IEEE Consumer Communications and Networking Conference, CCNC 2010*, 2010, pp. 1–5.

[11] N. Magharei and R. Rejaie, "Understanding Mesh-based Peer-to-Peer Streaming," in *Proceedings of the 2006 international workshop on Network and operating systems support for digital audio and video.*, 2006, p. 10.

[12] N. Magharei and R. Rejaie, "PRIME : Peer-to-Peer Receiver-drIven MEsh-based Streaming," pp. 1415–1423, 2007.

[13] M. Zhang and Q. Zhang, "Understanding the Power of Pull- based Streaming Protocol : Can We Do Better ? Presented by Rabin Karki Background," *IEEE J. Sel. Areas Commun.*, vol. 25, no. 9, pp. 1678–1694, 2007.

[14] H. B. H. Byun and M. L. M. Lee, "HyPO: A Peer-to-Peer based hybrid overlay structure," in *2009 11th International Conference on Advanced Communication Technology*, 2009, vol. 1, pp. 840–844.

[15] Q. Huang, H. Jin, and X. Liao, "P2P live streaming with tree-mesh based hybrid overlay," *Proc. Int. Conf. Parallel Process. Work.*, no. 60433040, 2007.

[16] B. C. Canada, "mTreebone : A Hybrid Tree / Mesh Overlay for Application-Layer Live Video," in *In Distributed Computing Systems, 2007. ICDCS'07. 27th International Conference on*, 2007, p. 49.

[17] P. K. Govil M.C, Ahmed Mushtaq, "A New Hybrid Approach for Overlay Construction in P2P Live Streaming," in *ICACCI*, 2015, pp. 431–437.

[18] P. K. Govil M.C, Ahmed Mushtaq, "Comparative Analysis of New Hybrid Approach for Overlay Construction in P2P Live Streaming," in *ERCICA*, 2016.

[19] I. Baumgart, I. Baumgart, B. Heep, B. Heep, S. Krause, and S. Krause, "OverSim: A Flexible Overlay Network Simulation Framework," *2007 IEEE Glob. Internet Symp.*, pp. 79–84, 2007.