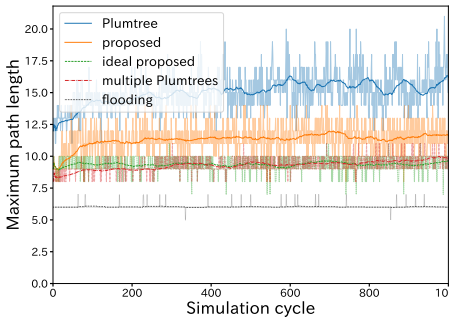

Fig. 2. Maximum path length for `Random Graph`.

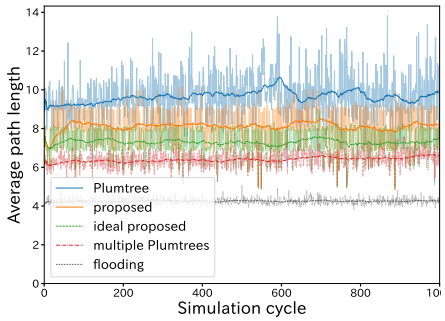

Fig. 3. Average path length for `Random Graph`.

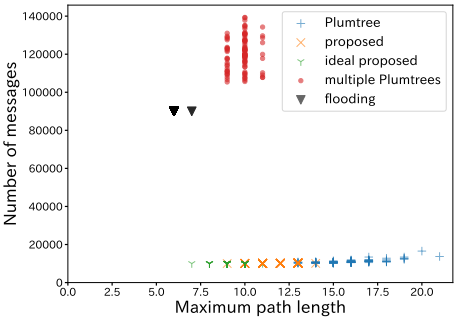

Fig. 4. Relation between the maximum path length and the number of messages for `Random Graph`.

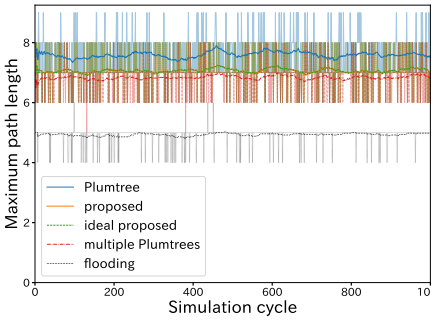

Fig. 5. Maximum path length for `BA Model Graph`.

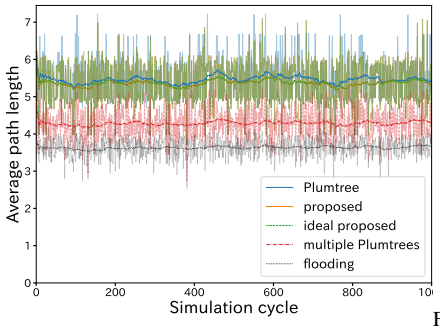

Fig. 6. Average path length for `BA Model Graph`.

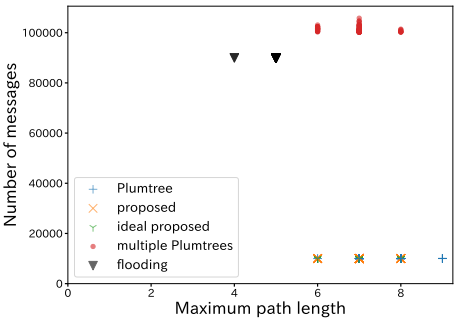

Fig. 7. Relation between the maximum path length and the number of messages for `BA Model Graph`.

when broadcasting. This reduces the frequency of inefficient broadcasts for multiple source nodes. It thereby achieves shortening routing path lengths while maintaining a small number of messages.

The evaluation experiments show that the effect of the proposed method on the path lengths is dependent on the topology of the overlay network. For graphs that closely resemble realistic network topologies, the paths tend to be shortened, especially for a random graph, with a reduction ratio of approximately 28% compared to Plumtree. Moreover, the number of messages was almost the same as the number of nodes. This shows that the proposed method shortens path lengths while maintaining the small number of messages.

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References

[1] G. DeCandia, D. Hastorun, M. Jampani, G. Kakulapati, A. Lakshman, A. Pilchin, S. Sivasubramanian, P. Vosshall, and W. Vogels, "Dynamo: Amazon's Highly Available Key-value Store," in *Proceedings of Twenty-First ACM SIGOPS Symposium on Operating Systems Principles*, ser. SOSP '07. New York, NY, USA: ACM, 2007, pp. 205–220.

[2] N. Ramzan, H. Park, and E. Izquierdo, "Video streaming over P2P networks: Challenges and opportunities," *Signal Processing: Image Communication*, vol. 27, no. 5, pp. 401–411, May 2012.

[3] A. Yahyavi and B. Kemme, "Peer-to-peer Architectures for Massively Multiplayer Online Games: A Survey," *ACM Comput. Surv.*, vol. 46, no. 1, pp. 9:1–9:51, Jul. 2013.

[4] A. Dorri, S. S. Kanhere, and R. Jurdak, "Towards an Optimized BlockChain for IoT," in *Proceedings of the Second IEEE/ACM International Conference on Internet-of-Things Design and Implementation*, ser. IoTDI '17. New York, NY, USA: ACM, 2017, pp. 173–178.

[5] P. Ruiz and P. Bouvry, "Survey on Broadcast Algorithms for Mobile Ad Hoc Networks," *ACM Computing Surveys (CSUR)*, vol. 48, no. 1, pp. 8:1–8:35, Jul. 2015.

[6] J. Leitao, J. Pereira, and L. Rodrigues, "Epidemic Broadcast Trees," in *2007 26th IEEE International Symposium on Reliable Distributed Systems (SRDS 2007)*, Oct. 2007, pp. 301–310.

[7] M. Castro, P. Druschel, A.-M. Kermarrec, A. Nandi, A. Rowstron, and A. Singh, "SplitStream: High-bandwidth multicast in cooperative environments," *ACM SIGOPS Operating Systems Review*, vol. 37, no. 5, pp. 298–313, Oct. 2003.

[8] V. Venkataraman, K. Yoshida, and P. Francis, "Chunkyspread: Heterogeneous Unstructured Tree-Based Peer-to-Peer Multicast," in *Proceedings of the 2006 IEEE International Conference on Network Protocols*, Nov. 2006, pp. 2–11.

[9] A. Rowstron and P. Druschel, "Pastry: Scalable, Decentralized Object Location, and Routing for Large-Scale Peer-to-Peer Systems," in *Middleware 2001*, ser. Lecture Notes in Computer Science, R. Guerraoui, Ed. Springer Berlin Heidelberg, 2001, pp. 329–350.

[10] M. Ferreira, J. Leitão, and L. Rodrigues, "Thicket: A Protocol for Building and Maintaining Multiple Trees in a P2P Overlay," in *2010 29th IEEE Symposium on Reliable Distributed Systems*, Oct. 2010, pp. 293–302.

[11] M. Jelasity, S. Voulgaris, R. Guerraoui, A.-M. Kermarrec, and M. van Steen, "Gossip-based peer sampling," *ACM Transactions on Computer Systems*, vol. 25, no. 3, pp. 8–es, Aug. 2007.

[12] J. Leitao, J. Pereira, and L. Rodrigues, "HyParView: A Membership Protocol for Reliable Gossip-Based Broadcast," in *37th Annual IEEE/IFIP International Conference on Dependable Systems and Networks (DSN'07)*, Jun. 2007, pp. 419–429.

[13] M. Al Hasan, "Methods and Applications of Network Sampling," in *Optimization Challenges in Complex, Networked and Risky Systems*, ser. INFORMS TutORials in Operations Research. INFORMS, Oct. 2016, ch. 5, pp. 115–139.

[14] P. Erdös and A. Rényi, "On random graphs I." *Publicationes mathematicae*, vol. 6, no. 26, pp. 290–297, 1959.

[15] A.-L. Barabási and R. Albert, "Emergence of Scaling in Random Networks," *Science*, vol. 286, no. 5439, pp. 509–512, Oct. 1999.