

Figure 10: Stress tests of client adaptation in CDN server failure cases.

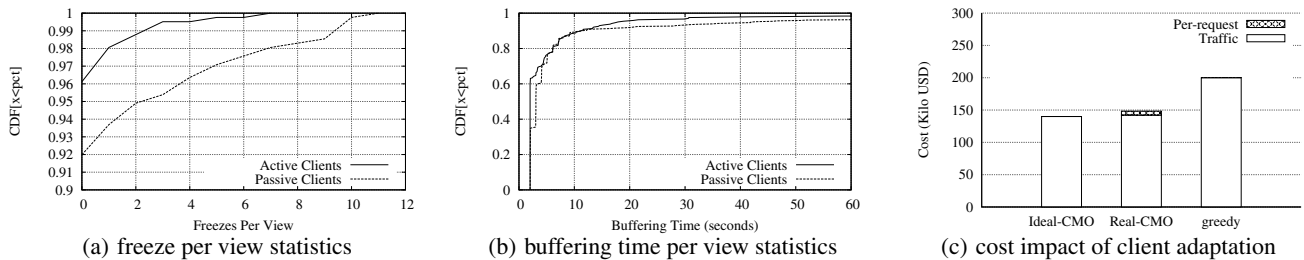


Figure 11: Per-view QoE in PlanetLab experiments.

## 9. CONCLUSIONS

In this paper, we have conducted the first systematic study on content multihoming, by introducing the CMO algorithm and the client adaptation algorithm to optimize both the cost and the performance for content multihoming. Our realistic evaluations show that our content multihoming algorithms reduce publishing cost by up to 40%, and reduce viewer QoE degradation by 51%.

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## 10. REFERENCES

- [1] 01box. <http://cdn.01box.net>.
- [2] V. K. Adhikari, Y. Guo, F. Hao, M. Varvello, V. Hilt, M. Steiner, and Z.-L. Zhang. Unreeling netflix: Understanding and improving multi-CDN movie delivery. In *IEEE INFOCOM'12*.
- [3] H. A. Alzoubi, S. Lee, M. Rabinovich, O. Spatscheck, and J. Van Der Merwe. A practical architecture for an anycast CDN. *ACM Trans. Web*, 5(4):17:1–17:29, Oct. 2011.
- [4] D. Beaver, S. Kumar, H. C. Li, J. Sobel, and P. Vajgel. Finding a needle in haystack: Facebook’s photo storage. In *USENIX OSDI'10*.
- [5] G. Bertrand, E. Stephan, G. Watson, T. Burbridge, P. Eardley, and K. Ma. Use cases for CDNI. IETF Draft, Jan. 2012.
- [6] D. Bertsekas. *Convex Analysis and Optimization*. 2003.
- [7] CDN expert. <http://cdnexpertonline.com/node/45>.
- [8] Cisco Systems. Cisco Visual Networking Index: Forecast and Methodology, 2011–2016.
- [9] Convida. <http://www.convida.com>.
- [10] F. Dobrian, V. Sekar, A. Awan, I. Stoica, D. Joseph, A. Ganjam, J. Zhan, and H. Zhang. Understanding the impact of video quality on user engagement. In *ACM SIGCOMM'11*.
- [11] Dyn CDN manager. <http://dyn.com/>.
- [12] Geo best-of YouTube. <http://geobestofyoutube.gmapify.fr/>.
- [13] D. Goldenberg, L. Qiu, H. Xie, Y. R. Yang, and Y. Zhang. Optimizing cost and performance for multihoming. In *ACM SIGCOMM'04*.
- [14] A. Ioffe and V. Tihomirov. *Theory of Extremal Problems*. Elsevier Science Ltd, 1979.
- [15] R. Krishnan, H. V. Madhyastha, and etc.. Moving beyond end-to-end path information to optimize CDN performance. In *ACM IMC'09*.
- [16] Level 3 Intelligent Traffic Management. [http://www.level3.com/~media/Assets/brochures/brochure\\_intelligent\\_traffic\\_management.pdf](http://www.level3.com/~media/Assets/brochures/brochure_intelligent_traffic_management.pdf).
- [17] Lighthouse Traffic Load Balancer. <http://www.lighthouse.com/traffic-load-balancer/>.
- [18] H. H. Liu, Y. Wang, Y. R. Yang, H. Wang, and C. Tian. Optimizing cost and performance for content multihoming. Technical Report YaleCS-TR1456, May 2012.
- [19] MetaCDN. <http://www.metacdn.com/>.
- [20] B. Niven-Jenkins, F. L. Faucheur, and N. Bitar. Content distribution network interconnection problem statement. IETF Draft, Jan. 2012.
- [21] OnePica. <http://www.magentocommerce.com>.
- [22] R. S. Peterson and E. G. Sirer. Antfarm: efficient content distribution with managed swarms. In *NSDI'09*.
- [23] R. S. Peterson, B. Wong, and E. G. Sirer. A content propagation metric for efficient content distribution. In *ACM SIGCOMM'11*.
- [24] I. Poesse, B. Frank, B. Ager, G. Smaragdakis, and A. Feldmann. Improving content delivery using provider-aided distance information. In *IMC'10*.
- [25] T. Ristenpart, E. Tromer, H. Shacham, and S. Savage. Hey, you, get off of my cloud: Exploring information leakage in third-party compute clouds. In *ACM CCS'09*.
- [26] N. H. Sleumer. Output-sensitive cell enumeration in hyperplane arrangements. *Nordic J. of Computing*, 6:137–147, June 1999.
- [27] XDN. <http://www.xdn.com>.