level is also shown (the ideal rate is the rate predicted from the Table 1, considering any functional scenario, for instance scenario 2).

Shorter queues (below size 20) do not reach the ideal rate. This is especially visible for l_2 and l_3, since they usually have higher rates. This effect happens due to the fact that shorter queues are more prone to send NACKs (they can easily drop packets).

On the other hand, the deviation bars show that for lower priorities (l_0 and l_1), larger queues (150) tend to have more deviation for the interest rates. It happens mainly when the sub-shaping rates are transitioning (as Fig. 19): longer queues will take more time to send NACKs and therefore the AIMD consumer will synchronize later.

Higher priority services always get faster shaping rates, which produce NACKs more easily. Thus, the higher deviations appear for p3.

VI. Conclusion

In this paper, we presented a mechanism that offers QoS on top of a congestion control solution. The hop-by-hop interest shaper is improved to use 4 sub-shapers in order to provide differentiated QoS to 4 priority levels. Results showed that higher priority applications have higher throughputs, while lower priority applications never starve. Our solution reacts instantly and dynamically to any configuration of requests, always using optimal bandwidth (even in cases where all not all priorities exist). Several simulations with complex scenarios have emphasized the validity of the proposed method.

References

[1] Abdel-Hadi, A., and Clancy, C. (2014, February). A utility proportional fairness approach for resource allocation in 4G-LTE. In Computing, Networking and Communications (ICNC), 2014 International Conference on (pp. 1034-1040). IEEE.

[2] Abdel-Hadi, A., and Clancy, C. (2013, September). A robust optimal rate allocation algorithm and pricing policy for hybrid traffic in 4G-LTE. In Personal Indoor and Mobile Radio Communications (PIMRC), 2013 IEEE 24th International Symposium on (pp. 2185-2190). IEEE.

[3] author = Ingo Ltkebohle Itu, R. (2008). ITU-R M. 2135: Guidelines for evaluation of radio interface technologies for IMT-Advanced.

[4] Oh, J., and Han, Y. (2012, September). Cell selection for range expansion with almost blank subframe in heterogeneous networks. In Personal Indoor and Mobile Radio Communications (PIMRC), 2012 IEEE 23rd International Symposium on (pp. 653-657). IEEE.

[5] Richter, F., Fehske, A. J., and Fettweis, G. P. (2009, September). Energy efficiency aspects of base station deployment strategies for cellular networks. In Vehicular Technology Conference Fall (VTC 2009-Fall), 2009 IEEE 70th (pp. 1-5). IEEE.

[6] Wireless Systems Research Lab, Hitachi America Ltd, Cellular Network Topology Toolbox Implementation Documentation, http://www.ltehetnet.com/sites/default/files/NetworkToolBox_Documentation.pdf,2014.

[7] Chinipardaz, M., Rasti, M., and Nourhosseini, M. (2014, September). An overview of cell association in heterogeneous network: Load balancing and interference management perspective. In Telecommunications (IST), 2014 7th International Symposium on (pp. 1250-1256). IEEE.

[8] Ghosh, A., Mangalvedhe, N., Ratasuk, R., Mondal, B., Cudak, M., Visotsky, E., and Dhillon, H. S. (2012). Heterogeneous cellular networks: From theory to practice. Communications Magazine, IEEE, 50(6), 54-64.

[9] Fehske, A., Fettweis, G., Malmodin, J., and Biczok, G. (2011). The global footprint of mobile communications: The ecological and economic perspective. Communications Magazine, IEEE, 49(8), 55-62.

[10] Blume, O., Eckhardt, H., Klein, S., Kuehn, E., and Wajda, W. M. (2010). Energy savings in mobile networks based on adaptation to traffic statistics. Bell Labs Technical Journal, 15(2), 77-94.

[11] Wang, Y., Rozhnova, N., Narayanan, A., Oran, D., and Rhee, I. (2013, August). An improved hop-by-hop interest shaper for congestion control in named data networking. In ACM SIGCOMM Computer Communication Review (Vol. 43, No. 4, pp. 55-60). ACM.

[12] Zhang, L., Afanasyev, A., Burke, J., Jacobson, V., Crowley, P., Papadopoulos, C., and Zhang, B. (2014). Named data networking. ACM SIGCOMM Computer Communication Review, 44(3), 66-73. Chicago

[13] Mastorakis, S., Afanasyev, A., Moiseenko, I., and Zhang, L. (2015). ndnSIM 2.0: A new version of the NDN simulator for NS-3. Technical Report NDN-0028, NDN. Chicago

[14] Wu, T. Y., Lee, W. T., Duan, C. Y., and Wu, Y. W. (2014). Data Lifetime Enhancement for Improving QoS in NDN. Procedia Computer Science, 32, 69-76.

[15] Oueslati, S., Roberts, J., and Sbihi, N. (2012, March). Flow-aware traffic control for a content-centric network. In INFOCOM, 2012 Proceedings IEEE (pp. 2417-2425). IEEE.

[16] Carofiglio, G., Gallo, M., and Muscariello, L. (2012, August). Joint hop-by-hop and receiver-driven interest control protocol for content-centric networks. In Proceedings of the second edition of the ICN workshop on Information-centric networking (pp. 37-42). ACM. Chicago

[17] Floyd, S. (1994). TCP and explicit congestion notification. ACM SIGCOMM Computer Communication Review, 24(5), 8-23.

[18] Moret, Y., and Fdida, S. (1997, November). ERAQLES an efficient explicit rate algorithm for ABR. In Global Telecommunications Conference, 1997. GLOBECOM'97., IEEE (Vol. 2, pp. 801-805). IEEE. Chicago

[19] Zhang, F., Zhang, Y., Reznik, A., Liu, H., Qian, C., and Xu, C. (2014, August). A transport protocol for content-centric networking with explicit congestion control. In Computer Communication and Networks (ICCCN), 2014 23rd International Conference on (pp. 1-8). IEEE. Chicago

[20] https://github.com/wygivan/ndnSIM

[21] https://github.com/wygivan/ndnSIM

[22] Zhang, L., Estrin, D., Burke, J., Jacobson, V., Thornton, J. D., Smetters, D. K., and Abdelzaher, T. (2010). Named data networking (ndn) project. Relatrio Tcnico NDN-0001, Xerox Palo Alto Research Center-PARC. Chicago

[23] Jacobson, V., Smetters, D. K., Thornton, J. D., Plass, M. F., Briggs, N. H., and Braynard, R. L. (2009, December). Networking named content. In Proceedings of the 5th international conference on Emerging networking experiments and technologies (pp. 1-12). ACM. Chicago

[24] Saino, L., Cocora, C., and Pavlou, G. (2013, June). Cctcp: A scalable receiver-driven congestion control protocol for content centric networking. In Communications (ICC), 2013 IEEE International Conference on (pp. 3775-3780). IEEE.

[25] Yi, C., Afanasyev, A., Wang, L., Zhang, B., and Zhang, L. (2012). Adaptive forwarding in named data networking. ACM SIGCOMM computer communication review, 42(3), 62-67.

[26] http://blogs.parc.com/ccnx/

[27] Jiang, X., and Bi, J. (2014, April). nCDN: CDN enhanced with NDN. In Computer Communications Workshops (INFOCOM WKSHPS), 2014 IEEE Conference on (pp. 440-445). IEEE. Chicago

[28] Zhou, J., Wu, Q., Li, Z., Kaafar, M. A., and Xie, G. (2015, June). A proactive transport mechanism with Explicit Congestion Notification for NDN. In Communications (ICC), 2015 IEEE International Conference on (pp. 5242-5247). IEEE.