EmNet: Satisfying The Individual User Through Empathic Home Networks: Summary

John R. Lange J. Scott Miller Peter A. Dinda
{jarusl,jeffrey-miller,pdinda}@northwestern.edu
Northwestern University

Categories and Subject Descriptors: C.2 (Computer-Communication Networks), C.4 (Performance of Systems), H.5.2 (User Interfaces)

General Terms: Network Management, Human-Computer Interaction

Keywords: Networks, Empathic Systems, Human Factors

1. INTRODUCTION

Increasingly, computer systems and networks are used to run interactive applications, where the effects of control decisions are perceived directly by the user. Extensive user studies (e.g. [4, 7, 3]) have demonstrated in contexts outside of networks that measured user satisfaction with a given control operating point exhibits considerable variation across users. Measuring *individual user satisfaction* online and then using such measurements directly in the control process makes it possible to exploit this variation to the mutual benefit of users and systems (e.g. [9, 5, 6]).

We claim that the control of networks can similarly benefit from the idea of exploiting measurements of individual user satisfaction. In the present work, we consider the claim in the context of the home network and its connection to the larger Internet. Previous studies have shown that this is a challenging and important environment in an of itself [1].

We conducted an extensive user study in which participants used a range of interactive web-based applications while we varied the cross-traffic going through the home network's WAN link. Similar to results in other domains, we found there is a large degree of variation in user satisfaction for identical cross-traffic scenarios. It is not the case that a per-application utility model, or other aggregate, captures this variation.

Optimizing a home network by using an objective function that does capture this variation among users misses two opportunities. First, some interactive users will be more dissatisfied than necessary, while others will be over-provisioned. Second, ignoring the variation among users is likely to result in lower performance for non-interactive flows than necessary.

In response to these observations, we designed and implemented a system, EmNet, that captures and uses individual user satisfaction feedback for web-based and other interactive applications. The system schedules the outgoing link using weighted fair queuing (WFQ) [2]. Non-interactive traffic is given a specific weight, and the weight of each user's traffic has upper and lower bounds. The user can at any time adjust a slider control that is overlaid on top of their current web page or desktop environment to affect his weight.

We evaluated EmNet through a second extensive user study. The results suggest that EmNet successfully allows individual users to personalize their home network performance, trading off perceived satisfaction and cost.

Effort funded by the National Science Foundation under awards CNS-0720691, CNS-0721978, and CNS-0709168. Lange was partially funded by a Symantec Research Labs Fellowship.

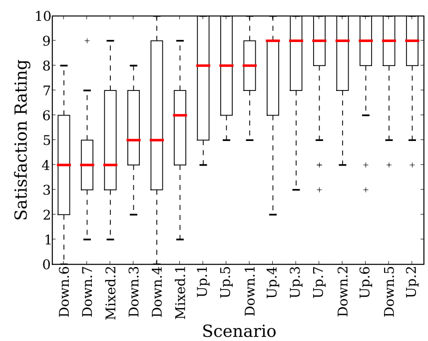


Figure 1: Prompted user satisfaction under different cross-traffic scenarios for video streaming, sorted by increasing median satisfaction. Notice the considerable variation for each scenario, which often swamps aggregate differences between scenarios.

A more detailed treatment of this work is available elsewhere [8].

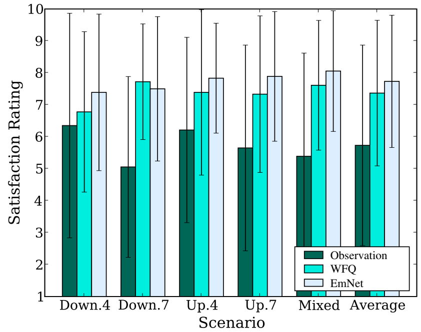
2. VARIATION IN USER SATISFACTION

We conducted an controlled user study with 20 paid participants of diverse backgrounds recruited from the general population of Northwestern University. Each participant completed tasks using online tools (Wikipedia, the Google Image Labeler game, and streaming video) on an emulated home network while we introduced a variety of cross-traffic scenarios and prompted them for their satisfaction. Our testbed is capable of not only emulating present-day home networking configurations, but it is also able to add user, application, and network instrumentation, and to introduce cross-traffic that competes for the WAN link of the emulated home router. In this study and the next, our testbed emulates a typical DSL-connected home network (3 Mbps down, 768 Kbps up).

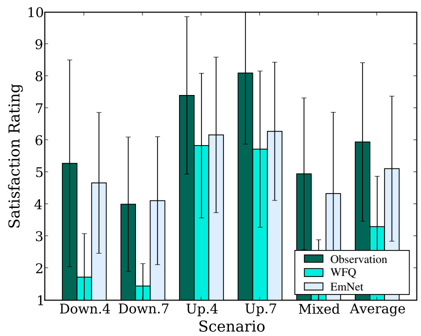
Figure 1 shows example results. As the figure indicates, and our analysis bears out, the variation in user satisfaction when confronted with some cross-traffic sceneraio is quite large. Furthermore, this variation is not explained by variation in application-level QoS measures, such as latency.

3. SYSTEM DESIGN

EmNet shapes network traffic based on individual user satisfaction. The system adds a user satisfaction user interface layer to existing web applications. In our prototype the unintrusive interface is currently a throttle with an indicator of the cost of the current



(a) Image Labeler



(b) Streaming Video

Figure 2: Comparison of mean user satisfaction for no link provisioning, link provisioning using static WFQ, and EmNet.

setting. The user's throttle setting is an input to a link-provisioning algorithm running on the home router. Based on these per-user inputs and other parameters, our algorithm computes WFQ weights for the different flow sets the router schedules on the WAN link of the router.

The EmNet architecture is designed to be fully implementable inside a commodity home router. The architecture consists of (1) a user satisfaction sensor (the throttle in our implementation); (2) a proxy server that injects the user interface into the user experience (the throttle display injected by the web proxy in our implementation) and tracks managed traffic; (3) a policy controller that uses a link-provisioning algorithm to configure the network control policies, and (4) a set of network control mechanisms that implement the control policies (WFQ in our implementation). Our prototype network controller is based on DummyNET on FreeBSD. We have developed a link-provisioning algorithm ensures hat no single user or group of users has the power to starve other users. Because the user sees a monetary cost to increasing his throttle settng, he has an incentive to choose the lowest throttle setting that is satisfactory.

4. EVALUATION

To evaluate EmNet, we conducted a second controlled user study with 18 paid subjects recruited from the general population within Northwestern University. We used the testbed previously described, augmented with the EmNet system. Our goal was to determine if users are able to use EmNet to increase their satisfaction with the network performance.

In the study, each of our subjects worked on tasks based on three network applications: (1) answering a set of thirty questions using Wikipedia, (2) playing the Google Image Labeler game, and (3) watching a 2.9Mbps streaming video. These tasks were identical to the ones in the previous study, to allow cross-study comparisons as much as possible. Each subject was given tasks in a random order to avoid ordering effects. During a task, different cross-traffic scenarios (a subset of the scenarios of the previous study) were applied, each for a fixed period of time. At the end of each period, the user was prompted for his satisfaction level.

Figure 2 shows sample results from our study. Most generally, our results show that users have a wide range of expectations of application-level performance. This implies that an optimal network provisioning strategy—that is, one that maximized the aggregate user satisfaction—is unlikely to be an even or static allocation of network resources.

Highly interactive low bandwidth applications can deliver very high satisfaction when low latency is guaranteed. Figure 2(a) shows that both static WFQ and EmNet provide this, while an uncontrolled network does not. We also see that EmNet provides a consistent if small increase in average satisfaction over the static WFQ configuration.

Video was unique among the three tasks in that its high bandwidth usage does not vary much across users. Figure 2(b) shows that EmNet does a better job of optimizing for user satisfaction than static WFQ. This is best seen in the scenarios with download contention, where a 44% and 37% increase in bandwidth resulted in a 268% and 267% increase in user satisfaction respectively.

Comparing all three network control configurations across both studies and all cross-traffic scenarios, our results show that EmNet increases average user satisfaction by 24% compared to a configuration without network control. Further, EmNet increases average satisfaction by 19% compared to static WFQ. Finally, EmNet achieves these increases in satisfaction with only a 6% increase in application bandwidth compared to static WFQ.

5. REFERENCES

[1] Athanasopoulos, E., Karagiannis, T., Gkantsidis, C., and Key, P. Homemaestro: Order from chaos in home networks. In *Proceedings of ACM SIGCOMM (demo)* (August 2008). Also see Microsoft Research Technical Report MSR-TR-2008-84.

[2] Bennett, J., and Zhang, H. Worst-case fair weighted fair queueing. In *Proceedings of IEEE INFOCOM 1996* (March 1996).

[3] Dinda, P., Memik, G., Dick, R., Lin, B., Mallik, A., Gupta, A., and Rossoff, S. The user in experimental computer systems research. In *Proceedings of the Workshop on Experimental Computer Science (ExpCS 2007)* (June 2007).

[4] Gupta, A., Lin, B., and Dinda, P. A. Measuring and understanding user comfort with resource borrowing. In *Proceedings of the 13th IEEE International Symposium on High Performance Distributed Computing (HPDC 2004)* (June 2004).

[5] Lange, J., Dinda, P., and Rossoff, S. Experiences with client-based speculative remote display. In *Proceedings of the USENIX Annual Technical Conference (USENIX)* (2008).

[6] Lin, B., Mallik, A., Dinda, P., Memik, G., and Dick, R. User- and process-driven dynamic voltage and frequency scaling. In *Proceedings of the IEEE International Symposium on Performance Analysis of Systems and Software (ISPASS)* (April 2009). Summary appeared in SIGMETRICS 2007.

[7] Mallik, A., Lin, B., Memik, G., Dinda, P., and Dick, R. User-driven frequency scaling. *Computer Architecture Letters 5*, 2 (2006).

[8] Miller, J. S., Lange, J. R., and Dinda, P. A. EmNet: Satisfying the individual user through empathic home networks. Tech. Rep. NWU-EECS-09-05, Department of Electrical Engineering and Computer Science, Northwestern University, April 2009.

[9] Shye, A., Pan, Y., Scholbrock, B., Miller, J. S., Memik, G., Dinda, P., and Dick, R. Power to the people: Leveraging human physiological traits to control microprocessor frequency. In *Proceedings of the 41st Annual IEEE/ACM International Symposium on Microarchitecture (MICRO)* (November 2008).