NSF NeTS-NBD Project 0626281
Human-Centered Networking in the Home
Georgia Tech and University of Kentucky
Year 4 Status (Sep 1, 2009 – Aug 31, 2010)

I. Participants

1. What people have worked on the project?

Faculty:

Keith Edwards (Associate Professor, Georgia Institute of Technology)—Principal Investigator managing the Georgia Tech collaboration with University of Kentucky. Led research activities focused on the development of user interaction with home portal device, including device and service set up, maintenance, and troubleshooting.

Rebecca E. Grinter (Associate Professor, Georgia Institute of Technology)—Co-Principal Investigator. Led empirical research focused on the development of user-centered mental models and understandings of home networking.

Students (Ph.D.):

Jeonghwa Yang (PhD CS, Georgia Tech)—Responsible for the creation and evaluation of our final home network management system, based on field work and prototypes created during earlier years of the project. This system focused on support for end-user management of the network (not just device introduction, which was the focus of the first version). Jeonghwa's work included formative user studies, front-end implementation in Flash and ActionScript, back-end implementation of network configuration code, and evaluative/summative user studies. Jeonghwa's research represents some of the first work we are aware of that is creating network management tools aimed at end-users, rather than systems admininstrators. This work formed the basis of her Ph.D. research, as she graduated during the final year of this project.

Students (Masters):

N/A

Students (Undergrad):

N/A

2. What other organizations have been involved as partners?

N/A

3. Have you had other collaborators or contacts?

This year, the PIs have presented this work in a number of settings.

- One of the PIs (Edwards) keynoted the UW/MSR Summer Institute, the focus of which will be tackling complexity in home networks. The other PI (Grinter) was also invited to the

Institute to present their work in home networking.

• Edwards gave the keynote address at the First SIGCOMM workshop on Home Networking (HomeNets).

• Edwards also presented the vision of this work in a number of industrial and academic settings to increase awareness of the challenges and opportunities in human-centered home networking, most recently Intel Research.

II. Activities and Findings

1. What were your major research and education activities?

Research Activities:

During this final (no-cost extension) year of the project we completed the last open thread of the project, which was the creation and evaluation of our end-user-oriented home network management system. This work built greatly upon the empirical work and systems prototyping done in the earlier years of the project.

This year, the final version of our visual home network management system, dubbed *Eden*, was finalized and evaluated in a range of user studies. This system provides a holistic interface to network management, with features driven and motivated by our earlier empirical work.

Eden provides a drag-and-drop style interface, implemented in Flash, that can execute on users' PCs or laptops connected to the home network. This front-end interface communicates via XML-RPC to the router (in our implementation, a custom Linux-based router), and provides a number of key features:

- Control over device provisioning and admission to the network.
- Support for "guest" access, in which visitors can be provisioned separately from resident householders (to allow access to the Internet while restricting access to other devices on the home network, for example).
- Support for a range of access control features, such as parental controls.
- Control over bandwidth and QoS prioritization.
- End-user interface to the portal's heuristic troubleshooting functionality.

During this year we completed a range of evaluative studies with users. Our results indicate significantly better performance using this tool for a range of home network management tasks than either of two competing approaches (using the built-in tools such as router web pages or TCP/IP configuration panels, or Cisco Systems' Network Magic tool).

Education Activities:

During this year, Jeonghwa Yang—the Ph.D. student leading this portion of our work—

completed her Ph.D. and has since joined LG Electronics' consumer electronics group to work on home networking.

2. What are your major research findings?

Our major research findings from this year have centered on our evaluation of our home portal system.

Our user studies indicate significant improved user performance (in terms of ability to complete common tasks, and formation of robust conceptual models of how to use the system) and user acceptance (in terms of preference) over existing tools. Users were able to complete a range of network management tasks—ranging from provisioning access to guest machines, to monitoring bandwidth utilization, to setting up parental controls, to provisioning external access to services running in the home—using the Eden system. With existing tools (such as the facilities built into the OS and consumer-grade routers, as well as specialized tools such as Network Magic) few users were able to complete any of the assigned tasks.

Further, use of Eden during the course of our trials imparted improved knowledge of networking to users; the visual presentation used by the system, for example, led to increased user knowledge about network topology (the role that the router plays in providing access to the external network) and common concepts (such as the fact that bandwidth is shared among all device on the home network).

We believe that these findings demonstrate the importance of combining topological and spatial views of the home network, interface metaphors appropriate for grouping and aggregation of access rights, and visualization techniques that successfully convey concepts such as bandwidth utilization.

3. What research and teaching skills and experience has the project helped provide to those who worked on the project?

Graduate students:

Jeongwha Yang extended and deepened her skills in user interface development, usability studies, systems programming, and protocol development. She has also leveraged this project towards the completion of her PhD thesis, building her dissertation topic on this project work. Jeonghwa was first author on a paper accepted to the *ACM Symposium on User Interface Software and Technology (UIST).*

4. What outreach activities have you undertaken to increase public understanding of, and participation in, science and technology?

None.

III. Publications and Products

1. What work have you published as a result of this work?

Conference Papers (period 9/1/09 – 8/31/10):

Jeonghwa Yang and W. Keith Edwards. Eden: Supporting Home Network Management Through Interactive Visual Tools. *Proceedings of the ACM Symposium on User Interface Software and Technology (UIST 2010).* New York, NY. October, 2010. Full paper.

2. What Web site or other Internet sites reflect this project?

The following websites contain information about the project.

http://www.cc.gatech.edu/pixi/

http://www.cc.gatech.edu/gvu/wpl

3. What other specific products (databases, physical collections, educational aids, software, instruments, or the like) have you developed.

The prototype portal, management, and visualization software; also data on home networking collected from empirical user studies.

IV. Contributions

1. Contributions within discipline

At Georgia Tech, the focus of this project is on Human-Computer Interaction (HCI), which is the science of making computer systems both useful and usable for their intended users. Currently, few if any HCI researchers are focused around the usability issues of home networking. Thus, our major contribution this year has been to continue to demonstrate, through software development, empirical studies, and publication, that home networking is not only a promising area for HCI research, but an area that is in critical need of HCI research. This work has shown how difficult current technologies are to use, explained why it is difficult for industry to innovative in this area, and highlighted how the next advances in computing (home health care, emergency response) depend on people being able to easily set up, maintain and troubleshoot networks. Further, in this year, we have identified specific requirements for next-generation network management systems for the home, including necessary aspects of visualization, and opportunities to better support remote troubleshooting. Based on these requirements, over the course of the project we have developed a number of working systems intended to making home networking easier and more manageable by end-users. These systems include tools for initial provisioning of clients on the network, visualization tools for home users, and comprehensive management interfaces for the home network. From an HCI perspective this project sets an agenda for research in this area by being the first effort to systematically identify the needs and suggest solutions.

2. Contributions to other disciplines

None.

3. Contributions to education and development of human resources

Our graduate student research team, all of whom are from under-represented groups in computing, has created an environment that fuels and encourages research among the team itself. However, it also extends to the mentorship of undergraduates. Over the duration of the project we

have engaged numerous undergraduates who have worked closely with the PI and the graduate students. These students have been participating in the project both through credit hours and through the REU supplement generously awarded as part of this project.

4. Contributions to physical, institutional, and information resources for science and technology

N/A

5. Contributions to the public welfare beyond science and engineering

N/A

V. Special Requirements

1. A brief summary of the work to be performed during the next year of support if changed from the original proposal.

N/A

2. Do special terms and conditions of your award require you to report any specific information that you have not yet reported?

No.

3. Do you anticipate that more than twenty percent of the funds under your NSF award will remain unobligated at the end of the period for which NSF currently is providing support?

No.

4. Has there been any significant change in animal care and use, biohazards, or use of human subjects from what was originally approved (or approved later)?

No.