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The Home Network as a Socio-Technical System: Understanding the Challenges of Remote Home Network Problem Diagnosis

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Abstract. Research focused on the user experience of home networking repeatedly finds that householders have difficulties setting up networked equipment. No research to date, however, has studied the in the moment interactions of householders with networking technical support professionals. In this paper, we analyze 21 phone calls to a technical support call center of a home network hardware manufacturer. The phone calls focus on overcoming difficulties during one particular task: adding a wireless router to an existing home network. Our results reaffirm prior studies in remote collaboration that suggest a need to support shared understandings of the problem at hand between remote parties. Our results also suggest that technical properties of the home network and the structure of the home itself complicate the social work of remote diagnosis and repair. In response, we suggest new approaches for remote home network problem diagnosis and repair, including resources for householders to reason about their home networks prior to call placement, and improved methods of inter-organizational information sharing between stakeholders.

Key words: home networking, remote diagnosis, technical support, troubleshooting

1. Introduction

Despite this rapid adoption of networked computing in domestic environments, previous research suggests that setting up and maintaining networked equipment for the home remains a formidable task (Bly et al. 2006; Chetty et al. 2007; Elmore et al. 2007; Grinter et al. 2005; Kiesler et al. 2000; Poole et al. 2008; Shehan and Edwards 2007; Tolmie et al. 2007; Yang and Edwards 2007). To date, however, no research has explored the practices—or the challenges—of remote technical support for home networking. In this paper, we analyze 21 technical support call center interactions focused on difficulties encountered by consumers introducing wireless connectivity in their homes. Although previous research exploring the user experience of home networking documented retrospective accounts of setup and troubleshooting difficulties, and noted that

householders often rely on outsiders to help them resolve these problems, no researchers have studied *in the moment* interactions of householders collaborating with remote, professional technicians to diagnose their network problems.

CSCW has an extensive history of research in phone-based technical support and expertise sharing, but phone-based technical support of home networks—especially those with wireless components—offers new challenges. In this paper, we focus on revealing how the pragmatics of networking in the domestic setting impact the experience of remote help and, in turn, what the practices observed say about the challenges and opportunities for future tools. In particular, many of the difficulties of remote help in this context arise because technical properties of the network complicate the social work of remote diagnosis and repair. Our analysis unpacks a number of these properties, including the *deep heterogeneity and multilayered nature* of home networking, the character of networking as an *infrastructure technology*, and the intertwining of the ephemeral, digital aspects of networking with the *physical infrastructure of the home*.

In the following sections, we first examine related research. Then we discuss our methods and provide an overview of the calls analyzed. We then detail our findings, exploring a number of themes in this domain that complicate remote diagnosis and repair. Finally, we conclude with discussion about the problematic nature of supporting home networking diagnostic tasks remotely.

2. Related work

Our study draws upon research in both home networking and call centers.

2.1. Home networking

Recently, researchers in HCI and CSCW have taken interest in the usability, technical, and social issues associated with networked computing in homes. Two issues motivate the empirical studies among this body of work. First, growing evidence suggests that householders have difficulties setting up and maintaining home networks. Second, we know little about the ways householders appropriate and integrate new digital technologies into their daily routines. Research on technical aspects of home networks has likewise focused largely on attempts at redressing the usability challenges of networking and on design explorations intended to reveal opportunities for new domestic technologies.

Studies of user experience challenges largely consist of qualitative inquiries (often supported by instruments such as sketching exercises or home tours), and have overwhelmingly found that householders have difficulties with network setup and maintenance tasks. In perhaps the earliest example of this genre, Kiesler et al. (2000) examined why and how people sought technical support for computer- and Internet-related problems. Their study suggested that those who called for outside professional support were often the most technically

sophisticated in their households; it is unclear whether these findings are true today.

In contrast, Grinter et al. (2005) describe the difficulties faced by householders coordinating with one another to manage the home network. In their study, one householder typically took the role of "reluctant administrator" to manage the home IT infrastructure. Others in the home—mere "consumers" of the technology—were disempowered when the network malfunctioned, and were likely to call for outside help. In many cases, confusion existed about *whom* to go to for help; most home networks are comprised of hardware and software from different vendors, and at times rely on multiple service providers to function. While Grinter et al.'s work has pointed to the existence and character of the *problems* that exist, however, it did not explore the *solutions* that householders pursue when seeking remote help.

In still other cases described by Grinter et al., enlisting professional help actually created additional problems. Householders reported that when professional technicians visited the home to setup or fix equipment on the home network, these technicians were unaware of local customizations or usage patterns of the network; the scripts these technicians followed often underestimated the complexity of the home network, breaking existing configurations. This local, embedded knowledge of structure and uses of the home network reflects the technical embodiment of routines in the home, as described by Crabtree and Rodden (2004). The day-to-day "digital housekeeping" practices described by Tolmie et al. (2007) reflect these customizations, and suggest that householders may have difficulties expressing "local knowledge" to outside helpers (e.g., applications that can be removed without trouble, and those that cannot). Although all of this work has outlined the character of the *problems* that exist, none of it has explored *how householders work with external troubleshooters*. Thus, our study builds upon and expands this previous body of research.

In another exploration of domestic networking, Chetty et al. (2007) describe the relationship between the infrastructure of the home and the evolution of the home network, using an analysis based on Brand (1994). This work underscores how the built environment can impose limitations on how home networks are setup, maintained, and upgraded. Work by Woodruff et al. (2007), has similarly examined how the physical plant of the home influenced routines of technology use—in this case, patterns of laptop use within the home. As we describe shortly, our findings corroborate the importance of the home physical infrastructure, and confirm that physical and spatial structure also plays a major role in remote help-seeking.

Some researchers from both networking and HCI argue that the difficulties with home networking are a structural and intrinsic side effect of choices made in the design of the core Internet protocols and architecture. For a more thorough discussion of these arguments, see (Blumenthal and Clark 2001; Calvert et al. 2007; Shehan and Edwards 2007). In response, there is a growing body of work attempting to provide a more usable core network infrastructure—and user interface to interact with the core network infrastructure—for the home (Calvert

et al. 2007; Poole et al. 2008; Yang and Edwards 2007). In the absence of such technical solutions, however, home networking setup and maintenance may continue to be problematic for many householders.

2.2. Call centers

The study of call centers has a long history in CSCW as well as in other disciplines. In the field of management, call center research focuses on issues such as scheduling the appropriate number of technicians at various times of the day or mechanisms for cost-effective call routing. For an overview this area of call center research, see Gans et al. (2003).

In CSCW, studies have focused primarily on the day-to-day activity of call centers, analyzing both details of work practices and conversations between callers and call takers; for an overview of work in this area, see Baker et al. (2005b). Of particular interest is Baker et al.'s analysis of call transcripts to a technical support center at a software company (Baker et al. 2005a). They found that in the initial stages of the conversation, callers provide accounts justifying why they are calling to convince the technician that they need help with a legitimate, substantial problem rather than a quirk. They also found that the technicians calibrate the advice they provide based on how much technical expertise they perceive the caller to have. In contrast, our primary interests focus on how technical properties of home networks complicate the processes of remote diagnosis and repair.

Several researchers have studied the difficulties of remote help giving for document machine repairs; all remark that a lack of shared access to the machine having problems can lead to difficulties in diagnostic processes (Crabtree et al. 2006; O'Neill et al. 2005; Whalen and Vinkhuyzen 2000). Similarly, Pentland (1995) performed an ethnographic study of tech support workers in the mid-1990s. He argues that a primary challenge of technical support is that the technician must work to understand the problem based on a fragile, sometimes inaccurate portrayal presented by the caller. He describes three techniques technicians use to get information from callers: asking for open-ended accounts of what the problem is, having the caller read information from the computer screen, and sending the technician log files or other data for interpretation. In a complementary study, Kraan (2005) studied the mental models that callers to technical support lines use to describe software problems. He found callers typically used three different models, often alternating between them during the call. The models included manipulation of objects in a direct manipulation environment, providing literal explanations of interaction with the interface (e.g. "I clicked on the start button"), and personification of the computer (e.g. "The computer won't let me in."). These same issues occur in our study, but are just one aspect of what make remote diagnosis of home networking problems difficult.

Pre-structured scripts are a common element in many phone support calls, and thus researchers have examined how script-based approaches can both improve

and detract from the quality of interactions between a caller and a call taker. Whalen and Zimmerman's (1987) study of emergency dispatchers found that the dispatcher's requirements to ask callers for specific information based on a script prior to dispatching emergency services often upset and frustrated callers, who did not understand how institutional structures limited the responses dispatchers could make. On the other hand, Houtkoop et al. studied a trouble ticket center at a Dutch bank. As part of their study, they introduced a script-based intervention for use by call takers. With this intervention, call takers read problem descriptions back to the callers after recording them (Houtkoop et al. 2005). They found that by having the call takers read back information, they were able to keep callers more informed, and increased correctness and completeness of trouble ticket information. Broadly, our study builds on this related work on remote technical support; we unpack how characteristics specific to home networking disrupt troubleshooting and pose different challenges and opportunities than revealed by prior work.

3. Methods

In contrast to earlier studies on the difficulties of home networking that focus on householders' retrospective recollections of problems and how they were solved, we provide an in-the-moment account of the challenges of remote home network problem diagnosis and repair, and unpack the unique properties of home networking that contribute to these challenges. Our data consists of 21 calls made by 20 customers[1] to a major home network equipment manufacturer's technical support call center in 2007. Our sample of calls varies in length from 8 to 98 min, with 13.1 h of audio in all. The manufacturer selected the data set for us; we did not specifically request to receive recordings of calls about wireless network setup, but all of the audio turned out to be focused on this particular issue. These calls are a small fraction of the volume handled by this company on a regular basis; this particular company receives several thousand calls per day. A variety of technicians handled the calls, and while we do not have specific information about each call center technician's educational or employment background, most typically hold at least a 2-year diploma in an IT or engineering field, and have experience with computer maintenance and troubleshooting tasks.

We transcribed call audio and coded the transcripts for understanding the steps taken during the diagnosis and repair processes, as well as difficulties completing these processes. We did not come into the analysis process with specific hypotheses, but like in many qualitative research traditions, we used inductive techniques to understand commonalities and themes in the data. However, we limited our analysis to understanding the steps taken during diagnostic processes, and difficulties that occur while taking these steps. We chose to examine this particular angle because diagnostic processes in home networking are not well understood; prior research on the user experience difficulties of home networking has focused solely on

retrospective accounts of diagnostic processes rather than what happens in-the-moment. In particular, we coded for the following categories:

- *Overall problem*: Why did the caller contact the call center? What was the problem and was it resolved during the call?
- *Actions taken*: What actions did the caller take (e.g. manipulating software or hardware)? Did the technician request these actions or does the customer perform them without prompting and report them to the technician?
- *Technology breakdowns*: What technology breakdowns did callers and technicians encounter during the diagnosis and repair processes? Technology breakdowns that emerged from the data included faulty hardware, faulty setup software, improperly configured client devices, interference of third party software, internet service provider failure, and components needed to setup network not present at caller's site.
- *Other difficulties*: Did the customer experience any difficulties understanding or completing action requested by the technician? What breakdowns or misunderstandings occurred between the technician and caller during the conversation?

4. Call analysis

All of the calls focused on difficulties encountered when introducing a wireless router to an existing network. The problems, detailed in Table 1, include setup CD failure or other inability to progress through the setup process, an unstable connection after introducing wireless connectivity, an inability to connect end-user devices to the wireless network, and misunderstandings about the capabilities of the equipment purchased.

Only three calls resulted in a successful network setup in which the caller reported that all end-user devices could connect to the network. In several calls, the technician and caller were able to add the wireless router to the network, but could not get end-user devices to connect. In these cases, technicians instructed callers to call yet another call center for a hardware manufacturer or OS manufacturer. The remainder of the calls led to no problem resolution. In four cases, the call terminated because the caller did not want to continue, or because the caller specifically mentioned that he or she wanted a local person to fix the problem.

Two calls ended because the call dropped unexpectedly, though it was unclear whether this was the customer hanging up or whether it was due to a connection problem. For calls that did not end abruptly, technicians instructed customers to attempt other strategies. Depending on the caller's situation, he or she may have been instructed to return faulty hardware to the store where it was purchased, to call his or her ISP, to purchase required components (e.g. another Ethernet cable), or to download drivers or other files for the router or for the operating system of end-user devices.

Table 1. Description of calls, call length, and whether/how the problem was resolved.

No.	Length	Problem	Was the problem resolved?
P1	0:08:18	Setup CD fails during wireless router installation	Partially—download file from manufacturer website. Technician does not help with installation
P2	0:10:30	Setup CD fails during wireless router installation+ end-user device are improperly configured	No—call drops and continues in T18
P3	0:10:18	Devices cannot connect to new wireless router	No—caller ends conversation prematurely due to poor phone reception
P4	1:28:14	Caller confused during wireless router setup+end-user devices are improperly configured	No—technician cannot determine source of problem
P5	0:14:17	Caller confused during wireless router setup	No—caller needs another Ethernet cable
P6	0:13:04	Setup CD fails during wireless router installation	No—caller ends conversation prematurely ("I have to pick up my fiancée")
P7	0:39:10	Devices cannot connect to new wireless router	No—contact end-user device manufacturer to configure wireless connection software
P8	0:24:23	Setup CD fails during wireless router installation and end-user devices are improperly configured	Yes—manually configured wireless router and each end user-device together
P9	1:12:23	Setup CD fails during wireless router installation and caller can't remember network key	Partially—download file from manufacturer website. Technician does not walk caller through installation
P10	0:13:24	Setup CD fails during wireless router installation	No—call drops
P11	0:31:13	Devices cannot connect to new wireless router	No—problem is due to an ISP outage. Call ISP to get more information

(*continued on next page*)

Table 1. (continued)

No.	Length	Problem	Was the problem resolved?
P12	1:16:46	Caller confused during wireless router setup+end user devices are improperly configured	Partially—network is configured, but some end-user devices still cannot connect. Call device manufacturer
P13	1:34:52	Caller confused during wireless router setup in combination with a wireless range expander	No—range expander is faulty. Return it to store where it was purchased
P14	0:13:09	Caller needs DSL account password to continue wireless router setup	No—call ISP to get the password reset
P15	0:22:16	Setup CD fails during wireless router installation	No—caller ends conversation prematurely ("I have to take care of my son")
P16	0:17:19	Setup CD fails during wireless router installation	No—caller ends conversation prematurely ("I'll just wait until the Geek Squad comes out and I'll have them set this up")
P17	1:38:02	Setup CD fails during wireless router installation	Yes—manual configuration together
P18	1:01:33	Setup CD fails during wireless router installation (continues T2)	Partially—network works but some end-user devices still cannot connect. Call device manufacturer
P19	0:49:56	Setup CD fails during wireless router installation +end-user devices are improperly configured	Partially—network works but some end-user devices still cannot connect. Call device manufacturer
P20	0:30:27	Connection is unstable on new wireless router+end user devices are improperly configured	Yes—cannot isolate cause, but reinstalled wireless router. During install, finds computer cannot use WPA encryption. Caller instructed to download and install OS service pack to use WPA, but is not provided with details of how to enable WPA
P21	0:12:21	Caller confused about how to set up a router to replace existing range expander/router combo	No—caller needs another Ethernet cable

4.1. What happens during a call?

The hardware manufacturer that provided these audio calls did not inform us about the protocols that technicians use to diagnose problems. When analyzing the transcripts, however, it became apparent that the diagnostics used by the technicians for wireless setup problems are highly scripted. To uncover patterns in the diagnostic process in more depth, we iterated through each call and created a flowchart of a call progression. We revised the chart as we uncovered similarities and differences between all of the calls. We describe a typical call for assisting with wireless router setup below.

4.1.1. *Wireless router setup: call beginning*

First, the caller and technician exchange greetings, and the technician provides his or her employee ID. The technician will then request contact information and ask the customer if he or she has a case number.[2] If the caller attempts to skip directly to describing his or her problem, the technician will continue to ask for contact information before proceeding.

4.1.2. *Wireless router setup: understanding the problem*

After collecting contact information, the technician invites the caller to describe his or her problem by asking the question "How may I help you?" Next, the technician asks for details about the product being added to the network. He or she may also ask for details about end-user (non-infrastructure) devices that are being connected to the network, as well as details about how devices are connected together. At any point during the call, the technician may interrupt the caller to ask for additional information or put him or her on hold.

4.1.3. *Wireless router setup: resolving the problem*

Next, the technician walks the caller through the installation process using the setup CD that came with the wireless router. The technician will ask the caller to read what is on the screen at various points. If the setup CD fails during the technician-guided installation, the technician will instruct the customer to remove and reinsert the CD and go through the setup process again. If the setup CD fails again, there are a number of choices for the next step. The technician may ask the caller to reboot the computer, go to another computer, verify how the network is physically connected, unplug/restart the router, or attach the computer directly to the cable/DSL modem to download files from the router manufacturer website, or to verify Internet connectivity using command line tools such as ipconfig or ping. In Table 2, we describe in detail the steps that a technician could direct a caller to take.

If these steps do not solve the problem, some technicians walk callers through a number of more advanced steps, including opening files manually from the CD or configuring the router without using the CD. Finally, if none of these steps

Table 2. Actions a caller may take during the phone call.

Provide information about hardware	Read model version no. on router, describe how hardware is connected, confirm how hardware is connected
Configure wireless router	Go to wireless router configuration website, change settings (wireless channel, security, SSID, network name, network key) or insert/remove setup CD and step through screens on the setup software
Modify or take note of router state	Manually reset router/cable modem using a pin and/or unplugging for 30 s, remember or write down WEP/WPA key and network name
Determine connectivity	Run command line tools like ping, ipconfig and read back results to the technician, visit a website to confirm connectivity, connect directly to the modem and disconnect wireless to check connectivity, read light patterns on router
Software/OS	Read what is on computer screen, describe icons in the system tray, disable or uninstall interfering software
Repair/restart	Auto-repair network connection on end-user machine, restart computer
Notify technician about computer state	Notify technician of computer freeze, info popping up on computer screen, or other state-related information
Change computer or physical location	Switch to a different machine to complete wireless setup (reason: machine does not work or is physically unable to be in an appropriate location for completing setup-related task)
Provide information about local context	How far is device from router? Which wireless networks are visible to end-user devices? How many signal bars do these networks have?
Check other devices	Check if other end-user devices can connect to the wireless network

work, the technician will inform the customer that he or she cannot resolve the problem. The technician will direct the caller to either call their end-user device manufacturers, OS manufacturers, places of router purchase, or ISPs for help.

4.1.4. *Wireless router setup: ending the call*

As noted previously, two calls dropped unexpectedly during the conversation. In the remaining calls, if the customer initiated ending the call prematurely, he or she offered an excuse and apologized to the technician. For unresolved cases, the technician would apologize to the caller and provide advice on the next step to

take. In all calls where the call did not drop unexpectedly, the technician would provide a case number if needed for future calls about the same problem, the caller and technician would exchange goodbyes and say thank you to one another, completing the call.

5. Findings

In this section, we describe themes that emerged from our analysis of householder interactions with a home networking call center. Reaffirming prior work in CSCW, our dataset shows that establishing shared understandings between parties is a problem for remotely troubleshooting home networking equipment. We also describe unique challenges for home networking; in particular, we describe how the physical infrastructure of a caller's home, as well as technical properties specific to home networks, complicate the social work of remote home network problem diagnosis and repair.

5.1. Common ground

Much CSCW research focused on remote collaboration emphasizes the importance of establishing *common ground*, which is shared knowledge and context for all participants involved in a collaborative task (Clark and Brennan 1991; Crabtree et al. 2006; Karsenty 1999; Kraut et al. 2003; Kuzuoka et al. 1994; Luff et al. 2003; Veinott et al. 1999). Our dataset reaffirms these findings; a number of difficulties in telephone-based technical support for home networking result from the fact that a telephone can be a poor medium for sharing complex state—the technician and caller cannot share views of the network, and must resort to verbal queries to build up a collective sense of the problem. Hence, technicians and callers spend much time gaining a shared understanding of information such as what is on the caller's home network and how it is configured. Further, maintaining a shared understanding of the steps in the diagnostic process is difficult; technician directives and subsequent caller activity in response to the directives may not always be well-coordinated. As previous research has suggested about solving technical problems, not having adequate vocabulary and mental models can make remote help giving difficult for home networking.

A particularly vexing problem with establishing common ground in the network setting is that this is a *two-way process* in which *both parties are simultaneously experts and novices*. The technician knows about the products offered by the company, and possibly about networking in general, but knows nothing about the particular—and likely deeply personalized—local configuration of the caller's network. Conversely, the caller knows situated information of how the home network is configured, the routines of its use, and how it is embedded in the physical and social context of the home, yet may know little to nothing about networking. As noted in the work of Grinter et al. (2005) and O'Neill et al.

(2005), troubleshooters need to know this situated knowledge; without this knowledge technicians often underestimate the complexity of the home network, and may produce "solutions" that actually make problems worse (Grinter et al. 2005). Thus, both parties—the technician and the caller—depend on one another to solve the problem at hand. This dependence and two-way exchange of information goes far beyond simply the caller describing the problem to the technician.

The following call excerpt, in which the technician is helping the caller cable her devices, illustrates a number of these issues. In this excerpt, P10 refers to the "blue cord," which is situated knowledge about the context of her home network that the technician cannot infer. Likewise, the technician speaks about the network using technical terms that are difficult to infer. In particular, the word "Internet" has multiple meanings in this interchange, leading to confusion:

Tech: Ok yeah. So we are now going to connect your modem to the router and your router to your computer, ok?

P10: Ok. Blue cord to the router and the other cord to the modem.

Tech: Uh huh, that's correct.

In the above portion of the exchange, the caller (P10) refers to local knowledge—in this case, the "blue cord"—as being the object in question. The technician has no way of knowing whether this is the "correct" cord or not, yet agrees, and proceeds along with the script. The call continues:

P10: Well my modem only has one port… so just pull out the cable to my computer?

Tech: Yes, that's correct. Disconnect from computer and connect the modem to the router

P10: Well… my computer is not connected to anything anymore

Tech: Yes, and we are going to connect your computer to port number two of the router.

P10: Wait… connect the what?

Tech: Connect your computer to port number two of the router

P10: Of the router?

Tech: Yes, that's correct.

P10: Ok, so I don't see any ports on the router oh wait… ok…umm…ok it's all hooked up

Tech: Can you tell me what lights are on the router?

P10: Umm…what lights are on the router?

Tech: Uh huh

P10: The power, the WLAN, and the Internet one?

Tech: The Internet is where the modem is connected right?

P10: The Internet is what?

Tech: The Internet port is the connection on the modem

P10: I guess

Tech: Is the computer connected to the router?

P10: Yeah, thru that Ethernet cable or whatever that is

Tech: All right and is it connected to port number 2 or…

P10: Yeah, port number 2…but there is no Internet even though my computer is connected.

Here we see a subtle—and particularly insidious—confusion of vocabulary. The technician uses the term "Internet" to refer to the particular outward-facing network port on the router, yet the caller uses the term to refer to the public network itself. In addition to problems of situated knowledge and specialized vocabulary, establishing common ground is also complicated by technical properties of the network itself. In the following sections, we explore some of these technical properties, and discuss their impact on the collaborative diagnostic process.

5.2. Networks offer unique challenges

Unlike single devices such as printers or personal computers, home networks offer more points for technical failures. The home network is a complex ecosystem of devices, connections, and settings. Network hardware (e.g. routers, modems), end-user devices, software on end user devices, add-on network cards to end-user

devices, connectivity to the Internet service provider, cabling between various devices, and software connections between devices can all be points of trouble.

5.2.1. *Challenges with multipurpose devices*

The devices that are on home networks are (mostly) multi-purpose devices with a wide variety of software. The software on these devices can (and often does) interfere with the larger function of the network. In a number of calls, there were difficulties related to third party software such as firewalls, virus scanners, and network card management software installed on end-user devices. However, callers often were unable to pinpoint that these pieces of software were the source of trouble—and often did not even know to tell the technician that these pieces of software were installed. In a number of cases, the technicians were unfamiliar with these pieces of software and could not guide the callers to a problem resolution.

5.2.2. *Challenges with multiple stakeholders*

In the home network, there are a number of stakeholders. Participants in the study of Grinter et al. (2005) of home network adoption indicated that householders regularly paid bills to three to seven different companies to keep their networks working. Our study reflects the difficulties associated with multiple stakeholders involved with the maintenance of the home network. Many callers were directed to a *different* stakeholder to resolve their problems. For instance, caller P22 called the router manufacturer to try to get his password for his DSL account, which is not a service that the router manufacturer could provide. While this call is likely an extreme case (we expect that many people would have known to call the ISP first for a DSL account password), there were a number of more subtle problems suggesting that householders often do not know where to turn for outside help. In particular, these difficulties manifest when it is difficult to tell whether a problem is due to the network itself or due to an issue with an end-user device.

5.3. Understanding network infrastructure

Misunderstandings of network infrastructure can also cause difficulties. Callers had difficulties understanding cause/effect relationships for diagnostic actions, had difficulties due to misunderstandings of device capabilities and had to complete complex, counterintuitive actions to troubleshoot problems due to properties of home networking infrastructures.

Householders often had fragile understandings of how their actions could affect the functionality of the network, as well as fragile understandings of what various components were and their capabilities were. Callers became become confused about how (and for how long) a wireless router can store information. The following exchange is illustrative of these fragile understandings. After manually stepping through wireless router setup, during which the technician instructed the

caller to unplug the router, the following exchange occurs between P12 and the technician:

P12: Say I unplug the power from the router. Does that erase all the stuff we did?

Tech: No, the stuff we did will stay there because it is already saved. Not unless you press the reset button [on the back of the router] will it be restored to factory settings.

Some calls highlighted what Bly et al. (2006) referred to as "broken expectations," in which people expect devices to have capabilities that they lack. For example, in call P2, the caller was upgrading an existing wireless network to get better signal. He previously had a range expander, which requires line of sight to a router in order to provide extra wireless signal to the home. After having difficulties with the range expander, he decided to replace this component with a second router. However, this caller did not understand that the wireless router—unlike the range expander—could not work without being physically connected to something already connected to the Internet (e.g. another router or the cable modem):

P21: No, it's not hooked up to the old router. [Referring to the 2nd router added to the network for better signal throughout the house]

Tech: Okay, now if it's not hooked up the old router, or neither to the modem, it will not give you an Internet connection, because where will, where would it be getting an Internet connection when it's not hooked up to the… a router?

P21: You mean it can't just pick up an Internet connection?

Tech: It will not pick up an Internet connection; rather it will only distribute an Internet connection, so it must be hooked up to a modem or to a router.

P21: Right, so there's no point having two routers?

Tech: There is a point, having two routers, but you have, we have to cascade it, meaning we have to hook up the second router to the old router so that it can get an Internet connection.

Both of these calls highlight a fundamental problem with diagnosing problems of home networks, either by one's self or with the help of a technician. Since networks are infrastructure technologies without direct user interfaces or cues indicating their functionality or limitations, householders may develop incorrect assumptions about what devices can and cannot do; this functional invisibility of

networking infrastructure may be a primary reason why householders may call for remote help for home networking problems at all.

5.4. Understanding the home infrastructure

Chetty et al. (2007) remark that there is an intertwined relationship between the space plans of the home and the ways that people set up their network: layouts determine where devices may be placed, infrastructure of the home itself (e.g., electrical wiring, cat5 wiring) may dictate which devices go where. The *home itself* offers a number of difficulties for remote, phone-based support. In particular, these problems related to phone reception, placement of devices, and boundaries of wireless networks.

Diagnostic techniques may fail because devices cannot easily be rearranged (e.g., they are too heavy or are in a different room or the customer cannot reach the cords because of inaccessible arrangements). The following excerpt illustrates these difficulties:

P4: It says now you can connect your router to your computer. I can't do that because it's upstairs and the computer is downstairs.

Tech: So there's no way to wire that computer to the router right now?

P4: No.

Tech: Okay. Now that's a desktop, right? You cannot bring it upstairs because it's too heavy.

P4: Right.

P4: It keeps telling me that I need an Internet connection. But that was the whole point of getting a wireless broadband router…. so that we could now have a way to link it up without taking everything upstairs.

Tech: Mm hmm.

P4: And that, what, is that what I'm going to have to do? Take everything up and link it up? And then configure it and bring it back downstairs for it to work?

Tech: Yes, that's supposed to be the uh connection. You need to get wired first, but since your computer is already set up downstairs can you just go bring over the router? Bring it over closer to your computer so that we can configure it manually.

P4: Then it, then it wont be, yeah, it won't be, it won't be hooked up to the, to the um, if I do that, if I unplug it and bring it downstairs then it won't be hooked up to the uh Internet

Tech: Yes, that's all right. We just want to manually configure it, and we're just going to set it up for your internet connection afterwards

Additionally, the locations where the network works are not always where the phone works. The simple issue of poor phone reception can greatly exacerbate difficulties with remotely collaborating to setup and fix home network problems, as the following call excerpt shows:

Tech: Let's go to your laptop computer which is connected directly to the router.

P3: The laptop, OK. One second. I'll try…hold on a sec…what's your name again, please?

Tech: My name is John, sir.

P3: John, hold on a second, ok?

P3: OK, can you hear me sir?

Tech: Yes.

P3: OK, and I'm…what…the location, the location where laptop is….it's stretched…my phone here is going [garbled]…but I'll try it now…can you hear me still?

Tech: Yes.

P3: Hello?

Tech: Yes, sir; yes, I can hear you.

P3: You can hear me?

Tech: Yes. Yes; I can; I can.

P3: [garbled]…because in that room I can't hear you for some reason.

Tech: Oh. OK.

P3: Um, can I call back and connect to you, or can I have your extension or something?

As the call continues, note that despite the poor phone reception—and a declaration by the caller that he needs to call back from another phone—the technician attempts to continue the diagnostic process:

Tech: All right, now uh sir, can you hear me?

P3: Yes, I can hear you now.

Tech: OK, sir, good, now um, turn off your laptop computer, turn off your router, and turn off your modem please…for 30…

P3: There's a problem actually. Um, the room where the laptop is, I cannot hear you on this phone. On this, on this, cell phone. I have to call you from a different phone. Can you hear me?

Tech: Yes. Yes.

P3: [garbled]

Tech: How would you like to turn off your router, turn off your computers, and turn off your modem?

P3: OK, I'll do that, ok?

Tech: Yes, please.

P3: OK, John, everything's off…John? … John?

Tech: Yes, I'm here.

P3: Hello?

Tech: Yes, I'm here.

P3: Hello?

Tech: Yes, I'm here.

P3: I'll call you again. Can I call you back, because this phone, can I call you back on a landline?

At the same time, however, using remote mechanisms *other* than phones are difficult in the context of home networking. Other mechanisms that rely on the network itself, such as shared views sent over a network, or chat-based programs to communicate with technicians are not practical when the medium used to communicate that information may not be functioning properly.

There are also issues of wireless and connectivity that are not always easily diagnosed considering the amount of information available to technicians. For example, in one call, it took a several minutes for the technician to discover that the caller was connecting to the neighbor's wireless and had not achieved setup at all. This example complements Twidale and Ruhleder's (2004) finding that people need to know where they are within a particular computer network. Unlike in that example, however, householders need to know not only where they are on their own network, but also whether they are on the *correct network at all* or one belonging to another person.

6. Discussion

Our work reflects some of the same considerations seen in other studies of co-located and remote technical support. Callers struggled with technical vocabulary as well as understanding computing and networking concepts. Callers and technicians often failed to establish shared understandings of the problem at hand with one another. Yet the interactions between callers and technicians at this call center also underscore that home networks offer new and different challenges for remote technical support. In particular, technical properties of the network itself exacerbate the difficulties of describing, understanding, and pinpointing problems. Neither callers nor technicians can see a holistic view of the network, and much of network functionality remains invisible; callers can only see symptoms of problems rather than the problems themselves. The sheer number of devices, connections, settings, and stakeholders complicate these issues even further. Properties of the home infrastructure—even seemingly simple issues of where a phone may have reception—can lead to no resolution of a remote help request. Given these constraints, how can we support householders who contact outside professionals for technical help?

6.1. Providing resources for local and shared understandings

Prior CSCW research, for instance the work of Crabtree et al. (2006), Gaver et al. (1993), Kraut et al. (2003), Kuzuoka et al. (1994), and O'Neill et al. (2005), suggests that shared views can assist with establishing mutual understandings of the problem at hand. In a number of the calls, the technician and caller struggled to troubleshoot because they did not have a shared view of the screen. Shared views of the caller's computer screen or the wireless router configuration page may also assist with making troubleshooting more effective and expedient. In

many cases, though, a simple shared view of a computer screen may not be enough to establish common ground. As an infrastructure technology, much of the network is effectively invisible to end users. It is a challenge to consider how one might create a shared view of invisible infrastructure.

Moreover, the mechanisms that can provide shared views may be impossible or impractical to deploy. Remote desktop technologies, for example, rely on having a working network connection. Since people are presumably calling to fix a network problem, they may not have a working network connection in the first place. But even if remote access is possible, allowing an outsider remote access into one's network also opens up a host of security and privacy concerns. For instance, how much of one's technological infrastructure can and should one show to a technician one does not know or trust? Previous research also suggests that the average person struggles with basic network security mechanisms (Stoll et al. 2008). In that light, how do we ensure that we do not open up new security vulnerabilities for people who may ultimately be the least prepared to manage the security of their networks proactively?

One alternative may be to provide resources such that a householder can perform some basic reasoning about what the problem may be prior to call placement. These resources could provide basic information about the presence of devices and their connectivity, capabilities of devices, and relevant information about the function of the network. With these resources in hand, the householder may be able to solve the problem prior to call placement, or have helpful information available for use when discussing the problem with an outside professional.

6.2. Long-term continuity: coordination between many stakeholders

Out of the 21 calls we analyzed, only three led to a full resolution of the problem; in the remainder, consumers were left with at best a partial solution, and at worst no solution. In many cases, technicians instructed customers to contact yet another call center—for instance, to an ISP or a laptop manufacturer. Some callers gave up on the phone-based process entirely, and terminated calls so that a local person—either a paid technician or a knowledgeable friend—could setup their devices.

When a householder is referred to another resource for help, however, he or she does not carry along a record about the steps that have already been tried. Given the number of parties possibly involved with the diagnosis and repair of home network related problems, future efforts in this domain may focus on understanding the challenges and opportunities for improving information sharing between the many stakeholders involved, as each of these stakeholders may have very different sets of expertise and knowledge about the network in question. We believe this is an especially fruitful area of future research, given that the piecemeal nature of home networks is

unlikely to change in the near future (Edwards and Grinter 2001; Shehan and Edwards 2007).

7. Conclusion

Visions of future domestic computing environments depend largely on the ability of householders to setup and manage networked devices. Yet the seemingly trivial task of adding a wireless router to a home network can be extremely difficult even with the assistance of remote technical experts. Our study suggests that technical properties of the home network and the structure of the home itself can complicate the social work of remote, collaborative home network problem diagnosis and repair. We call for future research efforts in the design of systems that help householders reason about their home networks prior to call placement, and improvement of methods for inter-organizational information sharing between stakeholders involved with home network problem diagnosis and repair.

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Notes

1. Two of the calls are the same caller diagnosing the same problem with two different technicians. During the first session, the call dropped and the caller had to restart the call with another technician.
2. If the caller is inquiring about a problem he or she has previously called about, the case number will allow the technician to look up relevant information recorded by the previous technician who spoke with the caller.

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