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ORIGINAL ARTICLE

Digital plumbing: the mundane work of deploying UbiComp in the home

Peter Tolmie · Andy Crabtree · Stefan Egglestone · Jan Humble · Chris Greenhalgh · Tom Rodden

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Abstract Deploying UbiComp in real homes is central to realizing Weiser's grand vision of 'invisible' computing. It is essential to moving design out of the lab and making it into an unremarkable feature of everyday life. Deployment can be problematic, however, and in ways that a number of researchers have already pointed to. In this paper, we wish to complement the community's growing understanding of challenges to deployment. We focus on 'digital plumbing'—i.e., the mundane work involved in installing ubiquitous computing in real homes. Digital plumbing characterizes the act of deployment. It draws attention to the work of installation: to the collaborative effort of co-situating prototypical technologies in real homes, to the competences involved, the practical troubles encountered, and the demands that real world settings place on the enterprise. We provide an ethnographic study of the work. It makes visible the unavoidable need for UbiComp researchers to develop new technologies with respect to existing technological arrangements in the home and to develop methods and tools that support the digital plumber in planning and preparing for change, in managing the contingencies that inevitably occur in realizing change, and in coordinating digital plumbing and maintaining awareness of change.

P. Tolmie (✉) · A. Crabtree · S. Egglestone · J. Humble · C. Greenhalgh · T. Rodden
School of Computer Science and IT, University of Nottingham, Jubilee Campus, Wollaton Road, Nottingham NG8 1BB, UK
e-mail: pdt@cs.nott.ac.uk

A. Crabtree
e-mail: axc@cs.nott.ac.uk

S. Egglestone
e-mail: sre@cs.nott.ac.uk

J. Humble
e-mail: jch@cs.nott.ac.uk

C. Greenhalgh
e-mail: cmg@cs.nott.ac.uk

T. Rodden
e-mail: tar@cs.nott.ac.uk

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1 Introduction

Digital plumbing refers to the actual work of installing digital technologies in a setting. It can be work undertaken by the inhabitants of a home or by dedicated service personnel. Digital plumbing is an essential part of how technologies arrive in people's homes. More than this, it is part of the larger body of work involved in making technologies at home in domestic environments such that they can become, in the first place, a mundane feature of our everyday lives and interactions. Whoever is undertaking the work, the problematic is quite simple: somehow what is being installed or deployed must be made to 'fit' with a whole constellation of pre-existing organisational arrangements, both physical and social, that together constitute a 'home' as an accountable and recognisable object. Digital plumbing, then, is a critical part of what has in other places been termed 'domestication' [21]—the integration of technology into everyday life and its adaptation to everyday practice.

A recent upsurge in the presence of network technologies in people's homes, and the concomitantly greater range of devices that can be hung off such networks and the services they provide, means that an important aspect of digital plumbing has become the installation and adaptation of home networks. Furthermore, the sheer complexity of installation and deployment in this space has led to digital plumbing becoming a very marketable commodity [27]. Now there are professional companies offering home network set up and maintenance as part of their ordinary portfolio of services. In that case, as the home network diversifies and grows to incorporate a wider range of ubiquitous technologies, the need to understand and support the demands of digital plumbing will almost certainly intensify. At the same time, the growing presence of network technologies in our homes has rendered what might once have been viewed as specialist or 'geek' devices a wholly mundane part of many people's lives. Routers, for instance, have become as much a feature of ordinary discussion and complaints in pubs as many of the other familiar devices we might encounter being spoken of in everyday conversations. At the same time the interactions between both people and network technologies (including the technologies underpinning the network itself and the technologies dependant upon the presence of the network) and between each other regarding the set up and maintenance of the network, are becoming evermore commonplace and mundane.

Against this backdrop of digital plumbing as an important aspect of how technologies can come to be 'made at home' [17] in domestic environments, this paper takes a look at the work of some UbiComp researchers who were involved in deploying advanced technological arrangements in real homes. This focus on (a) research deployments and (b) 'advanced technological arrangements' might, at first sight, seem perverse for the question at hand. However, when it comes to putting technology into real homes, there are many kinds of activities that just any digital plumber is going to have to engage in. The mundane work of deployment here was no different. Furthermore, the character of it as a research exercise only serves to throw the background expectations of ordinary householders regarding how deployment should proceed in their homes into greater relief. At the same time, although the underlying platform being used was essentially a research technology and the goal was to uncover novel means of supporting bespoke service provision, the actual visible technologies being worked with—mobile phones, temperature sensors, e-mail applications, display screens, lights, routers even—are all wholly mundane and recognisable technologies and were oriented to by the members of the household in that way. Thus, we find here that the work of digital plumbing we investigate in this paper provides a more than sufficiently perspicuous setting for observing something of what the mundane work of digital plumbing might look like.

Of particular relevance are the competences and skills that deployment relies upon. Even in research settings, the competences we see at work and the skills that are relied upon have 'real world, real time' purchase. While necessarily nascent in character, they are practically indispensable. Furthermore, they must evolve if the technologies they support are to make the transition from research lab to mundane features of everyday life. What we see by consulting the deployment of advanced technological arrangements in real homes are the practical demands that accompany making new technology into an unremarkable feature of the home. Those demands extend beyond the particular occasion of deployment and articulate a range of competences and skills that require continued development and support if ubiquitous computing is to continue its migration from the laboratory and become a genuinely 'invisible' feature of everyday life in the home of the future [24].

At the same time, and just as importantly with regard to what can be learnt from this investigation, it is broadly acknowledged that deployment is a valuable means of learning about the potential of UbiComp technologies and the settings into which they are intended to be placed and used. There are exceptions of course (e.g., [13]). Nevertheless, the real world is a very different place to the research lab and deployment provides valuable insights that would not otherwise be available [5, 7, 11]. Deployment usually consists of a short field trial, which typically lasts little more than a few weeks, 2 or 3 months at most (e.g., [9, 12, 18]).[1] Naturally the approach is not without its problems: field trials only provide snapshots of use [16]; ubiquitous computing systems are more complex and difficult to evaluate than previous technologies [2]; long-term deployment in the wild is required to understand the potential of UbiComp [19]. We would add to the growing list of issues that impact upon the deployment of UbiComp in home environments that the very *act* of deployment itself has much to teach us.

Focusing on the act of deployment from this perspective just as inevitably draws attention to digital plumbing. Without digital plumbing there can be no snapshots of use, no understanding of complexity, and no long-term deployment, etc. Everything turns upon it. Yet we understand little about it as a practical enterprise. The literature on installation and deployment as a practical job of work is scant. Some, like Fox et al. [7] note, "deployments are often expensive and messy [and], can involve a lot of effort that isn't really characterized as research." However, to disregard the practical demands of installation is, to borrow an aphorism from Garfinkel [8], very much like complaining that if the walls of a building were only gotten out

[1] The interLiving project (http://interliving.kth.se/) provides a rare exception.

of the way one could see better what was keeping the roof up.

It is, of course, the case that some work on the practical installation of network technologies has already been undertaken. Most notable here is the focus on how digital plumbing resides within a larger body of mundane work that might be termed 'digital housekeeping' [25].

The notion of digital housekeeping covers the routine effort involved in both bringing digital technology into the home, and then maintaining it. Because much of the digital 'stuff' of people's homes is now associated with the presence of a home network a great deal of digital housekeeping revolves around the creation and maintenance of that network. The work related to creating and maintaining home networks was first investigated in any depth by Grinter et al. [10] in a paper entitled *The Work to Make the Home Network Work*. Building upon a paper of almost the same name by Bowers [1], Grinter et al. sought to illustrate the increasingly ordinary or mundane presence of networks in homes and the ordinary troubles associated with keeping them running. These ordinary troubles included practically managing network complexity, handling the tensions that could arise between individual and communal needs, and dealing with the demands of administration and troubleshooting. Others in turn have noted a current paucity of tools for supporting the management of the home network [20]. Digital housekeeping [25] sought to ground this interest in networks still further in people's ordinary everyday, mundane interactions, by examining how management of networks was becoming embedded in broader household routines. As a part of this, digital housekeeping began to explicate some of the practical orientations in play when people first considered how to position technologies in their home and then subsequently went about the work of installation. To that end, it was commented that:

> "When digital resources enter the home they cannot just be positioned in any way within the household and its routines. Their entry into the home is not only managed for the here-and-now by household members but for the *future* as well and this is an integral part of how people reason about them when setting them up. Furthermore, it is clear that there are features of the work of setting up that get oriented to as 'chores' to be done as part of the larger round of housekeeping in the home. Where technologies are placed, how this placement is achieved, how these fit with the everyday order of the household, and how this change is prepared for and planned play a key role in making the home network at home." [25]

The materials in this paper extend upon this body of work by focusing quite specifically on the ordinary activities and interactions associated with actually getting technology into the home *when it is undertaken by other people dedicated to accomplishing just that as a job of work*.

Below, then, we present the findings of an ethnographic study of the deployment of ubiquitous computing applications in a real home. The study was conducted as part of an ongoing research exercise that is concerned with understanding and elaborating the potential for ubiquitous computing in the home. It reveals that the practicalities of digital plumbing in real home settings present significant challenges to the research exercise *and* to the practical realization of Weiser's vision for ubiquitous computing [28]. Of particular issue is the unavoidable need for UbiComp researchers to develop new technologies with respect to existing mundane and unremarkable arrangements of technology in the home if they are to migrate from the research lab. Findings show that the effort to deploy UbiComp in real homes requires the development of methods and tools that support the key competences and skills involved in deployment, including preparations for installation, tools that support the assembly of parts for installation, tools that support the management of contingencies during installation, and tools that support coordination and awareness of installation activities. These are not incidental features of research or the broader effort to make ubiquitous computing into a mundane feature of domestic life. They go to the heart of the matter. UbiComp is after all an explicit intervention into everyday life [28]. It seeks to change the way we live together. Digital plumbing is all about realizing that change.

Nor, as we have been at pains to point out, does it end there. The work of integrating technology into people's homes and lives in ways that can resonate with not only their interests and requirements but the very way they *lead* those lives is an integral part of 'making the technology at home' [17] in those environments. Yet the literature on 'domestication' (see, for instance [22]) gives little or no attention to the detail of the actual mundane work of putting technology into domestic environments in the first place. Here too, then, is an urgent need to get better sight to just what might be 'keeping the roof up'.

2 Context of the deployment

The deployment reported here was an exploration of the potential purchase of the equator component toolkit (ECT) to the development of ubiquitous applications for the home (http://equip.sourceforge.net). The researchers involved in the development of ECT decided to deploy it in a real home in order that they might come to better understand its 'real world' capabilities. They elected to install it in one of their own homes before seeking to move further afield.

ECT was therefore deployed in David's home. David is the lead computer scientist on the project (and this like the other names of participants here is not his real name). David lives in a moderate sized semi-detached house on the outskirts of a major British city. The other occupants of the house are David's wife, Miranda, and their three children: Hannah, 9; Philip, 7; and Samantha "the baby", 18 months. Hannah and Philip are both at primary school and Miranda is currently a full-time mother. The installation itself was undertaken by Michael and James—two researchers in the same department as David.

As part of a research exercise in developing real world UbiComp applications, the deployment was complemented by ethnographic study [3]. This involved the direct involvement of the ethnographer in all of the meetings prior to the actual installation of the technology, observations of all the work undertaken by Michael in preparation for the deployment, and direct observations of the work done by Michael and James to actually set up ECT-based technology in David's home. The ethnographer was also involved in all of the e-mail communication surrounding the deployment. This process, from planning to installation, occurred over a span of a little more than 3 months. We focus here on the work involved in installing particular arrangements of technology over 2 days, separated from one another by a 3-week period to accommodate the availability of the householder. That work, like the work that went before it and which has occurred since as part of an ongoing course of research, is necessarily cooperative. It occurs not only between the researchers but also between the researchers and David in his capacity as a household member. While we can easily imagine that commercial relationships will reduce installation to a single engineer, the work will remain cooperative as it necessarily entails collaboration between household members and digital plumbers. It should be noted that while David's technical competence cannot be dispensed with one should not presume that, because of his professional interests, his concerns as a *household member* were somehow suspended during the installation. His is a real house occupied by other people who were far-removed from the concerns of any academic enterprise. All of the normal household accountabilities were in play, making the deployment (sometimes frustratingly) real for those involved. In his house there was a pre-existing network that had been built for the home, not for professional curiosity. It was built because it was a sensible resolution to a burgeoning array of digital technologies in the home. Thus, for us, the interesting thing was that technologies borne out of an interest in potential future ubiquitous computing applications were to be grafted onto a pre-existing network that was already a mundane, taken-for-granted feature of the household setting. It therefore provided us with an opportunity to observe the work of deploying something novel in such a way as to fit with a network that had been installed to meet the routine needs of a household rather than a research deployment. One could imagine few circumstances more hostile to such a deployment and it therefore gave us a particularly apposite opportunity to examine the ways in which digital plumbers would have to work to make novel ubiquitous computing applications accountable to ordinary household concerns

We explicate below the nature of this work, and the range of interactions—many of them wholly mundane—that thus arose between the household members and the digital plumbers, along with the import this might have for future deployments and the role played by those undertaking the work of digital plumbing.

3 Deploying UbiComp in a real home

As we noted above, David already had a rudimentary home network set up, including a PC, laptop, and router. Michael and James, the digital plumbers, provided a range of equipment including a phidgets package (interface kit, analogue sensor kit, LCD screens, RFID reader and various tags), a mini PC for running the phidgets, a tablet PC, a 15 in. touch screen monitor, a wireless router, X10 modules and control units, Bluetooth dongles, hubs, and a wide range of cables. As part of an ongoing research exploration David had already installed a webcam application for observing the bird table in his garden. He had also configured a sensor to collect and display outside temperature, and had begun to set up an application to notify and display e-mail arriving to his wife's Yahoo account. David also had ambitions to place a temperature sensor in the baby's bedroom so that they could remotely monitor the temperature during the night, but had not got around to setting this up yet. Michael and James' task would be to set up and install the e-mail display and the temperature sensor in the baby's room. David naturally insisted that they do so at a time when the baby was awake so that they would not disturb her. The installation itself took place over 2 days in October 2006.

3.1 Preparing for installation

Like any new technology, deploying ECT requires considerable effort to move it out from the research lab into real settings. The deployment therefore needed a pre-installation check. Here Michael and David were obliged to discuss not only what they intended to install in the house, and with what physical devices and digital components this was to be achieved, but also where the installation was to be situated in the home:

Michael: I seem to remember you talking about constructing some artefact which gave you an indication of mail having been received.
David: I haven't really given it much thought. I guess it's going to be—well it wants to be reasonably noticeable without being daft.
Michael: Yes. So, when mail comes in where would you like
David: Well it's my *wife's* mail account, so it's more down to her in a way.
Michael: Right. Okay. Is she going to be around when we
David: I'm not sure. Well she might be around. Depends how long you stay. She'll probably be around some time after four.
Michael: Right. So we can—we can see how we get on. We can always put together some—we can put together something she might like. You know, it can be positioned
David: Yeah. I mean obviously—well the two main candidates are probably somewhere near the answer phone or somewhere in the kitchen.[2]

The pre-installation check enabled the digital plumber to plan what resources might be required to undertake the 'job' and to subsequently assemble the necessary 'parts'. This not only includes the specific devices and components of the installation, which have to be checked and repaired or replaced if needs be, but also the 'tools' that installation would require: the latest version of ECT, network software, software drivers, a PC for configuring the software, cables, wires, connectors, and so on.

This sounds simple and straightforward but anticipating just which tools the digital plumber requires is practically problematic. Software is not like the physical plumber's tools. Hacksaws and pipe cutters, blowtorches and flux may come in many different versions but they do the same thing. The same cannot be said about software versions, however. Consequently the digital plumber not only needs to take a significant number of tools along to the job, but also has to prepare in advance for contingencies, anticipating what problems might be encountered during the installation and what might be needed to fix them:

Michael: There's two commonly used versions of Java, 1.4 and 1.5. If I compile under 1.5 and David's only got 1.4, anything I compile won't work. It'll be a case of taking extra versions of Java.
Ethnographer: So it's not even like you have to carry one of everything with you.
Michael: No.
Ethnographer: And I'd be right in thinking—this is obviously a problem that relates to ECT—but you can assume it's a pervasive problem?
Michael: (nods emphatically) So the phidgets drivers we were doing just then? They're dependent upon Microsoft.Net framework. There's a big difference between version 1.1 of .Net and version 2 of .Net. The phidgets are a really good example actually. We bought some new phidgets—they didn't work with the old drivers. Turns out that these new phidgets required new drivers but the new drivers had been entirely re-written from the old drivers. So really it's a case of ripping out the old drivers and putting the new ones on, which requires installing a whole new load of software that they depend upon. Then your tool, which you're providing people with to control them, it's a case of getting the right version of that to work against the right version of the drivers. And it's hidden! Drivers are just files on your computer and there's no—they're not writ—they're not very good tools to examine their interface. Knowing what version of your tool requires which version of which driver is *not always easy*.

In addition to putting the tools he envisioned the job would need on a USB stick, Michael also prepared for contingency by creating a network solution that enabled him to make a range of potentially useful resources available on site via the Internet.

3.1.1 What's keeping the roof up

The amount of work that is involved in pre-installation checks and the scale of the practical problems that face digital plumbers should not be underestimated. Even for a small installation Michael had to assemble an up-to-date version of ECT, the phidgets library and different versions of phidgets drivers, two versions of Microsoft.NET framework, Java 1.4, a version of YPOPS, and create a set of zip files and a network solution that would enable him to download resources as contingencies might dictate. He also had to set up a mini PC with a wireless antennae, which involved installing extra RAM and relevant patches and updates. Beyond all this work, it is also important that we take the process of pre-installation into account. It is in part a cooperative process that relies on consultation with householders to determine what is to be installed and where it is to be placed. It relies on planning to determine what resources are required to carry out the installation. It relies on the assembly of appropriate parts and tools to carry out the job. And it relies on resources that support the handling of contingencies on the ground. Each part of the process represents a distinct aspect of the work that has to be undertaken before putting technology into real homes.

[2] The vignettes provided here are edited and illustrative in nature. They are intended to give a flavour of the work rather than evidence it in exhaustive detail, space unfortunately precludes that.

What we have seen here is something that amounted to being first time through for the digital plumber involved in doing this work. The value of this is that, as practices become routinised and resources established and taken-for-granted, the extent to which these are actively pursued and assembled becomes more hidden from view. Yet without these various elements of assembly, provisioning, and consultation, digital plumbing could not hold together as an enterprise. It is in a proper understanding of the methodical ways in which these are realised that any future design to support such work must therefore be grounded.

3.2 Installation day 1

Day 1 of the installation involved just Michael and David. They first concerned themselves with setting up the e-mail display. David had decided to use the tablet PC as the principal machine to support the installation. Michael first established network addresses for the machine then checked that David wanted the whole ECT data space running on it. David then instructed Michael where he wanted it placing:

> Michael: Okay. I guess we can get going with the wireless access points in a minute and see what the range is like. So we can start off maybe installing the screen you were talking about to flash up e-mails. So where would be a good place to start off putting that?
> David: I think, well (baby crying in background)—I'll have to go and get baby in a second—I think probably the safest thing to start off would be, if this tablet sits on top of here (on the cupboard) by the phone.
> Michael: Yeah, I'm sure we could work out how to display something onto that screen there couldn't we?
> David: Yeah.
> Michael: Okay, that sounds good. So I'll start getting, I'll start doing an ECT installation on it.
> David goes to get the baby.

In the meantime Michael downloaded the relevant software on David's desktop PC and checked the network speed. It was delivering around half a megabyte a second, which Michael considered fit for purpose. David returned with the baby and Michael, having established that he had directories he would rather weren't touched, created another to preserve existing arrangements. Michael then set about configuring and testing YPOPS. This proved to be problematic although a lack of feedback made it unclear whether the problem was down to the e-mail software, the ECT components, the service installed on the computer, or something at Yahoo's end. To work around any potential problems with the local e-mail application, Michael installed Mozilla Thunderbird instead, which he was familiar with, and tried setting the e-mail up via another account.

While they were waiting to see if this would solve the problem, Michael and David turned their attention to how to best display the notification:

> Michael: So, we should talk about exactly how you'd like mail to be displayed on this machine—there are various possibilities. Depends whether you want to know the contents of the mail or whether you just want an indicator saying that e-mail has been received.
> David: Hmm. Probably better if it just indicates there's new mail received because there's not an awful lot of mail that we get that we'd necessarily want to make public.
> Michael: So, what's the best way of doing that then? We could open up a web page, web browser on this computer, and when a new message was received, you'd have a kind of browser interface with a piece of html saying a message was received.
> David: Yeah, give it a go.

Michael then created the necessary components and configured them in the ECT editor. This too proved to be problematic, however, as the browser wasn't accepting URLs from one of the components. Michael tried to resolve the problem but then reported that the e-mail server had frozen anyway. In response, David suggested that they try the X10 controls out instead, using a light as a means of notification:

> Michael: If we try to control lighting we've got a constraint—it's got to be between 50 and 300 W.
> David: Well these (lights in the living room) won't be 50 W, they're fluorescent.
> Michael: Oh, they're fluorescent, okay. There might be a problem I think, X10 doesn't work very well with anything other than normal kind of standard incandescent.
> Michael: (goes into study, unpacks X10 units, then goes over to the tablet PC) I'm just going to install the drivers we've got on this little mini CD here (runs install).
> Michael: What this is (holds X10 component up), is a sender unit and that thing there is a receiver unit. The constraint, though, is that they have to be on the same ring main in the house and lots of British houses have got at least two of those. Sometimes more.
> Ethnographer: And is that evident, without actual trial?
> Michael: No. So, we'll just try to find a spare socket to plug it in and see if the computer can actually detect it (takes the receiver unit out into the kitchen and finds a socket under the cupboards). I'm just going to stick it in here because it's as close as possible physically to that one over there. Maybe that'll give us a better chance of being on the same ring main.

Michael: (goes back into the other room and starts building a connection in the ECT editor) Every time you plug one of these devices in then a new comm port should appear on Windows. Yeah, you see, I can guess from this there's something happening. If you look here on this (points to screen) 'USB to Serial comm port'. I know that's the name of the device and the thing we've connected up, so I can guess it's comm three but if there were any other similar devices connected to the system it would make it more difficult to work out which one was ours.
Michael: It would be nice to have something to actually plug into it to (picks up desk lamp from beside computer and carries it out to the kitchen, plugs it in and the light comes on). That's on. I'm going to try and turn it off now.
Michael: (goes back to the other room and the ECT editor). So let's set that to 'off' and it should go off (looking out of doorway to see if it works). So that's working, at least, so we know these are on the same ring main.

The two then turned their attention to configuring the e-mail notification itself. Michael first checked the status of the e-mail server but still there was still no progress so he switched accounts again. He then configured ECT to deliver the e-mail notification to the X10 unit/lamp. At this point it was realized that this would require that the light be turned off again every time an e-mail arrived for it to be of any use:

Michael: How it's set up at the minute, the light will go on when e-mail's received and then you'd have to re-click the button on the screen (pointing to screen) here to reset the system.
Ethnographer: Because otherwise what would happen is the next time an e-mail's received it would effectively turn it off again.
Michael: Yeah, that's right. Or you could set it up so that it changed.
Ethnographer: So its state wouldn't be informative in that case would it because
Michael: Yeah. So it's a choice isn't it? I should probably check with David what he'd like (goes into kitchen). So design-wise, would you like the light to flash on and off when an e-mail's received, or would you like it to turn on?
David: In general it's more likely than not that no-one will be here when it turns up, so it would be better if it was something persistent.
Michael: So you don't use the button on the screen in there to reset it?
David: Yeah 'cause (gestures towards room with computer) you'd have to go through there, y' know, to bring it all up.
Michael: Right. So that's that then.

Michael then configured the necessary changes so that the light could be reset from the computer. After this he returned to configuring YPOPS but the e-mail server had frozen again so they packed up the tools Michael had been using and went upstairs to plan the installation of the temperature sensor for the following visit:

David: There's tons of possible sites. I'll show you where this room is.
Michael: Okay.
David: (tapping wall as they go upstairs) External wall.
Michael: Wireless?
David: Yeah (they arrive at the baby's bedroom). I wouldn't be at all surprised if it takes at least another router setting up. Power's there (points to socket). That's all the power there is.
Michael: Okay.
David: Initially I'd assumed we'd set it up in here in one of those boxes. But (looking around the room) I guess the alternative would be to run an extension lead right round and put it here in the cupboard or on the cupboard somewhere. It would be more inconspicuous.
Michael: So if there were going to be another router do you think it would have to be connected through a long cable then?
David: I've never tried to get wireless up here. It goes fine to our bedroom but that's not—it's not through the external wall. I can try my laptop quickly (goes downstairs).

On returning to the room David sat himself on the chair in the corner and tried to get a wireless connection. He got two bars and they both felt that this would be sufficient with an antennae connected to the mini PC. The two then discussed how the temperature would be displayed:

Michael: So if we were sensing temperature in here is it just a case of display onto the LCD or would you want it to be displayed somewhere else as well?
David: Well the point is to be somewhere else because that's the current display over there (points to thermometer).
Ethnographer: You have to come into the room physically to discover what the temperature is.
Michael: Right. So where would you like to display it do you think?
David: Well, in—well we need to be able to access it from our bedroom, because in general obviously we're in bed. The baby cries and the question is 'are they too hot or too cold?' So something I could access off my phone I guess.
Michael: Off your phone?

David: Because I keep the phone by my bed to charge overnight. And that's got Bluetooth.
Michael: Right, okay. So I should talk to James then and find out how that all works. I'll have to get him to check it and sort out a phone.
David: Yeah okay.
Michael: Yeah, okay. We can do that then.
David: Well—er—other bits could be but it can be my own phone.

Michael and David then went back downstairs and wrapped the day's work up. In all the installation had taken them some 3 hours.[3]

3.2.1 *What's keeping the roof up*

We would suggest that the work of installation might be usefully understood in terms of plans and situated actions. One of the defining characteristics of realizing a plan is the contingent nature of its accomplishment; making the plan work is invariably subject to the local conditions of work on the ground [23]. The work of installation is inhabited by contingencies—like the walls of the house that keep the roof up, they cannot be removed from the situation and there is a need for researchers to develop a sensitivity towards them. Thus, we can see that actual deployment is not simply a matter of downloading the software that one has planned to use and installing it on a number of machines and devices. Rather, the digital plumber, in cooperation with householders, must decide just where new technological arrangements are to be situated and just how they are to be physically and digitally connected, all of which is contingent upon existing physical arrangements in the home: where such things as cupboards and shelves are available to place things; where power is available; that proposed devices are compatible; and so on. The same concern with the physical organisation of the home, and how that relates to the social organisation of the home, is something that was manifest in previous studies of digital housekeeping [25]. The digital plumber similarly needs to respect existing technological arrangements in the home and make new installations fit in with them. This in turn requires that the digital plumber have a range of technological competences. He or she will need to have networking skills so that new technology can be incorporated into the home network; need to know how various operating systems are organized so that new installations do not adversely effect existing arrangements; and need to know-how particular software applications work so that new services which utilize them may be configured. He or she will also have to configure bespoke services in cooperation with householders, handle the contingencies of installation (such as establishing wireless network availability at specific locations in the home, that the correct drivers are available, that devices are on the same ring mains, etc.), and then test new configurations. This will inevitably involve an understanding of where troubles might be expected to occur and of troubleshooting and faultfinding. Nevertheless, it is by handling a range of contingencies—physical and digital—that the digital plumber actually comes to install new technology in the home. At the same time, it is not as if these contingencies have no orderly or expectable properties: there will be a network with or without wireless elements; there will be an operating system and applications and drivers to be handled; there will be a need to manage physical placement of devices; there will be a need to troubleshoot. And in each of these there will be, to a greater or lesser degree, a need to engage with members of the household to establish 'best fit'. The exact what's and where's of these working expectations are things that evolve over time as part of a developing professional practice. More than this, the ways of working these things on the ground are themselves constituted of the methodical practices that make up digital plumbing and that, too, is something that is still largely nascent as what makes it a recognisably distinct body of practice evolves. We can see some of what it will take here. But just what we would reasonably expect to see a digital plumber doing or not doing in our homes is something that will become more sharply defined as our encounters with it become more frequent. Here, then, we begin to see that work of discovering what digital plumbing might be about taking place just as much *for members of the household*. And of course, in large part it is informed by what we might reasonably expect of just anyone coming into our homes to do jobs of maintenance and installation. These are the gross or vulgar features against which the more specific features of digital plumbing practice will be defined.

3.3 Installation day 2

The second day of installation involved Michael, James and David. James took part because of his expertise in configuring mobile phones and Bluetooth, components that were a part of the proposed temperature application. James had created a new digital component that would enable a mobile phone to get a piece of text out of ECT, which could subsequently be converted to a temperature reading. He created the component in Java 1.5, which meant that they would have to update the installation. He also prepared for

[3] David and Michael never got the e-mail display working with the tablet PC. The ECT component that 'talked' to YPOPs broke down and would not even work in the lab again. Furthermore, the installation was abandoned because of what David called household "conflict over work surface usage" and the "machine overheating, etc."

contingency by taking a midlet application along in case discovery problems emerged. Michael would also need to install the phidgets drivers onto the mini PC and the right .NET set up which the phidgets depended upon on. Michael and James began this phase of the installation by updating and installing the necessary software.

Michael set to work installing the phidgets set up on the mini PC, which required access to the wireless network, and James started setting up the Bluetooth components on the tablet PC and setting up a connection with a mobile phone. He then tried to get the set up working but could not find a Bluetooth signal:

> James: What's wrong with this thing?
> David: It's a tablet PC. You mean apart from that?
> James: (Looking at Bluetooth connection wizard) 'Unable to detect remote device'. How do you know? It tried for like a second.
> James: (Brings up preferences pane and shows David) So I put that in (makes entry) but it still doesn't throw it up. It still doesn't recognise it. (Clicks to list of devices) It should show up here.
> David: Where is it? You don't get anything off the properties either?
> James: No, you just go back to this (wizard) screen but that doesn't seem to be loaded because I do the discovery (selects to hunt for device but gets 'Unable to detect remote device' message again) It's not—it can't be possible. Let me just go get my phone (goes and gets his phone from the dining room table and brings it back through)
> David: I've turned Bluetooth on on my phone as well.

By way of addressing the problem, James ran the ECT compiler from a USB memory stick, scanned a range of directories to check whether the necessary components were installed, ran the Bluetooth connection wizard several times more, re-installed the components through the ECT editor a number of times, and after multiple attempts replaced the memory stick with one of the Bluetooth dongles before working through the re-installation and the connection wizard once again. A connection was finally established without any clear reason and James then showed David how the process worked:

> James: I've tried like a million times. I've no idea why it did it now. Look, now it works. I hate this. This does not improve my karma.
> James: Okay, so here's the way it works. (Shows David the phone and PC) It should get in its cache now. So it won't be as fussy later then. So (holds up PC) you have a simple server. You see the message I've put there?
> David: Yeah
> James: Okay, just do send, or it should be connect or something like that because it's like this server accepts the command and then replies with something. So I'm sending it a command that says get me the message or something (clicking on phone) and it will get to you every time.
> David: Okey-doke

Michael, meanwhile, was having troubles of his own. He had to install the .NET framework and the phidgets drivers on the mini PC and remove Java 1.4 before installing Java 1.5. Again, without any obvious reason, the process was painfully slow and was still running when James joined him some 40 minutes after he'd started setting up the Bluetooth components. The two went back into the study as they were waiting for the process to complete. They talked about the problems of the install process, suggesting that running a network cable upstairs to the mini PC would be a "more reliable" way of doing the set up. James also warned Michael to "watch out" if updating ECT on the tablet PC because he had put the jars for the new components directly into the install folder. They then discussed how to handle any possible disconnections.

> James: It's just disconnection on the things that run on the same machine as the data server that's the problem.
> Michael: Right, okay. But this is running down here isn't it, or have I got that wrong?
> James: I think the dataspace—wherever the dataspace is that's where we need to configure. Everything else is fine.
> Michael: Right, okay. So we don't need to do anything to the exporter scripts on there (indicating mini PC in other room)?
> James: No, except. What?
> Michael: We need to supply the IP address of that machine to the exporter scripts (pointing to tablet PC)
> James: Yes.
> Michael: So do we know the IP address of this machine?

Michael set about locating the required IP address on the tablet PC and once he had configured a static address he followed James and David upstairs to do "a reccie of the bedroom" at David's request. Having decided where to situate the installation—next to a chest of drawers—Michael then started to assemble the components they would need. As he did so he chatted with James and suggested that it would be much easier if they had set up a "remote desktop" to support the exercise. He then put the mini PC in a plastic box to protect it, started it up, installed the phidgets interface kit and sensor, and set about putting the installation on the network. To do this they needed the encryption key. The mini PC only offered WEP whereas David's network used WPA. It was also unclear which wireless protocol the mini PC worked on, B or G? David's network was G.

To address the first of these issues David decided to change his network to WEP and set up a second router. David first looked to using the household computer in the office to do this. However, it quickly became obvious he could not do it that way. He then began to wander around the office and the kitchen, looking for possible sites for the second router, using the power supply of the router as a measure of where the cable might stretch to. He finally settled on a location on the floor next to a cupboard in the office. After this David began to configure the settings for the router using his work laptop, with some assistance from James who provided information from the router documentation. At the same time as David was doing this Michael was trying to discover whether the wireless protocol was B or G.

David: It’s probably old enough that it’s B which is also a nuisance ‘cause I’m on a G.
James: You can always test it.
Michael: Is there any way I could find out from the computer at all?
James: I think it’ll give you the name probably if you just go to IP config. That’ll give you the—it’ll probably say something like B or G or
Michael: Okay (goes upstairs).
Michael: (Comes back down) No, just says wireless USB adaptor.
James: Did it say the hardware or the driver for it?
Michael: No, it didn’t say. I could maybe right click on My Computer and look at device information
James: Yes, the driver info.
(Michael goes upstairs and then comes back down again)
Michael: No, there’s nothing specific. It does say the data rate is 11 megabytes per second. Which is B is it?
David: Mm.
James: Yeah. If it was G it would have said G at that time ‘cause it’s like
Michael: Special?
James: Yeah.

With the second router set up and the network working on WEP, they went back to the bedroom and Michael started configuring the mini PC. The connection failed at the first attempt but worked second time round. After checking the IP address, Michael ran the ECT exporter on the mini PC and checked the phidgets interface for an output value. He then went downstairs to configure the service on the ECT editor. He started the Bluetooth component, entered the ID for the phidgets interface kit, then created a component that would change the output value into a temperature reading. The component didn’t work as expected, however. Michael had installed it on the mini PC but it needed to be on the machine hosting the data space so he re-did the installation on the tablet PC and received a reading of 21°C. James and David now set about trying to connect through their phones:

David: 21°C!
James: I’ve got an error connecting.

Michael went upstairs to check that the sensor was working. First of all he put his finger on it. David then got a reading of 29. David tried reconnecting several times to monitor the change then suggested that Michael try putting it out of the window. David then kept reconnecting and monitored the temperature falling through 26, 24, 22 and 19. During this time James managed to get a connection as well.

With the temperature monitor successfully set up, they started to pack their tools away but David felt they should undertake one final test so he went to the plug for the router, turned off the power, then turned it back on again. They had specifically scripted to cope with the need to recover from disconnection like this. For a moment it looked like nothing too serious had happened, but suddenly the contents of the ECT editor disappeared.

David: Now that shouldn’t have happened
James: No. Oh I think because I should have put in the equip address on the editor itself as well. So let’s do that.
Michael: Aw, yes! (as the components reappear). It’ll be interesting to see if the components have—it says the phidget interface kit hasn’t been re-created!
David: That’s because it’s upstairs and the networking is still off.
Michael: Oh the networking’s still off. Right.
(David then got the network restarted and logged back into the machine upstairs)
David: That’s it for upstairs. Theoretically what will happen now? The other one shouldn’t have lost it’s IP.
Michael: Can you just drag in the phidget interface kit and see if it’s
David: (Dragging it in) Ah, it hasn’t, because it’s—it thinks it’s configured and it’s not connected.
Michael: Not connected? So you sometimes get that when it’s had an error in trying to connect to the device.
David: And the best way to fix that is? Unplug and replug the physical USB or remake the components?
Michael: Probably remake the components I guess.

David set about recreating the links between the components but the installation still failed to work. They tried restarting the interface kit on the mini PC, but without luck, so Michael tried setting the ECT exporter on the mini PC up so that it restarted automatically. Nothing. It was only after the installation that David discovered what the problem was: the original component was actually still running but was not visible because it hadn’t closed properly. In all the installation took some four and half hours.

3.3.1 What's keeping the roof up

Installing research prototypes in real homes is characterised by what one of the researchers involved here calls a "litany of problems". As Davies [5] reminds us, however, "only through deployment can we learn about unexpected problems that might be critical in real systems." In this case problems are evident from beginning to end, though there is no reason to suppose that there is anything particularly unusual about this particular ensemble of researchers' experiences. From setting up a working Bluetooth connection between components, to upgrading the mini PC, to incorporating the temperature monitor into the wireless network, to testing the robustness of the network configuration, problems inhabit the work and require that solutions be worked out in situ to make the technology work. It is not only the case that problems are encountered in the course of installation, however, but also that solutions are devised by digital plumbers to handle those problems. In addition to the practical work they undertake to resolve problems and the kinds of solutions that the digital plumbers themselves project as being useful—such as using network cables or remote desktops to support installation—what is especially interesting here is the cooperative nature of problem-solving and of coordination and awareness raising between the digital plumbers to track and manage potential problems. Thus, and for example, we can see that new components (e.g., another router) need to be installed to resolve problems and that this relies on David's technical competence, or that James sees it as necessary to inform Michael of certain upgrades that he has performed. Technical competence—know-how—and *socially distributed* technical competence at that, is key to solving the problems that installation inevitably occasions.

It is important to recognize that this distributed know-how extends well beyond the particular technologies that researchers or commercial practitioners intend to install in peoples homes. It is part of an evolving body of practice that this know-how begins to become a concrete feature of how the work is resourced and organised. Thus, on the one hand, practitioners evolve a set of specific ways of organising their interactions with inhabitants of the setting to best support the work they are going to undertake. Heating engineers, plumbers, electricians, kitchen fitters, have certain kinds of questions they know they will need to ask and certain kinds of discussions they know they will have to undertake to make their work most productive and least interruptive to the people whose homes they are entering. This is not about having a script but about knowing what, on the ground, is going to be the most meaningful question to ask of the inhabitants. And often just what a meaningful question might be can only be uncovered once the work is underway. It is out of this body of recognised thematics that a cooperation between a practitioner and a householder can evolve. It is not like a digital plumber can just ask you what you had for breakfast that morning, or not without some specific account. To even ask where you are going on holiday this year is not a topic that is normally on the table. But to ask you just when you downloaded a certain set of drivers and from where may prove to be highly pertinent. Yet to ask such questions of all drivers as a matter of course would be painful to everyone involved. It is about recognising in situ what may inform the task in hand, even if it is not always evident to the householder why such a question might arise.

The other part of this cooperative work towards resolving issues is the work that happens between the digital plumbers themselves. Service personnel in other professions frequently share amongst one another stories of previous troubles and their resolutions and this serves to build up a shared understanding amongst them of how particular issues might be tackled. Ethnographic study of just this kind of work has already been undertaken and serves as a reference point to which we can relate an evolving understanding of how the cooperative work of digital plumbing gets organised. The work of Julian Orr in relation to the activities of printer service engineers is exemplary in this respect [14].

4 Stating the obvious?

It might be thought that we are simply stating the obvious but if that is the case we might ask where is the support for the digital plumber? Digital plumbing is not only about practical necessity—not something that just has to be done—it goes to the heart of home-oriented research and, as home network technologies increase and diversify, to the heart of commercial activity and the mundane realization of ubiquitous computing as well. Digital plumbing is quite simply indispensable. Consequently, there is a need for researchers working in this domain to move beyond thinking about delivering services in purely technical terms and consider it in practical terms too. Ultimately, someone has to *do* installation (even if it is the householders themselves) and there is a need for research to complement innovation with support for the work of digital plumbing. Our study of the work of digital plumbing suggests several points at which we might consider making a start.

4.1 Beyond the research lab

First we might consider what it takes to make technological innovations work in *existing home environments*. This is the baseline. While new technologies may work in the lab it does not necessarily follow that they will work in the wild. Indeed, much of the work involved in digital plumbing revolves around integrating new technology with existing arrangements, which may well stand outside the research. Cleary there is a need then for UbiComp to engage with existing arrangements in the home and develop technologies that not only work in the lab but work in real homes as well. UbiComp researchers have already recognized that the primary market for ubiquitous computing is not the future home but existing housing stock [6]. Consequently we suggest that a broad shift in orientation is required where whatever is developed in the lab is developed with respect not only to future possibilities but to existing infrastructure in the home as well. Broadband and 802.11 wireless networks are rapidly populating the home environment along with an increasing array of digital devices and network solutions. The ubiquitous home is already here and it places distinct demands on the development of future ubiquitous applications.

We get a sense of what some of those 'demands' are when we consult the work of digital plumbers seeking to install advanced technological arrangements in a real home. The first thing we notice is that one cannot simply migrate new technology out of the lab into the home no matter how well designed it might be. A great deal of *preparatory work* has first to be done. This work relies in important ways upon collaboration between the digital plumber and household members in the first instance. Like any service provider—be it a builder, electrician, joiner, plumber, decorator, etc.—the digital plumber is engaged in installing something that household members want placing in their homes. This orientation to digital plumbing does not necessarily sit well with research. Homes are often seen as sites where technological possibilities envisioned by researchers might be explored with little respect to what household members actually want. In other words, technological research is often something that is 'done to' household members rather than something that is 'done for' them [26]. Insofar as UbiComp researchers wish to address the challenges of domestication [15, 21], then it is incumbent upon them to take seriously the ordinary ways in which technology is 'made at home' [17]. The first step along this road is to make the installation of research prototypes into something that is being done for household members.

As the study makes perspicuous, making this move will involve planning what is to be installed and where it is to be situated with household members. In cooperation with householders the digital plumber must, in effect, survey the home environment, mapping what devices and services household members want installed and where they want them placed in the home. Right now the surveying is done through talk and while talk will remain the vehicle of articulation there is no need to exclude the use of supporting methods here. Site visits must be made (our researchers were already familiar with the layout of David's home) and the digital plumber might make plans of various kinds—drawings at their most simple—of the physical environment much as other service providers do. The purpose of the exercise is, as it was for David and Michael, to specify what is to be installed and identify candidate locations where the technology might be placed [4].

There is a necessary degree of negotiation involved in preparatory work. While householders may want this or that technology installed, there are constraints on the placement of things both social and technical. Socially, it depends on who the installation is for and where they want it. Technically, it depends on whether or not it is feasible to install this or that technology in the desired location. Not only does the availability of such things as power and need for cabling impact upon deciding where to put things, placement is also effected by existing technological set ups in the home such as the availability of the wireless network across candidate locations. This takes us beyond current research practice, where such issues are worked out on the ground in the course of installation, to extend the mapping exercise. Rather than grappling with these issues on the ground it might make more sense to treat them as part of preparatory work and so decide in advance just where the technology is to be placed, which in turn will enable the digital plumber to determine with greater accuracy just what will be required to carry out the installation.

Extending the mapping exercise may necessitate developing tools that support surveying—tools that enable the digital plumber to quickly and easily check the availability of the wireless network across candidate locations, for example. It will certainly require the digital plumber to map the existing technological landscape of the home in much finer detail than is currently done. Understanding the particular configurations of devices—PCs, base stations, routers, etc.—is essential to effective digital plumbing. Similarly, understanding software configurations, what versions of operating systems are running, the drivers that are required, and so on is a matter of major impact for the installation of new technologies in the home. Whether or not tools can be developed to support fine-grained mapping of the existing technological landscape is an open question, particularly with respect to the kinds of versioning problems associated with drivers. That it has to be done is not so debateable, however, and methods most certainly need to be developed that better enable the integration of new technologies with existing set ups.

There is then the need to consider support for the digital plumber in *assembling parts and tools* to carry out the installation. While an enhanced mapping process may increase the efficacy of assembly, giving it more focus and specificity, getting the right tools together and on site is still a distinct job of work. It ranges from configuring and testing the hardware to be installed (such as installing extra RAM on the mini PC), to assembling all the bits of software that (a) *will* be required (the applications, components, drivers, etc.) and (b) *may* be required (different software versions, updates, patches, etc.). Whilst it is relatively straightforward to provide online solutions for small, one off installations, scale and diversity raise serious challenges for support. It might otherwise be asked, should the digital plumber have to assemble the required parts and tools anew each and every time he or she undertakes a job or does the possibility exist to archive parts and tools and make them available to reuse as and when occasion demands?

One of the reasons we ask this question is because of the inevitable contingencies that will emerge on the ground. No matter how well prepared the digital plumber is, something will not go to plan. Our experience as household members of having service providers of all kinds carry out work in our homes reinforces that blunt fact. Why should the digital plumber be any different, especially the research variety who is working with prototypes rather than more stable products. Contingencies inhabit the work of digital plumbing and there is a need to consider how the *management of contingencies* in the course of installation might be supported. The provision of an online archive may go some way to addressing contingencies. However, it is also important to appreciate that the work of troubleshooting and faultfinding that underpins the handling of contingencies relies in important respects upon the technological competences the digital plumber possesses. The range of competences required for even a small installation are impressive: bespoke system knowledge (e.g., of ECT), network knowledge (e.g., how to configure wireless networks and routers), specific application knowledge (e.g., of Outlook Express or Bluetooth), electrical engineering (e.g., the electrical operating range and demands of the X10 units), and so on.

Installation relies on technical competences that extend far beyond the research technologies that may be deployed (such as ECT components). In the case of our study, those competences are not located in any one person and it seems reasonable to assume that, even with training, the unpredictable nature of contingency means that it never will be. Thus, the management of contingencies means that there is a need to consider how technological competence might be supported to underpin troubleshooting and faultfinding. What we are speaking of then is the kind of support tools and resources that one finds in other areas of professional practice ranging from local constellations of cooperation and assistance to online resources, knowledge management databases, FAQs, remote diagnosis of faults, etc. Some of these may seem like extreme solutions to the problems UbiComp researchers working in small teams encounter, but as more and more applications start to make the move out of the research lab there is a real need for digital plumbers to share their experiences, make their technological competences available to one another, and ultimately for design teams to provide support for the resolution of problems on the ground. Furthermore, if UbiComp is to make it out of the lab and into the mundane fabric of everyday life, then such solutions would seem to be an essential ingredient in any large-scale commercial endeavour which will inevitably be characterised by bespoke installations no matter how common the parts.

The final point of consideration to emerge from our study revolves around the topic of *coordination and awareness*. The study presented here makes it perspicuous that where multiple digital plumbers are involved in installation there is a need for them to update one another as to the changes that they have made and what action if any needs to be taken in response. This scenario is likely to be common amongst UbiComp researchers if not commercial digital plumbers. In either case there exists the possibility for support, however, which is brought about by the need to track and manage change. Tool support might therefore focus on developing a ‘record of works’ to make changes visible and available to members of the research team and allow digital plumbers to annotate the record so that the implications of change might be explicitly articulated. Such support may be of particular value in research situations where installation is prolonged and takes place over weeks and potentially months. Furthermore, even if installation takes but 1 day, the chances are that at some point in the future someone will come along to make further changes. Whether it be a commercial digital plumber upgrading an installation or extending it, or members of a research team coming into add new devices and components or to maintain the set up, it may be useful to develop support for coordination and awareness to make previous installation activities perspicuous. There is no guarantee after all that the same digital plumber will turn up to do the work and it may be a matter of some importance then to understand what has been done in the past and what implications this has for future work.

5 Conclusion

Digital plumbing is indispensable to the migration of research technologies out of the lab into real homes. It is a largely ignored area of work, however, recognized as necessary but not central to research. We disagree. To reiterate our objection, arguing against the salience of digital plumbing to home research and the mundane realization of research visions is very much like complaining that if the walls of a building were only gotten out of the way one could see better what was keeping the roof up. UbiComp is an explicit intervention into everyday life, one which seeks to change the way we live together, and digital plumbing is 'all about' realizing that change. More than this, digital plumbing as an ordinary everyday job of work is becoming more commonplace. It is therefore incumbent upon us to understand the challenges of deploying new technologies in existing home environments in order that we can better understand *how* to make them into a mundane feature of everyday life, both for purposes of research and commercial development alike.

It can, of course, be argued that installation work in many ordinary professional domains, from conventional plumbing to fitted kitchens, has already taken on-board some of the lessons we point to in this paper, and that there is little beyond that for design to be addressing. However, digital plumbing offers several distinct problematics. These extend beyond just the fact that digital plumbing is a nascent enterprise. Networks and their associated devices are currently opaque in many ways to both experts and non-experts alike. This is not just about opacity to sight but about opacity to reasoning. When networks fail the level of difficulty involved in unravelling just what might amount to the source of trouble is non-trivial, even with the most seemingly trivial of troubles, and even where expertise can be claimed. As installation of networks almost inevitably seems to involve some amount of ongoing problem resolution to tailor the network to the setting, this has to be taken as a matter of some significance, even though the outcomes might be quite trivial. That is something made particularly visible in the examples we have recounted here. In addition, as networks are premised upon computing systems that have been heavily customised to the local setting, with a plethora of associated legacy issues, the order of complexity to be managed is not to be underestimated. Indeed, as we pointed out in a prior publication [25], understanding what can be done with some particular network involves access to degrees of reasoning about the household, its routines, its practices, and its current priorities, that is hard for any non-member of the setting to acquire.

The need for support that is addressed to these matters is therefore both urgent and challenging for design. It is about more than just learning what any plumber or heating engineer might tell you. It is about providing tools for managing contingent circumstances of a wholly different order to anything that more familiar installation practices might have to contend with. Not least here is the fact that so many *different* services can all ride together upon the adequate provision of a home network. Because so many more household practices, routines, and activities are coming to turn upon the provision of mundane network technologies, the level of potential intercept with a whole gamut of distinct household concerns through an apparently simple intervention around something as seemingly mundane as a router is quite staggering. This is something far beyond the kinds of impact current installation engineers are used to having to contend with. What we have begun to look to here, then, is how design might go about supporting this critical new enterprise. And critical it certainly is, for home networks are springing up in every corner of our streets, villages, towns and cities. The sheer pervasiveness of equipment such as wireless routers makes the home network as mundane a feature of our technological landscape as almost anything else these days. Yet, at the same time, its resistance to mundane reasoning makes it an urgent candidate for new kinds of approaches and resources to facilitate such reasoning. When it comes to the work of installation, yes, of course, some of the fundamental practices involved in making an installation work are familiar to anyone engaged in an installation enterprise. How could it be otherwise without it becoming something other than installation? However, how those wholly ordinary practices are going to be best supported and facilitated is by no means such a straightforward question. Furthermore, many of the answers to how one might begin to approach such support and facilitation may extend beyond the work of installation alone, to how we are going to begin to make home networks into the accountably mundane technologies we might wish them to be.

In this paper, then, we have presented and begun to use the findings of an ethnographic study of the installation of ubiquitous technology in a real home to start an exploration of what some preliminary answers to these kinds of concerns might look like. In this respect, the study has revealed four major areas where the development of support for digital plumbing might be considered:

- *Supporting preparatory work*. The deployment of research technologies in real homes requires a great deal of preparatory work. This includes planning what is to be installed and where in cooperation with household members, and understanding existing technological arrangements that new devices and components will be integrated with. The development of methods and tools that enable the digital plumber to map these may be of considerable use to the work of planning.
- *Supporting the assembly of tools and parts*. In order to install planned arrangements the digital plumber needs to assemble the right tools and parts for the job. This includes configuring and testing the necessary hardware and assembling the software that will definitely be

required and that which will possibly be required. The development of online solutions, including extensive archives of software versions, drivers, updates, patches, etc., and which permit reuse, may be of considerable utility to the work of assembly.

- *Supporting the management of contingency*. No matter how well planned an installation is, contingencies inevitably arise. Online archives may go some way to addressing them, though troubleshooting and faultfinding rely on technical competences that extend beyond the particular technologies being installed. The development of online resources, including FAQs, knowledge databases, and even remote fault diagnosis, may be of considerable benefit in the effort to manage the contingencies of installation.
- *Supporting coordination and awareness*. Installation occurs over time and often involves more than one digital plumber, whether working consecutively or one after the other. Tracking and managing the changes made by particular digital plumbers therefore becomes a matter of some importance. The development of a ‘record of works’ that detail changes and their implications may provide useful support for coordination and awareness amongst digital plumbers.

It would be right to say that these insights into the work and demands of digital plumbing provide no solution at all. What they do *do* is articulate the component parts of a problem—a researchable problem—that requires the development of methods and tools to support the installation of ubiquitous computing technologies in the home. Installation is already a mundane achievement, so much so that it is an ignored or overlooked feature of research explorations of the home. Nevertheless, digital plumbing lies at the heart of the effort to realize grand visions in design. It is an essential part of getting the technology out of the lab into real homes and it is time that research took it seriously to ensure that ubiquitous computing does become an unremarkable and thus ‘invisible’ feature of everyday life.

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