APPROPRIATE HOME TECHNOLOGY:
Depending on Dependable Technology Systems

Guy Dewsbury, Karen Clarke, Mark Rouncefield, and Ian Sommerville

CSEG
Computing Department
Lancaster University
Lancaster
LA1 4YR
England, UK

g.dewsbury | k.m.clarke | m.rouncefield | i.sommerville @lancaster.ac.uk

Main Contact: Guy Dewsbury, g.dewsbury@lancaster.ac.uk

Paper to be Presented at the ENHR 2002 Conference in Vienna, 1-5, July 2002

APPROPRIATE HOME TECHNOLOGY: Depending on Dependable Technology Systems

Guy Dewsbury, Karen Clarke, Mark Rouncefield, and Ian Sommerville

Abstract

> Dwelling with computers, they become part of the informing environment, like weather, like street sounds. A house that is true to its house nature must have a certain quiet, even stolidness. Through a thousand subtle cues, computers will help turn our houses into homes. Weiser (1996)

This paper is interested in explicating some of the multiple concerns involved in designing appropriate technology in domestic, or home, settings. As society becomes increasingly reliant on computer-based systems, and as domestic settings become increasingly technologised, the systems themselves have become increasingly complex and the need for dependable systems correspondingly important. Achieving sufficient dependability in these systems, and demonstrating this achievement in a rigorous and convincing manner, appears crucial in moving towards an inclusive Information Society. The paper reflects our interest in making some initial steps towards developing improved means of specifying, designing, assessing, deploying and maintaining complex socio-technical systems in domestic contexts where high dependability is crucial. As computer-based systems and artefacts penetrate more and more into people's everyday lives and homes, the 'design problem' is not so much concerned with the creation of new technical artefacts as it is with their effective and dependable configuration and integration. It is evident that satisfactory resolution of such concerns demands major, interdisciplinary breakthroughs in understanding the development of complex socio-technical systems in domestic environments since inadequate understanding of the context of the lived reality of use and user needs is often a significant cause of lack of dependability. The paper also explores the ongoing DIRC project which is currently investigating these areas within its Project Activity 'Dependable Ubiquitous Computing In The Home'. While this paper does not attempt to solve all of the presented issues it aims to illuminate and highlight some fields of investigation that might form the basis for future and ongoing research and development agendas for appropriate technological interventions in domestic settings

Keywords

Assistive technology, Smart home, Dependability, Home care, CSCW, Appropriate design

Introduction

The notable rise in the uptake, usage and general pervasiveness of domestic technology in the last four decades has had considerable, if not predictable, implications for the home occupant (Hindus, 1999, Hindus et al, 2001). Labour saving devices such as vacuum cleaners have enabled people to achieve cleaner households but have not saved domestic labour time, as standards of cleanliness have increased proportionately. There has been also been a blurring of the boundaries of technology within recent years, such that devices that were previously only seen in cars, offices, or hospitals are now finding their way into the average home. The home itself has undergone considerable alteration (Dewsbury, Edge & Taylor 2000), not necessarily or only in outward appearance or architectural detail, but in the way that it is used by its occupants (Crabtree, et al, 2001). The original design and layout of rooms, for specific and static purposes, has been modified such that there has been a blurring between designated spaces while activities are no longer confined to pre-designated spaces (Junestrand &Tollmar, 1998). Similarly as domestic spaces are created to meet needs of the individual occupiers, these needs are themselves often related to technological developments. The home computer, for example, along with games machines, televisions, videos etc now act as a determinant and identifier of these spaces.

New information and communication technologies, such as the home computer, have enabled the isolated to find friends, the person with speech difficulties to find a voice, the non-communicative to communicate, and the disabled person to be enabled. Clearly technology has empowered a number of people, just as, some suggest, it has the potential to enslave similar numbers. Technology has become part of everyone's life. We now accept that the key to ones car will lock the doors remotely, that the windows of the car will remain free of mist and that there is a good chance of walking away from a collision in modern cars. We accept that washing machines will wash clothes of all types and not shrink or allow colours to run and refrigerators will keep things cool whilst freezers keep things frozen. We accept that it is the norm for a home to have a television, a video, a cooking facility, a bathroom with shower, a stereo system, (or even a home theatre system) a mobile phone, and a personal computer. We are not surprised by houses or cars that have burglar alarms, and often ignore the sounds of these devices. We have clearly become a technologised culture (see Dewsbury 2001), relying and accepting the benefits and disadvantages of technology.

Although we may embrace it, technology can and often does work against us. Computer users will all recognise the blue screen or the feeling that occurs when the mouse pointer refuses to move any more as the computer has crashed. This usually happens at the worst possible time in the authors' experiences. Cars tend not to start in cold or wet weather, when they are needed most. Power is lost in extreme weather conditions for many remote communities. Technology systems are excellent when they work appropriately but can cause severe misery when they fail to respond in the appropriate or expected manner. It is this issue of dependability and appropriate design that forms the focus of this paper. We seek to consider and review the role of advanced technology in relation to homes and covers issues concerning assistive technology, home automation (smart homes), and telecare in relation to developing a potential model of 'appropriate' technology specification. Of course, delineating the parameters of appropriate design and determining how appropriate design might be achieved is an enterprise fraught with difficulty. We discuss a number of emerging features of appropriate design for technologies in domestic environments. Overall, appropriateness is based on, built around, developing interactions between users and the technology. These interactions are subject to various general kinds of reconfiguration and change such as evolving social demands and uses of domestic space; changes in technology usage and development as well as specific aspects of appropriateness related to the particular application or function and issues such as privacy or security.

Any attempt to examine home technology and appropriate design is fraught with difficulty as there are countless levels to the definition of what constitutes appropriate design. This paper attempts to highlight some of the most important issues around installing home technology, appropriate design and framing it within a context of dependability. The paper attempts to draw together disparate ideas from Computer Supported Cooperative Work (CSCW), Human Computer Interaction (HCI), Sociology, Engineering, and Psychology in an attempt to examine the relevance of these notions to the area of appropriate design and dependable systems. The paper may appear to be somewhat lacking consistency which is a reflection of the diverse range of topics that are covered within it. The paper also attempts to demonstrate that this area is highly relevant and important to current legislation and Government policies of ensuring people receive adequate care in their own homes. It is this issue of dependability and appropriate design that forms the focus of this paper. We seek to consider and review the role of advanced technology in relation to homes and covers issues concerning assistive technology, home automation (smart homes), and telecare in relation to developing a potential model of 'appropriate' technology specification. Of course, delineating the parameters of appropriate design and determining how appropriate design might be achieved is an enterprise fraught with difficulty. We discuss a number of emerging features of appropriate design for technologies in domestic environments. Overall, appropriateness is

based on, built around, developing interactions between users and the technology. These interactions are subject to various general kinds of reconfiguration and change such as evolving social demands and uses of domestic space; changes in technology usage and development as well as specific aspects of appropriateness related to the particular application or function and issues such as privacy or security.

The paper considers technology in the home, smart homes and their potential application as well as the problems of achieving a dependable system that is appropriate to the needs of users. Due to the diversity of features associated with dependability issues and technology in the home, the paper takes the form of a series of short insights into the range of issues that come to light when attempting to investigate this area. We provide a review of different approaches to the design of technology for domestic settings and a consideration of these approaches in terms of various notions of appropriate and dependable design. Dependability - as that part of a system that reliance can be placed on any service delivered is clearly critical to the development of robust, reliable and trustworthy systems. Again, however, 'dependability' can be viewed in different ways. Dependability issues often include safety, security, reliability and usability. This paper considers the work currently being undertaken by Lancaster University in the DIRC project (http://www.dirc.org.uk/) in relation to domestic technologies and asserts a model for considering dependability issues within whole house systems. DIRC is an UK project that is considering the role of dependability in systems (in the broadest sense) and is specifically looking at issues relating to assistive technology within the home. It considers how systems failures occur, what is a fault and what is an error; how systems can be made more reliable and safer; how issues of timeliness, structure, responsibility, diversity, risk and maintainability are addressed within the areas of advanced home technologies. The project is not considering any one proprietary system, but using the basis of all the home systems to consider the areas where problems might and do occur and how they might be resolved. The primary objective of this activity is to investigate the problems of ensuring that computer-based systems that are installed in people's homes are dependable. In this setting users are incredibly diverse and don't have specialised training. Consequently dependability is paramount. Users may rely heavily on such systems and may not be able to cope without them. Furthermore users capabilities may be impaired in a variety of ways. We believe that if these systems are to be both dependable and usable then we need to have a thorough understanding of users and the environment where these systems may be installed. Ultimately, our aim is to develop a set of design tools that will support the deployment and dependability assessment of assistive technologies in the home. These might include tools for hazard assessment, a needs assessment tool and a configuration deployment tool.

The justification for considering whole house systems is based upon the fact that as UK Government policies are encouraging disabled and elderly people to remain in the community, we are required to consider the most appropriate technological responses to meet their needs. Self-evidently, such a circumstance provides an opportunity for misplaced investment, for the installation of inappropriate, unreliable and undependable systems. Moreover, system configurations are required to be designed to specifically meet needs of particular groups and individuals and this signifies amalgamating and reconfiguring different systems together in order to meet this objective. While this paper does not attempt to solve these issues it aims to illuminate and highlight some fields of investigation that might form the basis for future and ongoing research and development agendas for appropriate technological interventions in domestic settings.

Home Technology and Home Networking

> It could be argued that smart systems for residential housing add some intrinsic value through incorporation of increased security, safety, convenience and comfort within the home. Petersen et al (2001, 522)

The pervasiveness of home technology has lead to an upsurge in the use of home networking. The increase in home networking is having great effects on the lives of older and disabled people. A home network allows a residence to be connected to the outside world through a residential gateway that passes information down an ISDN or DSL phone line. Home networking allows the home to become a fully connected entity that can be controlled externally as well as internally. The increase in telemedicine and telecare as initiatives that extend beyond the conceptual into the real world are only possible through the home network.

The smart home, (automated home, domotic, intelligent home etc.), in which devices are interconnected (networked) and programmed to act in predetermined patterns, has been extended through the home network to allow external monitoring and control. For a disabled or older person, home networking offers the potential for their home to be programmed to monitor and respond to cues whilst allowing the occupant the safety and reassurance that should a fault develop or a problem occur within their home then the correct people will be informed by the technology within the home network (Figure 1).

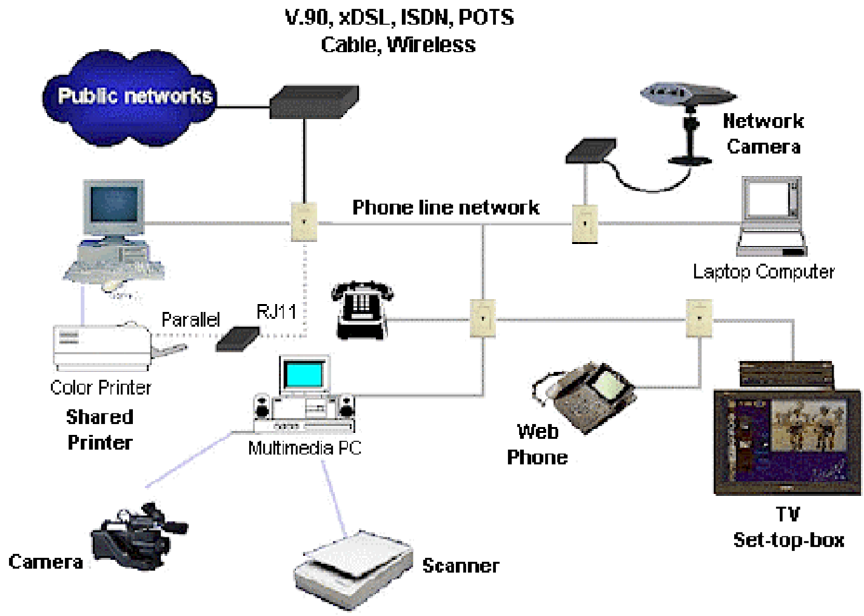

Figure 1: A pictorial representation of some of the devices attached to a potential home network

Source: Venkatesh, et al (2001a)

The home network has negative as well as positive aspects to it. One difficulty is caused by the ISDN/DSL connection which remains in the state of "always-on". This denotes the permanently connected home could potentially face threats from external hackers. Moreover, this "always-on" connection means that the system is constantly open to potential viruses and other attacks by malevolent programmers. This necessitates that the home network should have an updateable virus checker and a firewall to deter hackers.

The technological home of today and tomorrow embraces technology within its structure. Venkatesh and Sanjoy (1999) and Venkatesh et al (2001a & 2001b) considers that the role of technology is integrated into other living spaces, such as physical, social to make up the whole notion of home (see Figure 2).

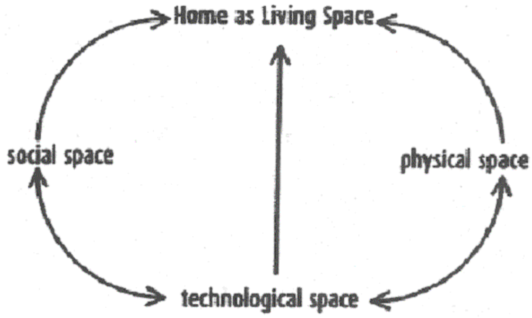

Figure 2: The spatial relationships within the home

Source: Venkatesh, and Sanjoy (1999)

Within Venkatesh and Sanjoy's model, technology (technological space) interacts with all other spaces. Even though the model is flawed by its lack of interaction (physical and social space clearly interact), it does provide an excellent framework to consider the importance of technological innovation within the home. As the 21st Century commences, technology can be used to enable people to derive an improved quality of life through the appropriate use of advanced technology. The home network can allow isolated individuals to retain contact with the world around them as well as allow for external monitoring of people who require this service.

A clear and practical use of technology is the introduction of home networks, involving smart homes, telecare, telehealth and telemedicine, to allow people with possible illnesses or disabilities to retain a quality of life within their own home. Home networks and smart homes can assist in undertaking operational tasks, telecare enables a person to remotely assessed and monitored by medical staff and telemedicine allows a full virtual medical service to be brought into the home of the person requiring the specialist service. The application of technology from the medical field into the home raises a number of interesting issues that will be considered below. Figure 3 illustrates, the role of technology is within the home is extensive. Moreover, the application of this technology extends into a number of areas which are enhanced by home networks.

Technology area	Applications
Supporting life at home	Smart house Multimedia environmental control Systems to support cognitively impaired people Assistive devices Aids for daily living 'Design for all' products
Remote care and services	Alarms/security Monitoring systems Telemedicine
Mobility and transport	Navigation systems within large buildings Accessibility information systems Advanced wheelchairs Road transport informatics
Control and manipulation	Compensatory devices Assessment tools
Restoration and enhancement of function	Optimised hearing instruments Portable communication equipment Rehabilitation systems Fitness devices
Interpersonal communication	Voice Text Video
Alternative media	Text interpretation Electronic newspapers Television text captions and audio description Multimedia translation systems Alternative interfaces
Access from a distance	Information access Teleshopping Telework Distance learning Entertainment and leisure

Key areas of research and development in community care technologies

Figure 3: Key Areas of R & D in Community Care Technologies

Source: Porteus and Brownsell (2001, 21)

The home network appears to be a manifestation of the twenty first century, as computer operating systems are adopting protocols that should easily interface with home networking products, and manufacturers are redesigning their products to allow for greater standardisation and interoperability.

Available Technologies

> The current offerings in Home Automation are both exciting and frightening. The means to automatically manage almost anything that uses electricity is available today. Until security is taken seriously in these systems, though, there is great risk in doing so. The favorable trend of making high tech devices easy to use is resulting in a diminished focus on reliability and safety. Designers of these solutions need to think about security at every level and stop considering it to be "Somebody else's problem". Brodeur, M J. (2001)

The appropriate design of home technology requires that the designer make choices concerning the most appropriate, available technology that is cost effective (Edge et al 2000, Dewsbury and Edge 2001). To this end, there are a number of different systems available. www.abledata.com/ lists approximately 19,000 devices available in 2000 different countries and the Disability Living Foundation (http://www.dlf.org.uk/centre/inventory/index.htm) contains 1489 pages on devices and distributors in the UK making AT a varied and widely accessible series of products. In fact, there are an almost infinite number of technologies available for older and disabled people. They range from individual one-off bits of kit to solve a specific problem through to whole house smart home/telecare systems.

Home technology is available in three main types: Powerline (X10, EIB Powerline, etc); Busline: (EIB, Cebus, Lonwork, Batibus EHS etc) and Radio Frequency (RF) (eg Bluetooth, Home RF, etc) (Barlow and Gann 1998a, 1998b Gann et al 1995, Dewsbury 2001, Venables and Taylor, 2001). Powerline systems are made of devices that can be connected directly into the main power supply (240v a/c current in the UK). These devices use the standard wiring to send data to the devices to activate or deactivate them. Powerline technology is used by amateur smart home enthusiasts as the devices are simple to configure and a system can be up and running cheaply and quickly. Should the system fail then the installer should be able to repair it on the spot or by locally sourced devices. Frequently, Powerline systems require a computer to be attached to the system to monitor the devices, change their status, although many newer systems use the X10 coding in proprietary systems, and have bypassed the need for computers by placing the chipsets into the system itself. Many Powerline systems are in use today and some are used to support older and disabled people. Often the major problem with this system is related to interference and power cuts, which can throw the system into chaos, as default reset values can be unsuitable for the client group. X10 and many other Powerline systems are easily available. This product is used frequently as it can be made from off the shelf items that are cheap, but Powerline systems have not been found to be reliable.

Busline smart homes use a separate 12-volt cable (twisted pair) to transmit data to devices (through the busline), which runs in parallel to the traditional mains cable. The use of this cable means that devices are independent of conventional mains borne power supplies. The busline devices can be configured to adhere to stricter operational parameters and therefore systems that are more complex can be envisaged. Busline has, to date be proven to be the most effect and reliable form of smart home, as it can be configured to prevent devices malfunctioning during power cuts. The two-way protocols also allow the systems themselves to monitor devices without recourse to external computerised systems. Figure 4 illustrates how busline technology operates alongside the standard wiring of a home and devices can use both cables to achieve their intelligence.

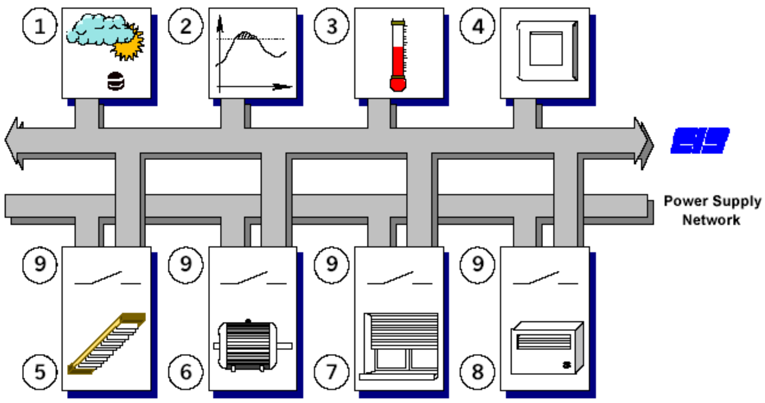

Fig. 1/2-1: Bus and mains networks

① brightness sensor ② threshold detection ③ sensor
④ monitoring ⑤ lighting ⑥ motor control
⑦ window blinds ⑧ heating ⑨ 230V switching

Figure 4: An illustration of the EIB Busline

Source: www.eib.com

Busline technology was developed for large buildings such as offices and factories and therefore uses high quality components that have been tested rigorously which is ideal for use in high dependency systems. This high specification for products is also reflected in the price of items that are expensive and not always easy to obtain, due to the small number of providers of the technology (ordering can be unreliable and there can be large waiting times for equipment). Konnex (a consortium of European busline manufacturers) have decided on a standardised protocol for all systems that was achieved in 2001, making interoperability between European busline products easier. A major issue concerning busline systems originates from the use of add-ons to the system. Many busline smart homes require the use of additional devices such as actuators which can be sourced from busline compatible companies, but this proves to be too expensive for most users, so cheaper non two-way protocol devices are used instead. This means the system can become weakened when these devices are added. The busline can usually tell what devices are connected to it and the status of each of these devices. Once non-busline devices are added the system cannot longer determine the status of these devices and has to assume they are working appropriately.

Radio frequency (RF) and Infrared (IR) systems are becoming increasingly more popular with users as there are no wires and therefore no modification to the home is required for installation. Most manufacturers of smart home technology have a RF product range. These products have tended to be perceived as less reliable due to problems with interference and short-range identification issues, although recently there has been a shift towards more robust whole systems. Many social care alarm systems are use RF components as standard although they may configure these into a busline or Powerline system for extra functionality. RF systems have been criticised as they could be broken into by an intruders with the correct IR code who could possibly gain access to the home or modifying the settings of devices.

Within smart home applications, the three main types of home technology have their own positive and negative points which are highlighted in Figure 5. A common negative aspect is that of security and standardisation. Reliability is also a critical issue highlighted by this table.

	RF - Wireless	Phoneline	Powerline
Pros	Mobility - UNTETHERED Broad geography support at specific frequencies Can compliment a wired network with bridging	Low cost and fast (10Mbps+) Strong Industry Alliance (HPNA) Dedicated home bandwidth Voice and data share existing lines	Electrical outlets in every room easy connection for non-PC appliances Low cost - will drop with silicon integration High performance (up to 10Mbps)
Cons	Relatively expensive - getting cheaper Distance limits & wall attenuation (150 ft/10 barriers) Security must be addressed Prone to narrowband interference	Phone jacks not near every PC in home Different phone lines (numbers) isolated International deployment issues	Must be robust in hostile environment (noise, stubs, vnet) International deployment issues (Regulatory issues) Security must be addressed Standards need to be addressed

Figure 5: The Pros and Cons of Home technology Systems

Source: www.xilinx.com

The most recent network protocol development is called Bluetooth which is an open source protocol allowing bi-directional networking between close proximity RF devices. The beneficial aspect of Bluetooth is that it enables a wide variety of interoperable devices such as WAP telephones, standard home networking and smart home devices to be configured together as expressed in Figure 6, which illuminates the protocol stack for the system. Bluetooth is modifying consistently and consequently is becoming more stable, robust and reliable. Although there are few Bluetooth networks available at present, this is one of the potential growth areas for the future telecare and smart home market.

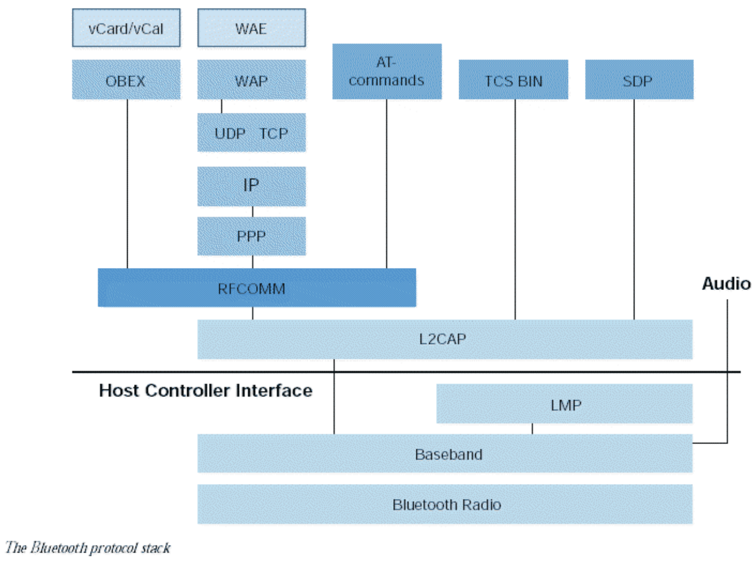

Figure 6: The Bluetooth Protocol stack

Source: Kardach (1998)

In a comparison between differing types of home RF system, it is noted that each has its own standardisation and standards body which it is required to meet. Figure 7 demonstrates that in comparison each RF system has its own vulnerabilities. For example, Bluetooth has the slowest data rate (negative) but also has the smallest range (positive for domestic use as less likelihood of conflicts between devices).

Technology		Standards Body /Proponent	PHY Layer	Data Rate	Range (meters)	Frequency (GHz)	Technology Aimed For
Wireless LAN	IEEE 802.11a	IEEE	OFDM	40	TBD	5	Office Environments
	IEEE 802.11b	IEEE	DSSS	11	100	2.4	
	HiperLAN2	HiperLAN2 Global Forum	OFDM	54	150	5	
HomeRF	SWAP 1.3	HomeRF WG	FHSS	1.6	50	2.4	Home Space
	HomeRF (NG)	HomeRF WG	FHSS	10	50	2.4	
Personal Area Networks	Bluetooth	Bluetooth SIG	FHSS	1	10	2.4	Consumer, short-range wireless personal area network communication
	IEEE 802.15 (high-rate)	IEEE	FHSS	2+	TBD	2.4/5	

Figure 7: Configuration details of Homes Systems

Source: www.xilinx.com

For a system to meet the needs of people with severe disabilities then a combination of the above systems might be required. This therefore increases the likelihood of system failures through protocol, configuration and interoperability conflicts.

Telecare, Telehealth Technology and Residential Gateways

> Technological advances are a major influence upon increasing longevity and improving, in a sustainable manner, the quality of life enjoyed by an ageing population. Kinder (2000, 72)

Telecare systems are still in their infancy and there are few proprietary systems available on the market at this time (Anchor Trust 1999, Porteus and Brownsell 2000, Tang 2000, Fisk 2001a, Fisk 2001b). Systems are usually designed using one-off AT devices such as blood pressure monitors and configured into a standard systems such as a smart house system or a call system. Both telehealth and telecare systems rely on the use of the Internet or telephone lines as a means transferring information from the source (the house) to the receiver (the doctor/nurse etc). This relies on a Residential Gateway (RG) and a number of security issues surround the use of this form of data transference. RGs allow the home to be connected to the outside world through a connection that sends signals to a remote location. RGs can be used within smart homes to allow installers to modify settings within the home without being required to visit the property. This is highly cost effective but is open to security issues should someone break into the code by dialling the numbers.

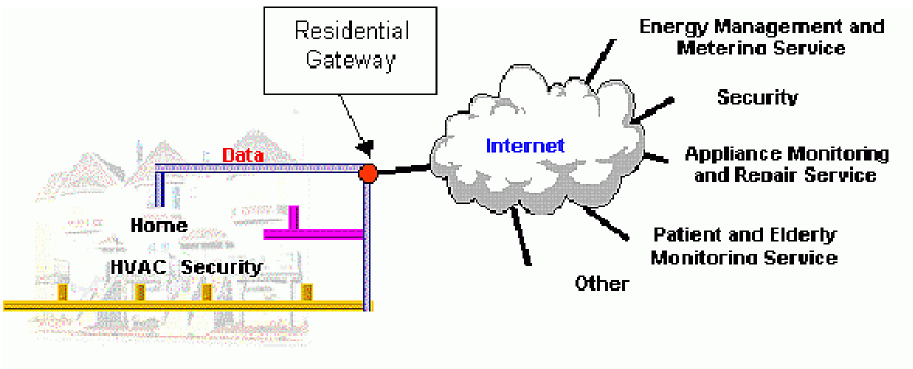

Figure 8: A standard Residential Gateway and Home System Configuration

Source: www.hometoys.com

It has been suggested that it could be possible for a whole house to be reconfigured whilst the occupant is away or for thieves to gain access to a property that might appear to be well secured by breaking in through the RG. RGs also rely on fast telecommunication protocols such that users should have ISDN, ADSL or DSL lines in their homes, hence the home is constantly connected to the external world and the security problems are increased. Herzog and Shahmehri (2001) demonstrate that within the e-service 'Monitor and Control' the residential gateway on the home net are accessible by e service clients via the internet only after authorisation at the system service provider. The RGs are configured to reject all other service traffic than that from the system service provider, yet they allow *ftp* download and web browsing from the home net without system service provider interference (See Figure 9).

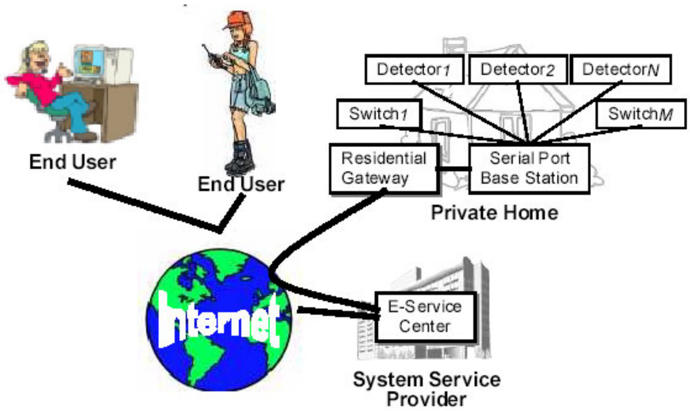

Figure 9: The Network Architecture of the Monitor and Control service

Source Herzog and Shahmehri (2001)

There are also a number of ethical problems associated with RGs. These concern the appropriateness of data transmission, what is ethically acceptable to be transferred to external sources. There is little control over the data that leaves the home; there is little control over who has access to this data and what is done with the transferred data. The Data Protection Act does not cover this form of data transference as it is still in its infancy.

Davies and Raverdy (2000) contend that future home networks will consist of multiple networking and platform technologies integrated through a series of gateways and shared devices. They go on to suggest that it is for developers to build heterogeneous middleware platforms that are irrespective of the operating system used. This does bode the question that the more heterogeneous middleware platforms there are which are working irrespective of operating systems there are, the more potential security threats and more holes that will be required to be filled leading to a possible unstable whole system. Wang et al (2000a) contend that there is a need to monitor device configurations to detect abnormal patterns. Wang et al (2000b) suggest that the home networking environment is more heterogeneous and dynamic than traditional network environments as consumer devices are likely to be connected to different networks, running different protocols and madder by different manufacturers. Jonietz (2002) illustrates that technology might be based on self-organising networks in which devices would automatically recognise what they are and what they should do with the information, "every element automatically recognizes every other element. Without any outside help, the devices must then determine how to get data where it needs to go" (Jonietz 2002).

Dependability

> The trick in designing technology is to provide situations that minimize error, that minimize the impact of error, and that maximize the chance of discovering error once it has been committed. The humancentered way. Norman (1993, 13)

The Issue of systems dependability is critical to the development of appropriate technology solutions which are robust and meet needs of users (Edge et al, 2000). Systems must be appropriate for the user. Gann et al 1999 suggest that appropriate design is divided in to six different components:

- Affordability
- Ease of use
- Flexibility and adaptability
- Functionality
- Interactivity
- Reliability and maintainability
- Replicability and ease of installation
- Upgradeability

As a benchmark, the above components demonstrates that systems are required to be responsive and flexible to the needs of the user, yet it suggests that the design process is standardised and uniform, which experience dictates is rarely the case. Dewsbury (2001) and Dewsbury et al, (2001) extend the discussion by offering guidelines for designers and stressing the fluidity of the design process. These papers demonstrate that meeting needs through appropriate design is not as straightforward as might be initially conceived.

Clearly, if design is to reflect real need then two preconditions need to be met. Firstly that the design is dependable and second that the needs are truly reflected in the design. Dependability is defined by Brian Randell (2000) in the following manner:

> A system is dependable to the extent to which its operation is free of failures. Then Dependability can be defined as that property of a computer system such that reliance can justifiably be placed on the service it delivers.

The notion of free of failures is complex in that some failures might be built into the programme as part of the design, where as other failures might be unforeseen and a consequence of unpredicted circumstances. It is useful to consider that there is a difference between failures and errors. Randell (2000) draws a distinction in the following manner:

> A system failure occurs when the delivered service deviates from fulfilling the system function, the latter being what the system is aimed at. An error is that part of the system state which is liable to lead to subsequent failure: an error affecting the service is an indication that a failure occurs or has occurred. The adjudged or hypothesized cause of an error is a fault.

Therefore, for a system failure to have occurred, an error or a number of errors, or deviations must have occurred somewhere within the system. It is useful to note that the system in question does not necessarily need to be software or hardware; it is as applicable to human/mechanical error and computer interaction as the following diagram (Figure 10) demonstrates.

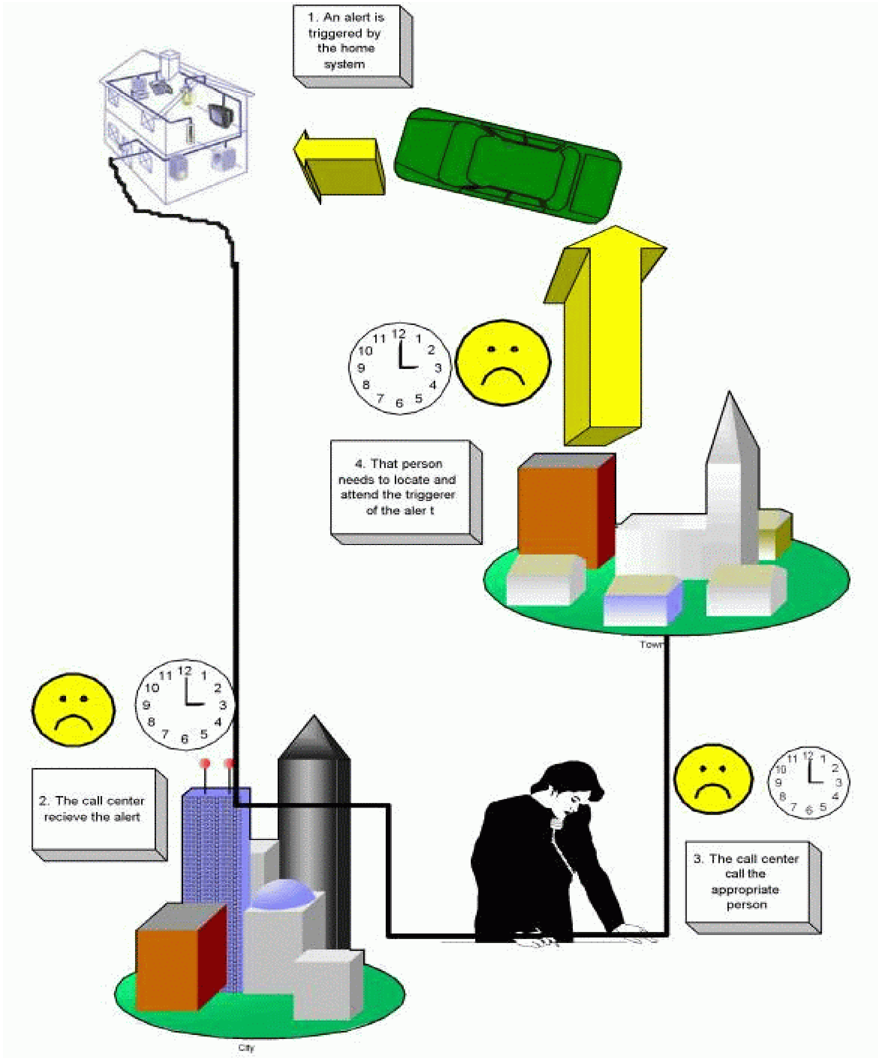

Figure 10: Possible points of errors leading to system failures within a call system

Figure 10 shows that within a standard call system there are a number of potential points where errors can occur. The diagram is designed to show how a simple alert to a call centre from a person in need can fail. These errors are not necessarily software or hardware derived; they could simply be human or mechanical in origin. The first point of error is that the signal needs to be detected and sent, if the hardware is not functioning correctly (device error) then this will not occur (system failure one). The second point is that the remote call centre needs to receive the call; once more the system could be susceptible to hardware or software problems, or simple human problems in that the person at the call centre is not able to action the call (system failure two). Having received the alert, the call centre is required to contact the appropriate person from a list. This clearly could be difficult if no one answers them or if there is a time lag that is too great (system failure three). Finally, the appropriate person assigned to deal with the alert is required to investigate the call. This in itself is open to a number of different issues such as mechanical failure (the car won't start) through to too much traffic, accidents etc (system failure four). The system can be seen to fail in any of these four areas but also can fail as a multiple failure when two or more states are incorrect. A further inferential failure is time which is connoted in the figure by the picture of the clock. Time is not always a critical feature, but will always be relevant to the type and severity of the failure. In the case of an alert being produced fro the home, it could be a false alarm, in which case time is immaterial. It could be a non-essential alert (the occupant might be confused, but safe) in which case time is important but not critical. It could also be a full-scale emergency in which case every millisecond could be critical.

By seeing the system purely in terms of hard or software the whole picture of failure is misrepresented as human and mechanical errors can play a significant part in the process.

Although it is difficult to control for human and mechanical errors, it is important to realise that they form an essential part of the equation when a person's health is at stake.

In order for a home system of interconnected devices to meet the needs of older or disabled people effectively, system failures must be minimised and controlled. This paper suggests that system failures are more than just simple acclimations of device errors; instead there is a complexity to the failure patterns within home systems. Figure 11, below, outlines some of the key features that make up possible system failures within a home system. The pattern of failure is synonymous with lack of good design protocol. Figure 11 suggests that there is a simple, almost linear, process to designing appropriate technological home solutions, allowing for iterations of the design to be undertaken throughout the process. Hence, in order to achieve a successful design, the designer is required to consider how the technology is to be used in the home, who is using it, in what ways will it be misused etc, based on the needs of the occupants. Then they are required to consider issues of dependability in relation to the most appropriate system to meet the needs with the most robust architecture to meet cost/benefit/user needs/availability requirements. The designer is further required to consider how each device is to be used and whether this is the most appropriate device based on the needs of the user(s). At this point, a systems design can be considered and the perspectives of the different users sought. The system can be redesigned to meet the real needs of the user. Finally the designer reviews the design and reconsiders aspects of safety, reliability and appropriate usage of the system before progressing to the final design architecture.

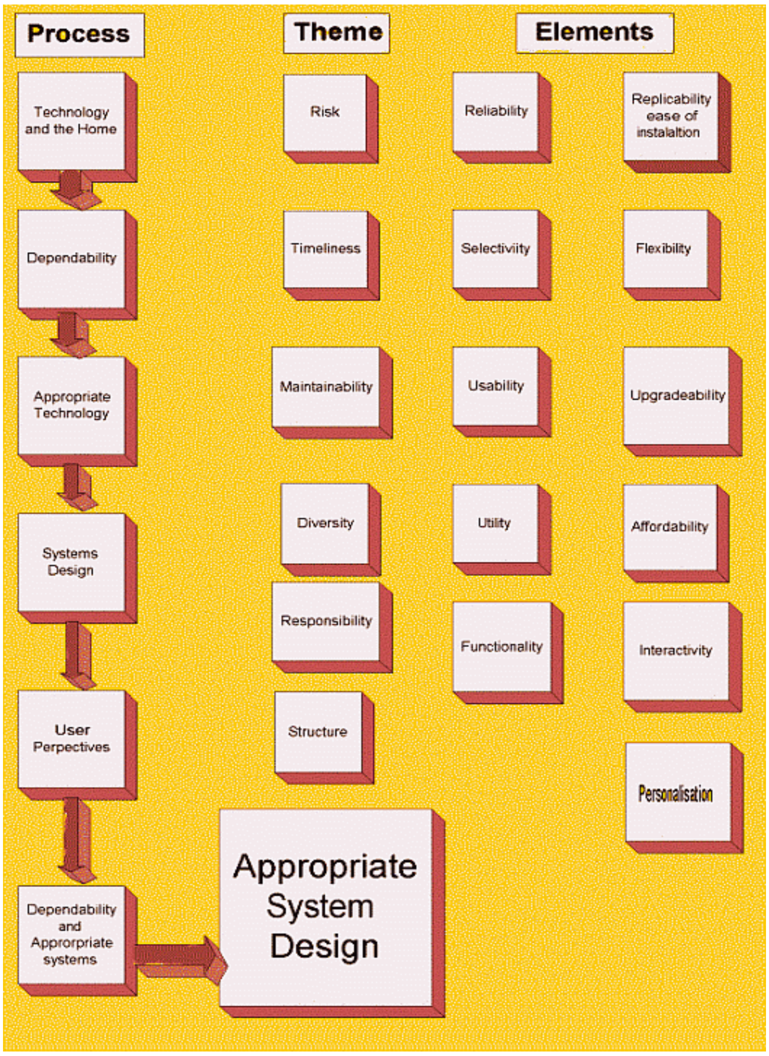

Figure 11: Some Elements of Appropriate Design

The designer undertakes what appears to be a standard process, yet within this process there are a number of non-linear elements that are required to be considered. The eleven main features of the complex scenario outlined in Figure 11 are described below

1. **Affordability**: Costs of installation and use, maintenance, Upgradeability, Is there built in obsolescence in the designed system?
2. **Configurational**: Location of devices, Are all the devices necessary? Are the devices compatible? Do some devices act as peripherals not talking to the main core devices effectively?
3. **Functionality**: Location aspects, Flexibility and adaptability, Ethical considerations (choice, privacy), Does the system do what the occupants expect it to do always? Security, Sensitivity, Safety.
4. **Interactivity**: How interactive should the system be, Can the level of interactivity be modified? Can the devices in the system interact reliably? Will the system be weakened by the addition of extra devices at a later stage? Privacy, Sensitivity, Safety,
5. **Interoperability**: Protocol issues, Standards of compatibility across applications and when upgrading within specific applications, Does the system have any points where protocols might conflict? Sensitivity, Safety.
6. **Maintainability**: Ease of installation and maintenance, Replicability, Foreseeable servicing costs, Upgradeability, Safety.
7. **Personalisation**: Dehumanisation of care, Anonymous care, Too much focus on physical needs with too little attention for social/emotional needs, Addressing non-existent needs, Does technology create needs, Lacks of information, Privacy, Personal Security, Safety, Sensitivity.
8. **Reliability** and **susceptibility to breakdown**: Does the system do what it is supposed to do? Are then any unforeseen events likely to occur? What happens if the system fails? What back-ups are required? Sensitivity, Safety,
9. **Technological**: Is the technology appropriate? Does it mean need? Does it produce dependence? Privacy, Security, Safety.
10. **Usability**: Ease of use, Complexity in use, Can the occupants use the technology appropriately? Sensitivity, Safety.
11. **Utility**: What is the use of the technology? Sensitivity, Safety,

The eleven elements, described above, are entwined in one another and are not static entities. Although each element is seeming insular and a part of a linear pattern they are in fact intermeshed elements. This elemental network provides the infrastructure for system failures and system security. Two elements stand out as cross elemental, namely safety and sensitivity. The issue of safety cuts through hardware and software dimensions as well as having validity within the human dimension. Systems are required to be safe, to provide a safe environment, to work together safely, to enhance personal safety and to be maintained safely. Similarly, any design requires sensitivity to personal and physical aspects and their relationship to technology, as well as sensitivity relating to how devices function. The correct pressure applied to the control unit should start or stop an operation within the home, too little or too much should not have undesired results. Devices themselves are sensitive and need to be set to the appropriate levels, just as configuring more than one type of system requires sensitivity to each protocol to avoid unwanted results or system failures.

The Dependability IRC (DIRC)

> Technologies can be understood as materials whose stability relies upon the continuous reproduction of their meaning and usefulness in practice. Suchman, (2002, 264)

The Computing Department at Lancaster University in conjunction with the Psychology Department at the University of York are currently looking at issues of dependability within the DIRC (Dependability Interdisciplinary Research Collaboration) Project Activity (PA7) entitled *'Dependable Ubiquitous Computing In The Home'.* DIRC is an UK project that is considering the role of dependability in systems (in the broadest sense) and is specifically looking at issues relating to assistive technology within the home. It considers how systems failures occur, what is a fault and what is an error; how systems can be made more reliable and safer; how issues of timeliness, structure, responsibility, diversity, risk and maintainability are addressed within the areas of advanced home technologies

The types of systems that we are focusing on here are so-called assistive technologies, by which we mean technologies that enable and support elderly and disabled people to live independently. These have to be dependable as the users may not be able to cope without them and have to be designed for users whose capabilities may be impaired in a variety of different ways.

We believe that if these systems are to be both dependable and usable then we need to have a thorough understanding of users and the environment where these systems may be installed. Therefore, the first stage of the project is a collaborative activity with a group of elderly people to help us understand how they might use assistive technologies and to get their opinions as to what technologies would and would not be useful.

Ultimately, our aim is to develop a set of design tools that will support the deployment and dependability assessment of assistive technologies in the home. These might include tools for hazard assessment, a needs assessment tool and a configuration deployment tool. The following figure demonstrates the iterative research design employed on PA7

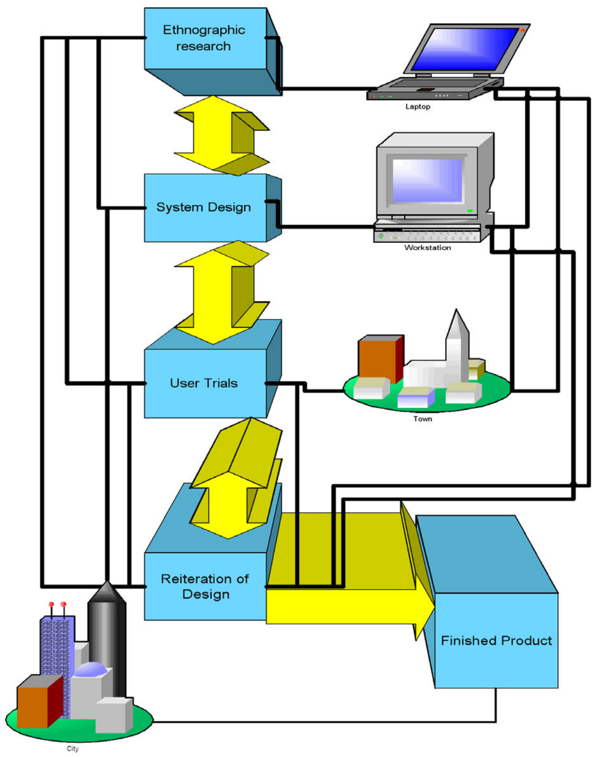

Figure 12: The Research Design Network of the DIRC PA7 Project

The primary objective of this activity is to investigate the problems of ensuring that computer-based systems that are installed in people's homes are dependable. This type of system is quite different from organisational computer systems because the operating environment of the system can't be controlled, users are incredibly diverse and users don't have specialised training. Consequently dependability is paramount.

The study is using ethnomethodological ethnographical designs to inform the design process (Rouncefield et al 1997, Sommerville). Ethnographic studies (Hughes et al 1993) claim to provide a ‘sensitising’ to the 'real world', 'real time' character and context of everyday life and the facilitation of what Anderson (1994) calls ‘the play of possibilities for design’. As part of this project we are undertaking 'lightweight' ethnographic studies with residents.. One way in which we have attempted to increase the repertoire of available techniques is through the employment and adaption of 'cultural probes'. 'Cultural Probes' (Gaver et al 1999), originating in the traditions of artist–designers rather than science and engineering, and deployed in a number of innovative design projects (e.g. the Presence project) may prove a way of supplementing ethnographic investigations. We use 'cultural probes' (cameras, diaries, maps, dictaphones, photo-albums, postcards etc) in the project, as a way of uncovering information from people that are difficult to research by other means and as a way of prompting responses to users emotional, aesthetic, and social values and habits. The probes furthermore provide an engaging and effective way to open an interesting dialogue with users (Kember et al 2002).

One key method of investigation that this PA uses is that of cultural probes (Gaver et al, 1999) in which a number of common items are given to older people to provoke inspirational and diverse responses. Through the use of the probes an understanding of how older people relate to technology can be uncovered. The cultural probes being used in the study are shown in Figure 13 and comprise of specially chosen items that can be used by the older people. The probes enable the older person to use a number of different methods to record their stories, including drawing, talking to a dictaphone, photography and keeping diaries. Not all of these methods will be used by each person; it is up to them to determine which method of recording is most appropriate to them. Should a person have disabilities that make it too difficult to use any of the methods, the older person is requested to seek a friend or family member to act as a scribe on their behalf.

Figure 13: Some of the Cultural Probes Used in the Field

The eclectic approach adopted by this project attempts to meet some of the ethical and moral dilemmas through careful involvement and acknowledgement of users in the design process. One particular technical concern, perhaps a dominant if unusual concern for a research project, is that of dependability and associated issues of diversity, responsibility and timeliness. Given the domestic setting it is imperative that technologies designed for the setting are reliable and dependable. Sidsel Bjorneby (2000, 37) notes that the reliability of the technology is essential. Just as technology can enable it can equally be the cause of disablement and low self-concept. In amongst the technical challenges are other issues concerning the location of the interface, the generalisability of design solutions, the transfer of skills to real world situations, and support for independent living in the community. These challenges highlight some of the moral and ethical components of the design enterprise, in particular the need to carefully think through and balance issues of 'empowerment' and 'dependence'.

Conclusion

> The Internet-connected Electrolux ScreenFridge, the NCR Microwave Bank and the new AutoPC appear to be primitive first steps in the direction of pervasive computing. If these efforts sound a bit outlandish, there's a good reason: the devices are solutions in search of a problem. Huang et al (1999)

The paper has considered technology in the home, smart homes and their potential application and the problems of achieving a dependable system that is appropriate to the needs of users. We have provided a review of different approaches to the design of technology for domestic settings and a consideration of these approaches in terms of various notions of appropriate and dependable design. Dependability - as that part of a system that reliance can be placed on any service delivered is clearly critical to the development of robust, reliable and trustworthy systems. Again, however, 'dependability' can be viewed in different ways. Dependability issues often include safety, security, reliability and usability.

> The theme of dependability reflects wider concerns about the reliability, security and trustworthiness of computer systems. Society's dependence on computer-based systems continues to increase, while the systems themselves -embracing humans, computers and engineered systems — become ever more complex. These trends coincide with pressure for systems to be brought to market faster and at lower (and more predictable) cost. Achieving sufficient dependability in these systems, and demonstrating this achievement in a rigorous and convincing manner, is of crucial importance to the fabric of the modern Information Society. Proctor and Rouncefield (2001, ii)

This paper has attempted to outline some the main issues relating to appropriate design of home technology to meet the need of the occupant(s). It has clearly shown that the notion of appropriate is required to be flexible and adaptive to evolving needs. Similarly, appropriate design is required to be reflexive and sensitive to future needs as well as technological needs. Finally, appropriate design is required to meet need through appropriate technology, which in itself is required to be dependable and reliable etc. Overall, appropriate design of home technological solutions required a dependable base set of criteria to be met. Technology is evolving, need is not static, people's relationship to technology in the home is constantly changing and as such it is important to recognise that the determination appropriate technology is malleable and requires system dependability to be reviewed in terms of its current state. There is no single definition or set of guidelines that will or could always be appropriate as technology is constantly changing and the designer of technology is required to be sensitive to the issues of these ebbs and flows as well as possible future issues and trends that might be of relevance.

References

Anchor Trust (1999) Using Telecare: The experiences and Expectations of Older People, The Housing Corporation, Anchor Trust, BT

Anderson, R. (1994) 'Representations and Requirements: The value of Ethnography in System Design' Human-Computer Interaction, Vol. 9 pp 151-182.

Avizienis A, Laprie J-C & Randell B, (2001) Fundamental Concepts of Dependability, UCLA CSD Report 10028, LAAS 01-145.

Barlow, J. & Gann, D. (1998a) "A changing sense of place: are integrated IT systems reshaping the home?" Electronic Working Paper Series, Science Policy Research Unit (SPRU): University of Sussex, Paper No 18.

Barlow, J. & Gann, D. (1998b). "Smart homes, unintelligent suppliers? Remaining barriers to home automation." Proceedings of Intelligent Buildings: Realising the Benefits, EIBG/BRE: BRE, Garston, England.

Berlo Ad van (ed) (1999) Design Guidelines on Smart Homes: A COST 219 bis Guidebook, Inclusion of Disabled and Elderly people in Telematics – http://www.stakes.fi/cost219/smarthousing.htm#Distributed%20intelligence

Bjørneby S, (2000), Signpost: 'Smart Houses': Can they really benefit Older People? 5, 2, October 2000.

Brodeur, M J. (2001) Security Concerns In Home Automation Technologies, System Administration, Networking and Security (SANS) Institute, June 27, http://rr.sans.org/homeoffice/auto_tech.php

Crabtree A, Hemmings T, Rodden T, & Schnädelbach H (2001) Patterns of Technology Usage in the Home: Domestic Legacy and Design. Technical Report Equator-01-015, University of Nottingham, The School of Computer Science and IT, November 2001. http://www.equator.ac.uk/papers/Ps//2001-crabtree-3.pdf

Davies N, & Raverdy PG, (2000) Position Paper: The role of platforms and operating systems in supporting home networks, Sony Distributed systems laboratory, San Jose, CA

Dewsbury G, (2001) The Social and Psychological Aspects of Smart Home Technology within the Care Sector, Published in New Technology In The Human Services, Vol 14, No 1-2,

Dewsbury G, Taylor B & Edge M (2001) Designing Safe Smart Home Systems for Vulnerable People, Paper Presented to the Dependability and Healthcare Informatics Workshop, Edinburgh, March 2001 Published in Proctor R, and Rouncefield M, 2001, Dependability in Healthcare Informatics, Lancaster University, ISBN 1 86220 109 9, pp65-70

Dewsbury G & Edge M, (2001) Designing the Home to Meet the Needs of Tomorrow, published in Open House International 2001, Vol26, No2, ISSN: 0168-2601 pp33-42

Edge M, Taylor B, Dewsbury G & Groves M (2000) 'The potential for 'smart home' systems in meeting the care needs of older people with disabilities, Seniors' Housing Update, Gerontology Research Centre, Canada, Vol10, Number 1, August 2000, ISSN: 118-1828 pp6-7 available at: http://www.harbour.sfu.ca/gero/shup/SHUPaugust00.pdf

Fisk M (2001a) Smart homes and lifestyle monitoring, Inview: Focus on Technical issues in housing, Northern Ireland Housing Executive May 2001

Fisk M (2001b) The implications of smart home technologies, in Peace S & Holland C (eds) Inclusive Housing In An Ageing Society: Innovative Approaches, The Policy press, UK

Gann D, Barlow J & Venables T, 1999, Digital Futures: Making Homes Smarter, CharteredInstitute of Housing, Coventry

Gann D, Iwashita S, Barlow J & Mandeville L (1995) Housing and home automation for the elderly and disabled, SPRU, Brighton

Gann, D, Venables T & Barlow J (1999) Digital Futures, Chartered Institute of Housing/Joseph Rowntree Foundation

Gaver B, Dunne T, & Pacenti (1999) Cultural Probes, Interactions, 6,1, Jan-Feb 1999, 21-29.

Herzog A & Shahmehri N, (2001) Towards Secure E-Service: Risk analysis of a home automation service, http://www.ida.liu.se/~almhe/publications/NORDSEC2001.pdf

Hindus D, (1999) The Importance of Homes in Technology Research, In Streiz, N, Konomi, S., Burkhart, H-J (Eds) Cooperative Buildings- Integrating Information, Organisation and Architecture, Proceedings of CoBuild 1998, LNCS, Springer, 230-247

Hindus D, Mainwaring S, Leduc N, Hagstrom AE, & Bayley O, (2001) Casablanca: Designing Socal Communication Devices in the Home, Paper presented to SIGCHI 2001, Seattle Washington.

Huang A C, Ling B C, Ponnekanti S, & Fox A, (1999) Pervasive Computing: What Is It Good For? Paper presented at International Workshop on Data Engineering for Wireless and Mobile Access (MobiDE) in conjuction with ACM MobiCom '99, Seattle, WA, April 1999

Hughes, J. A., King, V., Rodden, T., & Andersen, H. (1994) "Moving out from the control room: Ethnography in system design". In Proceedings of CSCW '94, Chapel Hill, North Carolina.

Jonietz E, (2002) Automatic Networks, Technology Review, May 2002

Junestrand S & Tollmar K, (1998) 'The Dwelling as a Place for Work', In Streiz, N, Konomi, S., Burkhart, H-J (eds) Cooperative Buildings- Integrating Information, Organisation and Architecture, Proceedings of CoBuild 1998, LNCS, Springer, 230-247

Kardach J (1998) Bluetooth Architecture Overview, available from www.bluetooth.com

Kember S, Cheverst K, Clarke K, Dewsbury G, Hemmings T, Rodden T & Rouncefield M, (2002) 'Keep Taking The Medication': Assistive Technologies For Medication Regimes in Care Settings, In Keates S, Langdon P, Clarkson PJ & Robinson P (eds) (2002) Universal Access and Assistive Technology, Springer-Verlag, London Ltd, 285-294

Kinder T, (2000) A Sociotechnical Approach to the Innovation of Network Technology in the Public Sector – The introduction of smart homes in West Lothian, European Journal of Innovation Management, 3, 2, 72-90.

Norman D A (1993) Things that make us smart: Defending human attributes in the age of the machine, Reading, MA: Addison-Wesley

Petersen T, Williams, P & Mils A (2001) Analysis of the value of home automation systems, Facilities, 19, 13/14, 522-530

Porteus J & Brownsell S J (2000) Exploring Technologies for Independent Living for Older People, A report on the Anchor Trust/BT Telecare Research Project, Anchor Trust

Proctor R & Rouncefield M (2001) Dependability and Healthcare Informatics, Proceedings of the First Dependability IRC Workshop Edinburgh, 22nd-23rd March 2001, Lancaster University

Randell B (2000) Facing Up to Faults, The Computer Journal,43,

Rouncefield M, Hughes J A & O'Brien J (1997) Ethnography: Some Practicalities of Ethnographic Analysis, Cooperative Systems Engineering Group, Technical Report Ref: CSEG/27/1997, Presentation and Workshop given at University of Karlskrona-Ronneby, Sweden, April 1997

Sommerville I Rodden T, Sawyer P & Bentley R, (1992) Sociologists can be Surprisingly Useful in Interactive Systems Design, Journal of Cooperative Systems,

Suchman L, (2002) Working relations of technology production and use, In Mackenzie D & Wajcman J, The Social Shaping Of Technology, Open University Press, UK and USA

Tang P, Gann D, & Curry R, (2000) Telecare. New ideas for care and support @ home. The Policy Press, ISBN 1 861342 16 0

Venables T & Taylor C, (2001) Smart Homes: A specification guide, JRF, York Publishing.

Venkatesh A, Kruse E, & Chuan-Fong SE (2001a) The Networked Home: An Analysis of Current Developments and Future Trends, CRITO Working Paper, 1-34.

Venkatesh, A & Sanjoy M (1999), "New Information Technologies in the Home: A Study of Uses, Impacts, and Design Strategies", in Mann T (ed) The Power of Imagination, Environmental Design Research Association (EDRA), p216-220.

Venkatesh, A, Stolzoff N, Chuan-Fong SE, & Sanjoy.M (2001b)"The Home of the Future: An Ethnographic Study of New Information Technologies in the Home," in Gilly M and Myers-Levy J. (eds.), Utah, Association for Consumer Research, Advances in Consumer Research, June

Wang YM, Russell W, Arora A, Xu J, & Jagannathan R, (2000a) Towards dependable Home Networking: An experience report, Microsoft Research Technical Report, MSR-TR-2000-26, 18th April.

Wang YM, Russell W, & Arora A (2000b) A toolkit for Dependable and extensible home Networking Applications, Microsoft Research Technical Report, MSR-TR-2000-07, 18th May.

Weiser M (1996) Open House, Rank Xerox PARC