Harvesting Home Area Network Knowledge from the Web

By

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Abstract

As the number of home network enabled devices increases the work of the professional system administrator has moved into the domestic arena. Setup, configuration and management of the Home Area Network (HAN) so that these devices, most likely heterogeneous and added piecemeal, can interoperate seamlessly are challenging tasks. Many home users possess neither these skills nor the will to learn them but still prefer to self manage the HAN rather than pay a professional fee.

Much HAN research has focused on the configuration, management, middleware and HCI aspects but this project offers a more flexible solution with a linked data approach. By fusing HANs, semantics and usability the goal is to inform the ordinary home user about their HAN devices, requiring minimal technical expertise, through automatic detection and retrieval of related information. It is this automation that is key to the usability of this approach from a novice perspective and to achieve this UPnP (Universal Plug and Play) is employed for detection while the interlinking of the Semantic Web is leveraged to accomplish the retrieval.

UPnP is a set networking protocols, aimed at the home or small business, to easily discover and control devices added to a network. The Semantic Web, particularly DBpedia, the machine-readable version of Wikipedia's structured data, is queried for the English abstract of the device detected on the HAN. The prototyping scope is limited to detecting the UPnP enabled devices on the network, informing the user by presenting device related information but not to troubleshoot or secure the network. To achieve network repeatability the evaluations were carried out in a laboratory with the user being asked to identify the devices from the information displayed and then critique the application and experience by completing a questionnaire.

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Chapter 1

1 Introduction

1.1 Background

Home Area Networks are growing in numbers but deciphering specific relevant information from the vast amount of technical information on the Internet is difficult. The purpose of this dissertation is to help Home Area Network (HAN) users find information about their interconnected devices and to enable them to understand how those devices work together with relative ease by presenting it in a user-friendly manner. The goal is to retrieve applicable information automatically and in a seamless manner to reduce the technical fear the user may have: automation being pivotal to the utility and usability from a novice perspective.

Universal Plug and Play (UPnP) [1] allows devices within a home discover each other and share data. Machine readable information for these devices e.g. PC, games console, modem, mobile phone, smart TV etc. is already being published by manufacturers on the web. The HAN device values detected are queried against linked data in DBpedia [2] and other collections and from there more user friendly data can be gleaned from Wikipedia [3] to help the user understand and use their HAN.

1.2 Motivation

In the research in this area many have investigated the issues relating to Home Area Networks i.e. configuration, management, maintenance, middleware and the usability and Human Computer Interaction (HCI) aspects surrounding HANs but this project centres on the linked data approach to harvest information from the Web. Most of research in the management of HANs does not use semantics so this project will attempt to bridge that gap to offer a more flexible solution by fusing HANs, semantics and usability.

The aim is to create a utility that will

- Discover the devices on the network
- Query the semantic web for information relating to those devices
- Fuse this information with local knowledge
- Display the retrieved information to the user

The system should inform the home user of the devices on their network and offer relevant information relating to those devices so that the user can delve further but the intention is not to troubleshoot the network as that is considered future work at this point. Privacy and security are important issues concerning wireless networks but, while mentioned, this work is not about securing a network beyond the boundaries of the home.

1.3 Objective

The objective of this dissertation is to fuse HAN research on user difficulties, desires and usability requirements with the interlinking of data on the Semantic Web to create a prototype to inform the novice technical user about the devices on the home network by harvesting information using linked data. Automating the detection and retrieval of information reduces the input and therefore technical expertise required by the target user i.e. the novice.

The factors influencing the objective of this dissertation are as follows:

- **HAN** – The State of the Art research on HANs, **2.2**, shows that users for varying reasons find themselves in a position where, to troubleshoot the HAN, unlikely to be a robust setup, the skills of a professional are required. This time consuming task can be frustrating compounded by the fear of making the situation worse.
- **Semantics** – Machine-readable interlinked data on the Semantic Web affords the automation of the retrieval of information relevant to the devices on the HAN.
- **Usability** – It is this automation that is considered crucial to the usability of the prototype from the perspective of the novice user attempting the work of a technical professional.

1.4 Research Question

Can the automation of retrieval of information from the Semantic Web reduce the technical knowledge and input required to inform a novice home user about the devices on the Home Area Network?

1.5 Contribution

The contribution of this dissertation lies in the automation of detection and subsequent retrieval of interlinked data; how open and accessible that data is; how relevant it is to a novice user and how useful and usable such a system would be for the non-technical user.

1.6 Dissertation Overview

The outline of this dissertation is as follows:

- **Chapter 2** is an overview of the State-of-the-Art in the areas of Home Area Networks, Middleware associated with the home, Linked Data and the HCI (Human Computer Interaction) and usability aspects taken into consideration where home networking is involved.
- **Chapter 3** is a merger of the design and implementation to explain the design considerations taken into account, the reasons behind the reassessment of the scope, the technologies used and the implementation details.
- **Chapter 4** discusses the results of the experimental evaluation carried out with volunteers on a simulated network.
- **Chapter 5** concludes with a discussion of the work carried out, its successes and limitations and how future work could extend the prototype.

Chapter 2

2 State of the Art

This section outlines the latest research in the Home Area Network topics associated with this project.

2.1 Overview

The following sections will outline many of the issues associated with Home Area Networks (HAN) for the everyday user e.g. little or no networking knowledge or desire to learn it, heterogeneous devices added piecemeal, understanding how the devices are connected and what communicates with what, the boundary of the wireless connection, security, privacy and being able to setup, configure, maintain and monitor the network. Some systems have been researched in the process e.g. Eden, ICEbox and HomeMaestro but these focus on network management and troubleshooting while the focus of this dissertation is to inform and help the user by harvesting data from the web about the specific devices on their network. Middleware for HANs and Linked Data are also investigated as Universal Plug and Play (UPnP) will be used to discover the devices: the values detected used to query the machine-readable datasets on the Web.

2.1.1 Use Cases

2.1.1.1 Overall System

To explain the end user's HAN the system will work as follows:

- UPnP will automatically detect the device on the HAN
- The Sindice client will query linked datasets for information about those HAN devices.
- DBpedia's data comes from the structured data in Wikipedia.
- The end user will get back user-friendly information about their HAN devices from Wikipedia.

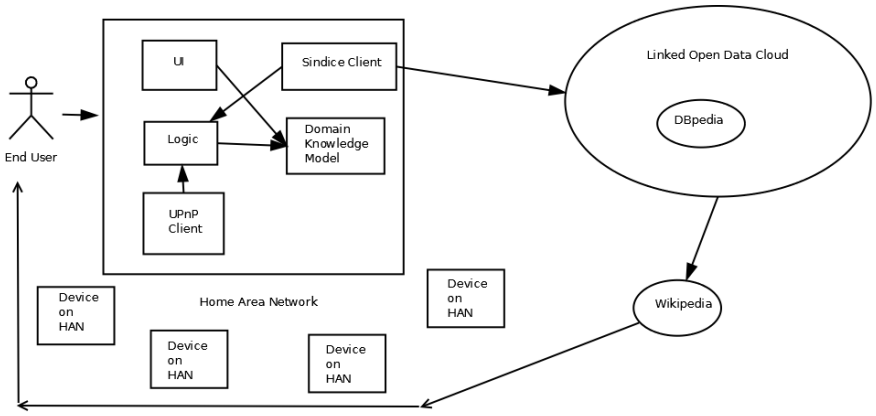

Figure 2-1: System Use Case

2.1.1.2 End User

The end user will be able to

- Browse the devices on their HAN.
- Locate the device they want more information about.
- Find more information about that device that has been harvested from the Web of Data.
- Find the manual for that device.
- Offer feedback to the relevancy of the data.

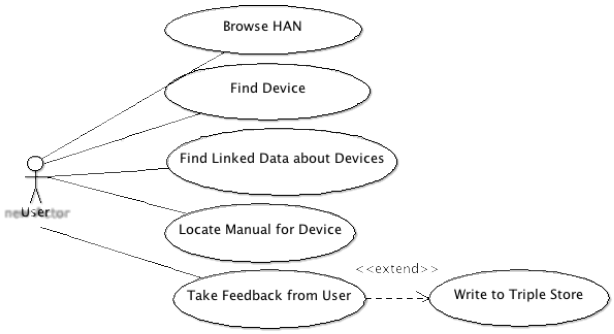

Figure 2-3: Use Case for the end user.

2.2 Home Area Networks

2.2.1 HAN Challenges

In [4] Edwards and Grinter discuss the seven challenges of ubiquitous computing in the smart home from a technical, social and pragmatic perspective. The seven challenges described are as follows: the 'accidentally' smart home, impromptu interoperability, no systems administrator, designing for domestic use, social implications of aware home technologies, reliability and inference in the presence

of ambiguity. Although the paper is aimed at the smart home the challenges are also applicable to the home area network.

Newer homes can be purpose built to accommodate smart technology, the majority of appliances can be added at the same time, adhere to current standards and as a result may be more likely to interoperate rather than being 'islands of functionality'. Older homes tend to add pieces of technology over time. These devices due to the disparate vendors, differing design constraints and considerations can prove more difficult to network.

With impromptu operability it is not just the connectivity issue but also that devices need to be able to interconnect with minimal advance planning or implementation. Many home users have some experience of installing software or upgrading hardware but very few understand or can troubleshoot a network.

Network and security administration is a complex task and, although necessary, most home users are not only, not familiar, but have little inclination to delve into what seems to be a dark art. The home user needs to understand how devices are connected and that the wireless connection extends beyond the boundaries of the home. With a wired setup it is easier to see what devices are connected as the user can follow the cable. The smart home needs to provide its occupants with the ability to see the current state of the system at a glance, an interface to manage the whole system and to avoid and repair accidents, the example given being a neighbour accidentally hijacking the wireless speakers. New devices need to be added, old ones removed, all co-existing from varying manufacturers and all easily accessible and controllable by a home user.

The difficulties of home networking has been the subject of an article in the New York Times, [5], but a more serious example of not managing to secure access to wireless in the home made headlines in the Sydney Morning Herald. “Lying on his family room floor with assault weapons trained on him, shouts of 'pedophile!' and 'pornographer!' stinging like his fresh cuts and bruises, the US homeowner didn't need long to figure out the reason for the early morning wake-up call from a swarm of federal agents. That new wireless router. He'd gotten fed up trying to set a password. Someone must have used his internet connection, he thought.” [6]

Grinter et al. found that some users in their study intentionally left their wireless unprotected and “sought to invite ‘good use’ by their neighbors, which meant that they did not mind if other people used their network as long as they didn’t then engage in bandwidth-intensive activities. In this mode, offenders would receive a physical visit from a member of the householder and be asked to refrain from downloading such bandwidth-heavy material.” [7] Also other “households exhibited a rather inconsistent policy” by securing their own network “while simultaneously feeling little remorse if they

ever used their neighbors' insecure networks. A few people even admitted to looking into their neighbors' networks, identifying devices and even opening files. But these same people spoke about a dilemma, while they wanted to tell their neighbors that they were insecure, householders valued being able to use that network, particularly when their own was down." [7]

Chetty et al. identified the social implications of revealing the invisible with their tool, Home Watcher, for bandwidth management and visualisation in [8]. "Parents also expressed concern about limits being overcome by industrious teenagers." [8] "All these examples illustrate how open access to a means of controlling household resources can create confusion when these controls appear to be at odds with the social order of the home." [8]

2.2.2 HAN Solutions

Yang and Edwards study the tools home users use, the issues relating to them and as a result suggest desirable features for a home management tool. [9] Each participant was interviewed to determine if they had carried out tasks within the following categories: connectivity configuration, security and access control, network monitoring and troubleshooting. They were also asked about the tools they used, their opinion of them and what features they would like to see in a tool. The findings showed that the users would prefer to manage their own networks if they had a user friendly management tool that supported all tasks rather than having to use different tools for different tasks. To help users configure and manage their networks the same group developed both ICEbox and Eden.

2.2.2.1 ICEbox

Yang and Edwards developed ICEbox (Installation Configuration and Evolution box) to counter some of the key usability features identified in their previous work: the difficultly with provisioning devices, reprovisioning due to the fragility of the network setup, configuring security, monitoring, maintenance and understanding the complex, though small, topology of a home network. [10]

ICEbox acts as a central point of control for the network and uses simple physical actions to complete complex tasks e.g. pointing and turning a key in a lock. A device can be added to the wireless network by pointing it at ICEbox and from that point on all future configuration is delegated to ICEbox. The approach taken to improve usability for security and access was to use a familiar concept i.e. a door lock

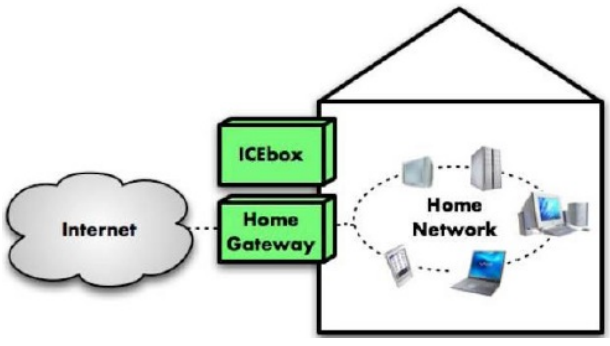

Figure 2-4: Location of *ICEbox* in the home network topology. [10]

metaphor, thus ICEbox becomes the logical front door by being located at the boundary of the home network and the Internet. This proved effective as all novice users managed to configure the network using ICEbox and all understood that using the lock meant that they were keeping outsiders out.

Figure 2-5: Touch screen visual interface for device monitoring. [10]

The touch screen displays icons for each device introduced and touching that icon brings up information about the device e.g. device and service descriptions and real-time connectivity status.

2.2.2.2 Eden

Yang et al. in [11] developed Eden, an interactive network management system, to tackle four areas identified from their analysis: membership management, access control, network monitoring and QoS policy for bandwidth priority.

Their interface uses a home layout to, at a glance, indicate the network boundary, the devices on the network, an ISP network centre between those devices and the Internet icon and a separate area showing new devices detected that are not yet part of the home network.

Users can drag-and-drop newly detected devices into a room to indicate membership. Until this happens the device has no access to the network or the Internet.

Enabling network status gives the user connectivity and performance information. Traffic links between devices are depicted using animated flows of dots while device specific applications, generating or receiving traffic, are shown as icons over the originating device.

They use the metaphor of a badge to indicate properties of a device or group of devices. Badges include Internet Restriction, Sites Restriction, Application Restriction, Devices Restriction, Faster, Slower, Web Server and File Sharing. A parent can restrict access to the Internet by dragging the Internet Restriction badge onto the child's computer. Quality of Service (QoS) parameters can be tweaked by using either the Faster or Slower badges. A badge can be placed on a device, room or the whole network itself.

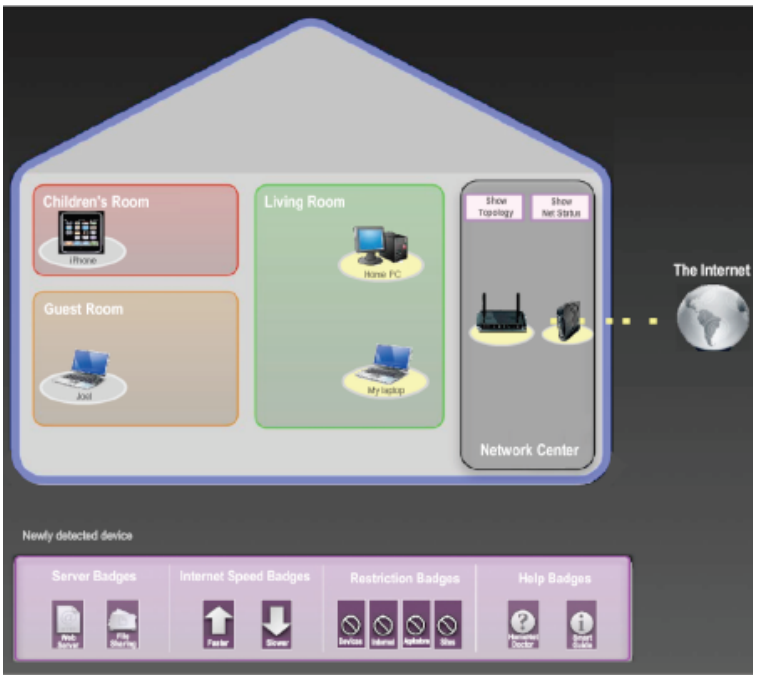

Figure 2-6: A screenshot of the *Eden* user interface. [11]

Eden is implemented "as a custom Linux-based wireless router/access point, intended as a 'drop in' replacement for the existing home router; the software we developed for the system can also run on PCs, as well as be flashed to the firmware of common consumer routers based on the Broadcom chipset, such as the popular 'WRT' routers from Linksys." [11] By placing Eden in a router position all traffic can be monitored and policy controls can be enforced. It can be accessed from any point in the network capable of running Flash by typing *eden* into the browser address bar.

2.2.2.3 HomeMaestro

The focus of the distributed system, HomeMaestro, implemented by Karagiannis et al. in [12] is on automating home network management to improve the user experience and they believe that this automation is the most important contribution of their work. Their solution revolves around determining competing flows or applications, based at the host rather than in the network, so as to assign traffic priorities to alleviate congestion and therefore ensure an acceptable user experience. They acknowledge that their solution is reactive as congestion can build up for a few seconds before the system reconfigures to relieve it.

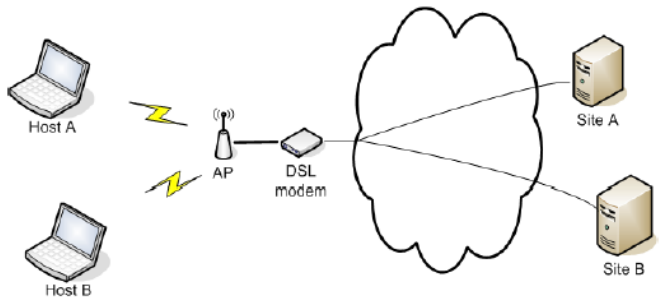

Figure 2-7: Experimental setup within a real home network. Two *HomeMaestro* instances were running on two laptops that are connected by wireless to the home access point. [12]

The experimental setup to monitor traffic consisted of 2 laptops wirelessly connected with HomeMaestro running on each and communicating messages to each other. "The home was connected

to the Internet through a consumer Internet Gateway Device (IGD) (with 3Mbps downstream and 800Kbps upstream nominal capacity) comprising a DSL modem, a wireless Access Point (AP), and a router, having common features and configuration such as NAT services, a firewall, etc." [12] To have as realistic a scenario as possible normal home traffic continued during the experiments e.g. browsing and email.

As this dissertation does not aim to troubleshoot or fix network issues for the home user the interesting sections of this paper are to do with their experimental setup and user participation and responses (more in **2.5.3**).

2.2.2.4 Recent Developments

Google's annual developers' conference in San Francisco made the news with its Android@Home announcement, [14, 15 and 16]: Android@Home, an initiative "which allows Android apps to discover, connect and communicate with appliances and devices in your home", [13]; and Project Tungsten for music playback control on the Android@Home network. [13]

Microsoft Research has implemented and evaluated a home operating system, HomeOS, with a HomeStore to complement it by helping users find applications that are compatible with their home devices and setup. They have tested it with a range of applications and drivers e.g. DLNA (Digital Living Network Alliance), [17], ZWave, a wireless communication protocol, a video camera and a Windows Mobile Smartphone believing that it will "create a new wave of innovation in the home", [18].

South Korea's LG Electronics has showcased their smart refrigerator, which can be controlled by a smartphone on WiFi and also plan to roll out other smart appliances including a fridge and a washer. The vice president of LG's home appliance unit, Kim Young-Soo, believing that the smart refrigerator will be more successful than its predecessor in 2000 due to the ubiquity of WiFi networks, smartphones and that the price is more affordable now. [19] "Market research firm Pike Research predicts the global market for smart home appliances will take off in earnest in 2013 and reach $26.1 billion in sales by 2019." [19]

2.3 Interoperability

One of the prerequisites for a working home area network is device interoperability. UPnP will be used for this project to discover the devices on the home network but as the focus is on retrieving information from the web of data and not on the interoperability the functionality offered by DomoNet [20] will not be required. Its value as a research paper for this project is in building a realistic home network scenario, where having being set up by a non-technical expert, most likely piecemeal, will have

a myriad of devices and software. The use of XML and XML schemas in DomoML is also interesting as the language to communicate the device information and capabilities.

2.3.1 UPnP

Universal Plug n Play (UPnP), originally created by Microsoft in 1999, aims "to provide a distributed computing framework based on web technologies for small networks, especially home networks". [21] UPnP Forum, [1], an independent organisation, now controls UPnP.

Reynolds describes the challenges posed and lessons learned from smart home research. The most important challenge identified is that, unlike a professional setup, the non-expert home user has to "choose, deploy, integrate, manage and operate most of the products and technologies in their homes". [21] Also identified are the same issues that crop up in all the papers; that home users do not have the IT skills to effectively manage and secure the network, devices are incrementally deployed, legacy devices need to interoperate with new devices, transient connectivity and lack of infrastructure services cause problems and if a component fails someone needs to be capable of identifying the issue before they can fix it.

The UPnP Implementers Corporation white paper describes the utopia of UPnP in [22]. "Usage of UPnP network devices offers numerous benefits and advantages to the end user. UPnP enabled devices create seamless interoperability and unprecedented simplicity, reliability and ease-of use." Among the advantages listed are that UPnP can run on any medium that supports IP networking (phone line, power line, Ethernet, RF, wireless and 1394), it is both OS and language independent, is based on common internet technologies (IP, TCP, UDP, HTTP, XML etc.) and manufacturers can add value-added services on top of the basic device architecture. "In the end, the big winner becomes the home network user who now has the ideal network that works automatically and harmoniously – no muss no fuss." [22]

Kim et al. in [23] describe the design and implementation of their home network system using UPnP middleware as it meets the requirements for dealing with a home networked system i.e. automatic configuration so that devices can join, learn about each other and exit without leaving unnecessary state information behind. Among the advantages mentioned: the use of HTTP, SOAP and XML for networking control and data transfer; platform independence and that it uses less hardware resources than a PC based solution, however, they suggest that improvements need to be made to its recovery methods, methods to change the Time To Live (TTL) parameter and additional bridges. The recovery methods used are heartbeat and timeout but a robust home networked system needs to be able to track all the changes and breakdowns. Methods are needed to change the fixed TTL parameter in the IP header so that UPnP messages do not spread to areas where they are not wanted and additional bridges are required to communicate with non-IP protocols.

"Home network systems consist of server-client programs, a scheduler for home users, appliance emulators, and embedded communication devices using Linux and Window CE platforms. The home scheduler in the home server system includes appliance on/off scheduling modules and energy management modules."[23] The User Interface on the developed system displays an icon for each device discovered on the network and by double clicking the appliance icon a user can not only control and monitor that appliance but also display detailed information about it.

While the goal for Kim et al. was to design a system to offer guidelines in the design of home systems using UPnP middleware with embedded interface modules for networked appliances Miori et al. [20] point out that it's unlikely that a home system will use only one middleware application as "it is improbable that there will be a single dominant middleware for the home computing that would be right for different appliances."

2.3.2 Domotic Interoperability

Miori et al in [20] implement a system, DomoNet (Domotic Network), to deal with and improve the interoperability of the mixture of middleware (e.g. UPnP, Jini and HAVi) and protocols (e.g. Konnex, LonWorks and X10) used in the home network. They believe that "it is absolutely essential to integrate all the devices into one open and universal home standard platform in which home appliances can interoperate and 'speak the same language'." To this end their approach is based on XML, Web Services and Internet protocols to avoid technology islands. They consider each middleware with interconnected devices a subnetwork, which, if each pair is to be bridged by a gateway, quickly becomes unwieldy.

"DomoNet (Domotic Network), an abstract layer for representing and controlling all appliances in an overall integrated system in which DomoML (Domotic Markup Language), is an XML vocabulary developed by the authors of this paper in order to support a clear separation between appliances resources descriptions and software or hardware platforms, languages, or protocols." [20]

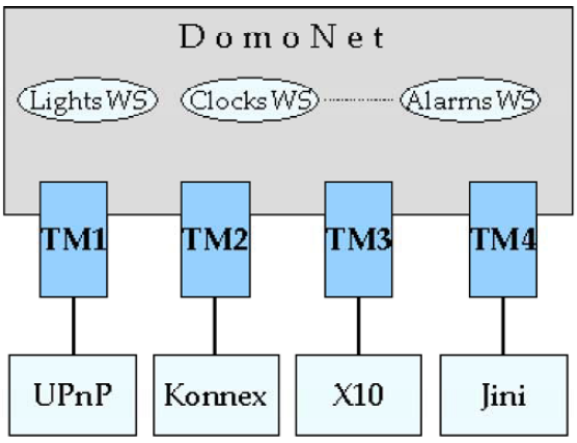

Figure 2-8: *DomoNet* Architecture. [20]

DomoNet connects TechManagers (TM) with Web Services. Each TM is an application gateway for the middleware to be interconnected while each Web Service (DeviceWS) handles a different device type.

DomoML is used for the communication between the TMs and DeviceWSs and describes datatypes, messages, devices and their services. Using this information a TM knows what services a DeviceWS e.g. LightsWS offers and as a result can operate a device on another middleware subnet.

Figure 2-8 illustrates a home setup using 4 different types of middleware (UPnP, Konnex, X10 and Jini) interoperating via the TMs with web services to control lights, clocks and alarms.

The aim is not to usurp existing middleware with a replacement technology but to work in conjunction with them to enhance interoperability by creating a standard to identify a generic device, its capabilities and to share that information.

"Using Web Services and other typical Internet standards, DomoNet makes the home a real Internet node; in this way, home environments could be managed and controlled from any remote location having access to the Internet. Users do not have to worry about the heterogeneous devices and protocols their homes are composed by: they could interact with their homes and take advantage of all their services, just as they do with modern web-based applications through usable and accessible interfaces." [20]

2.4 Harvesting Data

2.4.1 Linked Data

Linked data is a means of interlinking and publishing documents on the web so that they are more useful to both computers and humans, the guidelines described by Tim Berners-Lee in [24]. Bizer et al. in [25] state that despite "the inarguable benefits the Web provides, until recently the same principles that enabled the Web of documents to flourish have not been applied to data. Traditionally, data published on the Web has been made available as raw dumps in formats such as CSV or XML, or marked up as HTML tables, sacrificing much of its structure and semantics." Also that, the "original and on-going aim of the project is to bootstrap the Web of Data by identifying existing data sets that are available under open licenses, converting these to RDF according to the Linked Data principles, and publishing them on the Web." [25]

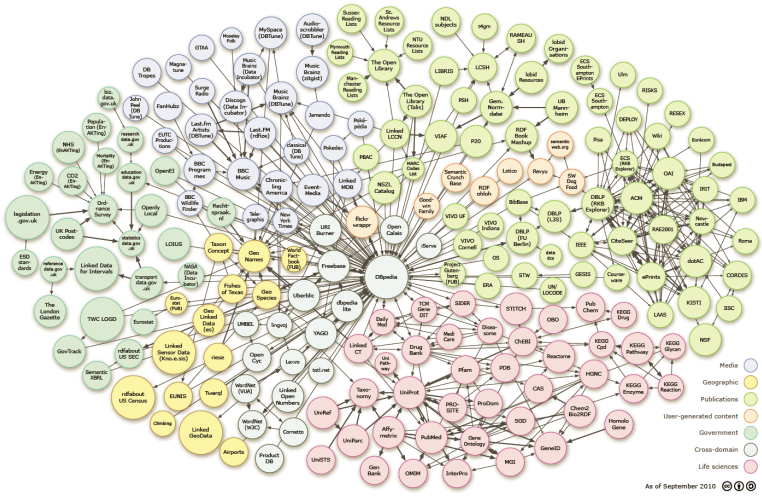

Figure 2-9: Linked Open Data Cloud. [26]

Bizer et al. in [25] described the Linked Open Data project the "most visible example of adoption and application of the Linked Data principles". Each bubble on the Linked Open Data cloud represents a linked dataset. The arcs show which datasets are connected with the heavier lines indicating a greater number of links between the sets.

2.4.2 DBpedia

The focus of the DBpedia project is to extract the structured data from Wikipedia, enabling it to be queried and interlinked with other datasets. From this structured data applications or mashups can be created. [27] DBpedia automatically evolves due to Wikipedia's constant community revision.

2.5 HCI and Usability

The role of HCI is to help produce systems that are useful, usable and used. If a user cannot use a system or if it makes human error likely then it is broken by design. To improve usability knowing the users, their capabilities, limitations, tasks and goals is necessary. Principles for improving design include: user interface consistency so a user knows where information is located and what to expect, informative feedback and error messages, allowing easy reversal of actions to remove the fear of doing something wrong, reducing the short term memory load and speaking the user's language. Novices require ease of learning while experts require ease of use and to be able to complete a task quickly.

Many of the papers touched on the HCI aspect of Home Area Networks to elucidate the causes to the barriers for the everyday user of a network.

2.5.1 Historical, Social and Technical Factors

Shehan and Edwards [28] give a detailed analysis of the historical, social and technical factors that have led, in part, to the technical difficulty experienced by the home user and propose a number of approaches to ameliorate the process. Home networking, in taking its influences from the packet-switched internet, has as a result, positive attributes e.g. scalability, extensibility and throughput but also suffers from certain assumptions made at the time i.e. that each machine and/or person accessing the network was trustworthy, that IP and TCP/IP make no quality of service guarantees and that ease-of-use was not an imperative due to the technical ability of those making use of the initial internet. Due to these assumptions "no low-level authentication or access control mechanisms were built into the core Internet protocols" and the lack of QOS guarantees can negatively impact steaming audio and video.

They also show that the design choice of limiting the network core capabilities and moving the intelligence out to the edges of the network, while meritorious, has a negative consequence for usability. To show that the networking barrier is not due to communication technology but the model

design, the comparison given is that of the public circuit-switched telephone network. With the telephone network the intelligence is in the network itself so the home user only has to contend with the physical telephone device and no configuration or management unlike the home network where the intelligence is at the end points i.e. the devices in the home. The user needs to be able to setup, configure, maintain and update the network so that it is robust enough to cope with adding and removing devices from different vendors adhering to different standards.

The challenges of the home environment are also discussed: configuration details to satisfy statefulness, management due to the dynamic, heterogeneous and piecemeal nature of network enlargement, configuration and misconfiguration of security tools and the reliance on a technically knowledgeable occupant.

The alternative approaches suggested are as follows:

- The Fresh Start Model,
- The Bandage Model,
- The Gateway Model,
- The Outsource Model,
- The Utility Model and
- The Ubiquity Model.

The Fresh Start Model is to start from scratch again using what has been learned in the past 40+ years of networking but points out that due to backwards compatibility and the difficulties involved in converting to such a large scale change it is unlikely to be achievable in a short time frame. "Internet flag day" in 1983 where only a few hundred machines switched to TCP/IP took several years of planning; the Fresh Start Model would involve millions of machines.

The Bandage Model pushes the impetus of alleviating the setup, configuration and maintenance difficulties onto the front-end with clever User Interface design over an unchanged infrastructure. The limitations involved with this model are that tools can only display information that can be communicated to them so if the infrastructure does not provide the information necessary to solve a problem then a tool is rendered ineffective for that issue as it has no information to derive a solution from.

The Gateway Model suggests that the home network can be a sub-network of the Internet with its own home-user centred protocols and infrastructure; translation facilitated between the two with a gateway. In this scenario it is possible to have the benefits of a fresh start but the downside is that there is a cost hit for the home user in that the existing devices would have to be upgraded to work

with the new protocols etc. The gateway also becomes a single point of failure but they explain that this is no different to the router or cable modem dying in the current system.

The Outsource Model is where setup, configuration, maintenance and management are outsourced to an expert. Again there is a cost implication for the home user and not all users manage their own networks out of interest, some have no option but to delve in, as they cannot afford to get a professional to do the work. There is also a privacy issue with allowing someone access to a PC with personal information stored on it.

The Utility Model draws comparisons with other utilities such as gas, electricity and the phone with the expectation that "it should just work". These utilities push the intelligence away from the user and into the network, with no configuration or customisation required by the home user. This idea does not marry for home networks, as personalisation is required so as to meet the needs of the home.

The Ubiquity Model moves away from the notion of the home network to a Metropolitan Area Network (MAN) provided by a commercial or community based entity. Other than connection users would not have to deal with networking issues. The benefits also include: easy mobility, access where infrastructure for conventional broadband does not exist and opportunities for collaborative applications. Due to the lack of firewall or router householders would need to secure their devices.

They conclude with "We believe that in order to improve the usability and accessibility of networking for all members of society – not just the economically and educationally privileged – the HCI and networking communities need to reflect deeply on these possible models and to engage in research that can lead to a future where networking is accessible to all." [28]

2.5.2 Network Management Tool Usability

The participants in the study carried out by Yang and Edwards in [29] identified usability issues with and desirable features for a home management tool. Listed are the problem areas identified.

- Hard-to-understand and hard-to-use tools
- Hard-to-find tools
- Inconsistent user interface of management tools
- No visual map of the home network
- Unusable manual or instructions of tools

The non-expert participants of the study either did not know or did not want to have to know about IP addresses, Mac addresses, wireless network configuration or DHCP parameters; for network security they just wanted to know that their network was secure. This highlighted the need for tools that are

easy to understand and use so that ordinary users can manage their networks without low-level technical knowledge.

Identifying the tools to manage their network, requiring more than one tool to accomplish a task and accessing the router built-in tools due to different default IP addresses were also issues for the users of the study. An all-in-one network management tool, easily accessible to all users would help in this area.

As tools differ between vendors, operating systems, devices and tasks it was felt that an all-in-one management environment would help users to accomplish tasks.

The users wanted some graphical representation of the entire network so that they could determine the speed of both the whole network and the individual devices. For privacy they also wanted to be able to see the communication between devices. This suggests that a tool with a visual map of the topology and communication is desirable.

It was felt that technical manuals were ineffective due to the technical knowledge required to understand and use them. More user-friendly help is required to overcome this issue; the examples suggested were instructional videos or animation.

Also mentioned was the desire to access the management tool from any device on the network, one program in one place supporting all tasks and that the users did not want to install extra software or incur extra cost suggesting that a built-in tool would be best.

The findings also showed that the participants would prefer to manage their own network if the management tool was user friendly. Although the system proposed for this dissertation would involve extra software it should also be capable of retrieving more user friendly data from the linked datasets as Wikipedia is the first port of call for a lot of people looking for technical information.

Figure 2-10: The *ICEbox* hardware prototype. [10]

Yang and Edwards in [10] considered integrating ICEbox into the home gateway router but felt that this would reduce the usability of the system so instead developed a physical box which could be locked to secure the network. If locked, devices cannot be added to the network unless ICEbox is physically unlocked by a key. Usability testing was carried out in the controlled networking conditions of a lab and all 10 users were able to secure the network using the key lock interface.

They also considered positioning within the home and the dimensions of the device. ICEbox is similar in size to a home security pad and also placed on a wall in a similar manner so as to avoid invisibility as they found that access points and routers were often hidden from view making it harder to notify users of problems with flashing lights. Grinter et al. in [7] noted, "Decoration also mattered in the sense that tidiness and appropriate visibility/invisibility came up for our householders. We found cases of DSL modems being hidden under couches, because householders did not like to see the blinking lights in their living rooms." Also, "We found at least one modem under a couch, and found a wireless repeater worked into a flower arrangement. Minimally, we suggest that this argues for making not just the end-user technologies aesthetically pleasing, but also for giving thought to the potential to disguise or camouflage the other devices in the network so that they can be 'hidden' in plain view." [7]

Users add a device over infrared by physically pointing it to ICEbox and this short-range communication forms a boundary so avoids the issue of neighbouring devices on the network. They acknowledge that pointing also has its issues e.g. pointing an Internet-enabled refrigerator at ICEbox and that desktops and printers need to be powered on to communicate. A detachable provisioning wand would help with larger devices and some users had difficulty with finding and facing the infrared ports as they were not familiar with it.

For the user interface of Eden Yang et al. included both spatial and logical information to accommodate both the novice and the expert users; the spatial showing devices within rooms in a house while the overlaid logical details indicated the traffic flows and topology. [11] The boundary of the house indicated the logical boundary of the home network and only devices within rooms had access unless the user using a badge restricted them. Badges could be dragged and dropped on a device to restrict access or easily tweak network parameters, hidden to the user, to improve the QoS of, for example, mpeg streaming. Traffic was indicated using an animated flow of dots.

2.5.3 User Participation and Evaluation

The most common evaluation techniques in the papers researched were questionnaires, the Think Aloud protocol and interviews. With Think Aloud the user is observed and asked to comment on what he is doing and why. It is of limited use until the user experiences problems with a task as the user is unable to communicate as fast as they think and act until the problem slows them down. All three are subjective and the questionnaires demand careful design.

Yang et al. in their evaluation of home management tools recruited 25 participants by word of mouth, emails to local organisations and on-site recruitment in public places e.g. cafes. The group consisted of a mixture of 7 skilled and 18 non-skilled users, ranging in age from 20's to 50's. [29] All had home

networks, mostly wireless, had one of more PCs or laptops connected to the network and although all had some experience of network management the skill levels varied. The non-skilled or non-expert group gleaned their basic knowledge from the Internet or friends or family. The group who had formal training were considered the expert group. Each participant was interviewed, the interview lasting between 60 and 90 minutes. The participants were asked about the network management tools they used, what they thought of those tools and what features they would like to see in a tool. From these findings a set of user requirements were identified for a tool to help users manage their own networks.

Usability and utility evaluation of ICEbox by Yang and Edwards, in [10], focused on three features of the system:

- Introducing devices to the network by comparing ICEbox with adding and configuring devices using the device manuals;
- Securing the home network with ICEbox or by using the wireless network wizard or the access point web interface;
- Monitoring the home network.

The study was carried out on a built home environment in a lab with an access point, ICEbox appliance, networked printer and several wireless laptops. The controlled conditions of the lab offer repeatability over the home network and this aspect is necessary for a usability study. Three males and seven females participated in the study, all with a home network. Half described themselves as novices while the other half had previous experience of setting up devices on a home network. For the device configuration the participants were asked to think aloud and their responses were recorded. "We also noted during our study that, although few participants referred to manuals (as might be expected), none of the ICEbox users referred to the instruction sheet in order to accomplish tasks. We believe that this demonstrates the utility of a simple set of physical interactions for network configuration, and especially the value of having tangible, physical affordances to functionality that is often hidden (such as security configuration)." [10]

Yang et al. involved the users at an early stage in the design of Eden. [11] They wanted a list of home network management tasks to gain an insight into users' needs so as to display only relevant information and not overwhelm them with technical details while at the same time giving them enough to diagnose issues. The formative study involved 14 users from novice to a professional network administrator and wanted this range of skills to see if they could help the novice users carry out more complex tasks that a professional is familiar with. Surveys and interviews were used to gather details about the participants' networking skills, home network setup, tools used and what they'd like to be able to do accomplish with their home network. Iterative paper prototyping was required for the interface design as some users were more comfortable with a spatial layout of devices while those with more networking knowledge wanted a logical layout. Think Aloud and questioning was also used for

this phase. The resulting interface was a mixture of spatial (house and rooms) and logical for the topology and traffic flow information. Drag-and-drop interaction was preferred over menus due to its simplicity.

For the evaluation of Eden they recruited 20 people, 15 novices, 5 intermediate and 3 experts. Eden is aimed at novice users so this accounted for the larger number of people with no technical knowledge of networking. The home network was a controlled set up in the lab consisting of a range of client devices and Eden. The conceptual evaluation was to test if the users gained a greater understanding of their network from using Eden interface and for this open-ended questioning and Think Aloud was used. "All users liked the visual traffic map of the home network. This visual map contributed significantly to 'teaching' the users about the basic structure of the network. During our study, ten users reported that exposure to the system showed them how network traffic is transferred from a computer in the home network to the router and then to the Internet, and believed that this knowledge would help them in 'fixing' the network in the future." [11] For functional and usability testing the users were asked to perform tasks with Eden and other comparable tools. The results were positive in that 17 out of 20 preferred Eden. [11]

Karagiannis et al. in [12] sought the help of sociology researchers to identify a small set of typical households and design a study so that they could get an insight into the application and traffic properties of a typical home network and see how the users perceived the performance of their network. All traffic, wired and wireless, was captured. Each study lasted 7 days and during that time the users kept diaries about application usage, problems encountered, assumed cause and their experience. This was to compare the actual traffic data with the user experience of the network. The sample graphed results presented in the paper were from two households, both with 4 users, connecting to the access point using a PC or laptop and where other devices existed as well e.g. gaming consoles. The graphs were annotated with labels to indicate the times and applications (e.g. W:Web, S:Streaming, G:Games, M:Media) where problems existed. Problems were encountered daily and at times when the network was lightly or moderately loaded. The users assumed cause was "No idea" [12] when the likelihood was that they were competing for resources and that "Internet in general slow at weekends" [12]. Also the network took the blame when numerous applications were open slowing down the responsiveness of the PC.

These methods are not practical for the time span of a dissertation project; apart from the time it would take to get 10 to 20 home networked users ethically involved, documenting information from an audio or video recording is very time consuming. For this reason a smaller scale evaluation will be carried out, most likely, initially an emulated model followed by enlisting acquaintances with home networks. To gather initial thoughts a short questionnaire could be used followed by 'Think Aloud' to

critique the usability, intuitiveness and efficacy of the system. An insight into the subjective Quality of Experience (QoE) can be garnered in this manner.

2.6 Summary

The challenges with home networking have been detailed in the above sections and while network management systems like ICEbox, Eden and HomeMaestro have all had their successes they each incur a technical cost for the novice user i.e. whether installed in addition to the gateway, a replacement for the gateway or having to install significant software. Karagiannis et al. in [12] stated that they considered automation to be the most important contribution of their work. Similarly, it is automation that is the key to the usability of the proposed prototype: automation of detection and automation of retrieval of relevant information.

Chapter 3

3 Design and Implementation

The State of the Art chapter discusses systems that focus on home network management and troubleshooting but the aim of this project is to inform the ordinary home user about their network devices without requiring an in-depth understanding of networking technologies. This chapter outlines the reasoning behind the layout of the GUI, the technologies used for detection on the HAN and linked data retrieval, the benefits of the design and summarises with possible improvements.

3.1 Design Requirements

There are three main aspects to this system: detecting the devices on the network, displaying those devices to the user and retrieving relevant information for those devices.

Based on these the requirements for this system are:

- **Detect** - To accommodate the ordinary home user, automatically detect the devices on their home network while requiring minimal technical input;
- **Display** – Automatically display these devices as they are detected on a non cluttered user interface to avoid relevant information becoming effectively hidden;
- **Inform** – Give the user a means to automatically retrieve information for these devices, ideally accurate and not overly technical, so as to foster confidence in the system and therefore make it usable, useful and used.

The key to assisting the novice technical home user is the automation of these steps combined with the relevance of the retrieved information.

3.2 Technologies and Resources

The initial project proposal was to retrieve applicable device information for the home user. To automate this, the data needed to be machine-readable therefore the focus was on the linked data of the Semantic Web. Complimenting this, but not the main focus, was the automatic detection of the devices on the home network, therefore, from the outset UPnP was chosen as the middleware employed, as this is what UPnP was designed to do. The bulk of the research centered on how to exploit this automation, detection and retrieval, to inform the user.

UPnP is a set of networking protocols designed to help small businesses and home users detect and control the devices on their network. The plug and play nature of the devices means that they announce themselves to other devices as they are added to the network. Also, a control point on the network multicasts discovery messages to detect any new devices added. To enable this messaging both multicasting and UPnP had to be configured by logging on to the router with its IP address, 192.168.1.1.

Cyberlink for Java, UPnP development package, [30], was used to create the UPnP Control Point and the mimicked UPnP devices: the evaluation with users used the mimicked devices on a simulated network, whereas only the control point is required in a home scenario. Jan Newmarch's Echo Device [31] was used as a template to create the mimicked UPnP devices while the UPnP/AV Device Capability Database, [32], provided the UPnP details required.

Both Sig.ma and Sindice were used in the design research: Sig.ma, a web application to generate a mashup of Semantic Web content for a query, [33]; Sindice, a Semantic Web indexer, [34]. Currently, the versions available are Sig.ma Enterprise Edition and Sindice Search API v3 but at the time of research the vesions were Sig.ma API and Sindice Search API v2. To query DBpedia, ARC, [35], the query processor of Jena, a Java framework for building semantic web applications, [36] was employed: SPARQL, the query language used.

The Graphical User Interface was designed using Swing: the code for the layout automatically generated using from the Swing AWT components on the design view.

3.3 Design Considerations

3.3.1 Graphical User Interface

Shehan and Edwards [28] pointed out that the HCI and networking communities must work together rather than in isolation to make networking accessible to all. To achieve a usable system the user interface was deliberately simplified so as to lead the user through the Detect, Display and Inform steps.

Figure 3-1: Detect, Display Inform Layout

A java application using Swing for the user interface was created so that the system can run on a PC or laptop on the home network. Various paper prototype layouts were created, the final version favouring a left-to-right succession of simple steps over top-to-bottom, tabbed or web page layouts as can be seen in **Appendix C** .

3.3.2 Detect

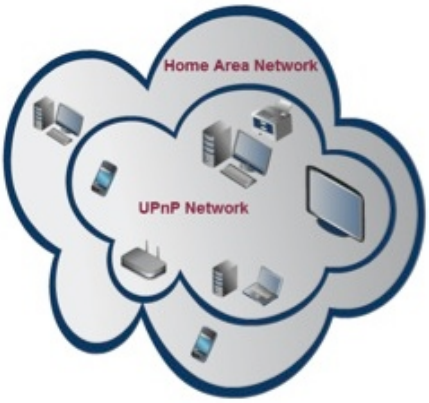

Figure 3-2: UPnP network as a subset of the Home Area Network

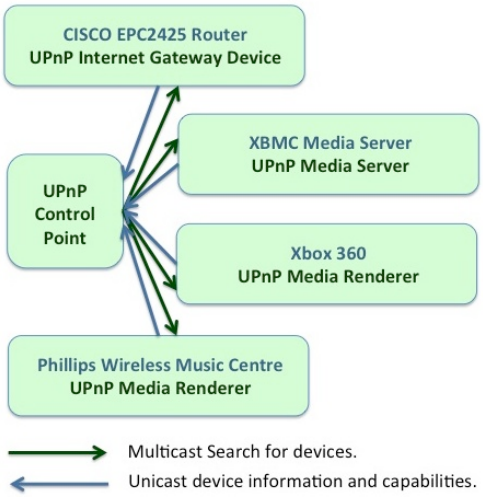

Figure 3-3: UPnP Control Point and Devices

The automatic detection of the HAN enabled devices for this system is accomplished by the Universal Plug and Play (UPnP) middleware. With the increase in devices from disparate vendors and manufacturers requiring a myriad of middleware it is acknowledged that, UPnP alone, will not detect all network-enabled devices within the home. The proof-of-concept scope of this project does not extend to including other middleware but focuses solely on those devices that are UPnP enabled. For example, a laptop using the HAN wireless and running Windows Media Player on Windows 7 will be detected due to Audio/Video UPnP client, however, without any UPnP enabled client running the laptop would not be detected. Therefore, the device detection scope is the subset of HAN devices that are UPnP enabled, Figure 3-2.

Cyberlink for Java, UPnP development package, [30], was used to create the UPnP Control Point and the mimicked UPnP devices on the simulated network for the evaluation. To detect the devices on the network the Control Point multicast a discovery message with the devices unicasting their presence and capabilities back, Figure 3-3.

3.3.3 Display

A Swing JTree was used to convey the basic hierarchy of the devices as child elements of the HAN root node rather than the actual topology of the network. To accomplish the dynamic display of devices in the JTree the Observer design pattern was used. As devices are detected they are added as an ArrayList of UpnpDevice objects to an UpnpDeviceList object. The GUI then becomes the Observer of the Observable UpnpDeviceList, dynamically updating the tree of devices as they are detected.

The information displayed to the user in the JTree is the UPnP information detected, using the model name as the device name in the tree: a snapshot of the UPnP details can be seen in Table **3**-**1** with a more extensive list in **Appendix B** . When the user hovers over the root node, 'My Home Network', or

the device name a tooltip is displayed, Figure D-9. Clicking on the device name populates the device information area with the result of the query to DBpedia for the Wikipedia English abstract.

UPnP Details Detected for Real Devices on the HAN					
UPnP Details	**Cisco EPC2425**	**XBMC Media Server**	**XBMC Media Renderer**	**Windows Media Player**	**Media Connect**
Device Type	urn:schemas-upnp-org:device: followed by				
	Internet Gateway Device :1	Media Server :1	Media Renderer :1	Media Renderer :1	Media Renderer :1
Friendly Name	Cisco EPC2425	XBMC: Media Server: (192.168.1.14)	XBMC: Media Renderer (192.168.1.14)	EMER-PC	media: connect: renderer [Emer Duffy's iPhone]
Manufacturer	Cisco	Team XBMC	Team XBMC	Microsoft Corporation	persona software®
Manufacturer URL	http://www.broadcom.com	http://www.xbmc.org/	http://www.xbmc.org/	http://www.microsoft.com	http://www.personasoftware.com/
Model Description	EPC2425	XBMC Media Center - Media Server	XBMC Media Center - Media Renderer	Windows Media Player Renderer	persona software® media: renderer: mobile
Model Name	EPC2425	XBMC Media Center	XBMC	Windows Media Player	M-DMR
Model Number	EPC2425	1.0	2.0	12	1.0
Model URL	http://www.broadcom.com	http://www.xbmc.org/	http://www.xbmc.org/	http://go.microsoft.com/fwlink/?LinkId=105927	http://www.personasoftware.com/
Serial Number	(unimplemented)			{C4D3CD50-DBF5-4463-	{b42581ce48a9bc6d37b9cdc4

				9FBA-2A3ADD584E51}	2e00c01bff94bb97}
UDN	uuid: followed by				
	upnp-InternetGatewayDevice-1_0-00223ad96e58	3ed5b5e3-d897-eaa3-20d-d7bca290c716	77d18804-0dce-3cf7-85c8-f11b300d24c2	80c99234-2576-43b8-8302-48ece294c409	3bf69843-9066-435a-ac5c-cf3849f1dfbb

Table 3-1: Snapshot of the UPnP details detected for the real devices on the HAN

3.3.4 Inform

Machine-readable data is required to achieve the automation necessary for the usability of the system from a novice perspective. Leveraging this aspect of the Semantic Web reduces the amount of input and technical knowledge required by the user of the system: the double-edged sword being that if the information is inaccurate or overly technical then a novice user will lose confidence in the system.

The initial project proposal was to retrieve, using linked data,

- Information about the device using Sig.ma
- Wikipedia's English abstract for the device and
- The manual for the device

As the project progressed and issues were encountered with retrieval using linked data the proposal was reassessed to get the details of the router and explain that device to the user. The following paragraphs will explain the reasoning for this.

3.3.4.1 Linked Data Retrieval

Initially the proposal was to query the Open Web of Data to create a mashup of information related to the device detected. Taking usability into consideration the devices were displayed first and then the user could choose whether to search for further information or not by clicking a button i.e. the 'More Info' button. Clicking on the button generated the URL to query the Semantic Web for interlinked data related to the device.

Both the Sig.ma API and the Sindice API v2 were tested to see if one returned better results: the parameters for the query string can be seen in Table **3**-**2**. Sig.ma uses the Sindice API so the Sindice Search API v2, [37], was used for this dissertation as Sig.ma did not return more relevant information and the atom feed result from Sindice was easier to interpret. The URL query to Sindice's API uses the

UPnP manufacturer e.g. CISCO, UPnP model name e.g. EPC2425, a qt parameter of term which is better than advanced for keywords, [37], and the mandatory page parameter set to 1 for the first page of results.

Sig.ma and Sindice API V2 Query Parameters	
Sig.ma	**Sindice Search API V2**
http://sig.ma/search? **q** - for keywords **raw** – Set to 1 to get the results without a header or footer. **format** - To specify the format e.g. JSON or RDF.	**http://api.sindice.com/v2/search?** **q** – for keywords **qt** – Set to term or advanced: term being better for a keyword search. **page** – Set to 1 to indicate the first page of results.
Query to Sindice Search API V2	

```
String qQueryStringSindice = "";
qQueryStringSindice +=
      "q=" + URLEncoder.encode(currentManufacturer, "UTF-8");
qQueryStringSindice +=
      "+" + URLEncoder.encode(currentModelName, "UTF-8");
qQueryStringSindice +=
      "&qt=" + qType + "&page=" + qPage;
qUrlSindice =
      "http://api.sindice.com/v2/search?" +
      qQueryStringSindice;

Where
      currentManufacturer is Cisco
      currentModelName is EPC2425
      qType is “term”
      qPage is the page number i.e. "1"
```

Table 3-2: Sig.ma and Sindice query parameters

Only the first page of results was considered, as a novice user is likely to lose interest if pages of results have to be examined for appropriate information. Table **3**-**3** shows that the results returned from Sindice for the devices detected using the manufacturer and model name would not be helpful to a novice user. Some results may be more accommodating to an experienced technical user e.g. result 3 for XBMC Media Center (the media server) and result 3 for XBMC (the media renderer) as the information is about similar applications but the results needed to be consistently good to foster confidence in the system. It was felt that, as these results would not be helpful to a novice user, possibly causing confusion or frustration, that it was better to amend the project scope to find the router on the HAN and then explain that device to the user starting with a sentence fragment like “This

is a ". A method to filter the results to a specific language is needed e.g. filtering out German and Italian in the results below leaving only English.

Yang and Edwards pointed out that "Manuals were too difficult to use, according to some study users, because they contained too many technical words that were not understandable or helpful", [29]. These users were probably the novice users whereas experienced users may find a link to the manual beneficial. To take this into account and to add value for the non-novice user it was hoped that the online manual or a 'Getting Started' guide would appear in the interlinked results if the term 'manual' was appended to the query: the results did not return the manual.

Sindice API v2 Term Search				
Keywords	**Results**	**Comment**	**Formats**	**Useful**
CISCO + EPC2425	Result 1	1 result only. "The requested URL was not found on this server."	Hcard RDFa	No
Microsoft Corporation + Windows Media Player Sharing	Result 1	16 pages of results, 10 results per page. A DBpedia HTML page for Windows 2000.	RDFa	No
	Result 2	Sponsored listings. Not relevant.	RDF	No
	Result 3	"Simple Virtuoso Installation & Utilization Guide for SPARQL Users (Update 5)"	RDF	No
	Result 4	DBpedia RDF for Windows Vista.	RDF	No
	Result 5	RDF with SIOC (Semantically-Interlinked Online Communities) links to http://shopper.cnet.com.	RDF	No
Team XBMC + XBMC Media Center	Result 1	2 pages of results. A news site, not in English.	RDFa	No
	Result 2	"The requested URL /flickr/people/29133065@N05 was not found on this server."	RDF	
	Result 3	A German weblog with some English. It's about a new media application based on XBMC. The best so far as it mentions XBMC but it would not explain XBMC to a novice user and it would be better to limit the results to a specific language i.e. English pages only.	MICRODATA XFN HCARD RDFA	Not really

	Result 4	"The requested URL /sioc/www.tuaw.com/xml/ was not found on this server."	RDF	No
	Result 5	"The requested URL /sioc/www.flock.com/xml/ was not found on this server."	RDF	No
Team XBMC + XBMC	Result 1	8 pages of results. It is the XBMC wiki but it redirects to a page with the list of people involved in the development of XBMC. It is related to XBMC but without further clicking it would not inform a novice user about XBMC. However, there is a link for the XBMC online manual on the left.	RDFa	Possibly
	Result 2	Redirects to the same page as Result 1.	RDFa	Possibly
	Result 3	Ericisson Labs Web Device Connectivity. The content is related, XBMC as a heading and mentions DLNA, but it might be too technical for a novice user.	RDFa LICENSE	Yes
	Result 4	It is the XBMC wiki page but it is about Google Summer of Code. As before the link to the online manual is on the left: if the user stayed on the page to read it and was not put off by the technical heading.	RDFa	Possibly
	Result 5	Redirects to the same page as Result 4.	RDFa	Possibly

Table 3-3: Sindice term search results for real devices

Using Sindice's advanced query did not improve the results, Table **3**-**4**, even though the domain and formats could be restricted: domain to cisco.com, productDB.org, [38], and/or ProductWiki.com, [39]; and format to the data formats allowed e.g. RDF, RDFa, Microformat and XFN (XHTML Friends Network). ProductDB's webpage states that its aim is to "be the World's most comprehensive and open source of product data. Not only do we want to create a page for every product in the world, we want to connect the underlying structured data together into one huge interlinked dataset" [38]. As it crawls both ProductWiki and DBpedia it was hoped that useful interlinked data would be returned. ProductWiki is a web based community wiki with the goal of creating "a comprehensive information resource that covers all products in depth" believing that "there needs to exist an unbiased, accurate and community-based resource for product information" [40].

Sindice API v2 Advanced Search		
Query	Comment	Results
http://api.sindice.com/v2/search? q= cisco &nq= &fq= domain%3Awww.cisco.com%20 format%3ARDF &interface= advanced	Search the cisco domain for cisco. RDF only. Results are not relevant to the dissertation goals – search term too broad.	7
http://api.sindice.com/v2/search? q= cisco%20epc2425 &nq= &fq= domain%3Acisco%20 &interface= guru	Search for cisco on cisco, not restricting the data format. It does not matter if www.cisco.com or cisco is used for the domain.	None
http://api.sindice.com/v2/search? q= cisco &nq= &fq= domain%3Awww.productwiki.com%20 format%3ARDF%20 format%3ARDFA%20 -format%3AMICRODATA%20 -format%3AXFN%20 &interface= advanced	Search for cisco on www.productwiki.com, allowing RDF, RDFa but filtering out XFN and HCARD. Specifying to include all formats or omit some made no difference.	None
http://api.sindice.com/v2/search? q= cisco &nq= &fq= domain%3Awww.productwiki.com%20 format%3ARDF &interface= advanced	Search for cisco on www.productwiki.com, restricting to RDF.	None
http://api.sindice.com/v2/search? q= cisco%20epc2425 &nq= &fq= domain%3Acisco%20 domain%3Aproductwiki%20 domain%3Aproductdb%20 &interface= advanced	Search using the manufacturer and the model name but limit the domains to cisco, productwiki and productdb. Not restricting the data formats.	None
http://api.sindice.com/v2/search? q= cisco%20epc2425%20manual &nq= &fq= domain%3Acisco%20 domain%3Aproductwiki%20 domain%3Aproductdb%20 &interface= advanced	The same search but add 'manual'.	None

Where q=keywords nq = ntriple query fq = filter query domain = domain of the document fomat = data formats e.g. RDF, RDFa, Microformat etc.

Table 3-4: Sindice advanced search results for real devices

In an effort to know how to direct the automation of the system, a number of sites were searched manually for applicable linked data, Table **3**-**5**. Another approach was to take something that is on ProductDB e.g. Sony MDR-V900HD, the sample resource mentioned on the webpage, then search Sindice for that product to see if ProductWiki or ProductDB appear in the results. 8 results were returned; none of them mentioned ProductWiki or ProductDB. As the linked data results were not consistent enough to use with a system where the goal is to inform rather than frustrate the novice user the focus was realigned to harvest the English abstract from Wikipedia.

Manual Search for Linked Data		
Website	Search Terms	
	Cisco EPC2425	XBMC
Wikipedia To see what might be on DBpedia.	Nothing for Cisco EPC2425. Searching for Cisco shows a link to Cisco Systems and from there a list of Cisco products but nothing for EPC2425.	Brings up XBMC so there is a DBpedia XBMC html page.
productDB A list of products crawled from the community wiki, ProductWiki.	Can not do a term search. Need a product code e.g. UPC, EAN, ISBN or ASIN. Also, investigated if the UPnP identifiers could be used to query this website but the UPnP UUID is not guaranteed to be unique and the Mac address was not relevant either.	
ckan.net A registry of datasets.	No datasets found for Cisco EPC2425, 1 for Cisco, Internet Topology Data Kit, but it is too technical.	No datasets found for XBMC. 8 datasets found for Microsoft but none appear appropriate.
infochimps.com datasets Some are free, some for sale.	No results for cisco or cisco epc2425.	No results for xbmc but 1,415 results for microsoft. Results for Microsoft are crime rates by state, average hours worked per day, teenagers etc. i.e. not relevant.

Sindice and ProductDB
Sony MDR-V900HD a sample resource given on ProductDB http://productdb.org/gtin/00027242450059 Term search Sindice for Sony MDR-V900HD `http://api.sindice.com/v2/search?q=Sony%20MDR-V900HD&qt=term&page=1` 8 results: None from ProductDB or ProductWiki

Table 3-5: Manual search for linked data

DBpedia, [2], evolves with Wikipedia's, [3], community changes and currently the dataset consists of 3.64 million things and 1 billion RDF triples: 385 million of those triples extracted from the English language version of Wikipedia, [43]. The labels and abstracts are available in up to 97 different languages and it is the English version of the abstract that is of interest to this dissertation: SPARQL (SPARQL Protocol and RDF Query Language), [41], the query language used to access that information through DBpedia's SPARQL endpoint, [42]. To accomplish this, ARC, [35], the query processor of Jena, a Java framework for building semantic web applications, [36] was employed.

The realigned scope to target the Wikipedia English abstract through DBpedia's interlinking was more successful as the SPARQL query allowed for filtering to a specific language. The UPnP details were used for both the queries to Sindice and DBpedia: manufacturer and model name to query Sindice with the device type mapped to a friendlier term to query DBpedia. The manufacturer and model name were not used due to the lack of consistent results and as the adjusted goal is to explain the router to the user, Table **3**-**6**.

DBpedia Results		
Keywords	**Results**	**Comment**
CISCO + EPC2425	While there is a result for cisco, which redirects to Cisco Systems there is nothing for cisco epc2425.	It needs to be about the device if it is to be useful.
Microsoft Corporation + Windows Media Player Sharing	Microsoft Corporation redirects to Microsoft. Nothing for Windows Media Player Sharing.	The model name for the media server is Windows Media Player Sharing. As it does not return a page hardcoding is required for automation.
Microsoft Corporation + Windows Media Player	As above but there is a page for Windows_Media_Player.	Accurate.
Team XBMC +	Nothing for Team XBMC.	XBMC Media Center is the model

XBMC Media Center	XBMC_Media_Center redirects to XBMC	name for the media server.
Team XBMC + XBMC	As above.	XBMC is the model name for the media renderer. Although the page is what is required there is no distinction between the media server and media renderer as one redirects to the other.

Table 3-6: DBpedia results for UPnP manufacturer and model name

3.3.4.2 Local Knowledge

To improve the probability of the retrieved data being user friendly and applicable, an xml taxonomy was created to map the detected UPnP device type to another term: this term was then used to query DBpedia for Wikipedia's English abstract. A rudimentary xml with the device type and the term to be mapped, as children of a device node, would have sufficed but to avoid limiting the flexibility of the mappings the device category structure from UPnP Forum's webpage on Device Control Protocols [44] was used. The hierarchy of this xml can be seen in Table 3-10, the mapped terms for each UPnP device type in Table **3**-**7**, a snapshot of the xml for the UPnP Networking category in Figure 3-4, with more detailed information in **Appendix E** . The schema for the xml was automatically generated using an online tool [45].

UPnP Device Type Term Maps		
UPnP Category Name	UPnP Device Type	Mapped To
Networking	InternetGatewayDevice	Residential_gateway
Audio/Video	MediaServer	UPnP_AV_media_server
Audio/Video	MediaRenderer	Portable_media_player
Printer	printer	Printer_(computing)
Scanner	scanner	Image_scanner

Table 3-7: Mappings for UPnP device types

Ideally the terms would be less hardcoded but it was a necessary step to ensure that some information was returned to the user and also that it would not be overly technical. DBpedia harvests its data automatically from the structured data on Wikipedia which is a community effort, therefore the pages can change at any time, Figure D-13: as a result each of the terms in Table **3**-**8** (and the more complete version of the table in Table **E**-**2**) were re-checked on the 24th of September 2011.

DBpedia Results for Mapped Terms		
UPnP Device Type	If Mapped To	Results from DBpedia
InternetGatewayDevice	Internet_Gateway_Device	Re-routes to

	[46]	Internet_Gateway_Device_Protocol [47]. Want returned information to explain what a residential gateway or router is. Protocol details are likely to be too technical for the novice user and may only confuse rather than inform.
	Router [48]	No English abstract.
	Router_(computing) [49]	OK but need to know in advance and take URL encoding into account i.e. Router_%28computing%29
	Residental_Gateway [50]	"No further information is available. (The requested entity is unknown)"
	Residental_gateway [51]	OK
printer	Printer [61]	No abstract in any language.
scanner	Scanner [63]	No English abstract.
Home Area Network		
HAN (Not from UPnP)	HAN [65]	Re-routes to Han. No English abstract. The content refers to a Chinese surname or ethnic group.
	Home_network [66]	OK
	Home_Area_Network [67]	"No further information is available. (The requested entity is unknown)"
	Home_area_network [66]	OK. Re-routes to Home_network.
	Residential_network [68]	Re-routes to ResNet [69]: a large Local Area Network (LAN) or Metropolitan Area Network (MAN).

Table 3-8: DBpedia results for mapped terms

Device Categories

- **Audio/Video**
  - MediaServer:4 and MediaRenderer:3
  - MediaServer:3
  - MediaServer:2 and MediaRenderer:2
  - MediaServer:1 and MediaRenderer:1
- **Basic**
  - Basic Device:1
- **Device Management**
  - ManageableDevice:1
- **Home Automation**
  - SolarProtectionBlind:1
  - Digital Security Camera:1
  - HVAC:1
  - Lighting Controls:1
- **Networking**
  - Internet Gateway:2
  - Internet Gateway:1
  - WLAN Access Point:1
- **Printer**
  - Printer Enhanced:1
  - Printer Basic:1
- **Remote Access**
  - RAServer:2 and RADiscoveryAgent:2
  - RAClient:1, RAServer:1 and RADiscoveryAgent:1
- **Remoting**
  - Remote UI Client:1 and Remote UI Server:1
- **Scanner**
  - Scanner:1
- **Telephony**
  - Telephony:1

Table 3-9: UPnP.org device categories [90]

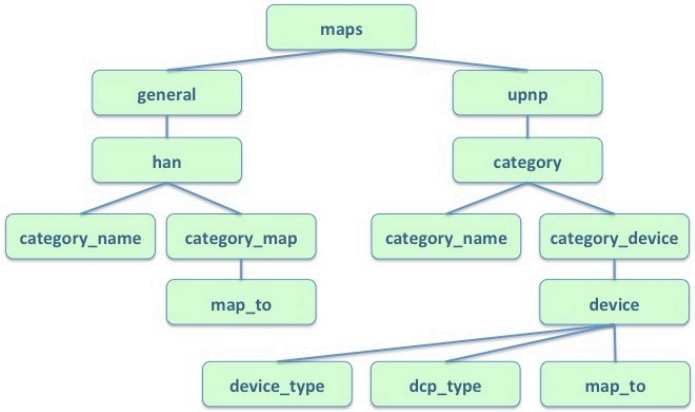

Table 3-10: Hierarchy of DeviceMapping.xml

```
<?xml version='1.0'?>
<maps
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:noNamespaceSchemaLocation="DeviceMapping.xsd">
...
<upnp>
    <!-- Other Categories e.g. Audio/Video, Printer, Scanner, Telephony -->
    ...
    <category>
        <category_name>Networking</category_name>
        <category_device>
            <!-- Other devices e.g. InternetGatewayDevice:1, WLAN Access Point:1 -->
            ...
            <device>
                <device_type>urn:schemas-upnp-org:device:InternetGatewayDevice:1</device_type>
                <dcp_type>Internet Gateway:1</dcp_type>
                <map_to name="Residential Gateway">Residential_gateway</map_to>
                <map_to name="Router">Router_(computing)</map_to>
            </device>
            ...
        </category_device>
    </category>
</upnp>
...
</maps>
```

Figure 3-4: DeviceMapping.xml code snippet for InternetGatewayDevice

3.3.5 Use Case

3.3.5.1 Overall System

The revised use case for the system is

- The UPnP client detects the devices on the Home Area Network.
- Those devices are displayed to the user as they are detected.
- When the user clicks on the device name, the UPnP device type is mapped to a user-friendly term e.g. InternetGatewayDevice to Residential Gateway.
- DBpedia is queried for the English abstract of this term using SPARQL.
- The abstract is displayed on the GUI to explain the device to the user.

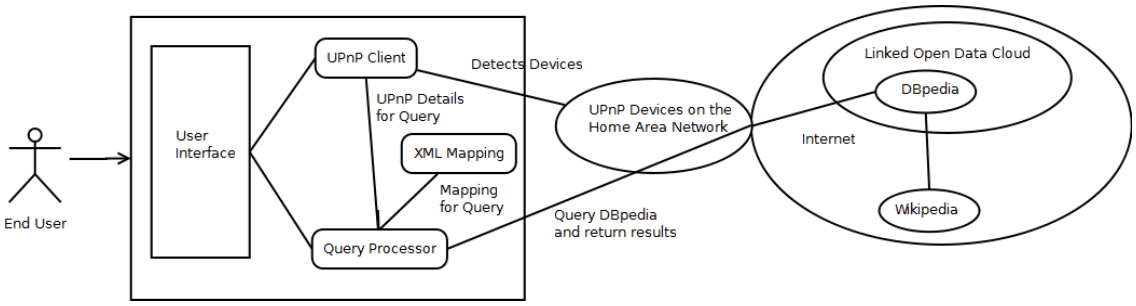

Figure 3-5: Use Case for overall system

3.3.5.2 End User

The revised scenario for the end user is

- A novice user wants to know what the device in the corner of the sitting room, that has something to do with the broadband, is for.
- He runs the system, which automatically detects the devices on his home network.
- The devices are displayed and he clicks on each link showing the details for those devices.
- Cisco is written on the front of the device so he goes through the list of devices until he sees a manufacturer called Cisco.
- He then clicks on the model name, EPC2425, and information is displayed telling him that it is a “home networking device, used as a gateway to connect devices in the home to the Internet or other WAN”. [51]

Based on this the steps for the use case are

- Browse the devices on the HAN
- Locate the device to be explained
- Click a link to retrieve information related to that device.

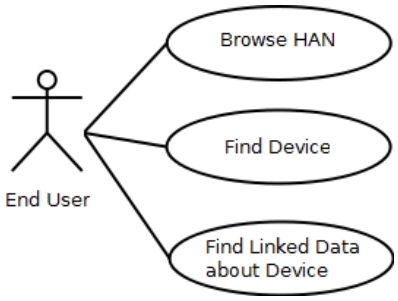

Figure 3-6: Use case for end user

3.4 Design Benefits

Taking the suggestion from the research on Home Area Networks that networking and HCI need to be combined to make networking accessible to all, automation and simplicity are the benefits of this design: the automation of device detection and information retrieval combined with the simplicity of the GUI to hide the underlying technical details.

UPnP enables the devices to be detected automatically so that the user does not need to be technically proficient while the interlinking between DBpedia and Wikipedia means that an abstract can be retrieved automatically to inform the user about a HAN device.

Simplicity is achieved by leading the user through three simple steps: Detect, Display and Inform. These steps are easily identified with an uncluttered user interface, helpful messages and tooltips. The only input required from the user is to click on a button, Detect Devices, and then a link with the device name e.g. XBMC Media Center to retrieve the information.

3.5 System Implementation

3.5.1 Classes

A description of the key classes, their fields and methods, in the development of the system follows with the class diagrams for the detectandinform and upnp packages in **Appendix F** .

3.5.1.1 DetectAndInformUI

This constructor of this class initialises the components for the Swing GUI and creates the instances for the XmlQuery and LinkedDataQuery classes. The methods for the Start and Stop buttons, jButton1ActionPerformed() and jButton2ActionPerformed() respectively, are called once the event of the user clicking happens. jButton1ActionPerformed() creates the instance of Controller to create an UPnP Control Point, listens for devices added and removed with addDeviceChangeListener() and activates the Control Point using start().

```
// Create a control point
// Pass this instance of the UI to use as an observer in
Controller.java
c = new Controller(this);
c.addDeviceChangeListener(c);
```

```
c.start();
```

The class implements both Observer and TreeSelectionListener interfaces. The Observer design pattern is used to update the user interface as devices as detected, the GUI being the observer observing the UPnPDeviceList for changes. The required update() method is called when the observable UPnPDeviceList changes i.e. when a new device is detected. This update() recreates the Swing JTree with the new devices.

```
// Get the current list of devices
ArrayList<UpnpDevice> result = new ArrayList<UpnpDevice>();
for (UpnpDevice ud : c.getCurrentUpnpDevices()) {

    // The device Model Name
    String mn = ud.getUpnpModelName();
    // Set a default value in case it's empty
    String udModelName = (!(mn.equalsIgnoreCase(""))) ? mn :
"default";

    DefaultMutableTreeNode deviceItem = new
DefaultMutableTreeNode(udModelName);
    devicesRoot.add(deviceItem);

    // Change the default icon
    if ((haveHanIcon) && (haveDeviceIcon)) {
        tree.setCellRenderer(new MyRenderer(hanIcon, deviceIcon));
    } else {
        System.err.println("Device icon missing; using default.");
    }

    // Don't want any lower nodes to be clickable

    // Children of the Model Name
    DefaultMutableTreeNode upnpDetailsItem = new
DefaultMutableTreeNode("UPnP Details");
    //DefaultMutableTreeNode mappedToItem = new

    // Children of the UPnP Details
    DefaultMutableTreeNode deviceTypeItem = new
DefaultMutableTreeNode(ud.getUpnpDeviceType());
// added for each getter e.g. getUpnpManufacturer()

    upnpDetailsItem.add(deviceTypeItem);
// added each UPnP value e.g. manufacturerItem

    result.add(ud);
}
```

The TreeSelectionListener interface is used to detect when the user has selected a node on the tree with its valueChanged() method, which then calls getDBpediaAbstractUsingMap() passing the UPnP device type. This device type e.g. urn:schemas-upnp-org:device:InternetGatewayDevice:1 is used by the xmlQuery instance to lookup a friendlier term for an Internet Gateway Device e.g. Residential Gateway. The linkedDataQuery instance uses the friendlier term in the query to DBpedia. The resulting abstract is displayed on the GUI.

```
// DOM NodeList for the mappings
NodeList mapNodeList = xmlQuery.getMapNodeList(mapType, deviceType);
// Only using the first mapping for now
String fristMapping = mapNodeList.item(0).getNodeValue();
// Use Mapping value to query Linked Data (DBpedia) for information
dbpediaAbstractList =
linkedDataQuery.getAbstractFromDBpedia(fristMapping);
dbpediaAbstract = dbpediaAbstractList.get(0).toString();
// Display the abstract on the GUI
displayAbstractOnUI(dbpediaAbstract);
```

3.5.1.2 UpnpDeviceList

The watched UpnpDeviceList class extends Observable with the update() method being called with changes. An UPnPDeviceList object contains an ArrayList of UPnPDeivce objects i.e. devices detected by the UPnP Control Point.

```
this.upnpDevices.add(ud);
// tell the UI that this has changed
this.setChanged();
this.notifyObservers();
```

3.5.1.3 UpnpDevice

An UpnpDevice object contains fields for each of the UPnP device details detected (upnpDeviceType, upnpFriendlyName, upnpManufacturer, upnpManufacturerURL, upnpModelDescription, upnpModelName, upnpModelURL, upnpModelNumber and upnpSerialNumber) with getters and setters for each.

3.5.1.4 XmlQuery

The XmlQuery class reads the content from DeviceMapping.xml and uses xpath to retrieve the friendlier term for the device type passed in to it.

```
// Create an XPathFactory
XPathFactory xFactory = XPathFactory.newInstance();
// Create a XPath object
XPath xpath = xFactory.newXPath();
xpath.compile("/maps/upnp/category/category_device/device[device_type=
'" + deviceType + "']/map_to[1]/text()");
// Run the query and get a nodeset
Object result = expr.evaluate(doc, XPathConstants.NODESET);
// Cast the result to a DOM NodeList
NodeList mapNodeList = (NodeList) result;
```

3.5.1.5 LinkedDataQuery

The LinkedDataQuery class has two main methods: checkIfDbpediaIsUp() and getAbstractFromDBpedia(). checkIfDbpediaIsUp() queries DBpedia's SPARQL endpoint with an ASK{} which if the return value is true then getAbstractFromDBpedia() queries DBpedia for the English abstract.

```
String queryItem = thing.replaceAll(" ", "_");
String service = "http://dbpedia.org/sparql";
```

```
String sparqlQuery =
        "PREFIX : <http://dbpedia.org/resource/> "
        + "PREFIX dbpedia: <http://dbpedia.org/> "
        + "PREFIX dbpedia2: <http://dbpedia.org/property/> "
        + "PREFIX dbont: <http://dbpedia.org/ontology/> "
        + "   SELECT ?abstract "
        + "   WHERE {  "
        + "       <http://dbpedia.org/resource/" + queryItem + ">
<http://dbpedia.org/ontology/abstract> ?abstract. "
        + "       FILTER langMatches( lang(?abstract), 'en') ."
        + "       FILTER (! regex(str(?abstract), '&')) . "
        + "   } ";
Query query = QueryFactory.create(sparqlQuery);
QueryExecution qexec = QueryExecutionFactory.sparqlService(service,
query);
```

3.5.1.6 Controller

The Controller class extends CyberLink's ControlPoint and implements the DeviceChangeListener to detect devices added or removed with the deviceAdded() and deviceRemoved() methods. The UPnP devices on the network automatically respond to the Control Point's search request. deviceAdded() calls addDeviceToDeviceList(), which creates the UpnpDevice for that device and adds it to the UpnpDeviceList.

```
UpnpDevice ud = new UpnpDevice();
ud.setUpnpDeviceType(deviceNode.getNodeValue("deviceType"));
ud.setUpnpFriendlyName(deviceNode.getNodeValue("friendlyName"));
ud.setUpnpManufacturer(deviceNode.getNodeValue("manufacturer"));
ud.setUpnpManufacturerURL(deviceNode.getNodeValue("manufacturerURL"));
ud.setUpnpModelDescription(deviceNode.getNodeValue("modelDescription")
);
ud.setUpnpModelName(deviceNode.getNodeValue("modelName"));
ud.setUpnpModelURL(deviceNode.getNodeValue("modelURL"));
ud.setUpnpModelNumber(deviceNode.getNodeValue("modelNumber"));
ud.setUpnpSerialNumber(deviceNode.getNodeValue("serialNumber"));
upnpDeviceList.addUpnpDevice(ud);
```

3.5.2 Mimicked Devices

To create the simulated devices, using dummy description and service xml files, for the evaluation Jan Newmarch's Echo Device [31] was used as a template with the UPnP/AV Device Capability Database, [32], providing the UPnP details for the Phillips Wireless Music Center and the Xbox 360.

3.6 Summary

Although the automation of detection and retrieval was achieved the value of the detected information was less successful than expected considering the vast amount of information interlinked on the web. As of July 2011, DBpedia's data set describes 3.64 million things with "6,300,000 links to external web pages" and "6,200,000 external links into other RDF datasets", [43], so the extent of manual intervention and hardcoding of terms to achieve results was not expected. Due to inconsistencies with the UPnP details hardcoding is required to facilitate the automation. UPnP issues include

- www.broadcom.com is the manufacturer URL and model URL for Cisco EPC2425: it would be more helpful if the URLs related to the device manufacturer and model.
- XBMC Media Center (the media server) and XBMC (the media renderer) use http://www.xbmc.org for both the manufacturer and model URLs: they should be different although ok for the model.
- Windows Media Player and Windows Media Centre when running on the same machine (though at different times) display the exact same information, Figure D-11 and Figure D-12. It would be more helpful if the products could be distinguished.
- The various IDs, presentation URLs and icon paths were of no use.

Chapter 4

4 Evaluation

4.1 Introduction

An email was sent to the Mobile and Ubiquitous Masters Course in TCD to recruit participants for an evaluation of the prototype. Ethics approval from the TCD Ethics Committee was sought and granted by submitting 5 documents: an ethics approval form, a participant information sheet, a participant consent form, a research project proposal and a questionnaire. The 30-minute one-to-one evaluations, with eight participants, were held over two days in the Westland Square Laboratory, Room 2.1.

To achieve a tractable experiment on a consistent platform, network, connection and with the same number and type of devices the simulation setup was as follows:

- A Java swing application running on a Macbook Pro OS X 10.6 with
- iPhone 3G tethering for web access so as to remove the possibility of intermittent WiFi access in the laboratory;
- 4 UPnP enabled devices and a UPnP control point mimicked with Java to simulate the UPnP enabled network;
    - A Cisco EPC2425 Router as the Internet Gateway Device;
    - An XBMC Media Centre as the Media Server;
    - An Xbox 360 as a Media Renderer and
    - A Phillips Wireless Music Centre as a Media Renderer.

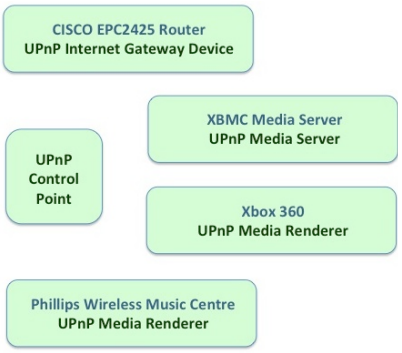

Figure 4-1: Simultated Network

The aim was to simulate a home network with typical devices sharing the bandwidth rather than a complex topology of subnets.

Each participant was given a consent form to sign, an information sheet listing the tasks to be completed, a questionnaire for feedback and was briefed about the setup. This briefing explained that the network and devices were mimicked for consistency so as to allay confusion about the lack of physical devices or expecting to see or use the college WiFi or access points. It was also pointed out that the anonymity of the participant would be preserved and that it is possible to withdraw at any time without explanation.

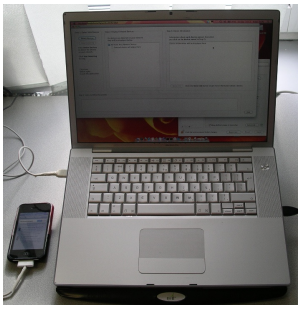

Figure 4-2: Evaluation Setup

The experiment was setup by attaching an iPhone 3GS by USB to the Macbook Pro for Internet Tethering as in Figure 4-2. A series of scripts were executed: firstly for the UPnP Control Point, then each of four UPnP devices followed by the Graphical User Interface (GUI). Once the user interface was displayed (Figure 4-3) a brief description of the layout was given. The participant started the trial by clicking the 'Detect Devices' button and was observed for the duration.

At the end when the participant had clicked on each device and retrieved information about those devices, as can be seen in Figure 4-4, a questionnaire was completed by the participant for qualitative analysis. This questionnaire took the form of 4 parts:

- **System Usability Scale** with 10 standard questions based on a Likert scale ranging from 1 to 5 indicating 'Strongly disagree' to 'Strongly agree' respectively;
- **Home Area Network Support** with 7 questions to critique the system;
- **Participant Profile** with 3 questions to allow the participants to self-assess their technical ability, HAN and Semantic Web knowledge and
- **Feedback** with 1 question for any additional information.

These questions are listed in **Appendix G** .

Figure 4-3: Graphical User Interface of Prototype

Although the prototype is aimed at novice network or non-technical users it was felt that for this first round of experiments a more technical person would be better able to determine the accuracy and the value of the information displayed. To gain greater insight into the usability of the system further evaluations would need to be carried out in the participants' homes, detecting the devices on their network that they are familiar with and also on the target group i.e. those who are less technical than students with a computing background.

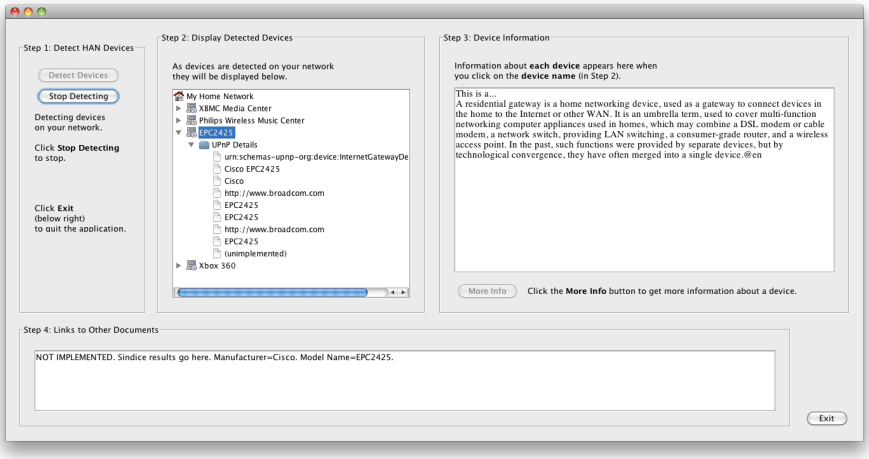

Figure 4-4: Information Retrieved for the Residential Gateway.

4.2 Goals

The evaluation was to establish how successfully four goals were achieved.

- Firstly, that the GUI was intuitive and easy to use so as not to frustrate the user while trying to complete the task.
- Secondly, to detect the devices on the network, in this case a simulated UPnP network with simulated UPnP enabled devices.
- Thirdly, to inform the user about those devices.
- Finally, that these tasks could be completed with ease while requiring minimal technical knowledge.

Human-computer interaction (HCI) focuses on whether a system is useful, usable and used and the above goals attempt to tackle each of these facets. The usefulness of the prototype i.e. whether the user can accomplish what is required, is taken into account with the second and third goals. Determining if the system is usable i.e. whether the user can use the system naturally and without fear of error, is the focus of the first and fourth goals while the combined goals should give some indication as to whether the system would be used or not. If the system fails to engage or attract the user or simply frustrates with over technical or inaccurate information then the system will not be used.

4.3 Evaluation Challenges and Considerations

The WiFi in the laboratory had been tested on a number of occasions: when using TCDwifi nothing was detected so that was ruled out as an option; however, COMPSCIwireless had been working consistently. The week prior to the evaluation COMPSCIwireless was becoming increasingly difficult to connect to or else not at all. Initially, the plan was to carry out the evaluations in the participants' homes but it was

felt that this scenario, at this stage, would involve too many variables: bandwidth; network topology; devices on the network; whether UPnP and multicasting were enabled on their router to start with and if not, would be acceptable to all household occupants to change such a setting. Using iPhone Internet Tethering was the work around for this situation with the accepted limitation of a slower connection; the knock-on effect being that the system hung quite frequently. This was explained to the participants during the briefing and although the system hung many times the participants were graciously patient.

With the 3G connection the query to Sindice was also causing the system to crash so this was replaced with a 'Not Implemented' message. Possibly with threads and a timeout this would be rectified.

Neither of these crashes occurred with the 20Mb fibre power broadband at home where devices were detected promptly, however, both were mentioned by participants on the questionnaire as can be seen in the following paragraphs.

4.4 User Evaluation Results

4.4.1 Introduction

The findings of the evaluation are based on the questionnaire results. The questions, listed in Appendix G , were designed to get an idea of the usability of the system, whether the participants felt it would be useful for novice users, their technical ability and general feedback.

4.4.2 System Usability Scale

The System Usability Scale is a Likert scale ranging from 5 to 1: the user strongly disagrees to strongly agrees, respectively. It is the composite score rather than the individual answers that is meaningful and gives an indication of the usability of the system.

As the target audience is the novice or non-technical user, the user interface was deliberately simplified into three main stepped sections: **Step1. Detect**, **Step 2. Display** and **Step 3. Inform**. The original design layered these steps vertically but it was felt that, due to reading left to right, it would be more user friendly to place these sections side by side.

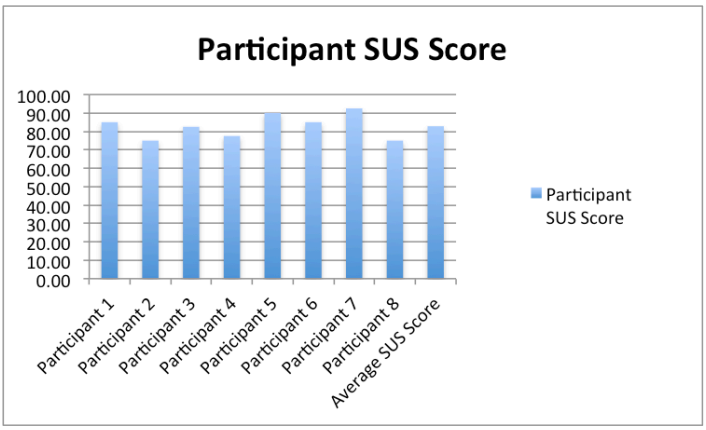

Figure 4-5: Individual and Average SUS Scores

The SUS scores range from 75 to 92.5 with a standard deviation of 6.6 so all scores tend to the positive side of usability. The 82.8 average SUS score is an

encouraging usability result, although as mentioned previously, the participants have a technical background and further evaluations would be required to determine the usability from a novice perspective. Encouraging also is that six out of eight participants mentioned the user interface in question 16: *What are the best points of the prototype*. Figure 4-5 shows the SUS scores for each participant along with the average of those scores.

The radar charts for each participant and the average of those can be seen in Figure 4-7. Participants 4 and 6 have a distorted star shaped chart due to picking the middle ground on question 8: *I found the system very cumbersome to use*. This may be due to the system's slow response or crashing as participant 6's comments are: "Nice interface and easy to use" but "Slow over network at times".

The scores varied mostly for questions 1, 7 and 8. While observing, question 1, *I think that I would like to use this system frequently,* seemed to stifle a quick response as a number of participants asked what frequently meant i.e. not looking for a translation or definition but how often is considered frequent and how it would relate to the system. It was explained that the SUS questions are generic and designed to give an overview of the usability of any system. Six out of eight participants scored question 7, *I would imagine that most people would learn to use this system very quickly*, with either a 4 or a 5 indicating that they agreed or strongly agreed with the statement. As ease-of-use is important and most mentioned the user interface in a positive light the variance was surprising but also indicative of the small sample size.

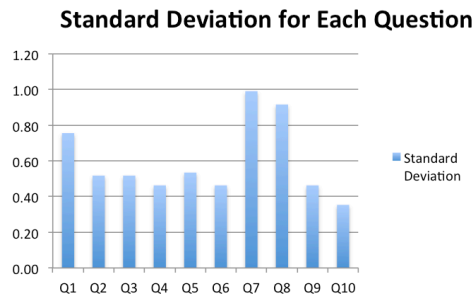

Figure 4-6: Standard Deviation per SUS Question

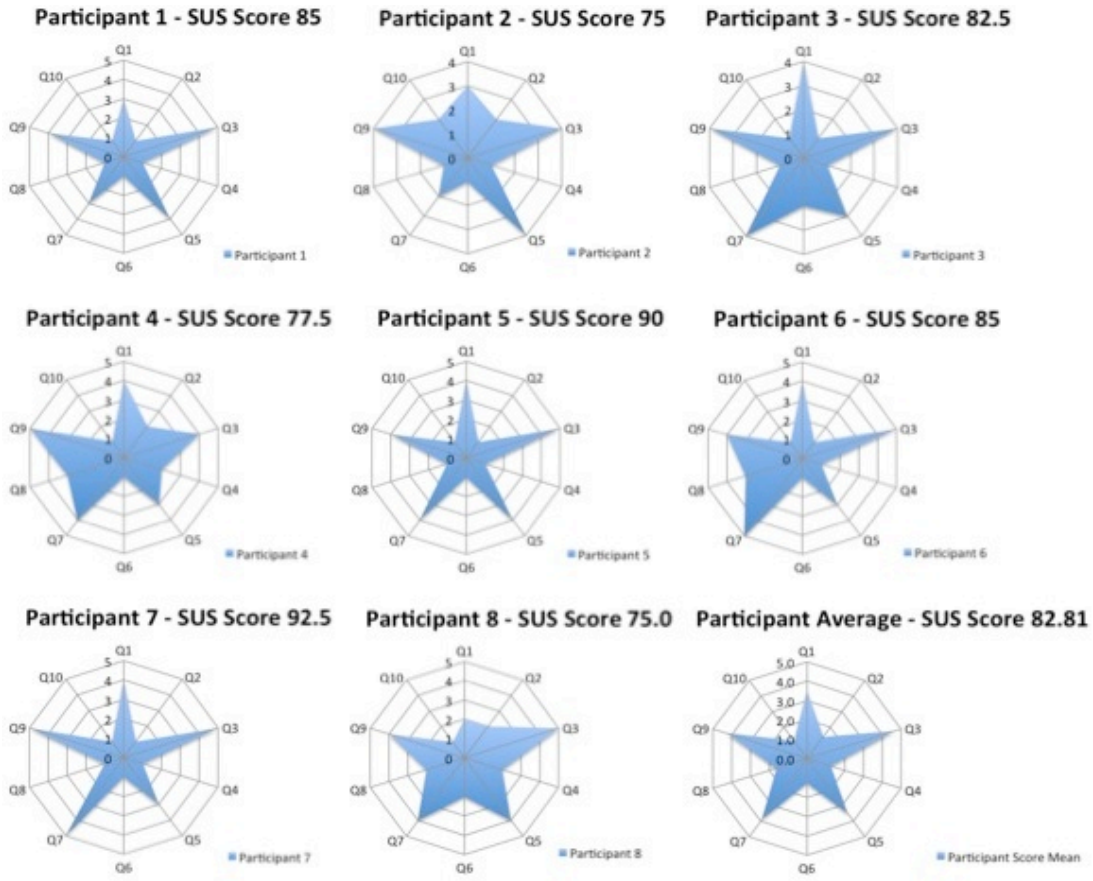

Figure 4-7: Participant Radar Charts

4.4.3 Home Area Network Support

The Home Area Network Support questions were designed to gain an insight into how well the goals were accomplished: if the system helped with the understanding of the HAN and would that be helpful to a non-technical user; whether the correct devices were displayed and if so was the information displayed relevant; there is also space to list the best points and worst points of the prototype.

4.4.3.1 Q. 11 - The prototype facilitates my understanding of the home network

No participant disagreed with this statement as Figure 4-9 shows: the lowest rating is 3, a 3.8 average and a standard deviation of 0.71. Step 2 of the GUI, Detect, dynamically populates a tree as the devices are discovered by the Control Point. The tree root element changes from 'My Home Area Network Devices' with a default icon to 'My Home Network' with a home icon when the devices have been detected; those devices displayed as child elements, Figure 4-8. Also, prior to detection, there is only one child leaf node: 'Detected devices will appear here'. The results suggest that the automatic icon and text replacement succeeds to some degree with HAN understanding.

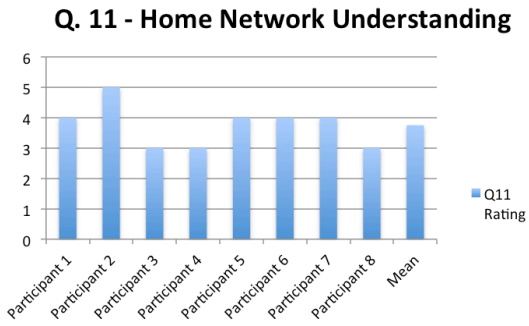

Figure 4-9: Q. 11 Results

Figure 4-8: Step 2 Display - Before and After

4.4.3.2 Q. 12 - The prototype helped me find relevant information for the network devices

Figure 4-10 shows the results for question 12: an average of 4.0, standard deviation of 0.76 and with two participants strongly agreeing that relevant information was detected. This result was surprisingly positive and it is possibly due to the technical knowledge of the participants. Less technical participants might find the Home Network or the Residential Gateway information helpful with the generic Media Server and Media Player less so.

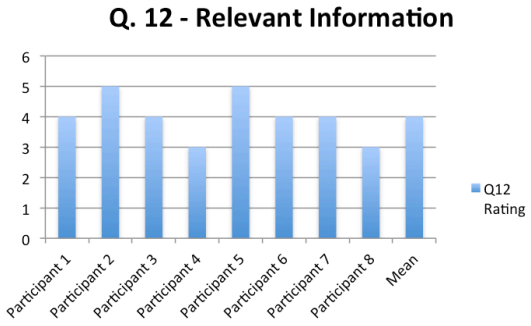

Figure 4-10: Q. 12 Results

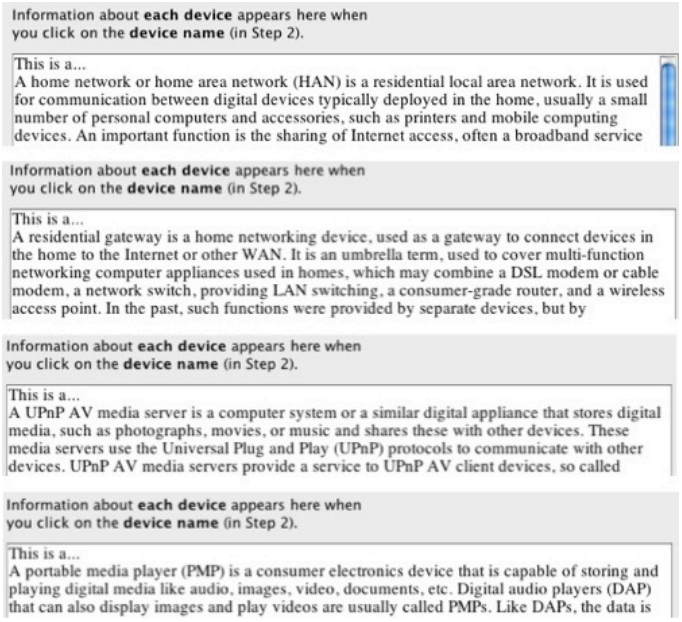

Figure 4-11: Information retrieved from DBpedia []

4.4.3.3 Q. 13 - I feel I successfully completed the tasks

All participants felt confident that they completed the tasks of detecting devices on a network and retrieving information for those devices. Half strongly agreed, half agreed giving an average rating of 4.5 with a variance of 0.53 attesting that GUI achieved its goals of simplicity and utility.

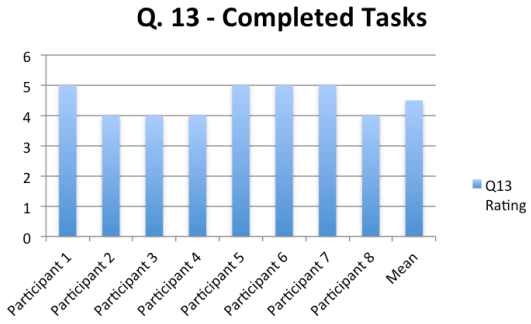

Figure 4-13: Q. 13 Results

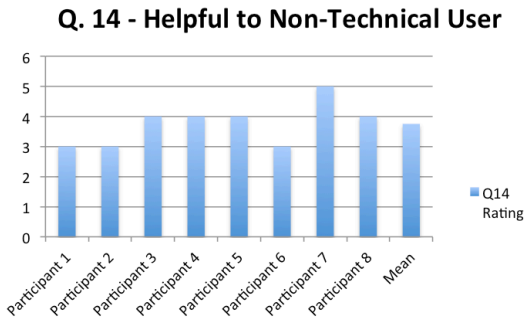

Figure 4-12: Q. 14 Results

4.4.3.4 Q. 14 - I feel the prototype would be helpful to a non-technical user

Figure 4-12 shows the results for question 14 with more than half agreeing that the system would be helpful to a non-technical user. Three participants are not convinced so this gives an average of 3.8 with a standard deviation of 0.71. Question 17, asking about the worst points of the system, gives some indication as to why two of these participants were not convinced: participant 1 put down "*Lack of information*"; while participant 2 wrote "*User interface might be unattractive to certain people*" and to the feedback question wrote "*It would need to have a shiny/attractive and easy to use GUI in order for it to be used by people with a lower technical ability*".

4.4.3.5 Q. 15 - Can you identify the devices on the network?

All participants managed to identify the items whether writing the names of the devices in the empty text box or ticking the box or writing "*yes*" to indicate that they understood which device was which.

Devices on the Simulated HAN	
Empty Textbox Title	Device Name
Router / Access Point	EPC2425
Media Server	XBMC Media Server
Media Renderer	Xbox 360
Media Renderer	Phillips Wireless Music Centre

Table 4-1: Devices on the Simulated HAN

4.4.3.6 Q. 16 - What are the best points of the prototype?

Most participants mentioned that the GUI was easy-to-use so simplifying the process into 3 steps to Detect, Display and Inform paid off, most gratifying are the comments "*It does what I was told it would do*" and "*It clearly lists all the devices in the home network*". Also encouraging is that some participants considered the information relevant and from a trusted source.

Comments from Participants	
Participant	Comment
1	UI – Simple and easy to use, clear what buttons do which task etc.
2	It clearly lists all the devices in the home network. Pulls back relevant info about each device found. It does what I was told it would do.
3	Easy to use. Collects useful info from trusted sources. Facilitates home network management.
4	Decision support and get description for home area network devices. The user interface helped use to make decisions.
5	Clear layout easy to use.
6	Nice interface and easy to use.
7	This prototype helps me to understand the devices at home.
8	Easy to use. Discovery of devices. Lot of info available.

Table 4-2: Participants' Best Points of the Prototype

4.4.3.7 Q. 17 - What are the worst points of the prototype?

Using iPhone Internet Tethering instead of WiFi means that it is no surprise that some participants mentioned the speed of the prototype. Also mentioned were a number of things that were thought of but never implemented for a number of reasons: time constraints where the 'More Info' button, device icons and User Interface are concerned and simply forgot to change the layout of the UPnP details to differentiate between device type, model name, friendly name, model description etc.

Comments from Participants	
Participant	Comment
1	Lack of information: Image of device would be great, available features, what to connect etc.
2	User interface might be unattractive to certain people. UPnP details; while they are successfully discovered, they are displayed without titles or headings so it's hard to tell what the field is describing.
3	Returns info displayed in plain text.
4	The user interface may be improved. And if it could display images for devices.
5	More info button not implemented.
6	Slow over network at times.
7	The system runs a little bit slow.

8	Slow.

Table 4-3: Participants' Worst Points of the Prototype

4.4.4 Participant Profile

For the DIY home user, technical ability and prior networking knowledge are key to the competent set-up, configuration and maintenance of the home network. For this reason the users were asked to self-assess their technical ability, networking and Semantic Web knowledge: Semantic Web for familiarity with Wikipedia, Dbpedia and Linked Data.

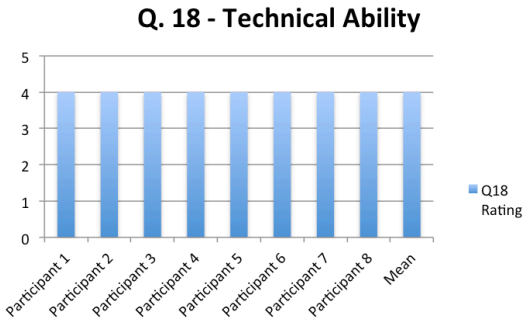

Figure 4-15: Q. 18 Results

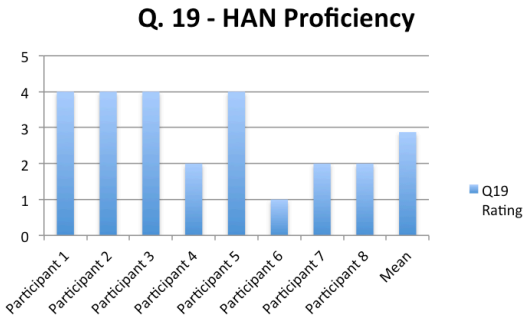

Figure 4-14: Q. 19 Results

4.4.4.1 Q. 18 - How would you describe your technical ability?

Figure 4-15 shows that all participants self-assessed their technical ability with a rating of 4: 5 being expert. This as previously mentioned was intentional to assess the relevance of the data retrieved and the ease-of-use of the prototype without the being put-off by an immature user interface.

4.4.4.2 Q. 19 - Your proficiency with a Home Area Network e.g. setup, configuration and management

Figure 4-14 shows that the HAN proficiency self-assessment is more varied with a 2.9 average and a standard deviation of 1.25. The ratings from participant 1 and participant 6 for the HAN support questions 11, 12, 13 and 14 are the exact same: 4 for facilitating understanding, 4 for relevant information, 5 for completion of tasks and 3 for helpful to a non-technical user (1 indicating strongly disagree, 5 indicating strongly agree).

4.4.4.3 Q. 20 - Your proficiency with the Semantic Web e.g. Wikipedia, DBpedia, Linked Data

Semantic Web proficiency varied as can be seen in Figure 4-16 with a mean rating of 3.5 and 0.93 standard deviation. Both participants 2 and 3 mentioned the information retrieved with "*Pulls back relevant info about each device found*" and "*Collects useful info from trusted sources*" respectively.

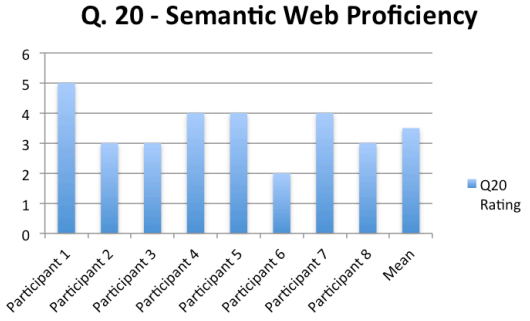

Figure 4-16: Q. 20 Results

4.4.5 Feedback

The final question simply afforded space for additional information that may not have been addressed by the other questions. Some of the comments mentioned ease-of-use and the need for more information but also it was noted that no in-depth tutorial was required to understand the system and that it could be helpful for a novice when seeking technical support i.e. the target group.

- "*I think this could be very useful for a novice user who has a network issue and wants to call tech-support but doesn't know anything about the devices in the network. It would need to have a shiny/attractive and easy to use GUI in order for it to be used by people with a lower technical ability*."
- "*The prototype can be improved by providing more information on the selected devices*."
- "*It is a handy use system for me to understand the devices at home easier. With simple operation and without complex tutorial. [Sic]*"

4.5 Summary

The overall tone of the evaluation is positive with robust SUS scores from 75 to 92.5, averaging 82.81. The four goals have been achieved with varying degrees. From the participants responses the GUI is easy-to-use and intuitive so that the tasks can be completed without frustration. All devices that are on the UPnP network are detected with information retrieved displayed when the user clicks the device name on the GUI. Having technically minded participants has pros and cons: pro that they are not blinded by an immature user interface; pro that they may well expect more from that interface so a positive result for the GUI from such a group is encouraging; pro that they can critique the displayed information; but con that this group is not the target audience and con that it is more difficult to determine whether a novice user would find the system useful, usable and therefore used.

Chapter 5

5 Conclusions and Future Work

5.1 Conclusions

The revised goal of the dissertation was to inform the home user, with limited networking knowledge, about the devices on the home network: automation the key to making the system novice-user friendly. The intention throughout was to work with both networking and usability in tandem. The goal has been achieved to some extent in that a prototype was developed capable of detecting HAN devices and retrieving linked data to inform the user about those devices, with a promising usability score of 83% from the evaluation, albeit with technical users. The usability objective was more successful than the prototype's ability to inform: the user interface with three leading steps was simple and intuitive with many evaluation participants commenting positively on it; however, manual intervention was needed to, not only determine the best path to appropriate linked data, but also to hardcode values to ensure an appropriate result. This hardcoding is in conflict with the necessary automation and reduces the flexibility of the prototype.

The middleware used detected a subset of the devices on the HAN. This was working-as-designed for the purpose of the dissertation but in reality a middleware to detect all devices would be required as omitting the device that a user wants information about would cause frustration and reduce confidence in the system. UPnP, however, works well for detection but for it to be more useful to retrieving machine-readable linked data and as a result fostering confidence in the retrieved information stricter adherence to the schema is required. As more DLNA compliant products are released to the market more products will be detectable by UPnP due to DLNA's UPnP certification requirement but the gap between the UPnP details and linked data needs to be bridged.

Can the automation of retrieval of information from the Semantic Web reduce the technical knowledge and input required to inform a novice home user about the devices on the Home Area Network? The answer to the research question is a cautious yes as although it is possible to automatically retrieve and inform manual intervention was required to bridge the gap between the retrieval details and the linked data. Also ideally, to increase usability for the novice user, the technical information would need to be simplified, along the lines of the Dummy series of books, [70].

5.2 Future Work

5.2.1 Linked Data Retrieval

Research on the upgraded Sindice Search API v3 could be carried out to see if a mixture of the query parameters could produce more applicable data for the devices detected: similarly with more sophisticated SPARQL queries. ProductDB was initially thought to be promising but requiring a specific ID meant that it could not be used for this dissertation. The website mentions that the beta version will allow a search using a URL, this could be of value if the manufacturers of the UPnP devices strictly adhered to the meaning of modelURL.

5.2.2 Middleware

Although there is potential for a lot of devices to be UPnP enabled it would be prudent to research how effectively other middeware, or a mixture of middleware, solutions detect the HAN devices and what information they offer as a source for linked data retrieval.

5.2.3 User Interface

The user interface could be improved by: adding device icons for each device; adding a print facility so that a user would have the information to hand for technical calls or when wanting to purchase compatible equipment for the HAN; a clearer display of the UPnP details; adding a panel for Internet search results along with a panel for the linked data results. Also, a mobile version of the prototype so that the user would have the information to hand, saved on the phone, for technical calls etc.

Appendix A Abbreviations

Abbreviations		
A	AP	Access Point
	API	Application Programming Interface
	ASIN	Amazon Standard Identification Number
B		
C	CKAN	Comprehensive Knowledge Archive Network
	CSV	Comma Separated Values
D	DHCP	Dynamic Host Configuration Protocol
	DIY	Do It Yourself
	DLNA	Digital Living Network Alliance
	DomoML	Domotic Markup Language
	DSL	Digital Subscriber Line
E	EAN	European Article Number renamed to International Article Number
F		
G	GUI	Graphical User Interface
H	HAN	Home Area Network
	HAVi	Home Audio Video Interoperability
	HCI	Human Computer Interaction
	HTML	Hypertext Markup Language
	HTTP	HyperText Transfer Protocol
I	ICEbox	Installation Configuration and Evolution box
	IGD	Internet Gateway Device
	IP	Internet Protocol
	ISBN	International Standard Book Number
J		
K	Kb	Kilobit
	KB	KiloByte
	Kbps	Kilobits Per Second
L	LAN	Local Area Network
M	MAN	Metropolitan Area Network
	Mb	Megabit
	MB	Megabyte

	Mbps	Megabits Per Second
N	NAT	Network Address Translation
O		
P		
Q	QoE	Quality of Experience
	QoS	Quality of Service
R	RDF	Resource Description Framework
	RDFa	Resource Description Framework in attributes
	RF	Radio Frequency
S	SIOC	Semantically-Interlinked Online Communities
	SPARQL	Simple Protocol and RDF Query Language
	SOAP	Simple Object Access Protocol
	SUS	System Usability Scale
T	TCD	Trinity College Dublin
	TCP	Transmission Control Protocol
	TCP/IP	Transmission Control Protocol/Internet Protocol
	TM	Tech Manager
	TTL	Time To Live
U	UDP	User Datagram Protocol
	UI	User Interface
	UPC	Universal Product Code
	UPnP	Universal Plug and Play
	URI	Uniform Resource Identifier
	URL	Uniform Resource Locator
	USB	Universal Serial Bus
V		
W	WiFi	Wireless Fidelity
	WRT	Wireless Receiver/Transmitter
X	XBMC	XBox Media Center
	XFN	XHTML Friends Network
	XHTML	eXtensible HyperText Markup Language
	XML	eXtensible Markup Language
Y		
Z		

Table A-1: Table of Abbreviations

Appendix B UPnP Details

UPnP Details Detected for Real Devices on the HAN					
UPnP Details	**Cisco EPC2425**	**XBMC Media Server**	**XBMC Media Renderer**	**Windows Media Player**	**Media Connect**
Device Type	urn:schemas-upnp-org:device: followed by				
	Internet GatewayDevice :1	Media Server :1	Media Renderer :1	Media Renderer :1	Media Renderer :1
Friendly Name	Cisco EPC2425	XBMC: Media Server: (192.168.1.14)	XBMC: Media Renderer (192.168.1.14)	EMER-PC	media: connect: renderer [Emer Duffy's iPhone]
Manufacturer	Cisco	Team XBMC	Team XBMC	Microsoft Corporation	persona software®
Manufacturer URL	http://www.broadcom.com	http://www.xbmc.org/	http://www.xbmc.org/	http://www.microsoft.com	http://www.personasoftware.com/
Model Description	EPC2425	XBMC Media Center - Media Server	XBMC Media Center - Media Renderer	Windows Media Player Renderer	persona software® media: renderer: mobile
Model Name	EPC2425	XBMC Media Center	XBMC	Windows Media Player	M-DMR
Model Number	EPC2425	1.0	2.0	12	1.0
Model URL	http://www.broadcom.com	http://www.xbmc.org/	http://www.xbmc.org/	http://go.microsoft.com/fwlink/?LinkId=105927	http://www.personasoftware.com/
Serial Number	(unimplemented)			{C4D3CD50-DBF5-4463-9FBA-	{b42581ce48a9bc6d37b9cdc42e00c01bff94b

				2A3ADD584E51}	b97}
UDN	uuid: followed by				
	upnp-InternetGatewayDevice-1_0-00223ad96e58	3ed5b5e3-d897-eaa3-20d-d7bca290c716	77d18804-0dce-3cf7-85c8-f11b300d24c2	80c99234-2576-43b8-8302-48ece294c409	3bf69843-9066-435a-ac5c-cf3849f1dfbb
UPC	(unimplemented)				
Presentation URL	/index.htm	http://192.168.1.14:8080/	http://192.168.1.14:8080/		/renderer.html
dlna: X_DLNADOC		DMS-1.50	DMR-1.50		M-DMR-1.50
dlna: X_DLNACAP					
microsoft: magicPacketSendSupported				1	
Device List	✔				
Icon List		✔ e.g. /images/platinum-120x120.jpg	✔ e.g. /images/platinum-120x120.jpg	✔ e.g. /upnphost/udhisapi.dll?content=uuid:e70007de-541e-4f81-8b1f-9741799d407b	✔ /icons/sericon120x120.jpg
Service List	✔	✔	✔	✔	✔

Table B-1: UPnP details detected for real devices on the HAN

Appendix C Paper Prototypes

C.1 Initial Thoughts

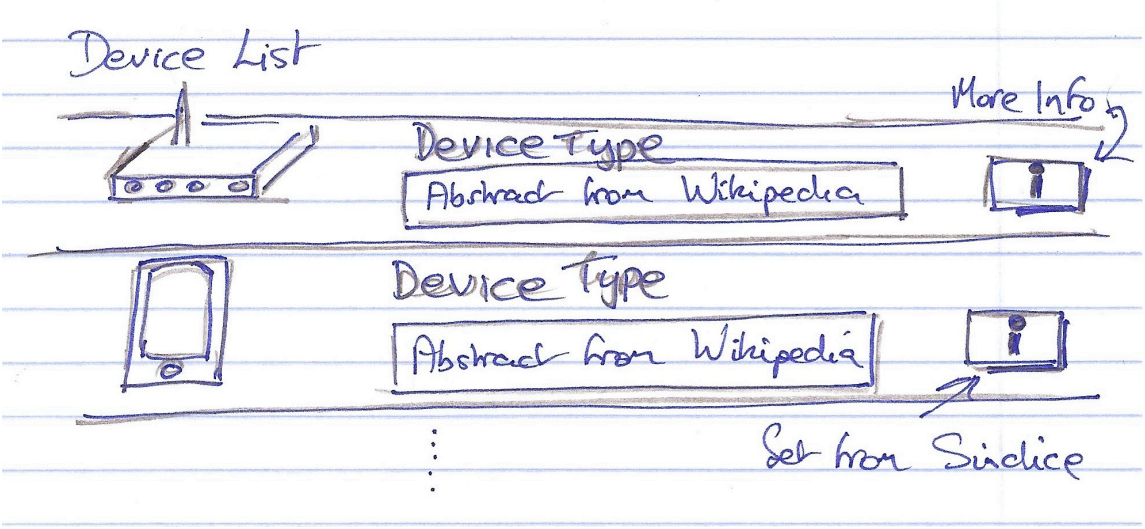

Figure C-1: Table Layout for Devices

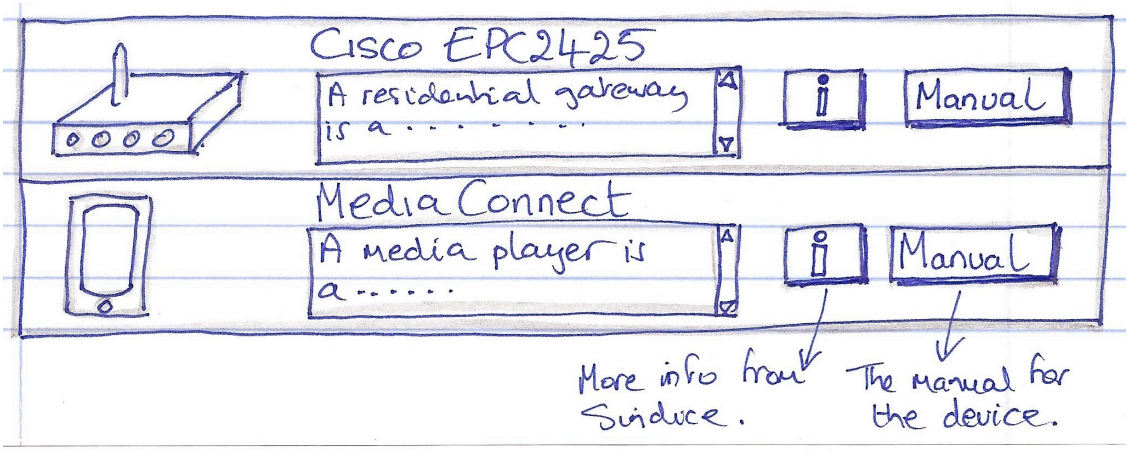

Figure C-2: Table Layout with Manual Button

C.2 Confirm Network

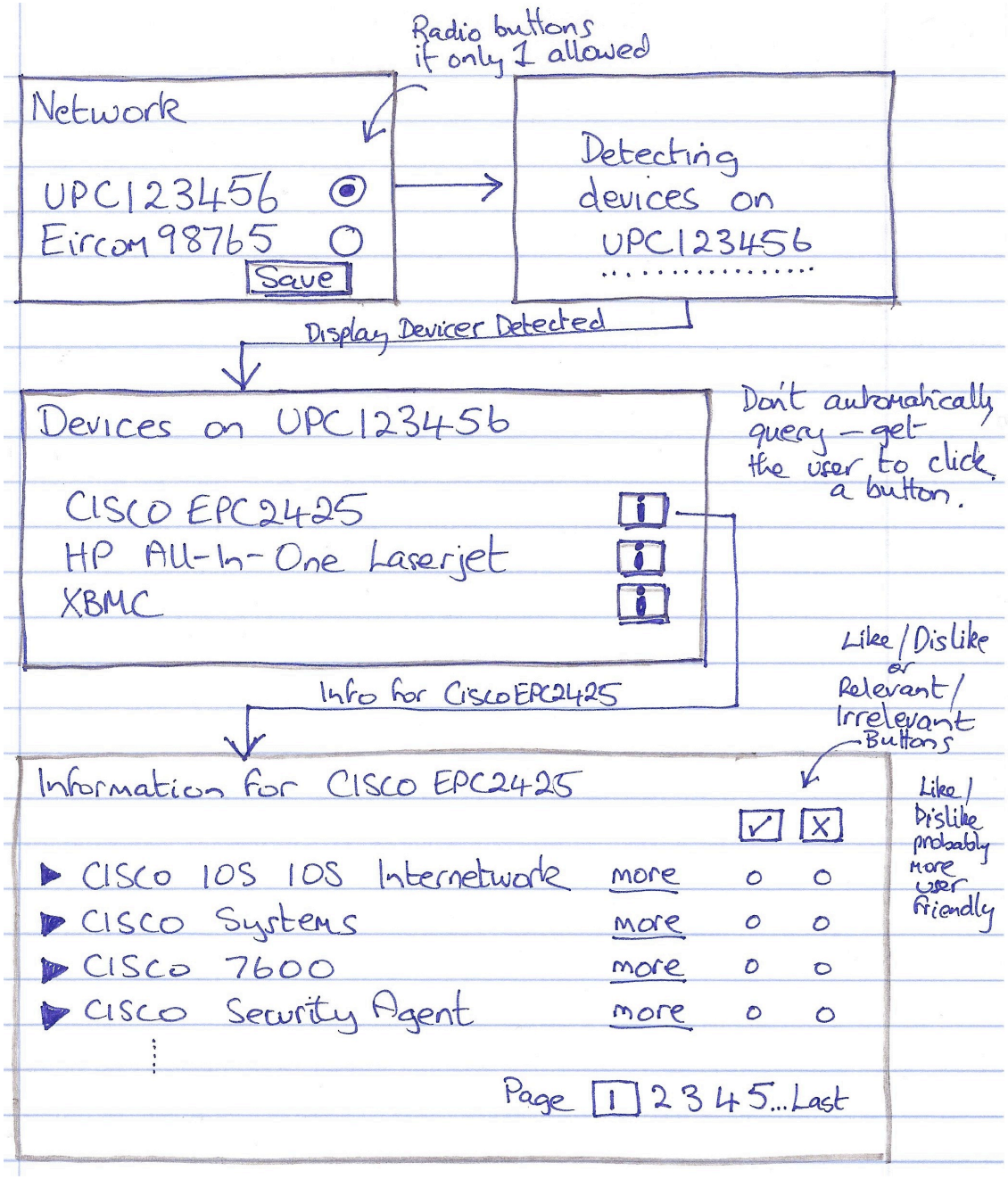

Figure C-3: Confirm the network with Like and Dislike buttons

C.3 Tabbed Layout

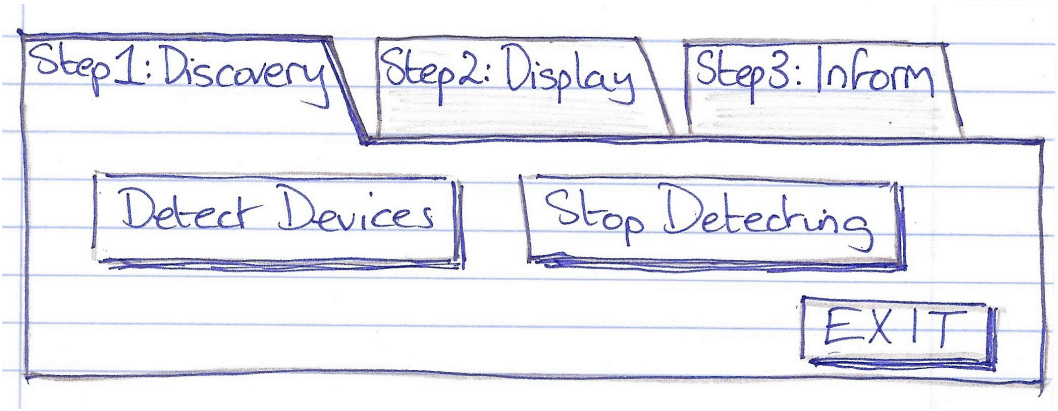

Figure C-4: Tabbed Layout for Devices

C.4 Web Page Layout

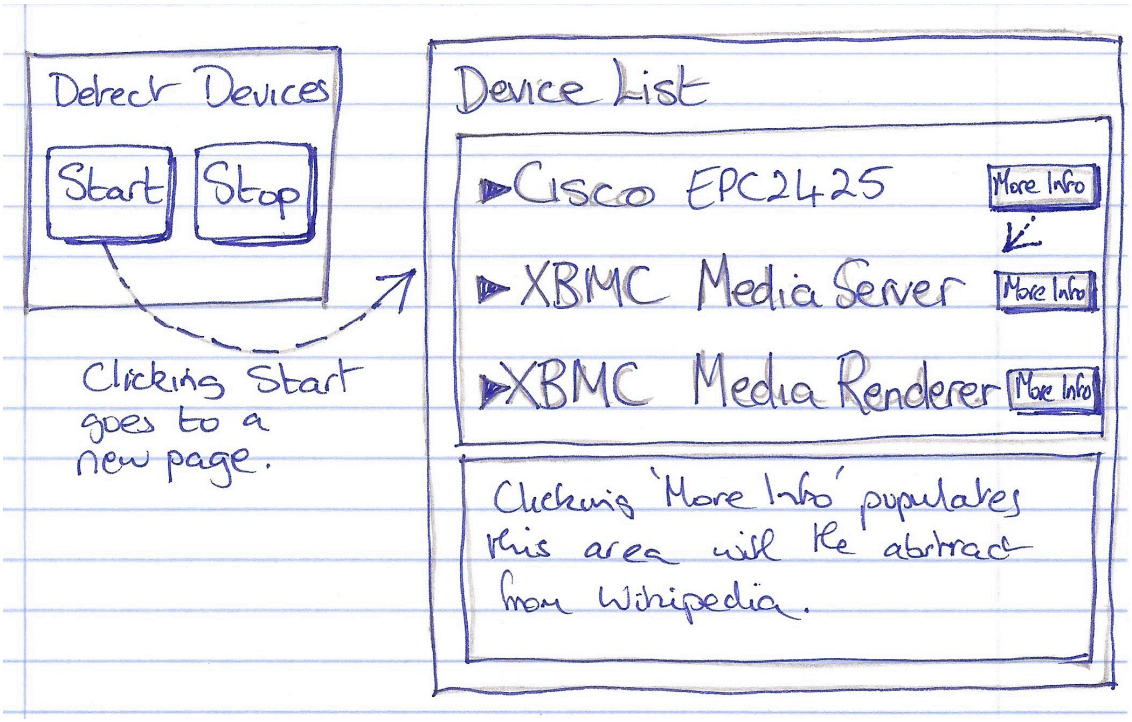

Figure C-5: Web Page Layout for Devices

C.5 Vertical Layout

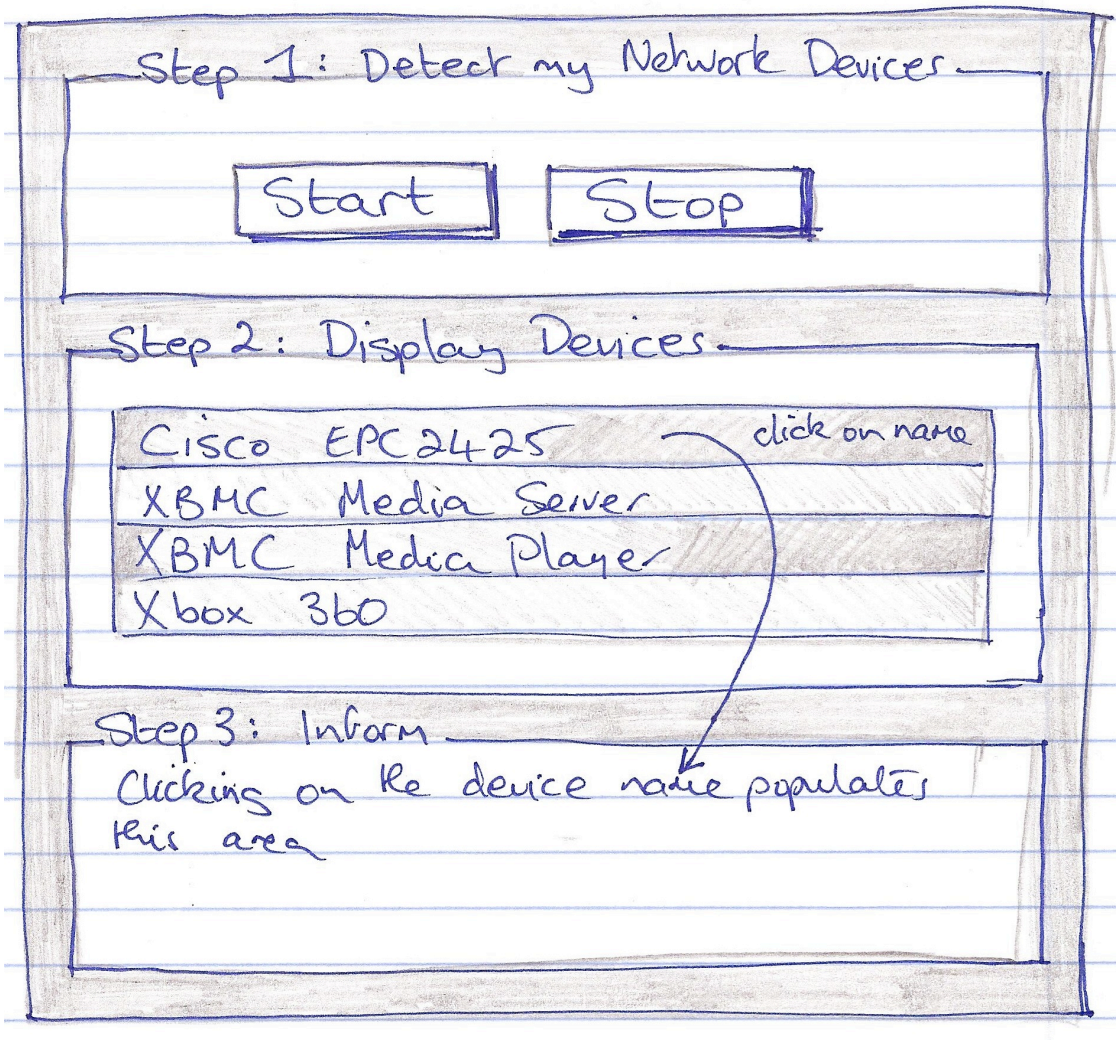

Figure C-6: Vertical Layout for Devices

C.6 Horizontal Layout

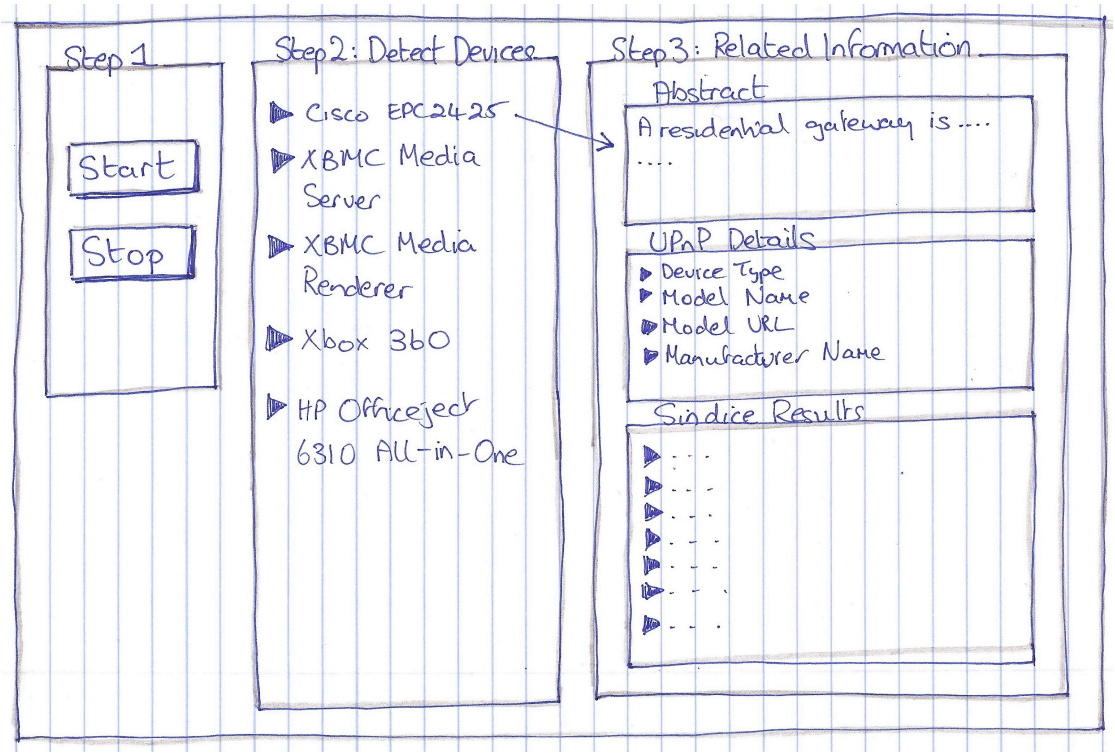

Figure C-7: Horizontal Layout for Devices

Appendix D Prototype Screenshots

D.1 First Screen

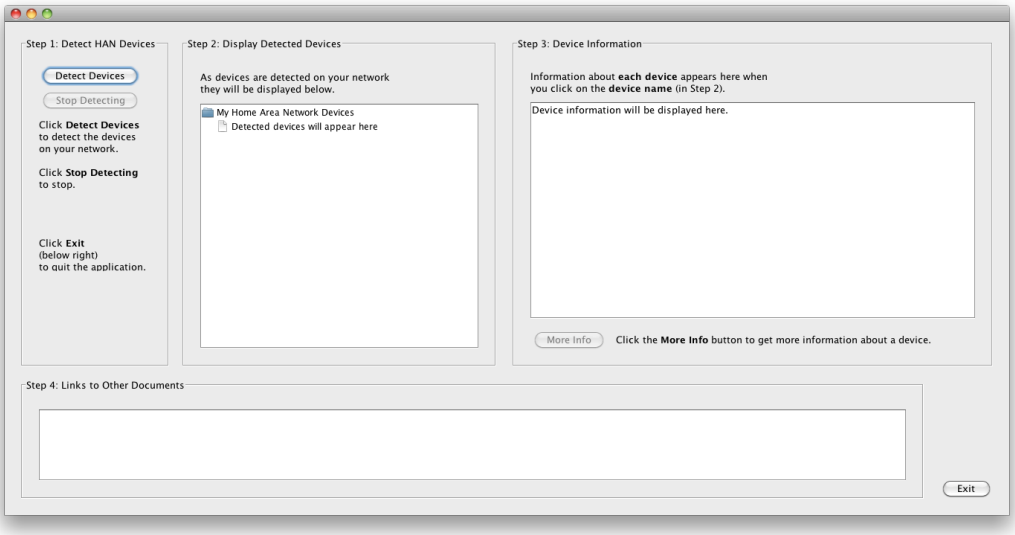

Figure D-1: Prototype Start Screen

D.2 Devices Detected on the Simulated Network for Evaluation

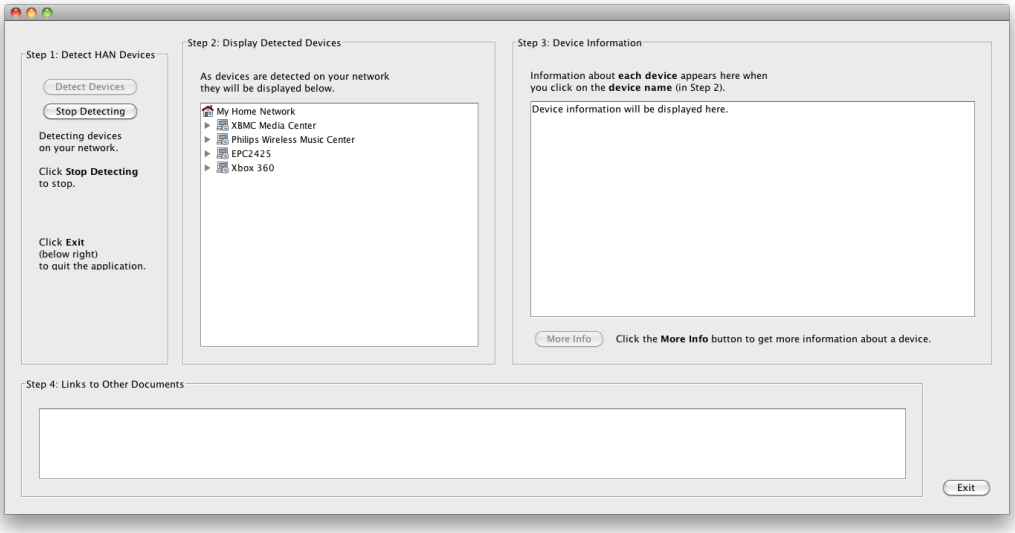

Figure D-2: Detected Devices on the Simulated Network

D.3 Devices Detected Using WiFi

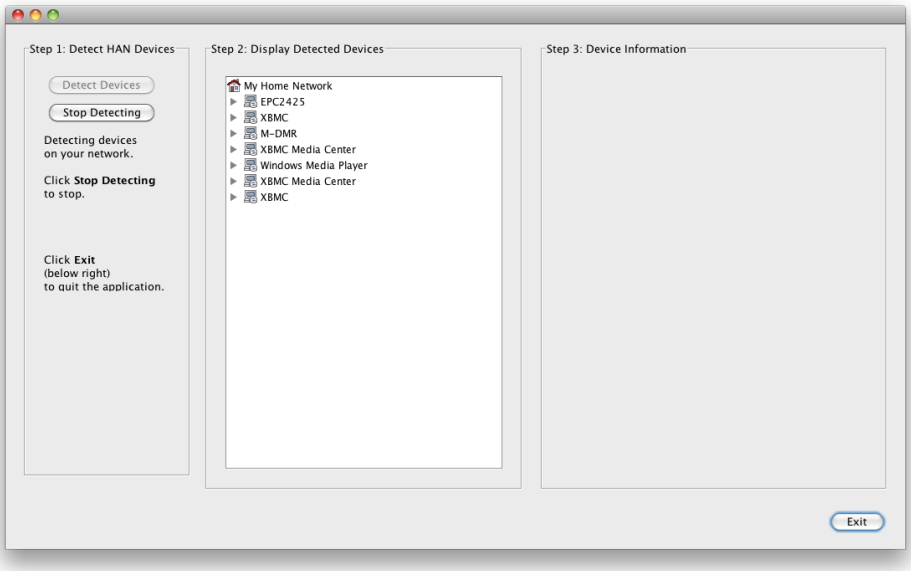

Figure D-3: Detecting Devices using WiFi with the same applications e.g. XBMC on different laptops.

D.4 Information Retrieval – My Home Network

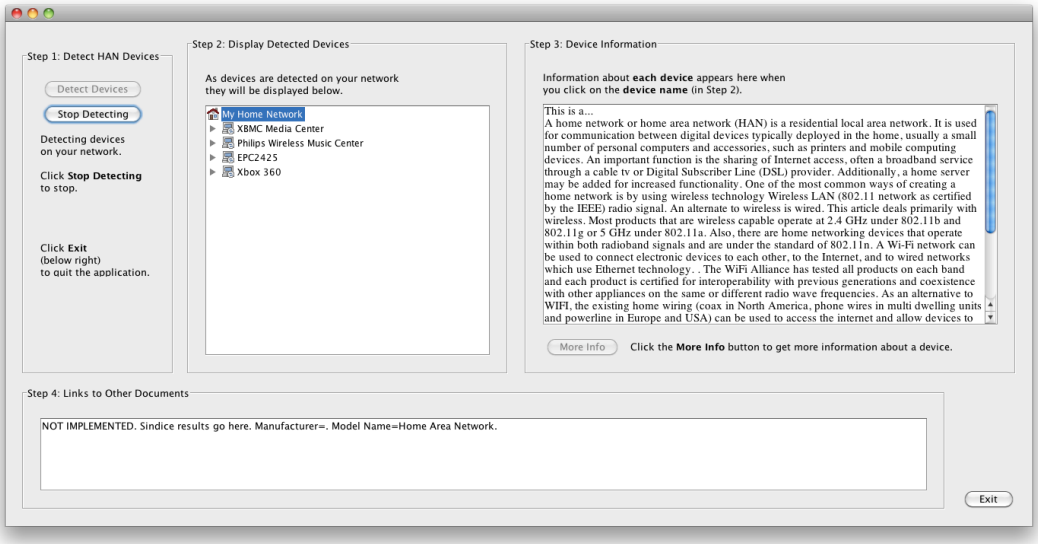

Figure D-4: Information Retrieval - Clicking on 'My Home Network' retrieves the Wikipedia English abstract for a home network by querying DBpedia's SPARQL endpoint.

D.5 Information Retrieval – XBMC Media Center

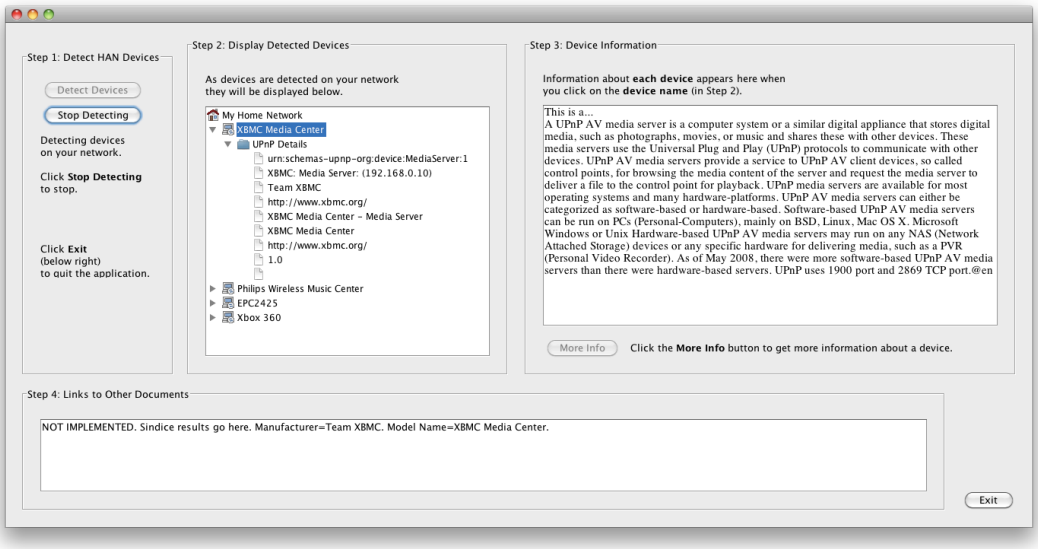

Figure D-5: Information Retrieval - Clicking on 'XBMC Media Center' retrieves the Wikipedia English abstract for a UPnP AV Media Server.

D.6 Information Retrieval – Philips Wireless Music Center

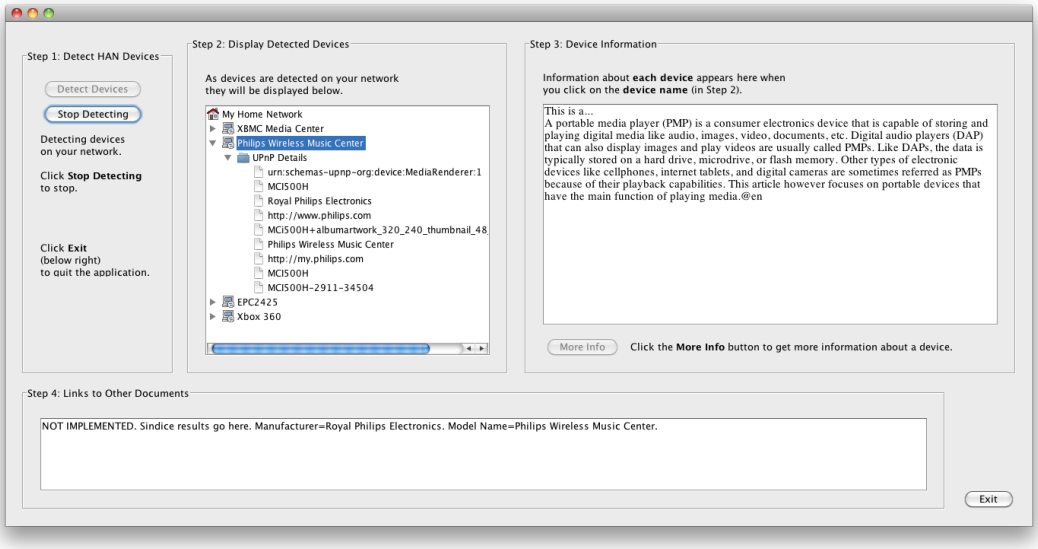

Figure D-6: Information Retrieval - Clicking on 'Philips Wireless Music Center' retrieves the Wikipedia English abstract for a Portable Media Player.

D.7 Information Retrieval – EPC2425

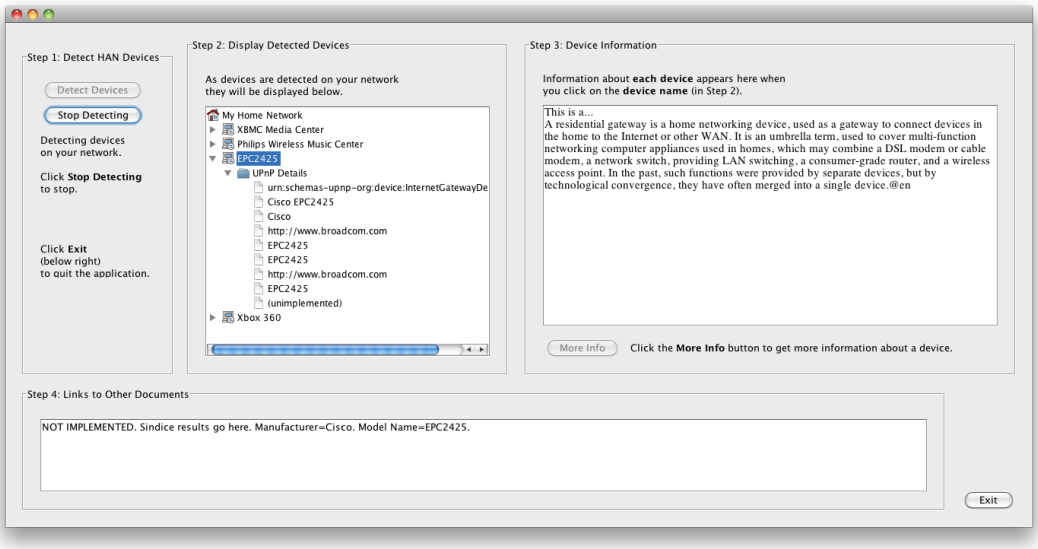

Figure D-7: Information Retrieval - Clicking on 'EPC2425' retrieves the Wikipedia English abstract for a residential gateway.

D.8 Information Retrieval – Xbox 360

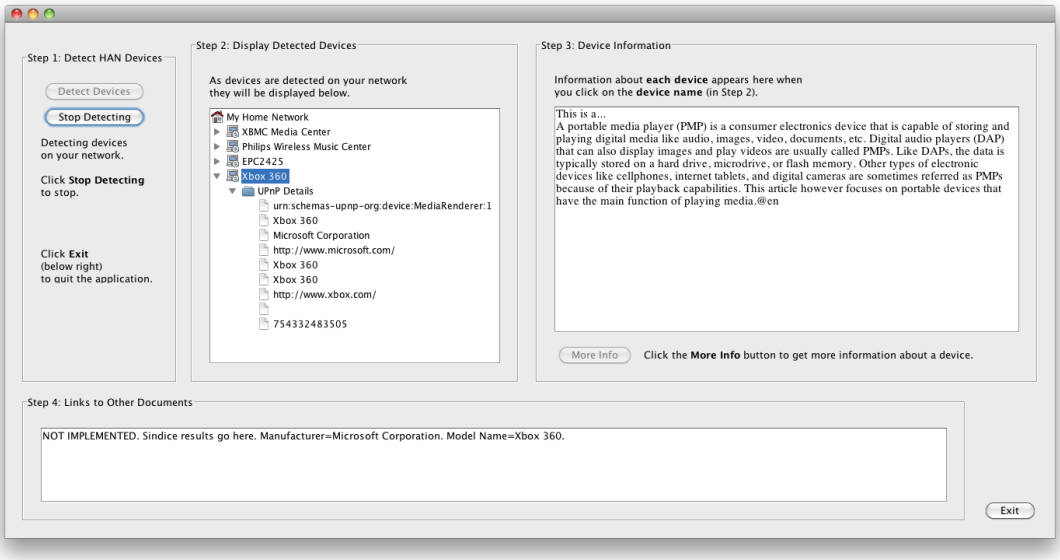

Figure D-8: Information Retrieval - Clicking on 'Xbox 360' retrieves the Wikipedia English abstract for a portable media player.

D.9 Tooltips on GUI

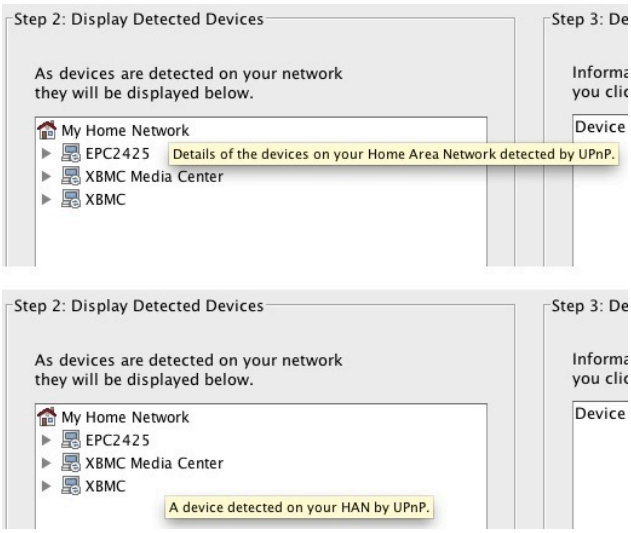

Figure D-9: GUI Tooltips

D.10 Differentiating by IP Address

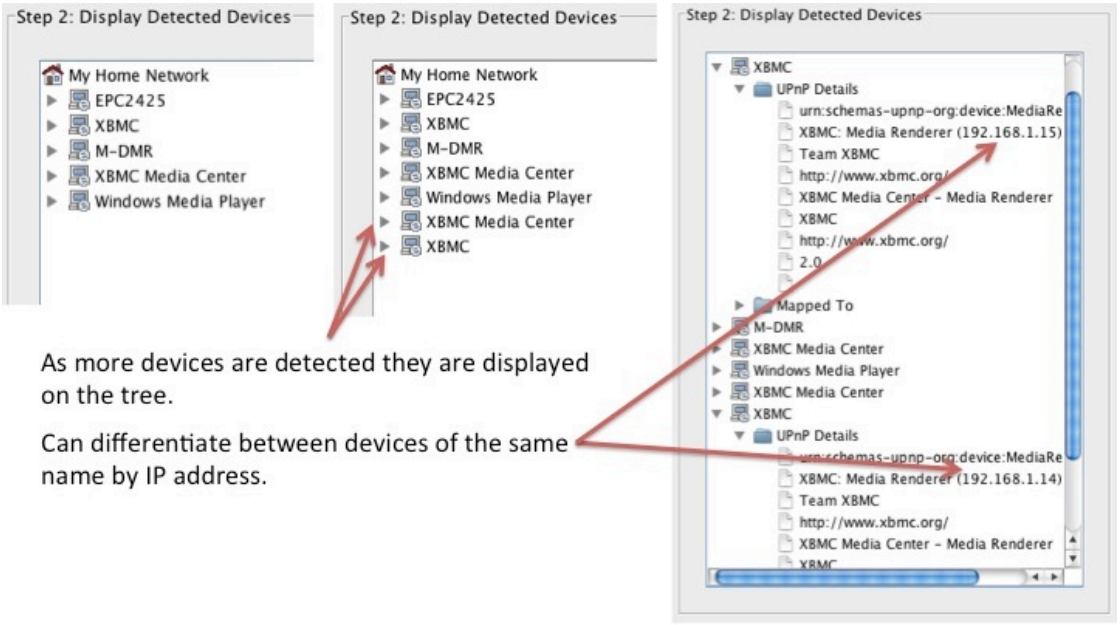

Figure D-10: Differentiating between the same appilcation on different laptops

D.11 Windows Media Center

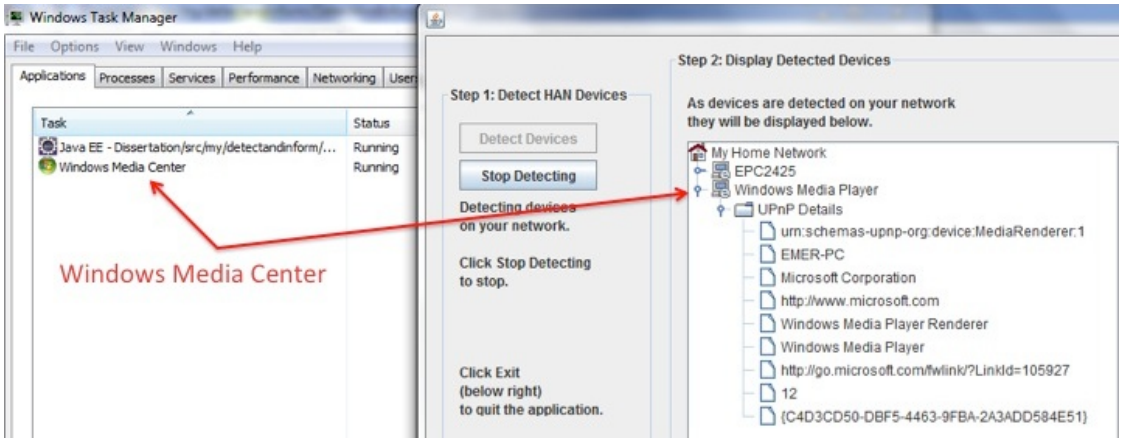

Figure D-11: UPnP details for Windows Media Center

D.12 Windows Media Player

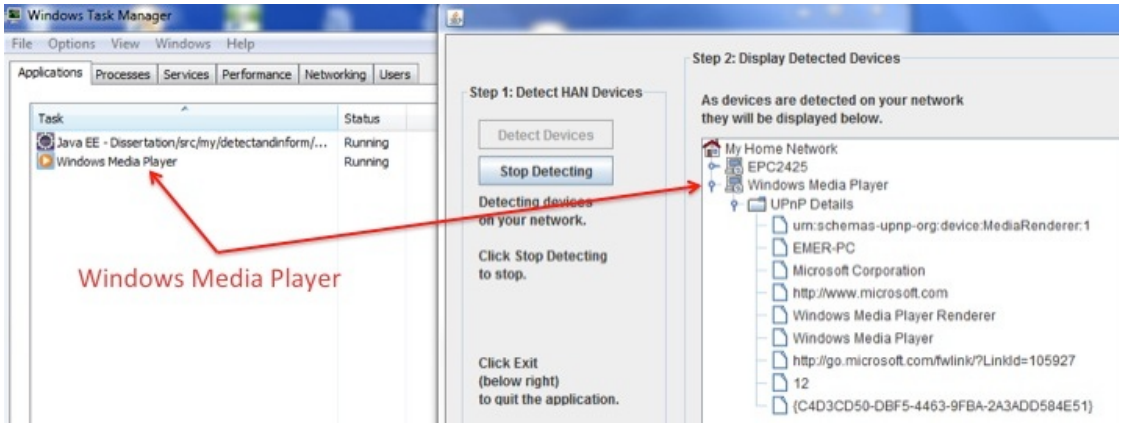

Figure D-12: UPnP details for Windows Media Player

D.13 Wikipedia Abstract for Residential Gateway

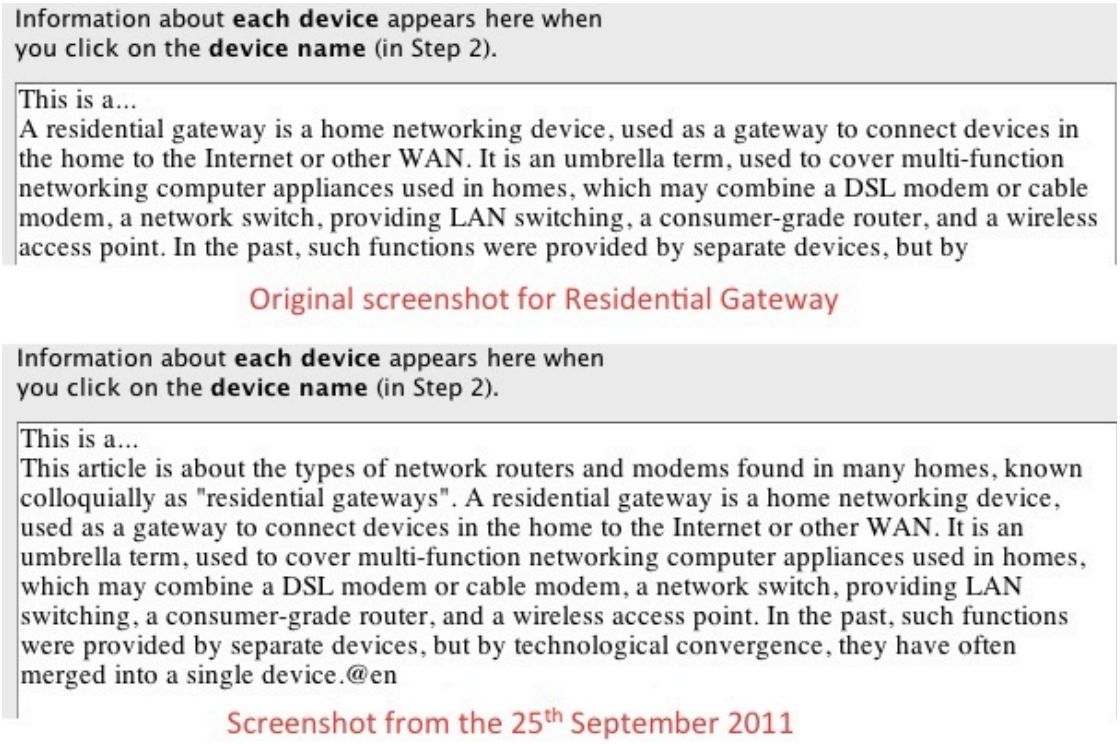

Figure D-13: Wikipedia's abstract for a Residential Gateway

Appendix E XML and Device Mappings

Mappings for Device Types	
Basic Requirements	Map InternetGatewayDevice to Residential_gateway. <maps> <device> <device_type> urn:schemas-upnp-org:device:InternetGatewayDevice:2 </device_type> <map_to name="Residential Gateway">Residential_gateway</map_to> </device> <!-- The rest of the devices --> </maps>
Device Mapping XML	<maps xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation="DeviceMapping.xsd"> <!-- Non UPnP mappings go in here e.g. Home Area Network --> <upnp> <!-- Other categories e.g. Audio/Video with Media Server etc. --> <category> <category_name>Networking</category_name> <category_device> <!-- Other devices within the category e.g. WLAN Access Point:1 --> <device> <device_type> urn:schemas-upnp-org:device:InternetGatewayDevice:1 </device_type> <dcp_type>Internet Gateway:1</dcp_type> <map_to name="Residential Gateway">Residential_gateway</map_to> <map_to name="Router">Router_(computing)</map_to> <!-- Any number of mappings --> </device> </category_device> </category> </upnp> </maps>

Table E-1: Taxonomy structure

DBpedia Results for Mapped Terms		
UPnP Device Type	If Mapped To	Results from DBpedia
InternetGatewayDevice	Internet_Gateway_Device [46]	Re-routes to Internet_Gateway_Device_Protocol [47]. Want returned information to explain what a residential gateway or router is. Protocol details are likely to be too technical for the novice user and may only confuse rather than inform.
	Router [48]	No English abstract.
	Router_(computing) [49]	OK but need to know in advance and take URL encoding into account i.e. Router_%28computing%29
	Residental_Gateway [50]	"No further information is available. (The requested entity is unknown)"
	Residental_gateway [51]	OK
MediaServer	Media_Server [52]	OK. Re-routes to Media_server.
	Media_server [53]	OK.
	UPnP_media_server [54]	"No further information is available. (The requested entity is unknown)"
	UPnP_AV_media_server [55]	OK
MediaRenderer	Media_Renderer [56]	"No further information is available. (The requested entity is unknown)"
	Media_renderer [57]	"No further information is available. (The requested entity is unknown)"
	UPnP_media_renderer [58]	"No further information is available. (The requested entity is unknown)"
	UPnP_AV_media_renderer [59]	"No further information is available. (The requested entity is unknown)"
	Portable_media_player [60]	OK. Has an English abstract.
printer	Printer [61]	No abstract in any language.
	Printer_(computing) [62]	OK.
scanner	Scanner [63]	No English abstract.
	Image_scanner [64]	OK

Home Area Network		
HAN (Not from UPnP)	HAN [65]	Re-routes to Han. No English abstract but the content refers to a Chinese surname or ethnic group.
	Home_network [66]	OK
	Home_Area_Network [67]	"No further information is available. (The requested entity is unknown)"
	Home_area_network [66]	OK. Re-routes to Home_network.
	Residential_network [68]	Re-routes to ResNet [69]: a large Local Area Network (LAN) or Metropolitan Area Network (MAN).

Table E-2: Term mappings for UPnP device types

Appendix F Class Diagrams

F.1 Package upnp

Figure F-1: Class diagram for upnp package

F.2 Package detectandinform

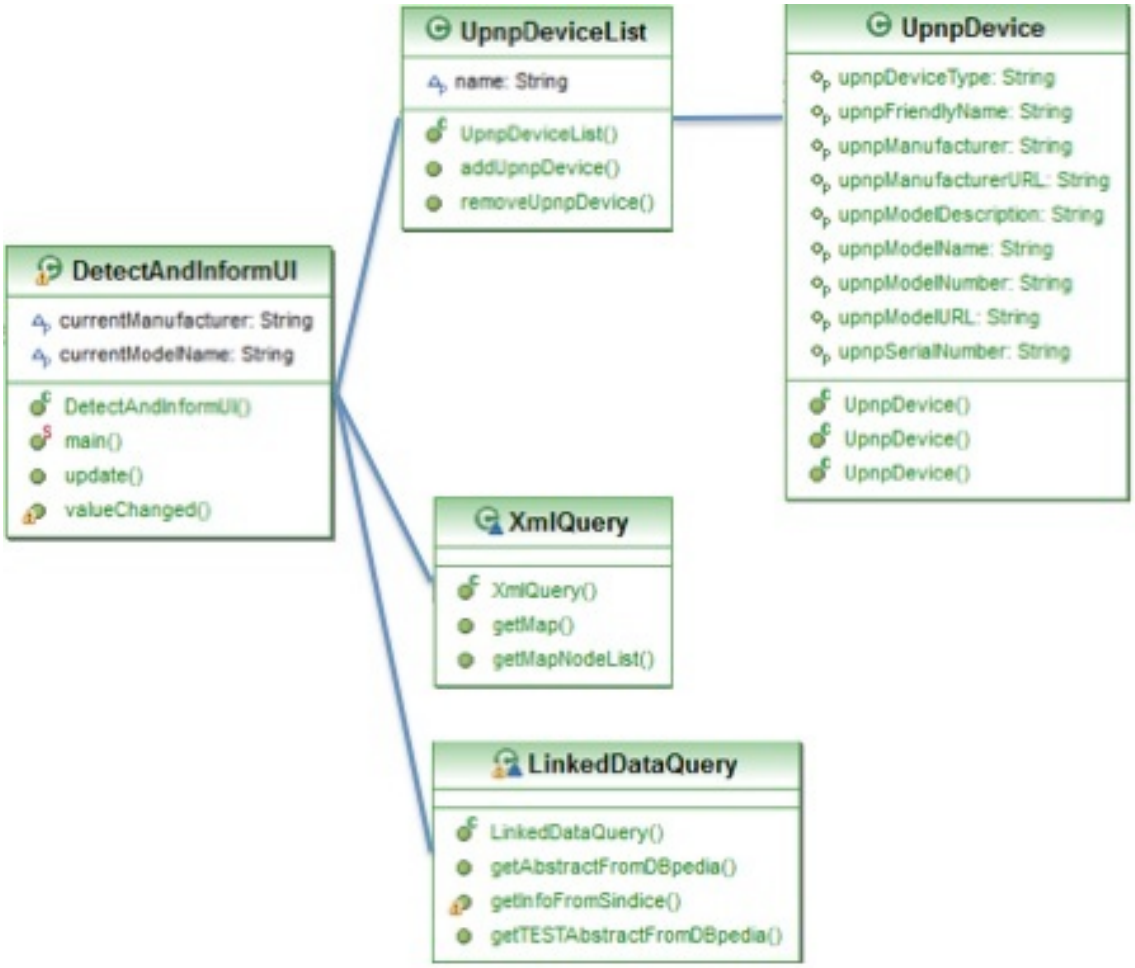

Figure F-2: Class diagram for detectandinform package

Appendix G Evaluation Questionnaire

Participant Questionnaire		
	Question	Range
SYSTEM USABILITY SCALE		
1	I think that I would like to use this system frequently.	Strongly disagree - Strongly agree 5 - 1
2	I found the system unnecessarily complex.	Strongly disagree - Strongly agree 5 - 1
3	I thought the system was easy to use.	Strongly disagree - Strongly agree 5 - 1
4	I think that I would need the support of a technical person to be able to use this system.	Strongly disagree - Strongly agree 5 - 1
5	I found the various functions in this system were well integrated.	Strongly disagree - Strongly agree 5 - 1
6	I thought there was too much inconsistency in this system.	Strongly disagree - Strongly agree 5 - 1
7	I would imagine that most people would learn to use this system very quickly.	Strongly disagree - Strongly agree 5 - 1
8	I found the system very cumbersome to use.	Strongly disagree - Strongly agree 5 - 1
9	I felt very confident using the system.	Strongly disagree - Strongly agree 5 - 1
10	I needed to learn a lot of things before I could get going with this system.	Strongly disagree - Strongly agree 5 - 1
HOME AREA NETWORK SUPPORT		
11	The prototype facilitates my understanding of the home network.	Strongly disagree - Strongly agree 5 - 1
12	The prototype helped me find relevant information for the network devices.	Strongly disagree - Strongly agree 5 - 1
13	I feel I successfully completed the tasks.	Strongly disagree - Strongly agree 5 - 1
14	I feel the prototype would be helpful to a non-technical user.	Strongly positive - Strongly negative 5 - 1
15	Can you identify the devices on the network?	Empty boxes titled with • Router/Access Point • Media Server • Media Renderer • Media Renderer
16	What are the best points of the prototype?	Space to enter text.
17	What are the worst points of the prototype?	Space to enter text.
PARTICIPANT PROFILE		
18	How would you describe your technical ability?	Novice - Expert 5 - 1
19	Your proficiency with a Home Area Network e.g. setup, configuration and management.	Novice - Expert 5 - 1
20	Your proficiency with the Semantic Web e.g. Wikipedia, DBpedia, Linked Data.	Novice - Expert 5 - 1
FEEDBACK		
21	If you have any comments on this study, please write them here:	Space to enter text.

Table G-1: Evaluation Questionnaire for Participants

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