Executive Summary

The Equipment Management (EM) trial was one of the practical initiatives conceived and implemented by members of The Application Home Initiative (TAHI) with strong support from the DTI, to demonstrate the feasibility of interoperability between white and brown goods, and other domestic equipment.

The trial ran from October 2002 to June 2005, over which period it achieved its core objectives through the deployment in early 2005 of an integrated system in trials in 15 occupied homes. Prior to roll out into the field, the work was underpinned by soak testing, validation, laboratory experiments, case studies, user questionnaires, simulations and other research, conducted in a single demonstration home in Loughborough, as well as in Universities in the East Midlands and Scotland.

The trial was conducted against a backdrop of continual commercial change. Despite this difficult operating environment, the trial met its objectives, although not entirely as envisaged initially – a tribute to the determination of the trial's membership, the strength of its formal governance and management processes, and especially, the financial support of the dti.

The equipment on trial featured a central heating/hot water boiler, washing machine, security system, gas alarm and utility meters, all connected to a home gateway, integrated functionally and presented to the users via a single interface.

The trial met its principal objective to show that by connecting appliances to each other and to a support system, benefits in remote condition monitoring, maintenance, appliance & home controls optimisation and convenience to the customer & service supplier could be provided.

The trial met this objective by:

- demonstrating that narrowband remote services from a variety of suppliers using equipment from different manufacturers, can be delivered to real homes;
- proving that communications with, and services related to, everyday appliances and home systems are deliverable with existing technology and relatively easy to achieve with broadband;
- finding that systems for the home environment need to be especially robust because of the nature of service demands and high customer expectations for reliable system integrity;
- identifying that customers want timely and meaningful data on energy consumption and are willing to interact with such a system in order to improve their home environment;
- identifying a range of potential service offerings for customers and demonstrating a selection of these for customer evaluation;
- showing that users are willing to cross over between loosely related services presented to them on the same home portal;
- finding that central user interface displays should:
    - include life saving alarms;
    - show information about damage to property;
    - give detailed information about electricity, gas and water use;
- finding also that:
    - central control of appliances is not popular;
    - data security is a major issue for respondents.

The EM trial identified exciting opportunities for the UK's domestic white and brown goods manufacturing sector. Despite the relative immaturity of some of the enabling technologies people seem interested in the use of smart home devices to improve their quality of life or just generally make things easier at home in their busy schedules. Whilst the enabling technology behind future smart homes is being developed at a rapid pace, it is the intelligent application and integration of this technology that will make the difference to the home consumer. Just because the technology provider can make a 'useful' device it does not necessarily mean that the consumer actually wants to buy the 'new' invention. The EM trial has successfully shown where certain technology can be deployed successfully and also identified areas where further work is required.

Introduction
Something across both trials?
Should this include a statement on the TOA and business modelling?

During 2001 the idea of an Applications and Services led Initiative was aired and The Application Home Initiative (TAHI) was launched. It now has some 40 organisations as Members of the initiative that are working to bring new applications and services to home-based users. The aims and objectives of TAHI are applicable to Service Providers, Customer Facing Organisations and Consumers world-wide.

TAHI is a Company Limited by Guarantee that aims to accelerate the adoption of networked applications and services by connected home-based users. It is identifying the applications and services that people want and will pay for.

Figure 1. TAHI overview

One of TAHI's key objectives is to use practical trials to learn about the business models, logistics, costs and customer benefits that make up the business case for major deployments of a wide range of services and applications.

For this reason TAHI members supported the creation of a number of trial projects to test or exploit the take up of applications and services in a number of sectors.

Two of these activities, the Equipment Management (EM) and Services Aggregation (SA) Trials, have now completed their work. Other trials are in varying stages of progress. Through this approach, TAHI is showing both service providers and the users of services the scope of what the future will bring. It will increase awareness and speed the take up of broadband.

TAHI also has active working groups that are bringing understanding of the wants and needs of consumers, the benefits of services provision, and the architectures for delivery. TAHI members are discovering new ideas and ways of bringing new and better services to the consumer to the benefit of all stakeholders.

TAHI EQUIPMENT MANAGEMENT TRIAL

1. AIMS AND OBJECTIVES

The Equipment Management trial was established by TAHI members with strong support from the DTI (Next Wave, Technology and Markets Programme) to accelerate the interoperability between connected devices around the home and thereby deliver added value through the provision of information services to the customer/end user. A trial objective was to show that by connecting appliances to each other and to a support system, benefits in remote condition monitoring; maintenance; appliance and home controls optimisation; and convenience to the customer and service supplier - may be provided.

The deliverables of the Equipment Management trial were to:

- Use a demonstrator and test facility to prove a TAHI specification which can be used for a Mark of Conformity;
- Create and demonstrate a home network using low data rate, plug and play technologies from a number of different suppliers;
- Create and demonstrate an infrastructure capable of supporting the network;
- Demonstrate the ability to manage remotely, fault identify and optimise the operation of white goods, heating and security products in the home;
- Provide a test bed to facilitate further research in ambient computing and knowledge based Human Computer Interactions;
- Demonstrate an easy to configure user interface that is accessible to all kinds of users;
- Demonstrate interoperability of sufficient capability so that conformance tested products can be added and maintained on the network;
- Identify costs and benefits in the areas of capital/initial on cost to equipment, revenue from maintaining the network and infrastructure and any other associated costs;
- Gather information about the technical requirements and about customer behaviour relative to the offered applications;
- Provide continuing feedback from customers about the barriers, merits and difficulties associated with adopting new technologies, products and services;
- Evaluate the customer value propositions and service provider value proposition for applications that maintain and manage the customers' equipment;
- Identify the gaps in required new products and services associated with the interconnected home, to feed into future R&D activities of the NWTM Virtual Centre for the Integrated Home Environment.

The main applications examined were:

- Remote diagnostics of washing machines and other white goods, and central heating boilers;
- Automatic meter reading and energy management;
- Security systems;

- Safety systems in the home, including natural gas, CO emissions detection, water leakage from appliances or main pipes, abnormal appliance energy consumption;

- The potential for back end services to carry out the remote diagnostics and equipment control, monitor conditions and optimise appliance/system performance;

- System and appliance interfaces with the customer.

The trial had two initial development phases, the first phase relating to a single demonstration home in which all organisations taking part scoped out their involvement defining their roles, resources and outputs. The second phase was a 15 home trial, where organisations gauged consumer reaction to the technology and the services offered.

The underlying theme of the trial was that although each application may be defined individually, none has an individual business case. Taken together, there are economies derived from the sharing of an infrastructure and this then makes the business case of the sum of the individual applications potentially viable. A key aspect of the trial was therefore to create an architecture which is generic and in which different devices, applications and services can be operated.

2. CONSORTIUM MEMBERS

The following organisations delivered the trial objectives.

- Advantica
- Centrica
- De Montfort University
- Department of Trade and Industry
- Dyson
- Ergonomics & Safety Research Institute (ESRI)
- Extrada
- Heriot-Watt University
- Horstmann
- Invensys
- Loughborough University
- Telemetry Associates

3. TRIAL OVERVIEW

Following extensive preparation, research, and development, 15 homes (46 inhabitants) were retro-fitted with smart appliances and networked systems to assess how they fared in the real world environment, as part of a Multi Home Trial (MHT).

In participant homes the central heating/hot water boiler, washing machine, security system, gas alarm and utility meters were connected up to a purpose developed home gateway. The system combined out-of-the-box technology with prototype products developed for the trial. The system this created is illustrated in the Figure below.

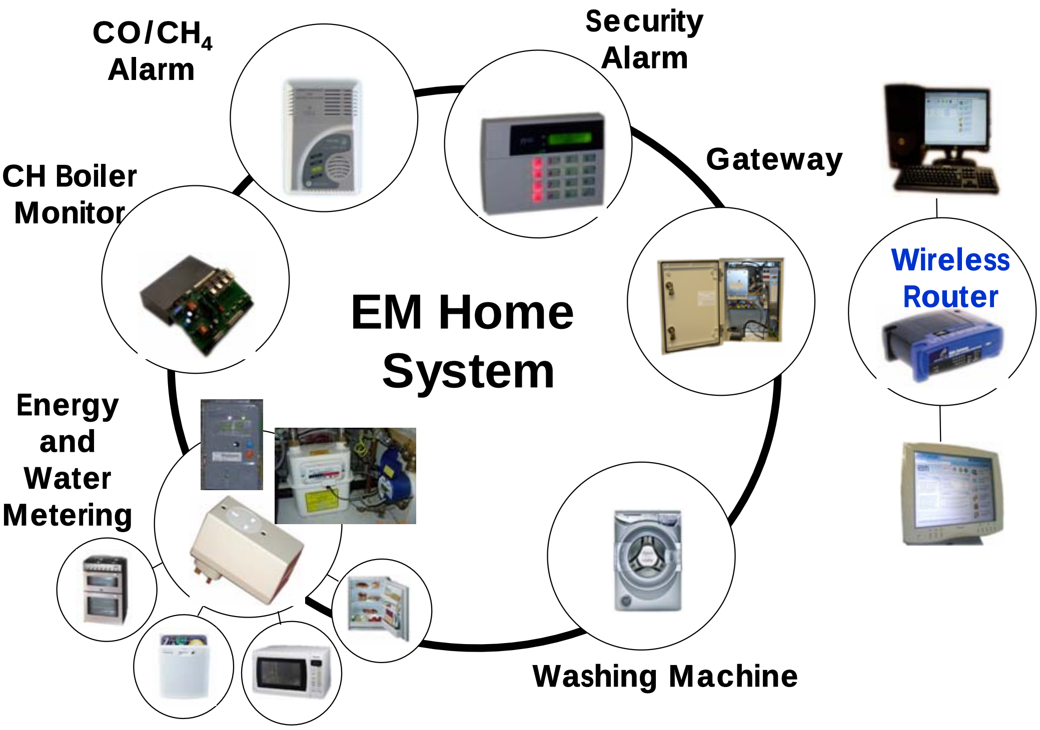

Figure 2. The Multi Home Trial smart system

- Secondary meters for gas, electricity and water allowed for remote meter readings and meant that graphs charting household energy use on a day-by-day could be presented to the users via the interface.

- White goods monitors were specially developed for the trial by Horstmann, to monitor and feedback detailed breakdowns of electricity use by appliance. It was originally intended that these modules would be fitted to existing white goods within the participant homes. However, technical difficulties meant that this component was not included in the MHT.

- The iCom, a device developed for the trial, was fitted to the boiler to monitor the flow and return and hot water temperatures, and boiler demand.

- A Dyson CR02 washing machine was modified for the trial. It utilised a powerline communication system to relay information back to Dyson and the homeowner via the home area network developed by the group.

- The CO/CH_4 alarm and security alarm were integrated in the system and an overview of their status was provided in a central interface.

- The residential integrator gateway was designed and implemented specifically for trial applications, with applications software running under an OSGi framework, on a single board computer.

- All of this functionality was integrated and presented to the users in a single interface on an iCEBOX™, a countertop Windows CE computer combining entertainment options in one single device specifically designed for the kitchen. The iCEBOX communicated with the gateway via a wireless router with a broadband connection.

- o Users and service providers in the trial could also access the home information remotely via various web browser screens. Some local, more detailed, information was also provided to householders directly from the gateway.

4. CUSTOMER FEEDBACK

Examples of the interface that was installed as part of the Multi Home Trial are shown below.

Figure 3. Multi Home Trial interface design

From the Multi Home Trial evaluation, a number of customer acceptance issues were raised. These included:

- o Participants liked the look and feel of the interface and found it to be well laid-out and easy to access. They liked the colourful interface design and felt it bought the system to life. They had found the interface easy to use and easy to navigate.

- o Participants had been disappointed in the usefulness of the energy data provided by the system. Householders wanted to be able to see and interrogate their energy data, but the trial was unable to deliver the detail they required.

- o Although many participants commented that is was easy to find things, some reported that it was not always entirely clear where to look for information on certain pages as it was sometimes a little technical. It was felt that an overview of the house presented at a top level, on the homepage of the system, might be useful. This could include some general information such as ‘today is above average’ so they would not have to search for information and deduce this for themselves.

- o Overall, people thought the whole concept was “very clever” and “could be useful in the future” but the content and functionality of the system was “not quite there” with respect to the trial equipment under investigation in their homes.

- o Energy data needs to be reliable, and consistently presented in order that people make use of it. People would like to receive advice to complement the energy consumption and add meaning to their readings.

- o Although money is the key driving force behind most energy saving behaviours, it was found that displaying breakdowns of energy consumption in monetary terms can also serve to de-motivate users. Pennies are not a big enough incentive; the benefits need to be perceived as significant in order that people alter their behaviour.

- o Half day totals of energy use do not convey anything useful to the user. The data need to be sampled at more regular intervals so that it better reflects the results of their actions.

- The ability to interrogate energy usage over longer periods of time (comparing one year with another or one season with the previous) was considered to be useful.

- People do not want to have to log in every time they interact with the system. Having to log in forms a barrier to free interaction with the interface and impedes the user experience.

- People do not want to be tied into one manufacturer. They would like to pick and choose system parts from different manufacturers with an in-built ability to communicate with one another.

- If an organiser is to be integrated within the system, consumers would like to see it integrated with existing calendars, for example their Microsoft Outlook organiser at work. If it worked in addition to, and in isolation from existing calendars, diaries and organisers, people would not be interested in using it.

- Future systems should have a more interactive element. People want to use the system to control their home; just being able to monitor their home does not engage the users.

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Customer Acceptance

The trial provided continuing feedback from customers about the barriers, merits and difficulties associated with adopting new technologies, products and services.

Research by Heriot-Watt University revealed high levels of interest among consumers for detailed energy consumption information in the home and a willingness to pay for such services if facilitated by the TAHI approach. The survey results indicated that a central user interface display should be aimed at 18-35 year olds, and cost around £400 or £10 per month.

Features in order of preference should include:

- Life saving alarms (e.g. for CH_4, CO).

- Information about damage to property (e.g. a water leak alarm).

- A security system with text messaging service.

- Detailed information about electricity, gas and water use.

However central control of appliances was less well received and data security proved to be a major issue for respondents (84% of respondents agreed to the appliance manufacturer or service provider accessing information about appliances securely via the web, but 93% wanted to be able to access all of this information).

Development of energy display technology on three levels was recommended:

- Local displays (appliance-specific and activity-based).

- Central displays (e.g. via a very smart meter).

- Hybrid displays (a combination of central and local displays).

The target customers for the EM trial products (home appliance remote diagnostics and monitoring) were identified as owner/occupiers, ABC1 consumers, 20 - 50 age group with young families. Two sub-markets were envisaged: the first is those who are cash rich but time poor and the second is represented by people to whom safety/security is important, who want to know what their outgoings are, and who tend to buy insurance products.

Consumer Values
Focus groups were conducted with six different groups of participants to reflect a wide selection of society and gain a richer understanding of how people feel. The groups were presented with seven scenarios supported by guidance questions to generate discussion. The scenarios covered the topics of energy monitoring, equipment monitoring, appliance repair, security, home ambience settings and welfare monitoring.

The focus groups showed that people are responsive to the services that Smart Homes can offer. There were particular concerns over control, security and cost. These issues must be addressed if the Smart Home technology is to be accepted in people's lives.

A photo study was used to gain a realistic understanding of the context within which future Smart Home technologies are likely to be used and how this fits with people's everyday lifestyle and activities. The study utilised methods of ethnography within a domestic setting, where participants self-documented their thoughts and ideas and captured images around their home.

Key findings from this include:

- People value people, space and memories most highly, rather than technology or physical possessions.

- The items valued most highly were consistently described with feelings of comfort, relaxation and sentiment.

- Technology and automation is viewed as saving people time and making household tasks easier, rather than adding value.

- Some captured images of places or objects which focused on pride, appearance and prestige. Smart Home technologies may invoke the same feelings in some users and in this way, could find their way into people's values.

- People do not display and share information in one single place; people often leave impromptu notes and messages left in context-specific locations around the home. A single, all-encompassing interface may not allow for this type of behaviour.

Basic Consumer Needs
These are needs which have been identified once the technology had been illustrated to potential user, i.e. spoken concerns which, if not addressed, could lead to significant dissatisfaction - clouding the overall benefit of the technology. These needs were identified from ESRI's initial focus group investigation of a spread of demographics. If these needs are addressed to a high level (high Performance) they can lead to high levels of satisfaction and even Delight (where the function exceeds expectation).

- **Enhanced Comfort & Well-being:** A better quality environment, enhanced sense of luxury, opportunity for Wow factor - able to create a sanctuary in your own home.

- **Informative / Useful information:** To be able to make better decisions, to have a better understanding, to provide helpful information - to reduce unknowns about your house.

- **Increased Convenience:** Reduced actions, easier to use, less effort (physical and/or mental), time saving - just faster.

- **Enhanced Peace of Mind:** Reduced worrying.

- **Money Saving:** Through the addition of the technology or system and the initial investment, it makes it subsequently easier to save money.

5. KEY TECHNICAL SUCCESSES

The trial produced a number of technical successes, including:

- **Proving the Technology in the Home.** It was possible to design, develop, build, install and monitor an equipment management system in existing, occupied, non-identical homes.

- **Reliability of Gateway and Installation Firmware.** For a prototype system of this type the TAHI EM installations were surprisingly reliable. Only 4 customer resets were required due to local system lockups and very few visits were required to resolve problems on gateways or devices.

- **iCom Bundle Development.** The Invensys iCom was able to derive a wide range of data and diagnostic parameters from the available information. With limited time, a mechanism was found to collect logging data from these units, which might form the initial basis of development of retrofittable appliance monitoring devices of this type.

- **Remote Management.** Monitoring and update of applications and management of the gateways and installed applications worked very well via the remote management applications employed in the trial. This proved that with a stable platform and infrastructure in place, it is possible to manage such installations without the need for many site visits.

- **Technology Demonstrator**. Real time monitoring, usage data and diagnostic information were possible though the technology demonstrator. White goods installed in the home were able to transmit information over low data rate powerline networks. The demonstrator proved these data could be collated in the home gateway and disseminated over a wide area network via the internet protocol. The white goods data were presented to the end user via an intuitive web interface and via daily status emails sent automatically from each home gateway. The technology demonstrator proved the end-to-end transport of useful data over a wide range of network technologies.

- **Trial Gateway**: Although not intended for commercial rollout, the EM trial gateway was surprisingly resilient for a Windows system and once setup, was stable. Power loss and network loss were all reliably recovered and in some cases after a few weeks retry still recovered.

- **OSGi Framework:** This was highly stable and the remote management function very efficient. Device discovery within OSGi XML queries from the remote server are effective and interoperability mechanisms are inherent. However, a technical capability is required of device suppliers to implement such a system and this is an issue for all technology choices. There is a wide range of network interfaces available. Various alternatives to OSGi have similar merits.

- **System Reliability**: Generally, once commissioned and teething problems resolved, the equipment was reliable, although there were unexpected hardware failures. A mainsborne interference problem in one house remains unexplained. LON and EHS ‘enrolment’ mechanisms were found to be straightforward and realistic for an installer to perform with no operational issues and LON and EHS communications co-existed successfully on the same powerline network. Mains Ethernet was problematic though in some cases.

- **Home Networks:** Piggybacking on an <u>ad hoc existing</u> network to provide services to home devices currently requires significant costs in setup and support. Reliable wireless installation is not guaranteed because of device positioning. Not all wireless devices are suitable; applications need to need to find the optimum device for the required platform and keep the wireless channel open for reliability. There is always the contingency that cable may have to be used. The installer must evaluate each installation and adapt the system to suit, with the unfortunate result that the installer then ‘owns’ the network issues! Deploying these services via the customer’s existing infrastructure is technically feasible but unlikely to be commercially feasible as the effort level and skill base required to install and maintain such systems will be prohibitive.

- **Bandwidth**: The EM system was originally intended as dial-up but broadband was chosen for expediency and useful experience was gained as a consequence: interfacing with the customer’s existing ‘arbitrary’ network was not straightforward, there being myriad router, PC, network device types, settings and physical installation issues.

- **Software Reliability**: This is dependent upon user actions, causing system changes that require investigation and resolution to maintain the service.

- **Remote Connection**: Access to devices in the home from remote systems is complex and there are connection and Firewall issues to overcome.

6. RESEARCH

As the trial incorporated a number of Universities, significant research successes were made, to underpin the technical and commercial work. Besides work reported elsewhere in this document, these included:

- **New research into interface design within the home environment.** As the use of any system must be considered in context, the trial provided an opportunity to develop research and understanding into the needs of consumers in relation to smart home technology. In particular the development of a user interface for the home environment was achieved, taking into account the context of use and users’ expectations, both of which can be demanding. To support this, new evaluation techniques were developed.

- **System Emulation:** Loughborough University developed a flexible tool to support pervasive computing research for future home environments. The aim was to provide an emulation of future home systems which was as realistic as possible so that users interacting with the system would behave as though they were interacting with a real system. The requirement for this system arose because there are many ways in which to present a user interface and these will be highly dependent on the user types and the systems deployed in the home. To introduce changes in a production home gateway would be prohibitively expensive and time consuming. An emulation solution enables the process of refining the user interface to be iterative and easily updated to reflect design changes.

Figure 4. The unoccupied test home at Advantica, Loughborough

7. MARK OF CONFORMITY AND OPEN ARCHITECTURE

The trial used a demonstrator and test facility to prove a TAHI specification which could be used for a Mark of Conformity. The main objective for the EM trial (in common with SA) was to carry out a test and verification process on devices developed for, and submitted to, the trial in order to ensure interoperability of the various system components. A key aspect of this would be the application of the TAHI Open Architecture (TOA) that would provide a reference to interpret into a realisable and testable solution.

The TOA provides an interoperable service open architecture to remedy the current situations where there are “islands of systems” where domain specific standards & architectures co-exist resulting into complexity in managing such systems. The TOA aims to provide a service architecture for delivery of services via broadband which will:

- Clearly define responsibilities and relationships between various stakeholders.
- Allow service resources to be “mixed & matched” easily to aggregate services.
- Support different business models (e.g. pay-per-use, subscription, etc).
- Enable resource sharing between different services.
- Enable service providers to deliver their services to a wide range of connected home users regardless of their home configuration.
- Enable connected-home users to retain freedom of choice.

The process of applying the TOA within the EM trial was to:

- Develop a series of interoperability specifications.
- Translate these interoperability specifications into a series of ‘test procedures’.
- Develop test applications for devices to exercise functionality independently.
- Test devices and report results.

The initial work on developing the interoperability specifications was completed and this formed a key basis for the EM trial system development.

The trial used a number of devices of different types (both in function and interface requirements):

- Echelon LON (powerline) for the metering device.
- European Home Systems (EHS) (powerline) for safety.
- EHS (powerline) for the washing machine.
- Hardwired security panel interface.
- EHS (powerline) for the heating appliance monitor.
- Network interfaces (Ethernet and Wi-Fi®).

The key issue of interoperability between these different application and communications types (which the open architecture and related methodologies attempt to address) was not a significant issue in the implementation due to the development of the interoperability specification and the use of the OSGi framework.

The OSGi standard provided mechanisms to discover new devices on the residential network, identify their capabilities and match this to applications available on the gateway. It also provides mechanisms to remotely manage applications available on the gateway and so to add new applications and update existing ones. OSGi had readily available interfaces for the EHS and LON protocols that would be required in the EM trial.

The experience of using this technology showed that the OSGi standard and its implementation was mature, reliable and well thought out. It leads to the view that the need to define an open architecture that provides mechanisms for device discovery and description of services and devices in an abstract manner is unnecessary as there are existing technologies that can do this adequately for effective deployment of solutions. This does not recommend OSGi as being the only solution and there are others that fill a similar need and probably also provide solutions but were not evaluated in the trial.

It was also evident through the development both in the trial, and via experience outside the trial as well, that product developers and service developers have a great deal of commercial sensitivity with the detail of their product developments and exposing this via open standards is not necessarily in their interest. Open architectures can of course support this through manufacturer specific sections of protocols but the point is that for any worthwhile (i.e. differentiated) product offering there is gong to be some specific end-to-end system development that does not have a need for totally open solutions.

Plug and Play Networking
The trial aimed to create and demonstrate a home network using low data rate, plug and play technologies from a number of different suppliers. Existing technology was used wherever possible, something that would not have been feasible several years ago.

Network technologies were based on those with which the development partners already had some experience. EHS and LON powerline protocols were used. The security systems were connected via hard wired interface.

The experience of this development was very positive. Both EHS and LON interfaces (hardware and software) were available for the OSGi framework used in the application development and so, with a little training, it was possible to build applications on this communications technology with limited detailed understandings of the technology. The integration of the EHS and LON drivers with the OSGi framework had been carried out very effectively by the suppliers of those subcomponents and it very much had the feel of established and stable technology. It should be noted that the OSGi understanding and application development is still a complex task!

The sharing of a single EHS interface on the gateway between three different applications was a concern but the system handled this all automatically and these devices, plus the LON devices could all share common physical layer network and interfaces with no interworking issues identified.

Performance of the networks in the homes was also reliable though there were some specific hardware failures of various powerline devices themselves, which could be attributed to their prototype nature.

It can be confidently concluded that (once the products are developed to a reliable level) their installation does not require substantial skill or training (unlike the gateway setup).

Wireless (WiFi) network connections were used between gateway and router in about half the installations and between iCEBOX and router in most installations.

A substantial amount of effort was required at the start of the project to find WiFi interfaces that would work properly with the gateway and iCEBOX. As the gateway was an embedded

Windows XP platform and the iCEBOX a Windows CE platform, there were some restrictions on device type and trial and error showed which devices were best suited. This shows that such installations are by no means a case of choosing any apparently suitable device off the shelf.

A WEP key was used on all networks to provide some security on the network. In most cases the wireless networking worked well and installation and set up was straightforward. In some cases the positioning of the antenna was very critical and required some time and effort to achieve good location. Loss of wireless configuration in the router or gateway occurred a few times causing apparent failure of the wireless network. This was not immediately obvious to diagnose but generally re-entering the network key at the gateway (or router) resolved the problem. In one installation the wireless transceiver on the gateway itself failed. Generally it can be concluded that wireless networking provides a good alternative to wired cabling but requires some initial effort to find and prove suitable devices and cannot be relied on in all installations.

The home gateway aggregated data from all networked devices in the home and communicated with external (internet based) systems in order to deliver services.

Network infrastructure
The trial aimed to create and demonstrate an infrastructure capable of supporting the network.

The trial's purpose was to provide the control and monitoring of equipment in the home, such as white goods, meters, security and home comfort. The trial began by focusing on the necessary architecture for delivering these services:

- Connectivity in the home and the concept and the management of the gateway.
- Local user interface (running on the gateway in the home).
- Remote access and management of the devices.
- Remote user interfaces for primarily service providers.
- Connection of manufacturers / service provider to the server hub.
- Data management – in and out of the home.
- Customer / equipment relationship management.

It was decided at an early stage to adopt the architecture below, showing the use case diagram for the EM system, identifying how the users and service providers interact with the system's software and hardware components. The architecture proved to be sufficient for the duration of the trial and only minor modifications took place. The main area where change took place was a decision that the gateway would have some (limited) capability to generate graphics for a local display without needing to be connected to the server.

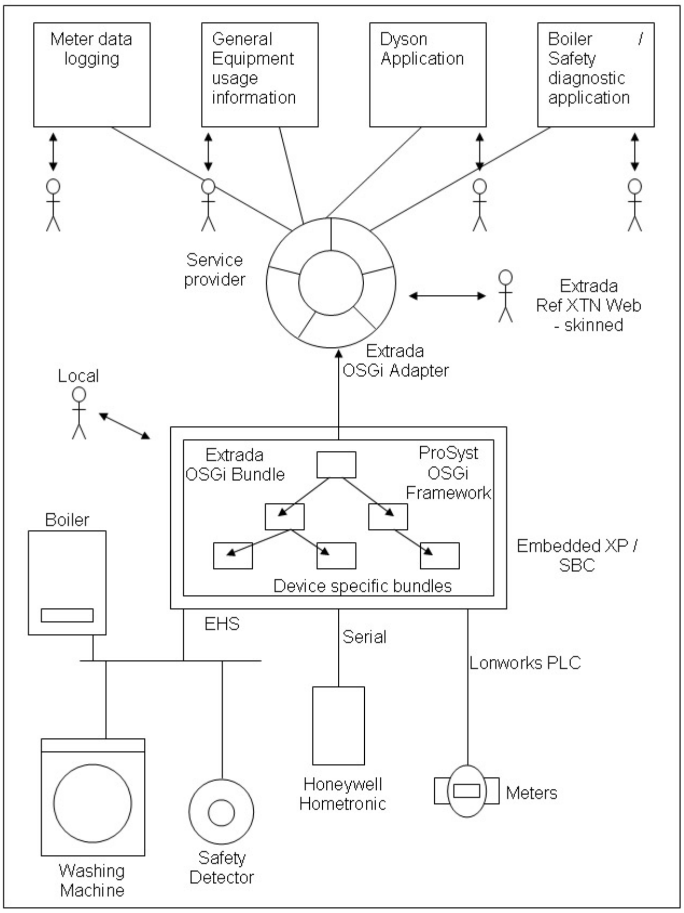

Figure 5. Use case diagram

The network and infrastructure for the EM Multi Home Trial was not initially seen as being a major area of development in that the intention was to use existing technologies for this. Its key elements were:

- EHS and LON home device networks for interfaces to appliances, meters and alarm devices.
- 'Hard-wired' connection between security system and gateway.
- Ethernet and/or wireless (Wi-Fi) connection between router, gateway and user interfaces (iCEBOX and the user's PC).
- Extrada's XTN™ hub as the basis of the server application communicating with the OSGi framework on the gateway via their OSGi 'glue' bundle.

It had initially been planned to use a dial-up connection for the remote connection from the home to the XTN hub and this was adequate in terms of bandwidth as no applications needed more than a few tens of bytes transmitted per day. However dial-up posed the problem of managing the dial up connection (i.e. when to dial in and how to buffer data until the connection was established). It was decided to use a broadband connection to avoid this problem and this gave the added benefit that the broadband connection would be a 'carrot' for participants to encourage them onto the trial. This extended the demands on the trial installation process to include integrating the TAHI home network infrastructure with the customer's network. The experience gained here was very valuable in understanding aspects of using each customer's IP network and broadband connection to provide device-based services.

Probably the major issue experienced in the trial setup was how to establish a communications channel from the gateway, through the customer's router and via the customer's Asymmetric Digital Subscriber Line (ADSL) connection to the Extrada server. The use of a VPN connection was found to be the only feasible solution in the trial as this guaranteed a known and fixed IP address to the server. This approach also had problems in that the VPN connection would stop supporting data transmission after a while on many gateways, though would remain open and apparently normal. In this situation, stopping the VPN at the server end and relying on the auto connect approach at the client end would remake the connection successfully. A process of checking the VPN status and auto disconnecting at the server would be needed for reliable maintenance of this service.

The use of a VPN for gateway-server communications is not really feasible for commercial rollout as the requirement on server resources is prohibitive so this issue remains as one that would require a satisfactory solution for any significant implementation of this type of technology.

In addition to the remote connectivity issue the need to integrate the TAHI home network with the customer's network posed many problems, including:

- Many existing broadband connections are Universal Serial Bus (USB) based and not suitable for creating a network so a new router must be installed (and the cost incurred).
- Many home PCs cannot necessarily be networked without modification if, for example, there is no Ethernet adapter. This also adds cost as the PC must be adapted.
- Wireless communications are often not reliable (even amongst only 15 trial sites), as a position for antenna giving acceptable signal strength may not be locatable. In this case Ethernet cable must be laid, with resultant cost.
- Once the TAHI network installer had set up the customer's system then the trial effectively owned the network in the customer's mind and as a result many queries were routed to trial support though not necessarily related to trial equipment.

These experiences all make it clear that to install a home network for the purposes of providing services into the home (to devices in the home) has a substantial cost of ownership for the service provider as hardware and support effort costs are substantial. No lesser issue is the fact that a high degree of installer training, experience and knowledge is required to enable dealing with the huge range of variation in network device, PC and system issues.

The powerline networks posed no particular issues and were easy to install (where the equipment itself was working correctly!) and use of these network types with dial up connection would likely give a stable and supportable infrastructure adequate for medium data rate applications.

Remote Management

The trial aimed to demonstrate the ability to manage remotely, fault identify and optimise the operation of white & brown goods, heating and security products in the home.

The experience of development, test and implementation of the TAHI EM trial covered a number of aspects of diagnostics and remote management, as follows:

- The ability to diagnose component faults on equipment in the home (heating appliance, washing machine, CO/CH_4 alarm and security system) through equipment self-test and monitoring.
- The ability to monitor whether devices are communicating (or not) and perform some analysis of network performance.

- The ability to remotely manage the gateway software and update applications in the home from a remote location.
- Automated functions that will provide local recovery mechanisms where possible.

The following figure shows the Extrada XTN reference screen for Trial Home 7, showing the type of information of value to a service provider and which can be selectively portrayed to the householder.

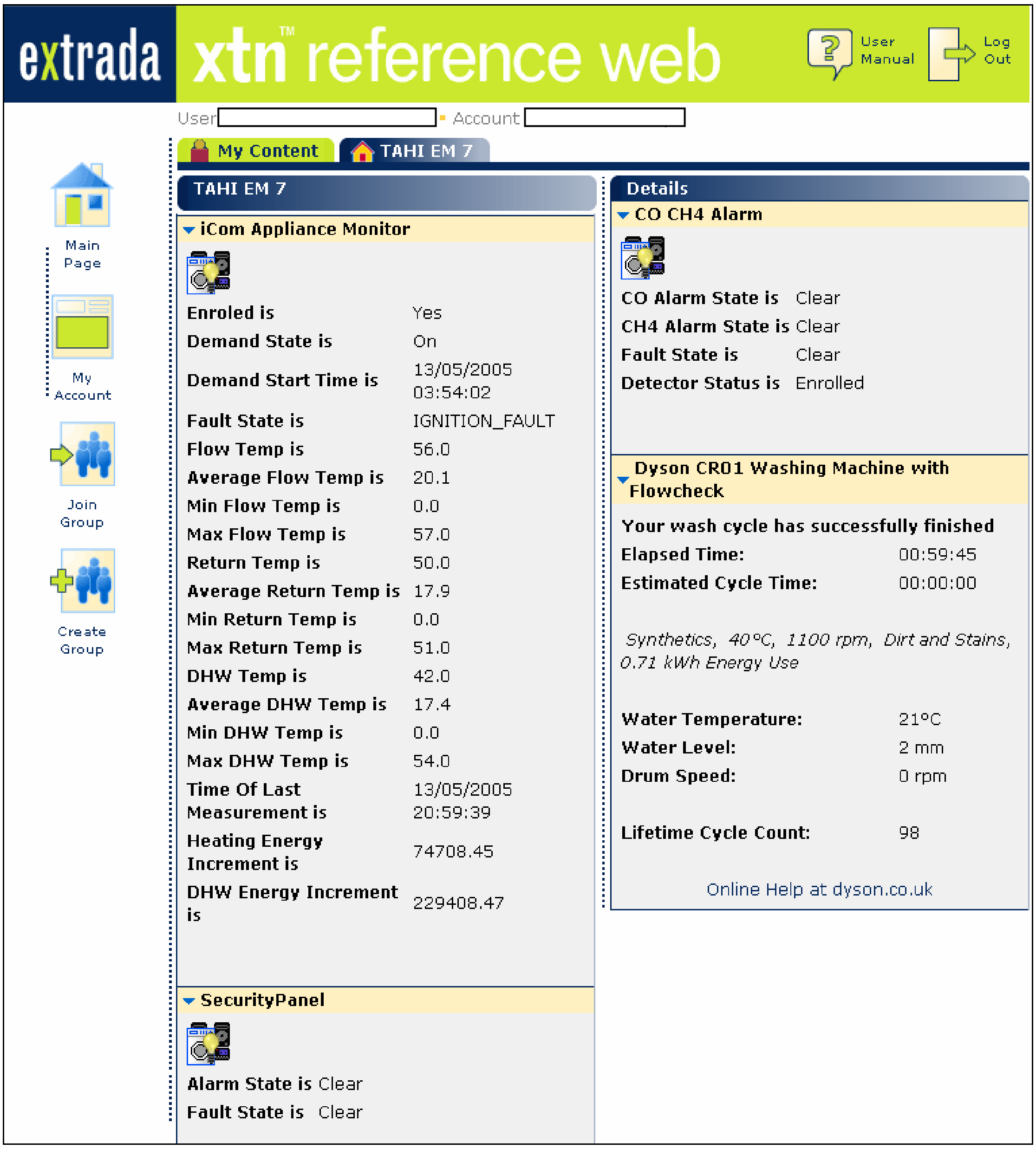

Figure 6. XTN Reference screen

Equipment Life Cycle Information Management System
A system was devised by De Montfort University which collects equipment life cycle data for enhanced service delivery to connected homes. These data can be used in different ways in many applications:

- Product development: data on failure modes and frequencies are good indicators for design modification to improve reliability beyond that achievable by laboratory tests or field trials.

- Appliance life monitoring: the system logs the input and output as well as the related actions of the appliance. Data logged at a defined period of time could be used for guarantee and insurance issues. Furthermore, system efficiency could be evaluated by comparing the actual and expected outputs.

- Diagnostics and failure prevention: Critical parameters can be observed in order to raise alarms, activate counter measures and feedback to maintenance / service. Data monitored could support convenient, cost-saving maintenance. For example, service personnel could obtain operational data to facilitate diagnostics and deciding on rectification action such as part replacement. Remote diagnosis before a service visit could help identify the spare parts required to keep travelling cost down.

- Lifetime and reliability prediction: Prediction of remaining life of the main components and safety related components supports maintenance and end-of-life treatment. Guarantees can be provided based on actual use rather than a fixed time period.

- End of life treatment: data could be accessed and used to optimise the end of life treatment of equipment. Parts removed can be classified for treatment according to their life histories.

The following Figure shows a screen shot from the system, demonstrating how a service provider could interact with on-line data relating to equipment in the home.

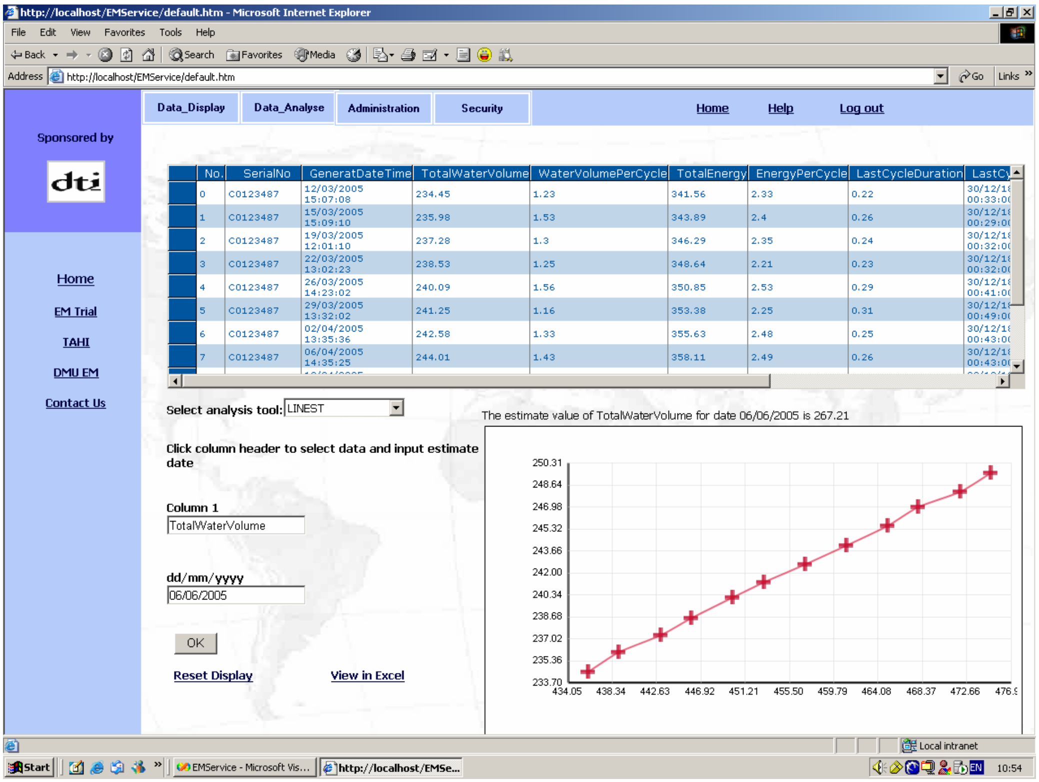

Figure 7. Screen shot from the Information Management System

8. PRIORITY AREAS FOR FUTURE ATTENTION

The trial identified the gaps in required new products and services associated with the interconnected home. The more obvious deficiencies in future smart home technology provision include:

Home Gateway
The home gateway represents a key link in the deployment of the integrated home technologies. The gateway provides the means to integrate all the enabling technologies in the home and also provide the link to the outside world. The lack of a clearly identifiable home gateway manufacturer in the UK currently is a significant factor. The TAHI Open Architecture represents one attempt at providing a framework in which home appliances will be able to communicate with one another. This is still in an embryonic stage and considerable work is required to get the buy-in from the wider market providers. There is likely to be a dominant presence in the EU in terms of home gateway standards and the USA are known to be active in this area as well. It is clear that standards will emerge in this area but at this stage there is no obvious leader. Until some degree of standardisation is achieved this could lead to various standards and inter-operability issues.

Unless a reliable and cost effective home gateway can be sourced then the future of smart homes will remain an issue.

Home Network Trades People
As soon as the gateway issue has been resolved and cost effective products become available, the next hurdle will be the integration of these systems into the home. There will be a requirement to support new and legacy systems in the home and it will not be easy to interface the home gateway directly with existing systems.

The home will require ‘wiring’ up so that the various devices can communicate with one another. The EM trials have shown the complexities of supporting inter-operability between different communications standards. This has highlighted the need for highly skilled network competent engineers. It is likely that the networking issues that will emerge will be beyond the skill set of domestic electricians and trades people. Therefore, if networked enabled home technologies emerge there will be a need for suitably trained people.

Improved Access Control
The trials have clearly demonstrated the consumer’s preference for easy to use interfaces. Though this was suspected at the outset, the trials have reinforced this view. Evidence has been obtained about which devices and appliances around the home need to be controlled. This information will help inform the design of future homes.

Privacy and Trust
Privacy and trust are key issues for the home consumer of smart home technology. As soon as devices are connected to an external network there will always be concern about system integrity. The use of wireless devices around the home also raises additional security concerns. Even though these problems will be surmountable, the consumer may mistrust the system.

Security
Security is essentially tied into privacy and trust but covers mainly physical integrity of the home system. As soon as the home system is connected to an external network it is vulnerable to external attack where someone could eavesdrop on the activities of the home owner. By looking for patterns of inactivity it is possible for an external person to improve their chances of breaking into the home undetected. Sophisticated attacks could also take place where the security of the home system is compromised and access to authorization codes and PIN could be extracted from the system. The need for low cost lightweight home gateways and protocols could actually increase the likelihood of such attacks taking place.

User Acceptance

One potential factor that holds people back with regard to employing smart technology at home is their lack of knowledge of it. People, especially older ones who form a large proportion of the population, resist new technology unless they have a thorough understanding of it. Therefore, just as there is a need for suitably trained engineers to install the systems, there have to be educators to conduct workshops, seminars, TV presentations etc to familiarize people with the system and to build trust.

Content Ownership

To save on bandwidth there is the potential for media caches to be deployed in the home. These are ‘black boxes’ with large amounts of storage space. This may be used to store temporarily Digital Rights Management (DRM) protected media such as Video on Demand. It may also be used for semi-permanent storage of media recorded from digital TV/radio. Or it may be permanent storage such as music libraries, home video footage, etc. Consequently, issues such as content ownership and reuse will need addressing. If the media cache becomes large then the issue of backup will be important for the home owner.