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Table of Contents

Table of Figures

Abstract

This deliverable describes the solutions adopted within DEHEMS for the provision of plug level electricity monitoring and overall domestic gas consumption.

The basis for this deliverable is Task 5.5 Hardware Construction:

> ***Ready for deployment in Cycle 2, the plug meters will be constructed from the previous hardware design tasks. The hardware will have been tested prior to this small batch production run and the only defect minimisation in this task will be around variability in the manufacturing process. (USal, IeAT, MCC and CL)***

The adoption of a solution for the provision of plug level metering has considered both powerline and wireless based network solutions and for both pragmatic and technical reasons, chosen to adopt a wireless sensor network solution that exploits a range of commercial products now available from the Plugwise company. These devices use the Zigbee wireless network standard which has been specifically developed for low data rate applications such as metering and the control of domestic appliances. Software has been developed within DEHEMS to integrate this technology into the DEHEMS data collector and hence, the user's dashboard interface.

Gas metering has proven a challenge for both sensing and network communications. Sensing is difficult because the retrofit of flow meters is complex and expensive and non-invasive sensing requires very expensive equipment. DEHEMS has found that the best method has been to optically read the dials on the meter with camera technology. This presents the problem of transmitting data where cabling and mains electricity are not commonly found. The approach has been to use GSM technology for the transmission of data back to the server. We feel that this is interesting research into the battery requirements, power minimisation, communication protocol and use of SMS over GPRS that can be used for what is emerging as a favoured approach in the roll out of smart meters.

Introduction

This deliverable is concerned with the solutions adopted within the Living Labs to provide a more granular analysis of energy monitoring by working at the plug level for electricity and by introducing other forms of energy usage monitoring, namely gas. All DEHEMS Living Labs homes are equipped with electricity meter reading devices with access to the DEHEMS online Dashboard for feedback however, only a limited number of homes will be provided with the additional ability to provide plug level monitoring of electricity and overall consumption of gas. Although limited in number, these homes will nevertheless allow us to assess from a research point of view the potential impact on behaviour change that can be achieved from the provision of such additional monitoring within Cycle 3. Hence, this deliverable concentrates entirely on the technical aspects of providing these additional levels of monitoring; the analysis and impact of providing such monitoring being addressed in a later deliverable reporting on the Cycle 3 findings.

When originally proposed, the DEHEMS partnership included Corinex Communications AS who are a manufacturer of networking products and who were tasked with undertaking the design and development of plug level electricity metering solutions.

However, Corinex withdrew from the partnership which meant that DEHEMS not only lost their expertise but also their manufacturing capability. However, on the positive side, the range of commercial products and off-the-shelf solutions now becoming available that offer the potential to provide plug level metering has grown steadily over the lifetime of the project. This in turn has also meant that we have been able to look more broadly at technical solutions than our initial focus on power line Ethernet which was specifically referred to in the original work package description. The same is not true though for gas monitoring where there is both an added complication of a more hazardous environment to monitor and also a general lack of existing products. Therefore our solution for gas consumption monitoring has been to seek to develop our own technical solutions.

The remainder of this deliverable is therefore organised into a review of electricity plug level monitoring that leads to our selection of a commercial product to provide this for DEHEMS Living Labs, followed by a section that describes the technology we have designed to provide gas monitoring.

Plug Level Electricity Monitoring

Providing plug level monitoring of electricity is achieved through the establishment of a sensor network comprising a set of plug mounted sensors that are able to communicate with one another and in turn, the DEHEMS data collector. A key question therefore, is how these sensors are to communicate. Two options were considered - using the existing power cables (power line) or via wireless communication.

During Cycle 1 power line networking research was undertaken to design a device that has the appropriate level of bandwidth, resilience and scalability for appliance level energy management and monitoring. It was concluded that ODFM techniques that are used in broadband powerline transmission provided an abundance of bandwidth but failed to scale above 32 devices on the mains power ring found in a home. X10, although originally designed for control commands, can scale to 256 addressable devices with at least 2400 baud of bandwidth. The hardware design was aimed to be modular with the gateway able to interface directly with 433 MHz wireless protocols and through serial, Zigbee and X10 interfaces.

However, subsequent to this work a more extensive review of technology has been undertaken and a greater range of relevant products have emerged within the marketplace that use the higher performance Zigbee wireless networking standard. These developments therefore caused us to reassess our initial position during the Cycle 2 phase of this project.

Power Line versus Wireless Networking Solutions

Power line communication (PLC) technology is considered as a quasi-WLAN technique, which uses the existing power line infrastructure as a medium for the transport of data. PLC can be an alternative to wireless technology in home networking as no additional new wires need to be installed. The HomePlug Powerline Alliance comprises industry leaders such as 3Com, Cisco Systems, Intel, Intellon, etc, working together to provide a forum for the creation of open specifications for high speed home power line networking products and services. The HomePlug Powerline Alliance has chosen Intellon's high-speed power line networking technology, the PowerPacket technology, as the baseline upon which to build the alliance's first generation specifications.

The HomePlug Powerline Alliance1 has defined the following specifications over the last 10 years:

- HomePlug 1.0 — Released June 2001 — Specification for connecting devices via power lines in the home. Theoretical speed of 14 Mbit/s.
- HomePlug AV — Released December 2005 — Designed for transmitting HDTV and VoIP around the home. Theoretical PHY data rate of up to 189 Mbit/s.
- HomePlug Access BPL (Broadband over Power Line) — under development — A working group to develop a specification for to-the-home connection.

[1] Global Standards Initiatives of the HomePlug Powerline, Alliancehttp://www.homeplug.org/tech/global_standards/

- HomePlug Command & Control (HPCC) — Released October 9, 2007 — It is a low-speed, very low-cost technology intended to complement the alliance's higher-speed powerline communications technologies. The specification enable advanced, whole-house control of lighting, appliances, climate control, security and other devices.

Power line is not considered as the best carrier for data because it is not specially designed for communications purposes. The problems of PLC include the noise on the line, the variable impedance of the line that leads to attenuation of signals and poor signal propagation along the 230V low voltage line, Schickhuber and McCarthy, 1997. A study on the static distribution of impedance values in the frequency range from 3 to 148.5 kHz has been carried out in three European countries. The results show that the Low Voltage distribution Network impedance is rarely greater than 20 ohms and 90% of the impedance values lie in the range of 0.5 ohms to 10 ohms. The most frequent impedance values of the Low Voltage Distribution Network are around 5 ohms, Negus et al, 2000. The distributed impedances include the inductances of the main wires, capacitive loads between live and neutral, resistive loads between live and neutral, and the coupling between the lines which occurs due to mutual inductance and parasitic capacitance between phases. The consumer loads such as cookers and fridges that are attached to the power outlet may also vary the impedance values of the power line. Therefore the choice of modulation technology is very important in order to obtain higher data rates.

Earlier research work was focused on the usage of power line for broadband internet access. The utility companies were interested in this technology as a means of competing with telecom operators by using the medium voltage lines as the backbones for data transmission. The latest technology offers data transmission systems of up to 200 Mbits/s at the frequency level of 1-30MHz. However, the major issue associated with these systems is the electromagnetic field radiation, Katipamula et al, 1999.

In Europe, the CENELEC has developed the standard EN50065-1 which specifies the frequency band allocation with their usage. The allocated bandwidth is low compared to the 350kHz allocated at 100kHz to 450kHz by the Federal Communications Commission (FCC) regulation in the USA. This implies that the power line communications systems in the USA have the ability to achieve higher bit rates than those in Europe.

Three types of standards are required for PLC; namely products, network and coexistence standards. Until now little has been achieved on the standardisation front. Frequencies used for both levels of PLC; outdoor and indoor are shown in Figure 1. Giunta, 2009, highlights the EMC emission problems due to the use of the low voltage power network for information transmission. This is the reason for PLC companies' hesitation between a desire to increase their networks and a potential risk of the radiation of PLC networks and the conducted disturbances.

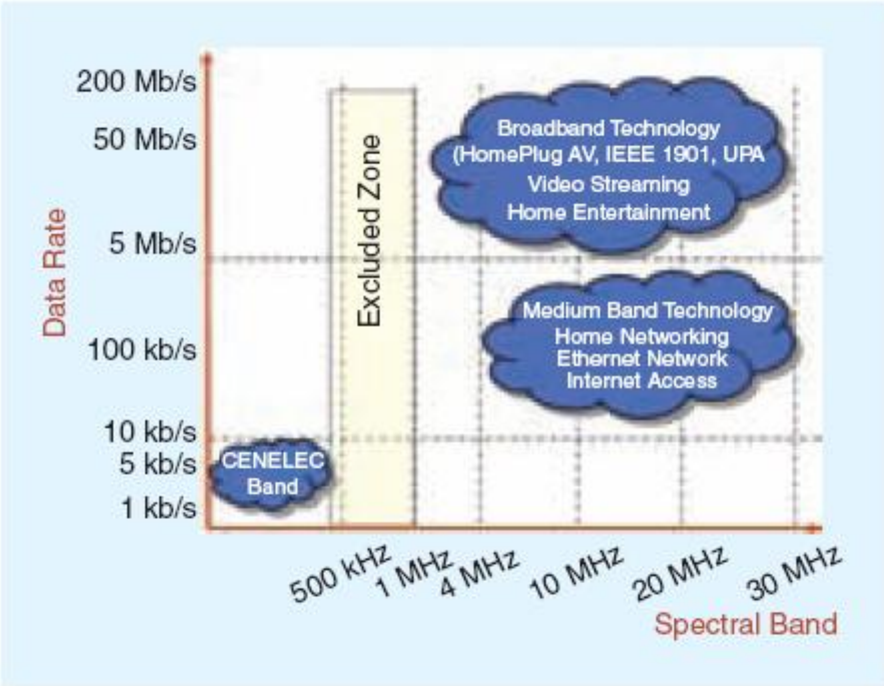


Figure 1 Powerline Communication Applications, (Giunta, 2009)

On one hand, the use power line as the home network communication technology is quite attractive as it has a number of advantages over other technologies; Lien et al, 2008; Giunta, 2009; San and Takruri-Rizk, 2001:

- No extra wiring will be required as the data will be communicated over the same wires that provides the electrical power;
- There are many access points (power sockets) in a home;
- Recent advances in modulation methodologies and digital signal processing techniques support power line communication networks at speeds comparable to local area networks and eliminates the noise and unpredictability previously associated with PLC.

On the other hand PLC has a number of disadvantages:

- Radiation: signals may travel outside the user's residence or business and be eavesdropped. The emission of electromagnetic noise may interfere with other systems such as public radio, fire alarms, military communications or radio amateur links.
- Lack of compatibility: The alliance certifies products for HomePlug compliance. Devices marked with the certification mark will interoperate with each other. However, they will not work with other power line technologies equipment providers that offer similar speeds.

The collection of plug level electricity consumption requires low data rates whereas most power line solutions aim to offer LAN data rates with common applications being to distribute domestic Internet connectivity within a building. Typical products are summarised in Figure 2.

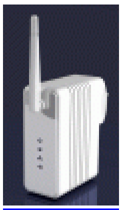
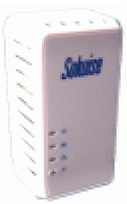
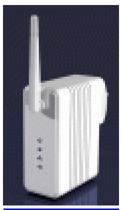
 Solwise 200Mbps HomePlug AV PIGGY Ethernet Adaptor with Simple Connect£34.73 - £132.50	 Solwise Homeplug 85Mbps Adapter and 54Mbps Wireless£30.50	 Solwise -Homeplug Turbo 85Mbps Twin Pack£37.00	 Solwise 200Mbps HomePlug iPlayer kit£54.00
 Solwise Homeplug Turbo 85Mbps Single Unit£19.50	 Linksys PLTK300 PowerLine 85Mbps AV Ethernet Adapter Kit£66.41	 Solwise 200Mbps HomePlug AV Ethernet Adaptor with Simple Connect£29.22	 Solwise VeseNET 200Mbps Home Plug AV 3£59.25
 Solwise 200Mbps Homeplug Wireless N Extender£47.50	 Devolo 200Mbps Homeplug Starter Kit£117.97	 Solwise 200Mbps Homeplug AV Adaptor with 54g WiFi£43.00	 Solwise High Power 200Mbps HomePlug AV Adaptor with Simple Connect£28.09

Figure 2 Selection of Powerline Home Networking Products

Given the low data rate requirements of energy monitoring a clear alternative technology to the use of power line communications is to provide a wireless network solution of which the leading candidate is Zigbee. Zigbee is a suite of standards based upon IEEE 802.15.4 for low rate wireless personal area networks. It is specifically targeted for in home applications such as light switches and lamps, electrical meters, and consumer electronics equipment. The technology is intended to be simpler, provide low data rates, long battery life, secure communications and to less expensive than its alternatives such as Bluetooth.

The ZigBee Alliance is an association of companies working together to facilitate the integration of Zigbee technology into everyday devices. ZigBee operates in the industrial, scientific and medical (ISM) radio bands; 868 MHz in Europe, 915 MHz in the USA and Australia, and 2.4 GHz in most jurisdictions worldwide. Devices intelligently form a mesh wireless sensor network in which data is routed using ad-hoc on demand distance vector routing protocols. Typical output radio power is 2 to 50mW at 2.4GHz giving a range 30m to 1km+.

Bill Ablondi, director of home systems research for Parks Associates said, “The time for manufacturers of home appliances and control systems to take advantage of recent technological advances in wireless and powerline controls is now." See Figure 3. "Consumers are more comfortable with digital technology, industry giants are looking for the ‘Next Big Thing,’ and communications protocols with low implementation costs and high reliability are a reality.”

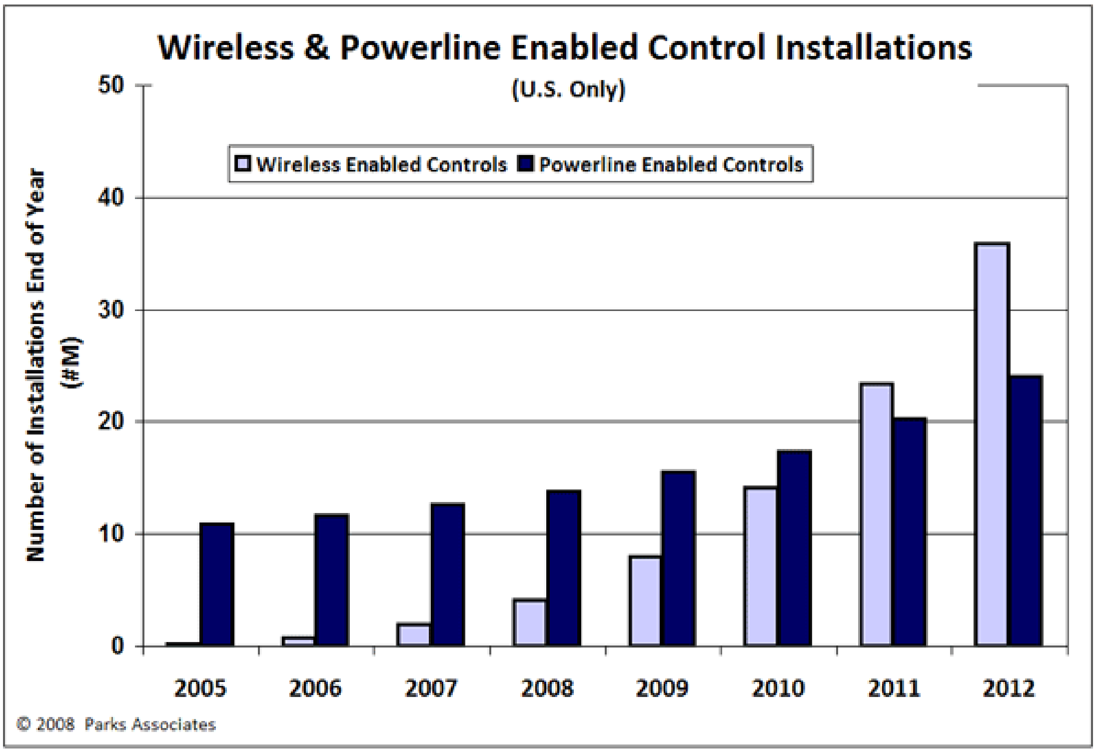


Figure 3 Potential for Wireless and Powerline Communication Applications (Parks Associates)

Uniband Electronic Corp (UBEC) cite the advantages of Zigbee as:

- offering minimal installation costs by virtue of the fact that ZigBee is a wireless standard in which nodes operate from local batteries.
- ZigBee data rates are lower than most powerline protocols, this simplifies signal processing, which lowers node cost as well.
- many ZigBee devices will be totally untethered and therefore significantly more mobile than powerline devices, which must be connected to a power socket for proper operation.
- offering a standards-based wireless network solution that is simple to develop and deploy, is optimized for low cost, low data rate applications, and demands long battery life, robust security, high data reliability, and product interoperability.

Related Relevant Research

A number of research projects and teams have investigated the use of both powerline and wireless network solutions for sensor and actuator networks and a selection are summarised in this section.

Kushiro et al, 2003 developed and implemented a home energy management system which is equipped with a residential gateway and integrated with latest internet technologies. The system was installed in 20 houses in Tokyo for evaluation. They used ECHONET(Energy Conservation and Homecare NETwork)2 on top of power line communication (PLC) for home networks and TCP/IP for wide area networking.

Osterlind et al, 2007, achieved an integration of wireless sensor networks with building automation systems (BAS) by implementing a BACnet (Building Automation and Control Networks) standard on top of a wireless sensor network. They recommended that when applying wireless sensor networks to building automation systems it is preferable to use existing BAS standards. As using existing standards, compatibility with already deployed solutions is ensured and future BAS protocol updates can be incorporated more easily. They have analysed a number of existing BAS protocols such as LonWorks, OPC, KNX and Modbus, and they chose the BACnet protocol, which is a data communication protocol for building automation and control networks. The main reasons for their choice were that BACnet is an open, widely used standard with support for many underlying network technologies including TCP/IP. They achieved a successful implementation of a design which is not originally designed for wireless sensor networks, using BACnet and TCP/IP networking. They demonstrated that it is possible to run BACnet over TCP/IP.

Kim et al, 2007designed a broadband power line communication (BPLC) home controller to control various domestic appliances and sensors. They used the Jini technology surrogate architecture as a home network middleware.

A Digital Living Network Alliance (DLNA) / UPnP-ZigBee gateway architecture was designed by Kawamoto et al (2007) to enable interoperability between the DLNA/ UPnP functions and the functions provided by

[2] Further information about ECONET is available on http://www.echonet.gr.jp/english/index.htm

ZigBee. The architecture includes the protocol conversion which enables device discovery, control and event notification via plug-and-play.

Eren and Fadzil (2007) set up a wireless instrument network based on ZigBee. They found that ZigBee based instrument networks are robust but susceptible to interference from other networks operating at the same ISM frequency such as WiFi and Bluetooth.

Plug Level Monitoring Product Selection

Having carried out a literature survey and market research and seeking a commercial product solution for plug level electricity monitoring, it was decided to adopt a Zigbee based solution. As previously described, Zigbee has been specifically developed for the type of application we require and, within the lifetime of the DEHEMS project, Zigbee products have become available.

Plugwise is a leading manufacturer of energy monitoring and management within buildings and has a range of products based upon the 2.4GHz Zigbee standard and approved for use within several European countries. Plugwise (www.plugwise.com) has developed a smart plug which is easily placed between the outlet and the plug of the appliance. The plug measures the energy consumption and transmits the data wirelessly. A Plugwise Zigbee USB data stick acts as a data sink for the wireless sensor network and receives data from the plug level meters. Software has been developed within DEHEMS to interface this to the DEHEMS data collector where received data is packaged and sent to the DEHEMS server where it is further processed and reported back to users as appliance level data via the DEHEMS dashboard.

The key advantages of the Plugwise solution to DEHEMS are that:

- It is available as an off-the-shelf product that is approved for installation in a range of European countries;
- It is standards compliant (Zigbee);
- It is extremely energy-efficient - the energy consumed by a Plugwise system is a mere fraction of the energy saved;
- It provides 128-bit AES encryption protection thereby safeguarding energy consumption data and privacy;
- It intelligently forms a wireless sensor network based on a mesh topology in which new appliances are recognized and incorporated automatically.

Details of the Plugwise Home Basic product is shown in the Figures 4 to 6.

Figure 4 Plugwise Home Basic Kit

Figure 5 Plugwise Devices in Home Basic Kit Showing Circle+ (Grey)

Figure 6 Plugswise Unit with Appliance

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Negus, Kevin J. and Stephens, Adrian P., Lansford, Jim,(2000) HomeRF: Wireless Networking for the Connected Home, IEEE Personal Communications, February 2000, Page(s) 20 – 27.

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Williams, E.D.; Matthews, H.S., 2007, Scoping the potential of monitoring and control technologies to reduce energy use in homes, Electronics & the Environment, Proceedings of the 2007 IEEE International Symposium on, 7-10 May 2007 Page(s):239 – 244.

Remote Gas Metering

There is a requirement within DEHEMS to be able to monitor and report domestic gas consumption. Whilst electricity monitoring can be provided at both a household and appliance level with non-intrusive and easy to install sensors, for practical, regulatory and health and safety issues, this is simply not possible for gas. Therefore the approach taken has been to seek a solution for monitoring household level gas monitoring using techniques that do not require any interference with existing gas installations. Consequently, this has resulted in the adoption of equipment which is able to read a gas meter using optical character recognition (OCR) and to then report this back to the DEHEMS server. Hence, this is analogous to the clamp meter being used to record household electricity consumption. An opportunity has also been taken to evaluate alternative methods of communication for data transfer between the household and DEHEMS server. Presently, the DEHEMS data collector uses 433MHz radio communication within the house to gather data from a clamp meter and Zigbee for acquiring plug level energy data from sensors with the resulting electricity consumption data being communicated via the household's broadband connection.

Gas installations are different to electricity; the gas meter is normally located external to the property with no internal point at which readings can be taken. Therefore, the a gas sensor has been developed that, in the first instance, will communicate its data via mobile phone (GSM) text messaging but with the ability to be provided with a 433MHz interface at a later stage for integration with the DEHEMS data collector. This approach therefore allows us to broaden our research scope to assess the relative merits of these two communication approaches and maximises our flexibility in terms of equipment installation.

Figure 4 provides an overview of the gas metering system architecture. In a house, an optical gas reader uses an Optical Character Recognition (OCR) module to obtain the current meter reading, a GSM mobile phone module periodically transmits this usage data to the DEHEMS server via SMS text messages, a microprocessor board controls the whole system and provides the interface between the OCR and GSM modules and power is provided from a local battery. Communication with the server requires a protocol to be defined that identifies the contents and format of gas readings to be sent from a gas meter to the DEHEMS server. It also defines status and configuration messages for reporting and configuration purposes. That is, status information of a gas reader, e.g. its battery level can be reported. The DEHEMS server can send configuration messages to a gas reader to update its internal settings. At the server side, a SMS server communicates with all DEHEMS gas meters. A web server provides the GUI (i.e. the Dashboard in DEHEMS) for end users.

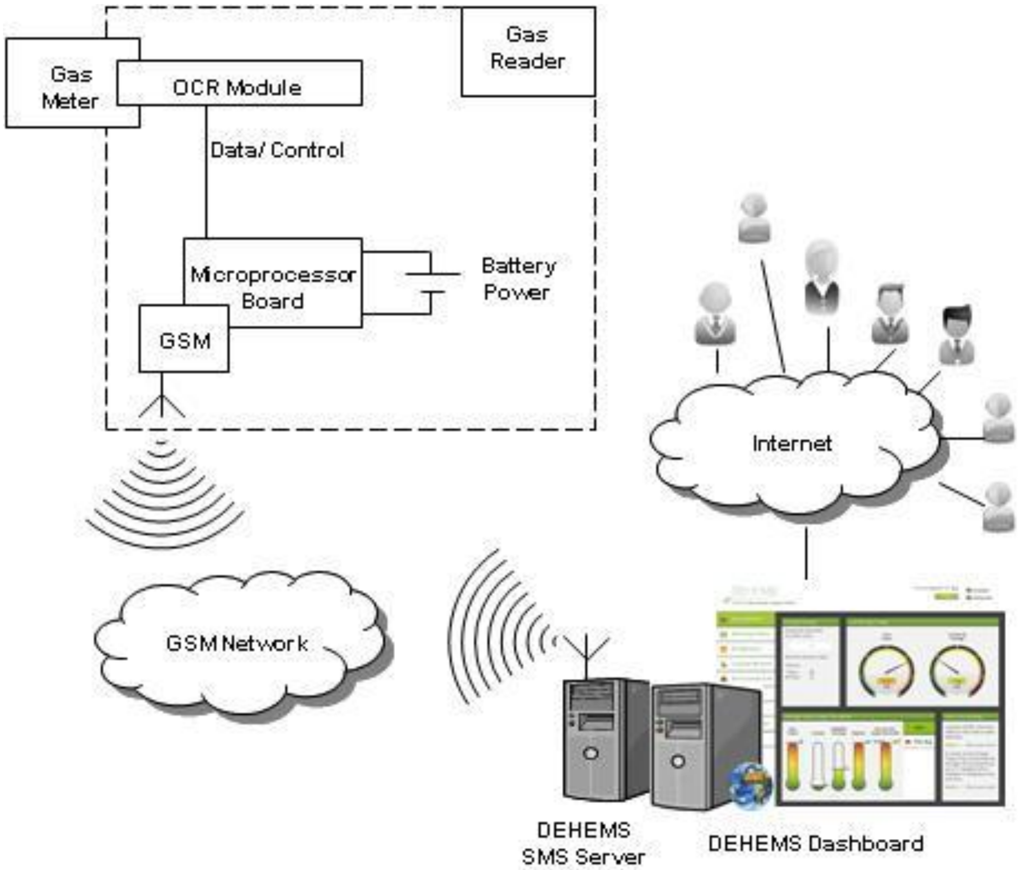

Figure 7 Gas Metering System Architecture

Each of these main components will now be discussed in more detail.

OCR Module Metering

The University of Coventry carried out a study of gas meters and optical character recognition devices and recommended DEHEMS should adopt the Xemtec Comet optical sensor produced by Enica Ltd Technical details can be obtained from the company's website at http://www.enica.co.uk/Products/index.html.

This device operates in two modes, either producing a series of electrical pulse which reflect energy consumption in real time or through a character orientated interface where commands can be issued that trigger the senor into transmitting a series of characters that represent the current meter reading digits. It is this second mode of operation that is being adopted.

System Hardware

The system hardware comprises a PIC16F76 based microprocessor board, serial interface, GSM communications module, program and system memory and timers as shown in figure 5. This unit has been supplied by Salford Electronic Consultants Ltd.

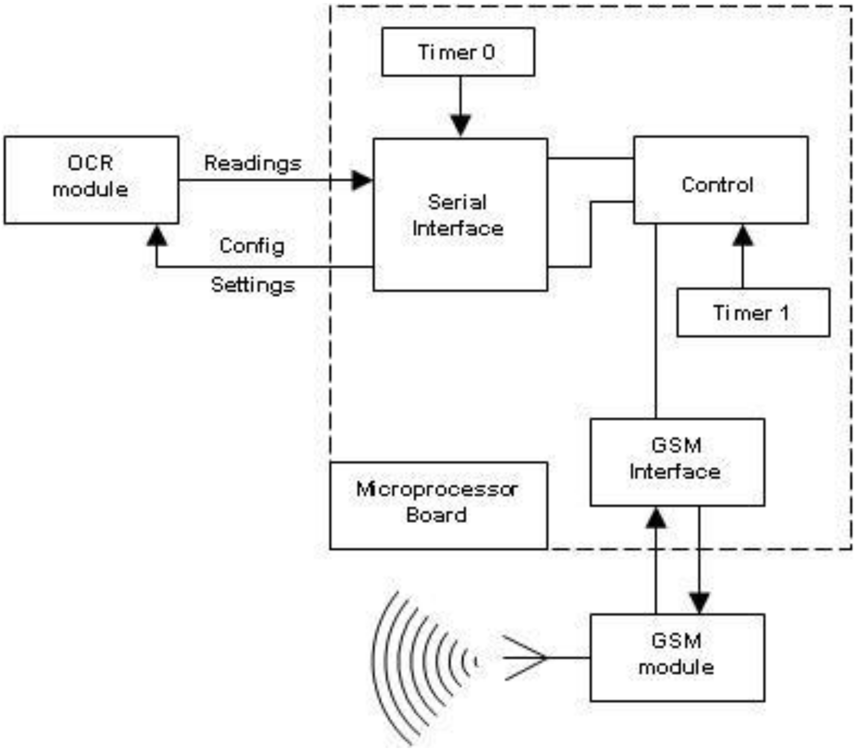

Figure 8 System Hardware

A timer, Timer 1 is set up to decide the frequency it wakes up; that is, Timer 1 determines how often the OCR module is interrogated for the current value of the gas meter reading. This reading is then transmitted via the GSM module within a SMS short message to the DEHEMS server. The value of Timer 1 can be modified by the DEHEMS server and communicated to the gas reader via its communications protocol. A second timer, Timer 0, is shown and this is used to control the baud rate of the serial communications with the OCR module. When not required, the GSM module is placed into a standby mode. The GSM module obtains current time and date information from the GSM network.

System Control Software

The system control software within the gas reader comprises a main program and a series of interrupt driven routines. The main control loop is shown in figure 6 and comprises, checking Timer 1 to determine when a reading should be taken and checking to see if a message has been received via the GSM mobile interface. Should either of these two prove to be true then appropriate action and further processing is undertaken. When sending meter readings to the DEHEMS server, a timestamp is added which is obtained from the clock within the GSM module.

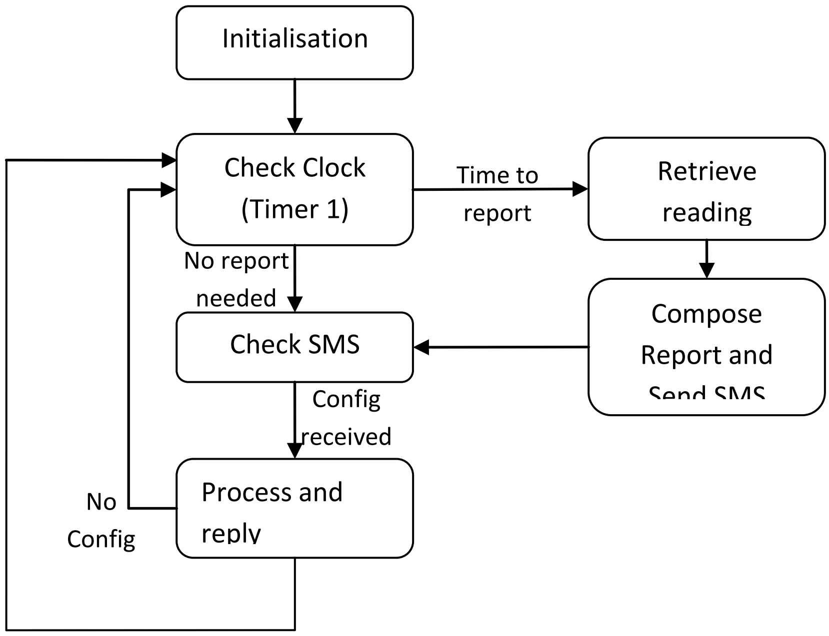

Figure 9 Main System Control Loop

There are three main sources of interrupt; the triggering of Timers 0 and 1 and receipt of a character from the GSM interface, i.e. an incoming SMS text message. The main processing functions associated with these three interrupts are shown in figure 7.

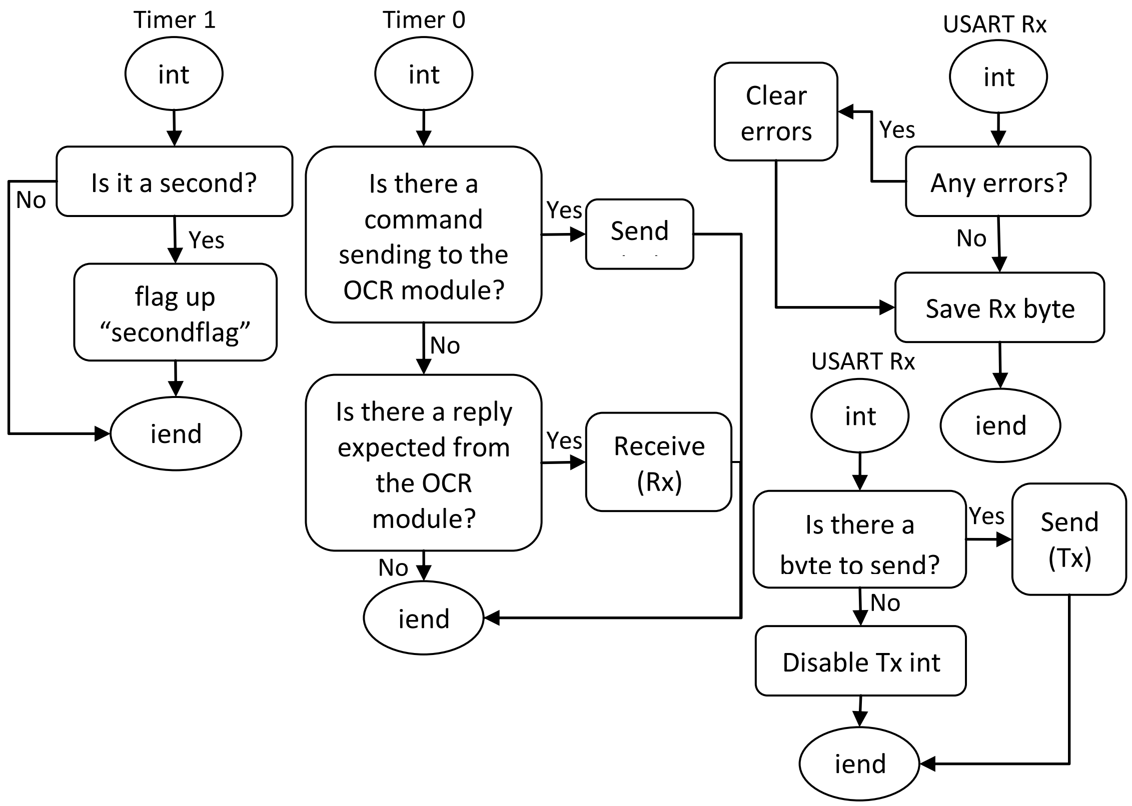

Figure 10 Interrupt Processing Routines

Communications Protocol

The purpose of the communication protocol is to firstly manage the transmission of gas meter readings from the OCR module to the DEHEMS server and secondly, to allow the DEHEMS server configure the gas reader system.

Packet Types and Format

Three types of packets are defined in the protocol, i.e. Data, Config and Status. Because an SMS message is assumed to be definitely received, no acknowledge message is required to confirm the reception of a packet.

Every short message contains a packet header and body. A packet is sent in 7-bit ASCII format and described in JSON with '{' and '}' as the preamble and ending character respectively. The packet header and body are separated by a colon ':'; sections of the header and body are delimited by a comma ','.

Packet Types

A data packet contains time series gas readings. It is generated by the microprocessor board when pulses are received. If no pulse is received when TSAMPLE_INTERVAL is due, no Data packet will be generated.

As shown in Figure 8, the header of a Data packet has two sections.

Type (1 byte): defines the type of the packet (D: Data);

Offset (4 bytes): counts the number of packets being sent; it is set to '0000' when overflow;

Timestamp (21 bytes): records the sending time of the message; e.g. "2010-06-10 13:07:45";

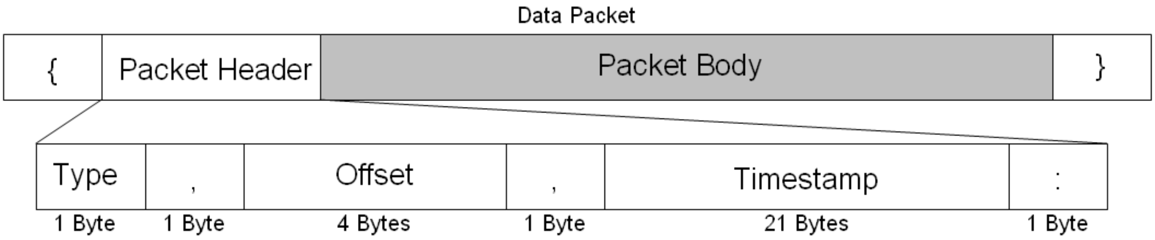

Figure 11 Data Packet Format

The packet body contains the reading from the gas meter.

Config Packet

A Config packet is transmitted from the DEHEMS server to the gas reader.

The header of a Config packet has three sections, i.e. Type and Length, as shown in Figure 9.

Type (1 byte): defines the type of the packet (C: Config);

Length (1 bytes): specifies the number of Config settings in the packet body;

Token (4 bytes): verifies the Config packet;

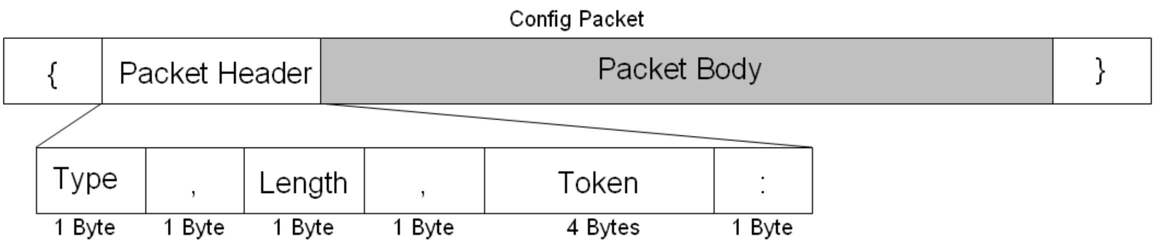

Figure 12 Config Packet Structure

The packet body contains the settings of the gas reader that need to be modified. At present, three parameters are defined as internal settings in the gas reader; these include Timer , the SMS number of the DEHEMS server NSERVER_NUMBER ('NS') and the authentication token PAUTH_TOKEN ('AT').

Status Packet

A Status packet reports the situation of the gas reader to the DEHEMS server.

The header of a Status packet has two sections; they are Type and Length, as shown in Figure 10

Type (1 byte): defines the type of the packet (S: Status);

Length (1 bytes): specifies the number of Status reports in the packet body;

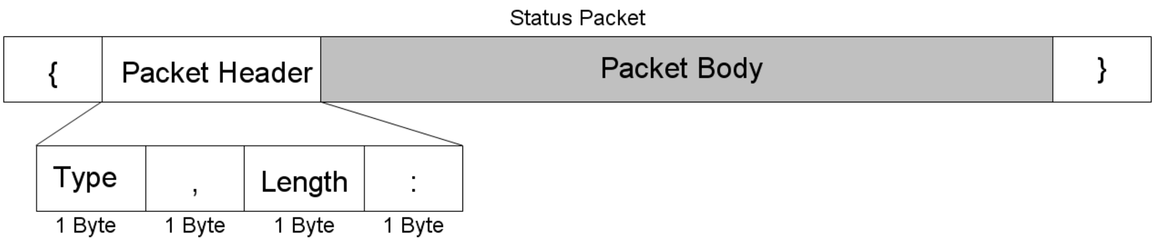

Figure 13 Status Packet Format

The packet body of a Status packet contains reports on the status of the gas reader. At present it has 1 status report, i.e. the Battery Level ('BL').

Transaction Details

When a gas reader is correctly installed and switched on for the first time, it has following settings preloaded:

Timer 1: 1 Hour (3600 seconds);

NSERVER_NUMBER: number of the DEHEMS SMS server;

PAUTH_TOKEN: randomly generated;

It firstly sends an initial Data packet to the DEHEMS server containing its initial authentication token, and then starts to send the gas readings according to its default settings.

The DEHEMS server can send a Config packet after the gas reader is initialised. Having received a Config packet, the gas reader updates its settings.

Figure 14 Gas Meter Display

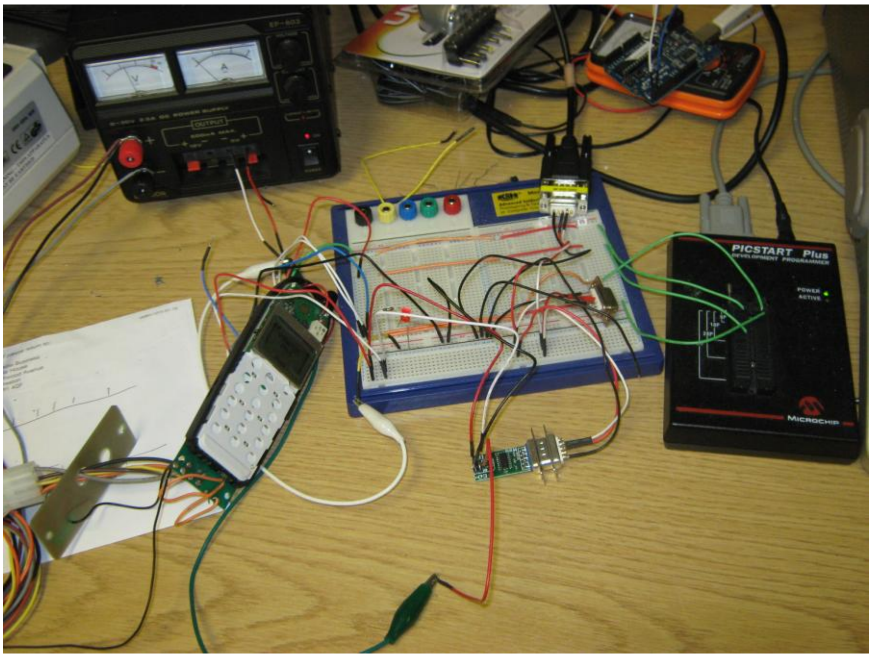

Figure 15 Test Bed

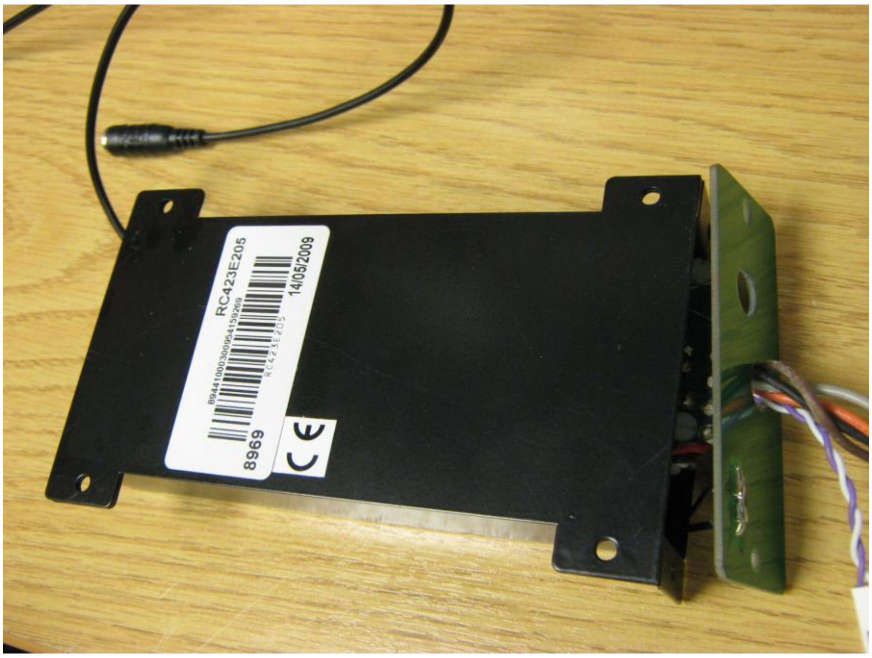

Figure 16 Case (Including Board and Phone)

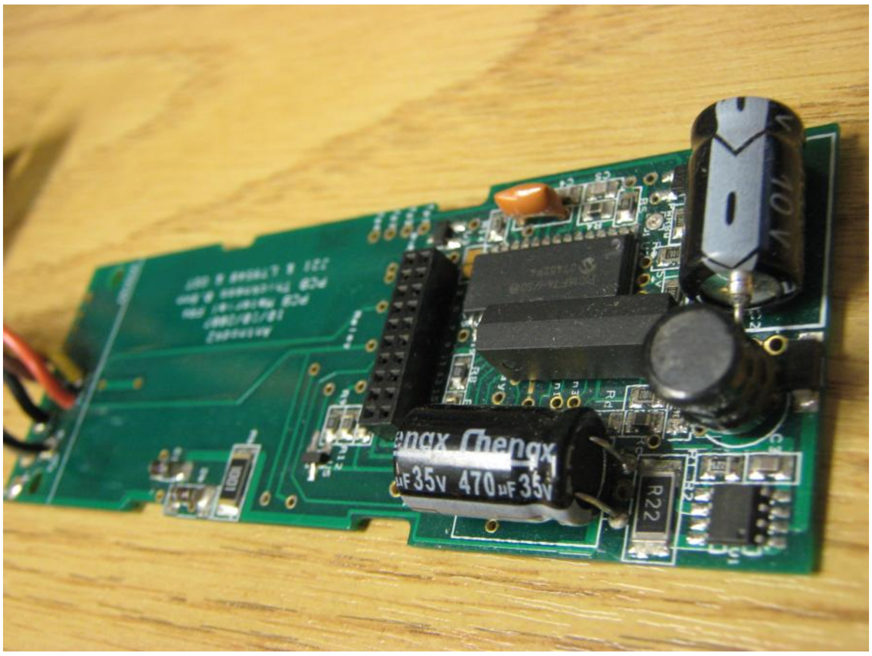

Figure 17 Communications Board

Regulatory and Installation Issues For Gas Metering

The gas meter solution being adopted for the DEHEMS project is expected to be subject to EU Directive 99/92/EC and EU Directive 94/9/EC both of which relate to explosive atmospheres. These Directives together define the minimum requirements for improving the health and safety protection of workers potentially at risk from explosive atmospheres and the laws of EU Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres. At the time of writing this deliverable it is unclear to what extent the gas reader will need to comply with these regulations however, placement of a GSM mobile interface in close proximity to a live gas meter needs to be investigated.

The above with either require the DEHEMS gas reader to undergo formal approvals and acceptance testing to receive a certificate of compliance or an installation guide and procedure will need to be authored to ensure that all installations are compliant with the Directives.

The solution adopted for measuring gas consumption can be extended to monitor any form of service consumption providing that usage of that service is recorded via a meter that is compatible with the OCR module being used.

Concluding Remarks

As stated in the introduction, this deliverable is concerned with the solutions adopted within the Living Labs to provide a more granular analysis of energy monitoring by working at the plug level for electricity and by introducing other forms of energy usage monitoring, namely gas. The original proposal for the DEHEMS project was to use the expertise of the consortium partner Corinex Communications AS, a manufacturer of networking products. It was their role within project framework to utilise their powerline technology to design and develop a plug level electricity metering solutions. With their absence and market developments, there was the opportunity to investigate the new range of commercial products meaning the project could examine a different technical than first proposed. Hence the implementation of Plugwise in the DEHEMS project.

Gas monitoring however has presented a different challenge with the complication of a more hazardous environment to monitor and lack of existing products. The project has therefore undertaken technical research and development in search of a solution with the development of a functioning prototype. The aim would then be to implement a small scale production.