Commission for Energy Regulation

An Coimisiún um Rialáil Fuinnimh

Electricity Smart Metering Technology Trials Findings Report

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Abstract:

This Information Paper outlines the findings from the electricity smart metering technology trials (conducted by ESB Networks as part of the CER Smart Metering Project) which examined a range of smart metering functionality and communications technology options in order to assess their performance and enable learning and better understanding of the risks that would be associated with a national electricity smart metering rollout to residential and small business consumers in Ireland.

Target Audience:

This paper is for the attention of members of the public, the energy industry, energy consumers and all interested parties.

For further information on this Information Paper, please contact Gary Martin (gmartin@cer.ie) at the CER.

Related Documents:

- Smart Metering Information Paper 4 – CER/11/080 – 16th May 2011
- Electricity Smart Metering Customer Behaviour Trials (CBT) Findings Report – CER/11/080a – 16th May 2011
- Electricity Smart Metering Cost-Benefit Analysis Report – CER/11/080c – 16th May 2011

Report On Smart Metering Technology Trials for Commission for Energy Regulation

Disclaimer and Limitations

Any correspondence should be addressed to:

Manager, ESB Networks Smart Metering Project,
ESB Networks Limited,
Clanwilliam House,
Dublin 2

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1 Executive Summary

Background

Smart metering is a hybrid technology consisting of three high level layers:
• Physical meters and associated devices
• Communications layer
• IT systems which manage the data, applications and services

It offers benefits for the individual electricity customers and for the electricity system in general. It can empower the customer to better manage their electricity consumption, support renewable energy and improve the electricity service. However, it is still a developing technology with many challenges ahead.

The Commission for Energy Regulation established the Smart Metering Project Phase 1 in late 2007 with the objective of setting up and running smart metering trials. As part of this phase ESB Networks undertook a number of smart metering technology trials.

The purposes of the smart meter technology trials were;

- To enable learning about providing supporting systems, testing, and deploying smart meters
- To assess the performance of representative available smart metering systems and communications technologies in the Irish environment. Uniquely in Europe, due to our settlement pattern, Ireland will need wireless communications to serve at least one third of all customers.
- To identify risks and issues for a smart metering roll out.

Customer behaviour trials were also carried out. The smart metering system we put in place to support these trials is also included in the technology trials.

Scope of Technology trial

The systems trialled were selected from those offered during the Pilot Project procurement process in 2008. The systems were based on the three key communications technology areas: power-line carrier, wireless LAN and point to point wireless.We focused on how these systems delivered a core set of smart metering functions which all require reliable communications. These functions and the required performance levels are at the advanced end of the smart metering scale and are more onerous than typical European roll outs to date. The functional and performance requirements for the full roll out here have not been decided and may be even more demanding.

Numbers installed

The numbers of customer installations for the field trials were as follows:

- Metering system with GPRS communications - 5,800 single phase and 500 three phase meters throughout the country for customers selected for the CBT.

- Metering Systems with PLC communications – 1,100 single phase meters for customers in Limerick and Ennis. Eight of the locations chosen were urban and three were village areas.
- Metering Systems with 2.4GHz Wireless mesh - 1591 meters installed in Cork City and 690 meters installed in the rural area of County Cork outside Bandon.

Desktop studies were carried out on two technologies – PLC from Aclara and 868 MHz RF from Elster.

Observations on communication technologies

It is noted that currently PLC could reliably deliver monthly readings. However, the PLC based communications trialled has major issues to be overcome to deliver reliable daily collection of profile data from every meter. Problems were also experienced with performance of on-demand tasks. Outside of ideal electricity network conditions the performance of the system deteriorated. These non-ideal conditions for PLC are frequently encountered on our network. Many of the issues we identified with performance of PLC are currently being addressed by ongoing work in Europe by major Utilities and vendors.

The GPRS based system generally worked well with good availability. Scaling the system to significantly larger numbers may be an issue. The longevity of GPRS as a technology in a large number of meters and mobile vendor lock-in is also a concern. However, if required to roll out a limited number of meters on a priority and dispersed basis over the next few years GPRS appears to be an appropriate solution.

The 2.4GHz mesh worked in the urban area where meters were relatively close to each other. The benefits of a mesh topology were shown here. The performance was disappointing in rural areas, where wireless is most needed.. This was largely due to the European Regulatory limitations on the signal power at this licence exempt frequency.

Mesh systems operating in the sub-1Ghz range and at relatively higher transmit power outside of Europe appear to address many of these issues. We believe that more suitable wireless spectrum should be made available in the sub 1GHz area to allow us access to a wider range of such solutions.

While developments on standardisation of the systems are advancing much work still has to be done. The recent entry of major communications systems vendors into the market is accelerating the availability of solutions complying with IP standards.

Importance of defining requirements and performance levels

The trial showed that the performance levels will have a significant impact on the choice of communications technology and its operational cost.

Meter design

Based on the meters used in the trial we believe there will be a good choice of available metering technology to meet the functional requirements for a full roll out. However, more progress needs to be made on the full adoption of open standards.

Installation work

For the half of our customers with indoor meters the management of access to install the smart meter was a key deployment issue. The time spent with the vendors to ensure that the meter install process was 'plug and play' was of great benefit. However, it is to be noted that technical issues were encountered in at least 3% of installations which required a lot more work than simply installing the smart meters in. This would have to be factored into the costing and planning of a full roll out.

Testing

The trial demonstrated the importance of a comprehensive testing strategy. Sufficient time must be allowed for soak testing of meters and devices in the field. Major security testing should also take place at this time.

Security and data protection

It is essential that all data collected and processed via the smart metering infrastructure be handled securely and that customer privacy is safeguarded at all times. The security associated with the solutions used in the trials were deemed fit for purpose. The trial included encryption of data and full compliance with Data Protection Legislation. As a general rule for a full roll out there will have to be an increased focus on areas such as

- standards based security solutions leveraging security protocols deployed in other sensitive industries such as internet banking, telecomms and defence
- robust mechanisms for protecting the integrity of the smart metering network
- secure hardware manufacturing processes and software development lifecycles
- a robust, secure and speedy process to provide firmware upgrades to meters and devices in the field.

Timetable

Smart metering is a complex program. The experience in the trial and that of other utilities who have undertaken smart metering deployment reinforces this view. The program can be up to 7 years duration with almost half the time required before full deployment. The key phases these phases include:

- Definition of requirements, design, planning, specification and procurement. At the end of this phase we will have selected the solutions.
- Design test and installation of IT systems including integration to meters.
- Roll out of comms. infrastructure and installation of meters and other devices.

Based on the above assumptions on the timetable we could be deciding in late 2012 on the full roll out solution.

Further work

The recent entry of major communications systems vendors into the market is accelerating the availability of solutions complying with IP standards which will be of benefit. It is important that we build on the learning from the technology trials and continue to be involved in examining other potential solutions as they arise

2 Introduction

2.1 Purpose of document

This document contains ESB Networks key learning's from the Smart Metering Technology Trial.

2.2 Background

In 2007 ESB Networks committed to CER to run a smart metering pilot. This pilot was deemed a necessary step in developing an understanding of smart metering.

The project was split between the Customer Behavior Trial (CBT) and Technology trials. ESB Networks agreed the plan and timetable with CER. These trials were incorporated in the CER's Program for Phase One of the National Smart Metering Plan.

The technologies selected from those offered during the Smart Metering Pilot Project procurement allowed ESB Networks to ensure that powerline, wireless LAN and point to point solutions were trialled. Ireland has a unique population settlement pattern and as a consequence the scale and nature of the resultant electricity distribution system means that we have challenges designing and implementing Smart Metering which are not as significant for other European countries.

ESB Networks' goals for the Technology Pilot were:

- To set up a pilot advanced metering infrastructure; composed of smart meters, communications infrastructure and head end collection software.
- Assess communications solutions
- To ascertain if smart metering technology has sufficient functionality, reliability and performance levels to meet core business requirements
- To quantify the technical issues faced in the customers premises
- To embed organizational knowledge on smart metering across the range of business and technology dimensions involved.

3 Technologies Selected for Trial

The Procurement process for metering systems commenced with an OJEU notice at the end of 2007, the specification for the trial metering systems was produced and the metering procurement process completed in mid 2008. Based on this process and on the offers submitted, technologies were selected by ESB Networks for the trial.

The Customer Behaviour Trial (CBT) was initially prioritised because of its scale and critical timetable. This trial was also a great learning opportunity in terms of smart metering systems design, testing, delivery and deployment. It also provided us with an excellent opportunity to assess GPRS.

In addition to the CBT, ESB Networks finalised the detailed project scope of the Technology Trials with each of the selected Suppliers. We were conscious of the need to minimise the cost and given that this was a trial, where possible we wanted to avoid major design, development and associated testing work. It is important to understand that the communications technologies were selected in 2008 based on what was offered at that time. Our objective was to see as many as possible of the major communications technology groups represented in the trials.

The technologies selected for field trials are summarised in the table below:

Communications Technology for Field Trials	**Description**	**Relevance**
GPRS (Elster Meters, EICT IT and Vodafone Network)	General Packet Radio Service (GPRS) is a packet-switched data service delivered over GSM networks. This network is provided by the mobile network operator.	This is a ubiquitous existing technology that covers almost the entire population. It is very suitable for a customer behaviour trial. Using this in a pilot gives us a good understanding of the issues with using an existing mobile network operator's infrastructure to support smart metering.
Distribution Line Carrier (SagemCom Meters and IT systems)	PLC uses the low voltage power-line for two way communications between the home and a data concentrator in an existing substation. It is generally based on IEC standards to which the metering system suppliers are largely compliant (IEC 62056). It uses frequencies in the Cenelec A band which is exclusively reserved for electricity utilities. The data concentrator uses GPRS to	PLC is the most widely used communications technologies in Europe. It is a solution that is primarily of interest for customers in urban areas, towns and villages. It uses the utility's own networks and is generally based on open standards and would be considered as offering a lower cost solution

	communicate back and forth with the IT systems.	
Wireless Mesh at 2.4GHz (Trilliant Comms. and IT with Iskrameko meters)	Mesh radio is a private radio network technology for communicating with meters, which uses meters as repeaters in a mesh configuration. The meter collector receives and transmits signals to meters which, in turn, pass these signals on to other meters. The frequency used is generally licence exempt. In the case of this trial we are using the licence exempt 2.4GHz spectrum. Wireless mesh tends to be a proprietary offering.	Wireless mesh is favoured for smart metering solutions in US and Australia. While the spectrum generally used for these deployments is in the 900MHz range and therefore not useable in Europe, the solution chosen is in the 2.4GHz range which is available for use in Europe. Given the large number of customers in Ireland (approx. 40%) outside the urban areas not reachable by conventional PLC it is important to look at the use of wireless and how it performs in Irish conditions

Based on the technologies offered in procurement in 2008 it was also decided to carry out small desktop studies on two of the other technologies offered.

Communications for Desktop Study	Description	Relevance
Power-line Carrier (Aclara)	This technology uses the power line to the home to carry a low bandwidth signal. Special equipment is installed in the 38kV station Signals are created by producing a unique pattern of current pulses in the field devices and detecting those pulses in the substation. The solution is proprietary.	The technology might offer an option for rural areas with low population density, depending on the performance requirements for a full roll out.
Wireless Tree at 868MHz (Elster\Coronis)	This is a private radio network technology for communicating with meters, which uses meters as repeaters in a tree configuration. The meter Data Collector receives and transmits signals to and from meters which, in turn, pass these signals either directly or via repeaters. The	This solution is currently used in Europe for water metering. We wished to examine if this solution could be used for rural customers.

	frequency used is generally un-licensed. In the case of this trial we are using the un-licensed 868MHz spectrum.	

WAN Technology

For the purposes of the trial GPRS was designated as the WAN technology for all the LAN technologies being trialled. This was done to facilitate flexibility and speed of deployment. The use of this mature, well understood, standards based, ubiquitous technology for the WAN, common to all the LAN technologies, allowed the project to concentrate its efforts on designing, deploying and assessing the more complex and less mature LAN technologies eliminating many possible areas of uncertainty. It should not be assumed that GPRS would be used as the WAN for a full roll out.

4 Delivery of the Trials

The final numbers selected for the field trials were as follows:

- 5,800 single phase and 500 three phase meters throughout the country for the customers randomly selected for the CBT had GPRS based communications.

- 1,100 single phase meters for customers in 11 locations in Limerick and Ennis were installed for the powerline carrier trial. Eight of the locations chosen were urban and three were village areas.

- 2,281 meters comprising of 1591 meters installed in Cork City and 690 meters installed in the rural area of County Cork outside Bandon for the wireless mesh trial. Desktop studies were carried out on the remaining two technologies – PLC from Aclara and 868 MHz RF from Elster/Coronis.

4.1 Systems Functionality

While the functional and performance requirements for the full roll out have not yet been agreed we focused on how the various technologies could deliver an anticipated core set of smart metering functions. The following core functions were evaluated:

4.1.1 Automatic Functions

- Automatic registration of the smart meter on the system
- Scheduled Daily Load Profile retrieval for 30 minute intervals
- Scheduled daily midnight register readings
- Scheduled events and alarms
- Event log management

4.1.2 On Demand Functions

- De-energisation and re-energisation (sandbox)
- On demand profile reading
- On demand register reading
- Re-configuration of parameters on meter
- Firmware upgrade capability
- Power quality monitoring

4.2 Stages of the Trial

Implementing a smart metering system, even as a pilot, required a number of key stages

4.2.1 Stage 1 - Design Stage

A design phase was carried out to agree areas such as:

- Overall solution architecture,
- Functionality of the system
- Communications performance model
- Data model
- Meter type and schema
- Security architecture
- Documentation and implementation plan.
- User Manuals and system support

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4.2.2 Stage 2 - Testing and Quality Assurance stage

There were multiple phases of testing designed to complete this critical stage of the technology trial. The phases of testing included:

- Factory Unit Testing (Meters) - demonstrated that the meter meets the functional requirements
- Factory System Testing (Full Metering System) - demonstrated the functionality of the complete metering system, including the MDMS/Head end, Communications devices and their integration with sample meters.
- Sandbox System Integration Testing (Metering System) - These tests were carried out prior to deployment of the system in a 'Live Environment' in ESB. The test was conducted on a complete, fully functioning system including the head end fully configured and running on the ESB Networks smart metering project Test environment, communications devices installed and communicating over the ESB WAN and with an adequate number of meters, installed in representative locations, needed to carry out the tests connected to the System.

Sandbox test environment (panel)

- Field Soak Test (Metering System) – The soak test involves installing a small number of meters in a production environment and verifying that they operate correctly over a reasonable period of time . The intention is to identify any type faults which might require rectification in the field before installing large amounts of the equipment
- Site acceptance, stress and volume testing (Metering System)

All testing for each of these stages were carried out jointly between ESB Networks and the Vendor.

4.2.3 Stage 3 - Deployment, upgrades and enhancements of systems in the field.

The stages in the deployment process were:

- Deployment Planning and Area selection – This involved selection of the trial areas and the network, meter position and customer types.
- Customer information - This consisted of written communications with all customers in the trial areas and responding to their queries,
- Pilot Deployment – This process was designed to test (i) ESB Networks deployment processes for the different types of meters and (ii) the performance of the different communications technologies on real networks, to identify any defects / enhancements required before proceeding with the full deployment.

- Communications models were developed to predict performance and to identify the best places to locate communications devices.
- Mass Deployment- This process was the installation of the customer meters. This work was carried out within the normal ESB meter replacement processes
- Upgrades / fixes for defects and issues discovered in the field.

4.2.4 Stage 4 – Measurement and Evaluation

Once ESB Networks had deployed the meters and baselined any subsequent firmware upgrades or other fixes for various defects that were identified in the field we commenced the measurement and evaluation phase. During this phase the performance of the system in relation to the various functionalities was measured. The trial areas were chosen with a view to developing an understanding of how the various technologies would perform in different scenarios. These scenarios explored also related to the technology under evaluation.

These scenarios included:

- Urban / Rural locations
- Overhead / underground network
- Indoor / Outdoor / Centralised Meter Position

4.2.5 Measurement and Evaluation Tools

All metering systems included head end IT systems which had a reporting capability. However as meters were being deployed in the field, it was felt that a visual tool would be useful to display the progress of meter installations and understand how the various communications networks were performing. ESB Networks developed a viewer tool to display the GIS view of the Smart Meter installations in the trial. The content of the information displayed was synchronized automatically each day. As meter deployment came to an end, the tool became essential for network tuning, daily reporting analysis and troubleshooting problematic meter installations.

A number of sample GIS views have been included below to demonstrate the capability of using GIS as a tool to aid in a Smart Metering deployment.

a) PLC Concentrator View by Status (Sample GIS view)

Legend

- St Senans Road DC
- Lifford Cottages DC
- St Senans Road Meters
- Lifford Cottages Meters

b) PLC Meter view by Status

Legend

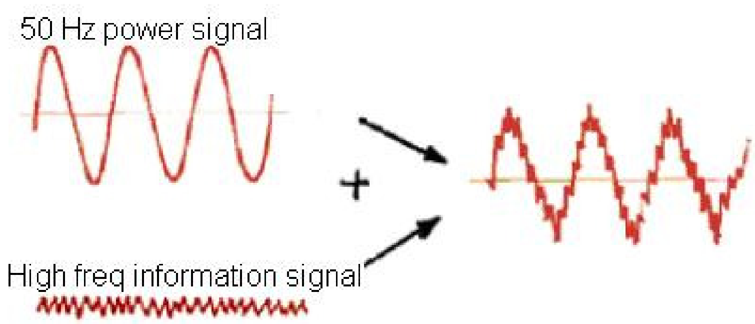
- Concentrator
- Installed
- Late Reporting
- Not Reporting
- Planned
- Reporting

5 Observations and findings from the Technology Trials

5.1 Distribution Line Carrier Trial

5.1.1 Overview of Technology:

The Power Line Carrier (PLC) Technology Trial Project was carried out with Sagem, in the period April 2009 – June 2010. The Trial employed 1st generation PLC technology which has been widely used for the past 10 years. The principle of PLC is that a high frequency information signal is added ('modulated') to the 50Hz power flow signal ('carrier signal') at the sending end and is removed at the receiving end ('de-modulated'), as shown in the following diagram:



The PLC product complies with IEC open standards. At the physical level, it uses a modulation scheme called S-FSK (Spread/Spaced Frequency Shift Key) which is defined by an IEC standard. This scheme uses a pair of discrete frequencies to transmit binary information. These frequencies are in the CENELEC A Band (9 kHz to which is reserved for Utilities Communication. Sagem employ a fixed data communication rate of 1200 bps. The communication protocol is defined by IEC in the DLMS/COSEM series of standards. The standards allow suppliers flexibility on how they implement certain functions. However, interoperability could be enforced by a utility defining the exact implementation schemes to be employed.

The Timescale for the Trial was:

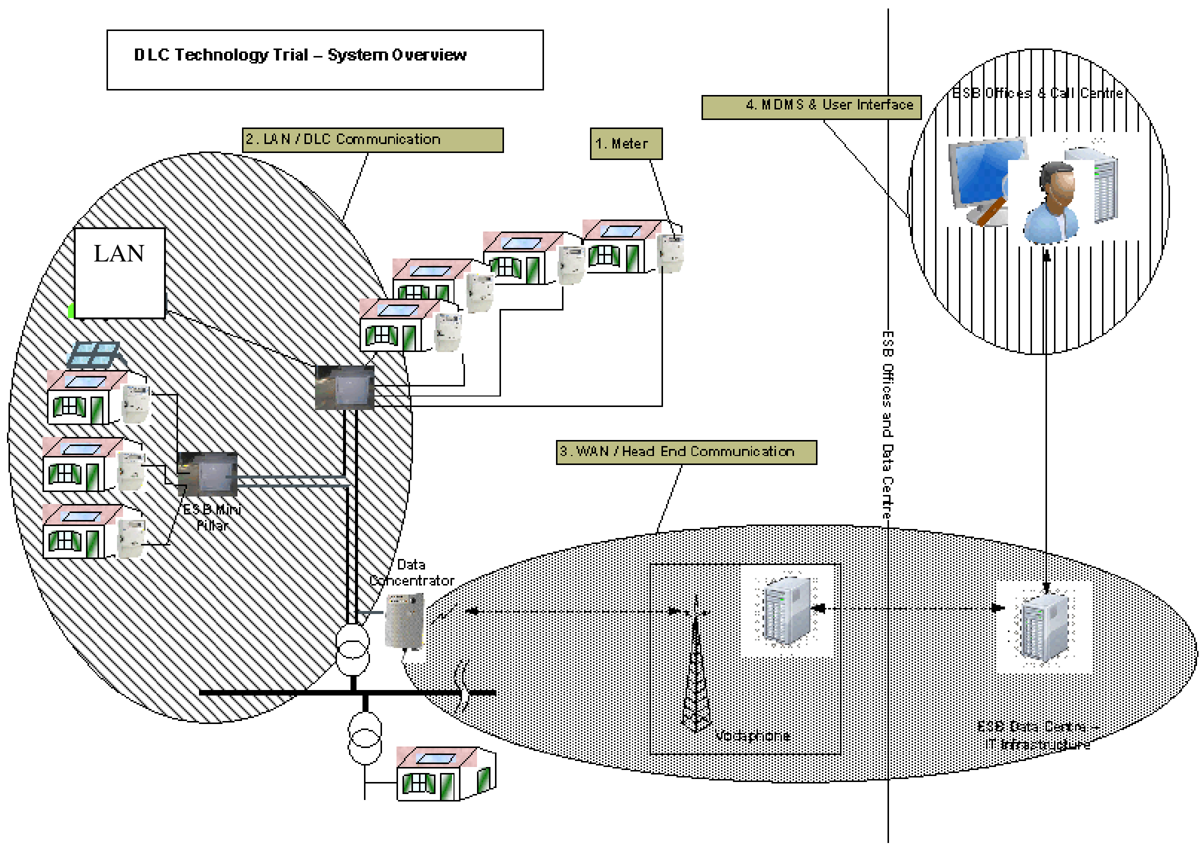
- System Design & Test, IT Infrastructure Deployment - Started in April 2009 and completed in July 2009
- Field Deployment - Started in August 5th 2009 and completed in January 2010
- System Commissioning - Started in January 2010 and Completed in May 2010
- Measurement & Evaluation - Started in May 2010 and completed in August 2010

5.1.2 System Installed for Technology Trial

The PLC Technology Trial System consists of 4 main components:

1. Electricity Meter, with PLC communication modem;
2. Local Area Network (LAN), using PLC Communications
3. Wide Area Network (WAN), using GPRS Communications
4. Head end System (Ionos)

A schematic drawing of the System is presented below.



Meter

The meter supplied by Sagem for the trial was a single phase meter. The meter delivered a standard range of functionalities including import, export and reactive power register readings, half hourly profiles and an embedded load-rated switch capable of remote operation. Alarm and event indications are available on the meter for Meter Cover open, Over Voltage, Contract Exceeded, and Meter Error.

Meters installed in Central Switch room ***Meter in Outdoor Meter Box***

Meters were installed in the selected areas by ESB Network technicians. Generally the exchanges were routine, no real problems were encountered during installation.

Data Collector and Local Area Network:

LAN (Local Area Network) communications processes are managed by the Data Concentrator (DC). The DC is connected to the 3 phases and neutral of the low voltage side of a MV/LV transformer, and communicates with each meter by PLC communication over the phase and neutral. The DC sends messages to one meter at a time. The communication protocol is defined by IEC in the DLMS/COSEM series of standards.

Wide Area Network:

The WAN (Wide Area Network) communications between the head end and data concentrators are managed through the Vodafone network. GPRS modems are installed in each of the Sagem DCs.

IT Systems:

ESB Networks installed the head end software on its own IT infrastructure. The head end is known as Ionos Network Management System (Ionos NMS). The first purpose of the Ionos application is to ensure data collection. Ionos performs automatic reading of the data collected by the DC and stores that data in the Ionos database. The data is then available for processing by ESB Networks. Custom reporting tools were developed by the project team to query the head end metering data repository to provide reports on the performance of the Metering System.

Implementation and Deployment:

The PLC trial was run on 11 low voltage networks in the Limerick/Ennis area, containing a total of 1257 customers. Smart meters were installed in 1057 customer premises. Meters were not installed in the remaining customer premises because:

- Only standard single phase customers were included in the trial
- The deployment relied on access to customer premises to carryout the meter replacement; in modern estates with outside meter boxes 100% access was achieved, but for older estates the figure was close to 80%.

Following commissioning, a 'Measurement and Evaluation' phase examined the functional performance delivery of the system, focussing on the time required to read the previous day's interval data from every meter, and the time taken and success rate of 'on-demand' actions.

The pictures below outline a variety of the connection types used during the course of the pilot, including connections to overhead and underground network.

Sub Station and OH network pole at Lifford Cottage

DC at Lifford Cottage Unit Sub

Annacotty North: DC connected to OH Network (Pole Mounted)

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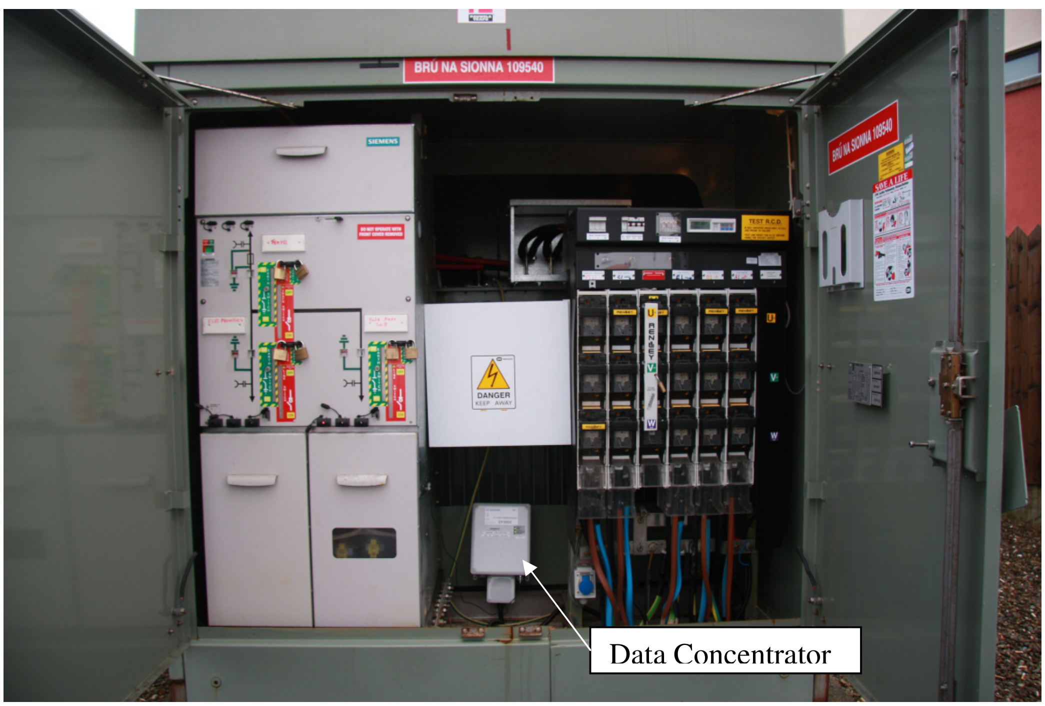


Data Concentrator installed in Bru Na Sionna

Data Concentrator installed in Barry's Flats Sub.

Firmware upgrades

Throughout the life of the project, software releases and firmware updates contained enhanced functionality, and patches/fixes for issues encountered during the trial were implemented.

5.1.3 Summary of PLC performance

(Sample Week 24th- 28th August 2010)

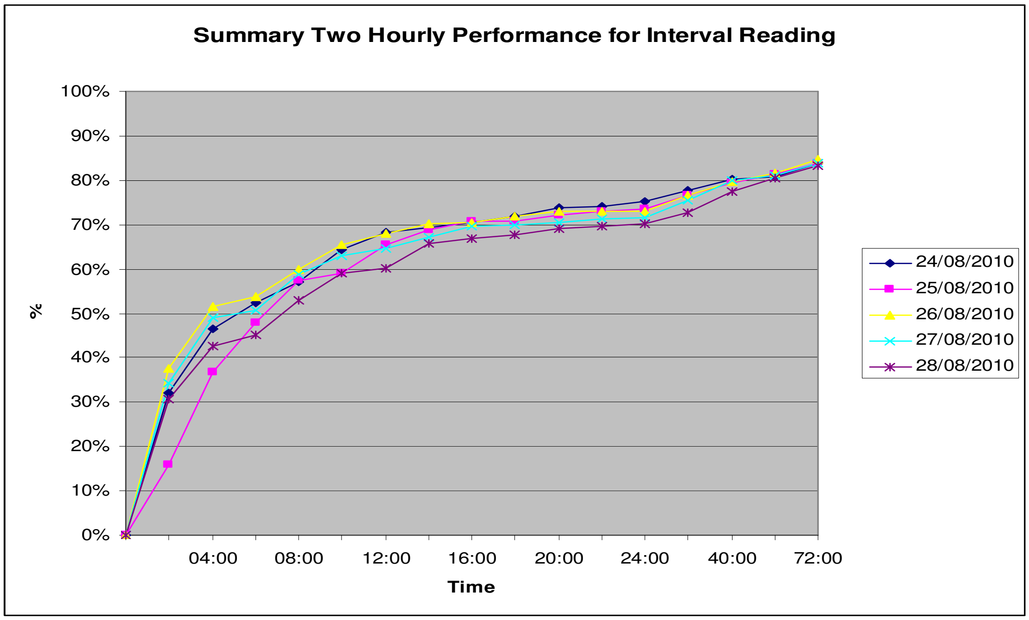
Auto Deployment / Self Registration

83% of all meters deployed self registered at the first attempt.

Daily collection of interval data

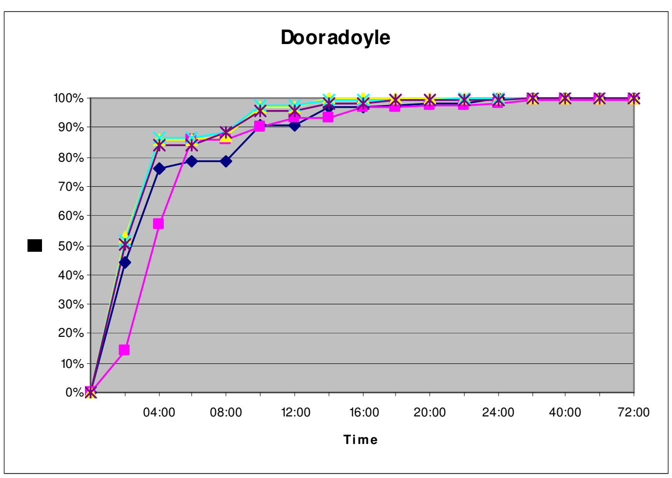
On average 60% of daily half hourly profile data was available at opening of business, rising to 75% by end of day and over 90% within 2 working days.

The chart below summarises how over a number of typical days the system performed in collecting profile data.

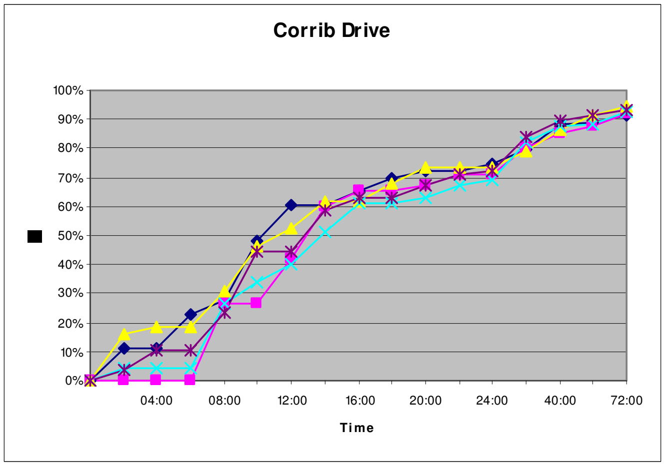


However, there was a big variation in performance depending on network with newer underground network performing best. We felt that improved systems software could improve performance but ultimately there was a finite limit beyond which this technology (S-FSK based) could not progress. Collecting register reads could be done with better performance levels but a significantly higher level of service could not be achieved.

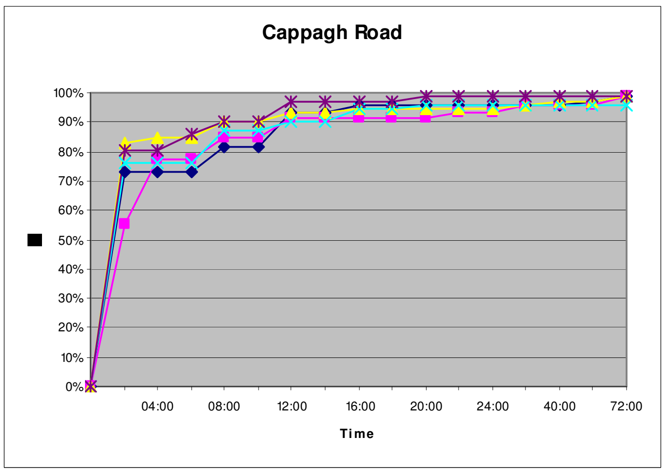
The graphs below give an indication of the different performance levels for different types of network for daily profile data.



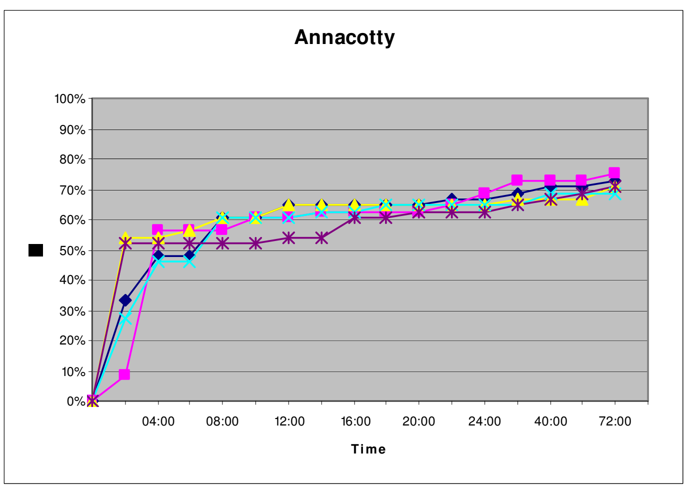
This is an example of underground network built in the past 15 years where the substation is well situated and the cables are in good condition.



Corrib Drive is an example of older underground network with multiple joints in the cables and small service cables to customers.



Cappagh Road is an example of mixed network which has substantial new sections.



Annacotty is an example of older overhead network.

On Demand Tasks
The success rate and time required to perform certain tasks was measured; all tasks were performed from the head end and the time measured is until reporting of the event completion at the head end.

On demand reads
Good network conditions gave a first attempt success range within 55% - 90%, but poor network is less reliable.

Notification of events and alarms
Alarms are reported cyclically throughout the day and events report once per day. No mechanism is provided for real time outage reporting at customer level.

Remote De-energisation/Re-energisation
Worked in sandbox but expect same performance levels as for on demand interval reads.

Remote Firmware Upgrades
Remote firmware upgrade is essential for the full roll out. This worked on meters where communications were good and meters not at extreme of network. Retries had a typical 10% success rate each time.

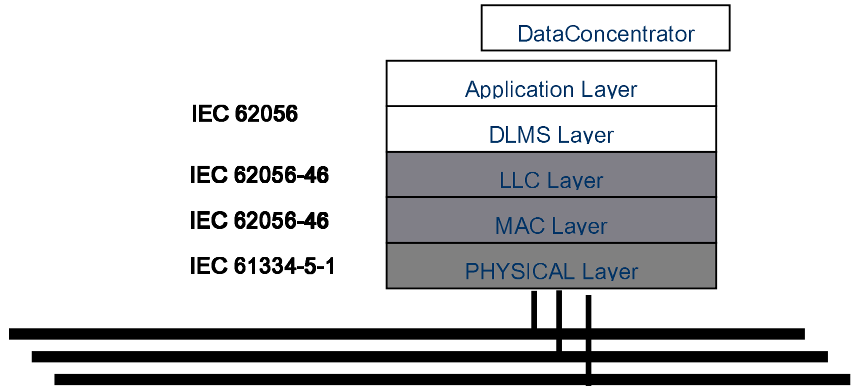
Latency
Typical latency values from 45 sec to 7 minutes were achieved for register reads in good networks. A meter ping typically takes 30 sec in good network.

5.1.3.1 PLC and Standards

The PLC standards defined by IEC are mature and generally comprehensive; the standards are specific in many areas, but leave some options available for manufacturer/utility specific implementations. This PLC trial focused on using an open standards PLC as far as possible**.** The IEC standards employed in the PLC are:

Lower layer protocols:
- IEC61334-5-1 is an S-FSK specific standard defining the physical layer (from the signal voltage and bit synchronisation, to data packet management).
- IEC 62056-46 is a metering specific phase of the widely used HDLC protocol.

DLMS/COSEM layer protocols:
- IEC62056-53: COSEM Application Layer
- IEC62056-61 Object Identification System (OBIS)
- IEC62056-62: Interface Classes



The DLMS User Association working groups review and manage the IEC62056-61, 62 standards, and these are then accepted by IEC; these standards are driven by metering system functional requirements. The other protocol messaging standards are determined by IEC working groups.

Other Power Line Carrier technologies in use in Europe include BPL from PPC and narrowband such as Echelon's LON and Enel's Telegestore. However none of these were offered for the trial.

Current developments in the PLC area aim to address many of the technical issues that we observed in the trial. The objectives of these developments include:

- Increasing data communications capacity;
- Improving reliability and performance in harsh communication environments;
- Supporting lower Signal/Noise ratios
- Delivering IP based communications network over PLC which could support other smart grid applications and IP based network management for the metering system.
- Continuing as a technology compliant with published IEC standards

Work now appears to be focused on the use of Orthogonal Frequency Division Multiplexing (OFDM) as the modulation technique. There are two main projects looking to develop standards for the OFDM PLC technology. Both projects have published their Phy. and Mac. standards.

The projects are:

- PRIME (Iberdrola and others) – Meters are currently being deployed in a major pilot project of 100,000 installations in Castillion, Spain.

- LINKY- G3 (ERDF, France) – Meters are expected to be deployed next year in a pilot project.

5.1.4 Key learning's from the PLC trial.

The performance of PLC communication trialled was very dependant on the electricity network conditions encountered. The technology needs to be able to deal with real network challenges such as high impedance, common mode interference between adjacent LV network areas, and other difficult and noisy operating environments

The service levels achievable in the best LV network were 90% of interval data delivered after 18 hours and 100% of interval data delivered after 48 hours.

The current generation of PLC trialled would not meet performance requirements of 99% next day profile data. Higher service levels would be achieved if monthly register read were the only read requirement, rather than 48 daily intervals reads.

While firmware upgrades were successfully carried out, they will not work well with poor communication network conditions.

PLC exists on utility owned spectrum, is a technology which can be based on published standards and likely has the lowest total cost of ownership

PLC is very much the technology of choice for most major European smart metering deployments. The ongoing developments in moving to next generation PLC based on OFDM will have to be watched closely. These newer PLC technologies should allow implementation of IP networking to meters.. Success in these developments would support the use of next generation PLC as the most suitable technology for urban areas.

5.2 2.4GHz RF Mesh Trial

5.2.1 Overview of the technology

RF (Radio Frequency) Mesh is a radio network technology for communicating with meters, which uses meters as repeaters in a mesh configuration. The majority of systems being deployed in North America and Australia use this family of technologies. Trilliant are one of a number of RF Mesh vendors. Trilliant offered a system which could operate in the licence exempt spectrum in Europe. Most of the others operate at 900MHz, which is not licence exempt for use in Ireland.

The Trilliant LAN operates in the 2.4GHz ISM band (Band 2.400 – 2.483 GHz). This band is licence exempt but subject to guidelines issued by ETSI. The radio EIRP had to be limited to 100mW to comply with EU standards. In North America EIRP of up to 1 Watt is permissible. The physical radios utilise standard IEEE802.15.4-compliant radio chipsets.

The meter itself was a DLMS/COSEM meter developed for the European market. Several key issues needed to be addressed for the solution to work. These included the integration of the Iskraemeko meter with the Trilliant networking technology and the optimisation of the system to work under the constraints of the European communications regulatory regime.

5.2.2 Radio Issues

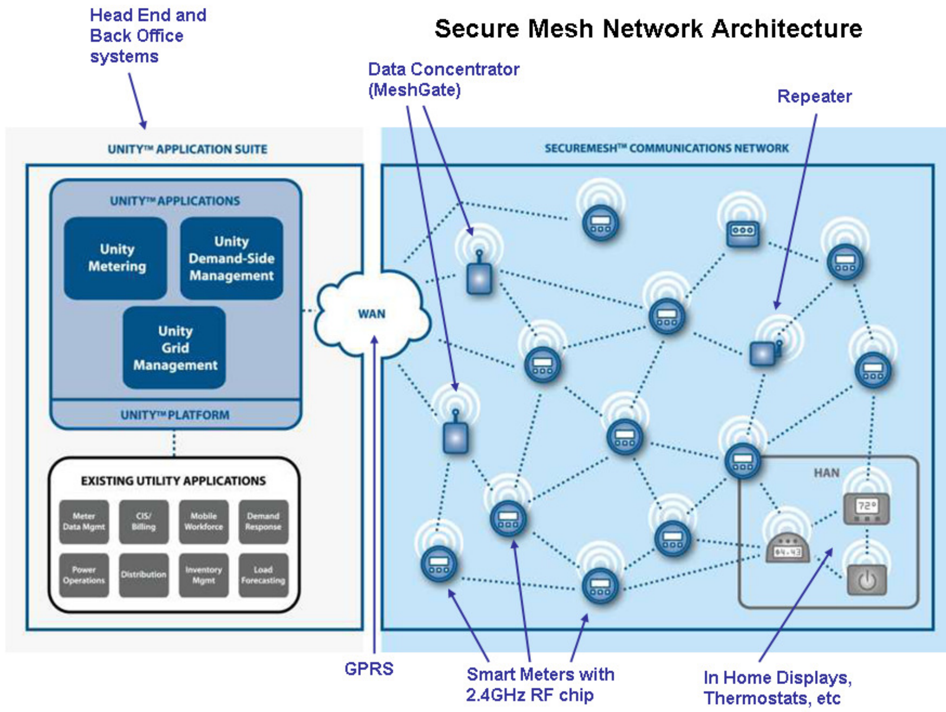
2.4 GHz is a licence exempt frequency. This means that any equipment manufacturer may use it provided the equipment adheres to the relevant EU regulations governing transmission power and duty cycle. Part of the RF trial involved evaluating common 2.4GHz devices on the market in Ireland to assess the likelihood and impact of interference both caused, and experienced, by the system.

5.2.3 Timescales

The Timescale for the Trial was:

- System Design & Test, IT Infrastructure Deployment - Completed in Sept 2009
- Field Deployment - Started in October 2009 and completed in January 2010. This was based on release 1.
- RF Planning, Deployment and Tuning – Started in January and completed in March 2010
- Upgrade to DLMS/COSEM release testing and implementation – January to April 2010
- System Commissioning - Started in January 2010 and Completed in May 2010
- Measurement & Evaluation - Started in June 2010 and completed in August 2010

5.2.4 System Installed for Technology Trial



The key components are the meter including the comms module, the repeaters, the MeshGate (Collector/Data Concentrator), the WAN modem and SerViewCom (the head end). These components and their functions are described in more detail below.

Meter

The meter is comprised of two major components, the measuring device itself and the network component.

Iskraemeko

The meter is a Single-phase, Whole Current (WC) rated meter. The meter is an IEC meter that utilizes DLMS/COSEM as its native protocol.

Iskraemeco meter,

The Comms module provides the interface between the meter and the SecureMesh network. It has a 2.4GHz RF chip and antenna. It reads the information from the meter and packages it for transmission onto the network. It is responsible for ensuring reliable communication between the meter and the head end either directly or via intermediate mesh nodes. It is also responsible for relaying data from other nodes onwards through the network to the head end.

Repeater:

The Repeater serves as an intermediate wireless node to relay messages to and from the meters. Its function is to fill in gaps in the mesh allowing isolated meters or groups of meters to mesh in with the network. These are typically mains powered devices mounted on poles.

Repeater Enclosure

Data Collector (SecureMesh Gateway)

The collector serves as an access point for meters. Each collector supports communications to and from the head end for the meters with which it communicates. It provides local data storage and minimises WAN communications requirements by compressing the data.

SecureMesh Gateway and Enclosure

The collector is typically pole mounted; collects data from meters and forwards this data over the WAN to the head end using its internal GPRS/3G modem.

Wide Area Network Architecture (WAN)

The WAN (Wide Area Network) communications between the head end and data concentrators are managed through the Vodafone network. GPRS modems are installed in each of the Trilliant data collectors.

IT systems

SerViewCom is the head end system provided by Trilliant which enables communications with the meters. It also allows for the storage of data together with a user interface. This was installed on ESB Networks IT systems.

5.2.5 Implementation and Deployment

Two trial locations, Inishannon in rural Cork and an area of Cork City, were selected to represent environments typical of those which would be encountered in the Irish context. These areas incorporated a mix of sparse and dense population, heavy foliage, hilly terrain, ribbon development, multi dwelling buildings, terraced houses and semi urban estates.

The numbers of meters installed were 690 in the rural area and 1,591 in the urban area. The large number of meters installed was determined by the need to ensure that an effective mesh could be formed and that observation of scenarios could be performed.

One of the major issues we faced was the work required to integrate the comms module with the meter. The meter itself had a high level of functionality. It captures time of use, profile data and events and alarms. The challenge was to access as much of this information as possible within the timeframe of the trial.

The implementation was split into two separate and distinct phases. The key objectives for the first phase of implementation were the integration of the comms module into the meter and provision of basic register and derived profile data to the IT systems. The second phase involved increasing the software interfaces between the comms module and the meter to make available actual profile data, and remaining events and alarms information from the meter. Both development stages required significant testing effort.

For the first phase testing went well in all respects in the Sandbox. All expected functionality was delivered and system functioned well. On the basis of the success of the testing it was decided to proceed with the deployment of meters in the field. Unfortunately, subsequent testing of phase 2 required a number of iterations.

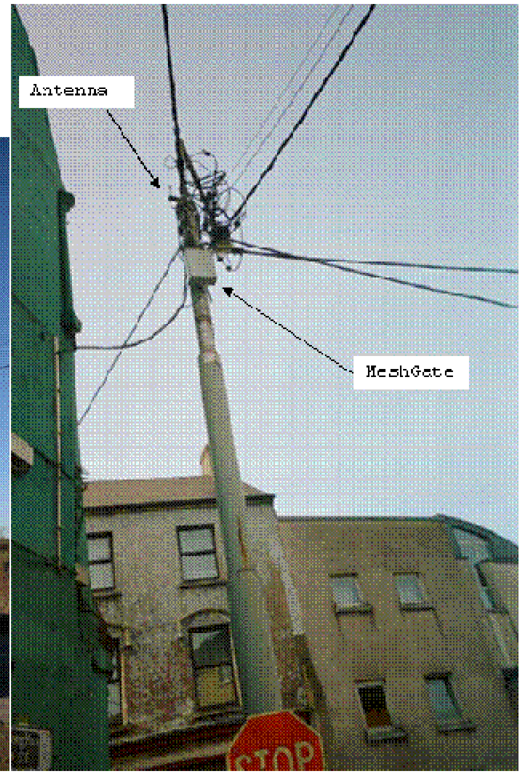
The RF planning stage included a field survey to ensure that the locations identified for network hardware are suitable and have clear RF propagation.

Based on network designs developed by network planning engineers, collectors were installed at strategic locations in both areas. As is usual with this type of technology a tuning exercise was carried out to fill gaps in coverage and optimise performance.

Initial results for phase 1 were encouraging in the urban area; however the rural area results were disappointing. A review of the trial areas and the installed meters was carried out at this point.

The performance of the Mesh in the rural area was investigated. The vendor provided a number of replacement meters with an enhanced antenna and these were tested in the field. These meters lead to improved performances in some cases. The antenna is part of the meter and therefore resolving this problem involves replacing the meter.

Phase 2 of the product was implemented later on by means of firmware upgrade while Phase 2 increased the system functionality; it had very little noticeable impact on the performance of the rural trial. A number of attempts were made to rectify this issue.



The photographs above depict MeshGate and Repeater installations in Urban and Rural locations.

5.2.6 Summary of RF Mesh Performance

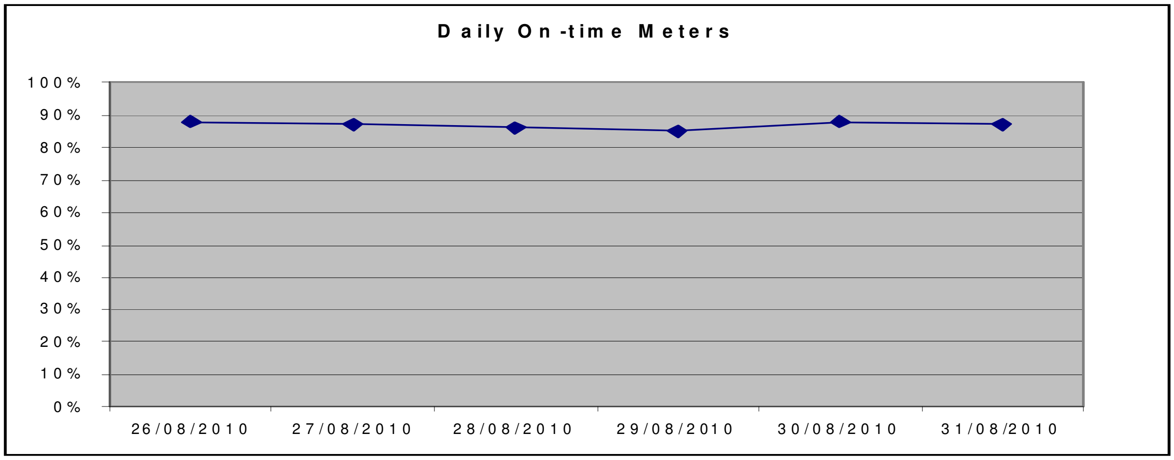
Data Collection and Operation

Data is collected from the meter by the communications module. The module firmware determines the data types collected including register, interval and power quality information. The information is then forwarded by the module to the Data Concentrator at predetermined intervals, hourly in the case of the trial system. The Data Concentrators are polled at regular intervals by the head end to upload the meter information to the back office system.

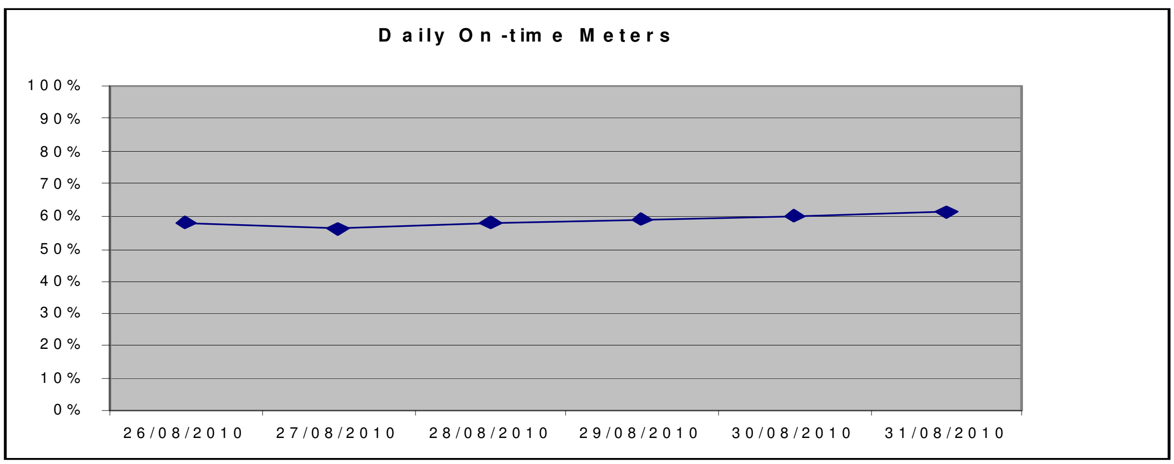
Auto Deployment / Self Registration - Good performance was achieved with 97% deployed where signal was available

Daily collection of interval data and register data - Overall performance was achieved on tuned network of 87% urban and 60% rural interval data next day 8.00 am. Additional repeaters, mesh-gates and enhanced antennae could bring performance up to 95% overall. The graph below gives the information in relation to the performance of tuned networks.

Urban



Rural



The graphs below show the performance at individual data collectors over a typical 5 day period

The collector below (Tower Street) is an example of a data collector performance in an urban area with outdoor meter boxes and higher density of dwellings.

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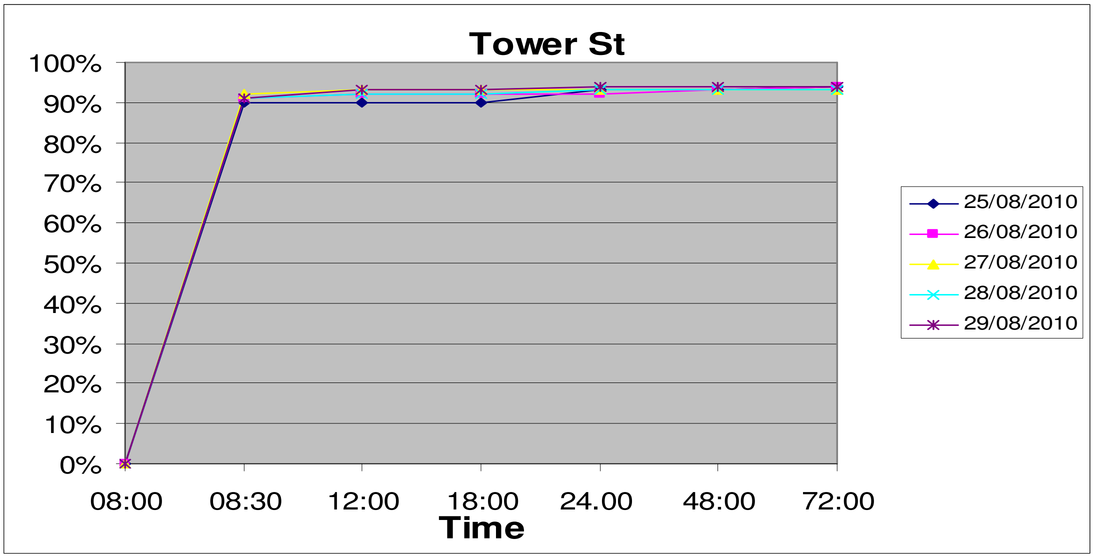
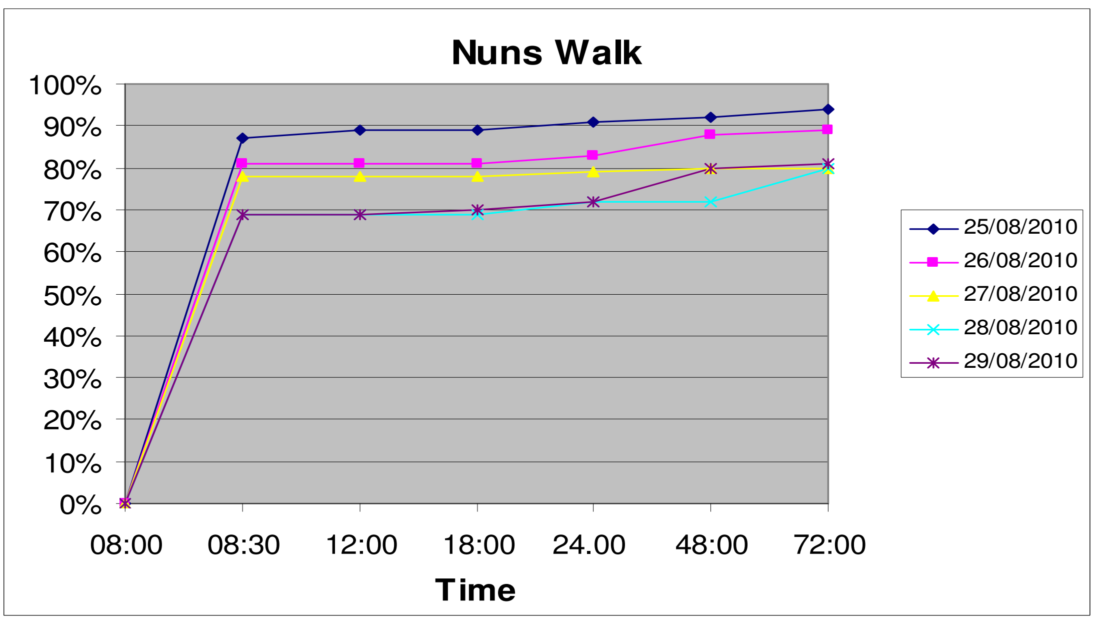


The graph below the performance of a data collector in a tuned network where most meters are indoors



On demand reads

As part of the evaluation, a series of tests were performed against the on-demand task capabilities of the meters. The success rate achieved can reach 71% on the first poll and rises to 89% for the third poll. The time to complete the read varied from 30 sec to 60sec.

Notification of events and alarms

Alarm and event notification is generally cyclical – events and alarms are received hourly at the data concentrator and polled regularly from the head end.
Last gasp reporting is in real time and was actually measured in the sandbox environment at 30 sec.

Remote operation

This was tested in the Sandbox environment. It was observed that the success rate and reliability of the commands was high, provided that the meter is reliably associated with the Mesh.

Firmware Upgrades

The system proved successful in delivering upgrades to the comms module on the meter. However, given the development involved, meter firmware upgrade capability was not delivered as part of trial.

Approximately 85% of the meters had the firmware on their comms module successfully upgraded. We also believe that the vast majority would eventually have upgraded given sufficient time.

Latency

As an indication of system latency the average time taken for an on-demand command to successfully conclude was measured to take between 30 and 60 seconds.

Geography and Terrain

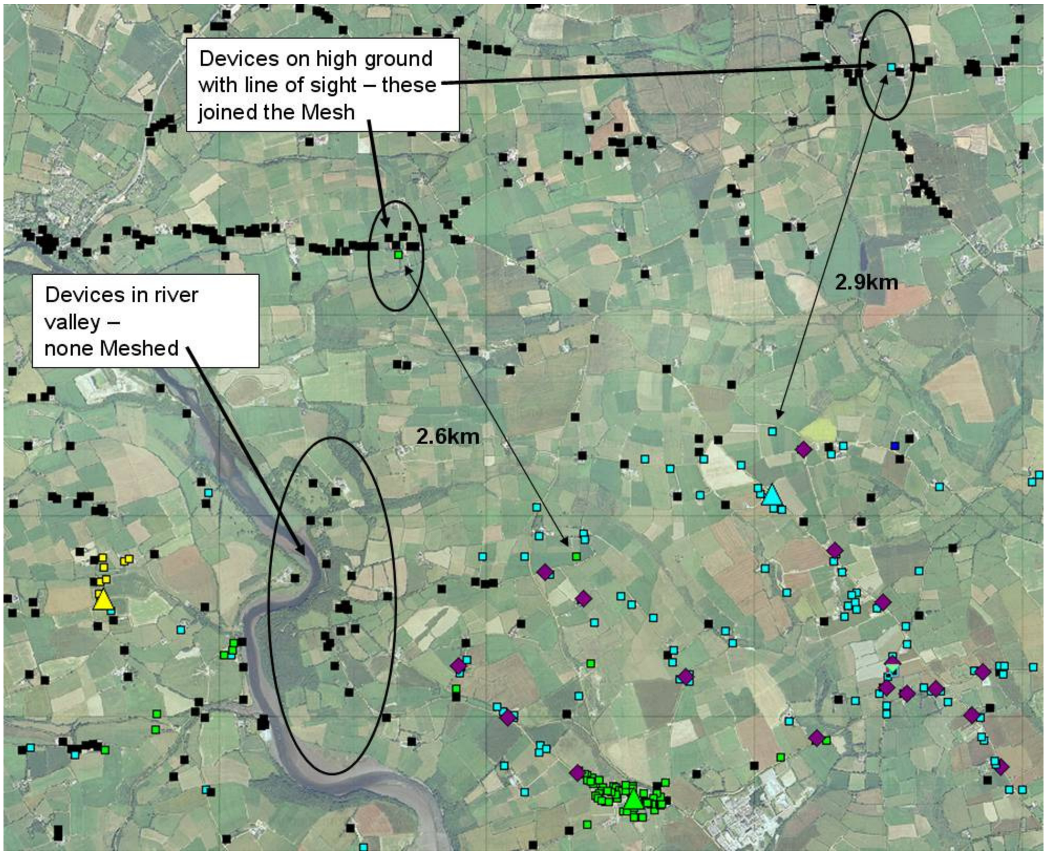
The rural area chosen for the trial is typical of any Irish rural setting. It includes open fields, hedgerows, tree lines, small wooded areas, walls, hills and valleys.

2.4GHz RF is essentially a line-of-sight technology. It doesn't pass through hills or bend around corners. Reflections are often necessary for links to form. In rural areas, direct line-of-sight between meters is rarely available. Meters which were located in valleys were generally unable to join the Mesh. This is in contrast to meters which were on top of hills with line-of-sight to other meters; two or three instances were observed where meters formed links of around 3km.

Difficult terrain can be overcome by the addition of Repeaters

Distances between Mesh devices

Generally speaking the distances between devices was not a major factor in Mesh formation. The other factors – terrain, population density and meter location – were much more significant. The map below shows that links can form over long distances if these other factors allow:



Line-of-sight effect on Mesh

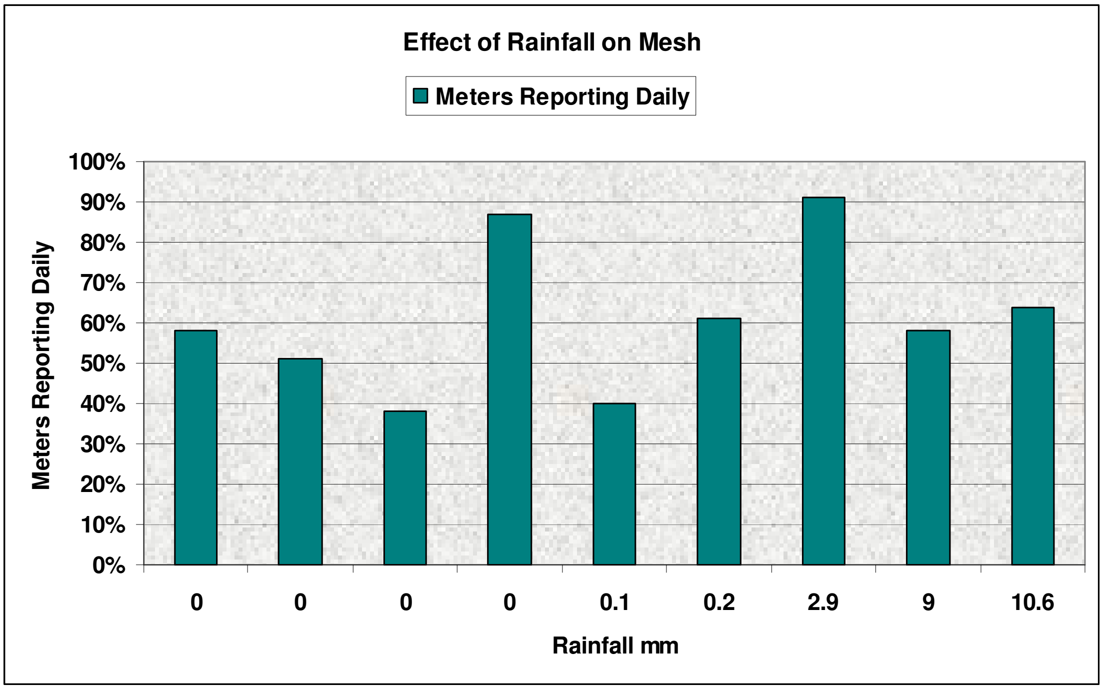
Population density

This had a high impact on the Mesh. In built-up areas, devices are much more likely to form a stable, reliable Mesh. There are several reasons for this:

- There are more network devices with which to mesh
- There are more surfaces, meaning more RF Reflections, meaning higher concentration of signal, and
- to a lesser extent, the distances between devices are shorter

Environment (vegetation, rainfall, etc)

These had a low impact on the Mesh. To measure the effect of rainfall, a sample of 9 random days was taken and the rainfall on the particular day compared to the number of meters that successfully reported their readings on the same day. These measurements were taken from the Cork City RF trial which consists of 1132 meters.

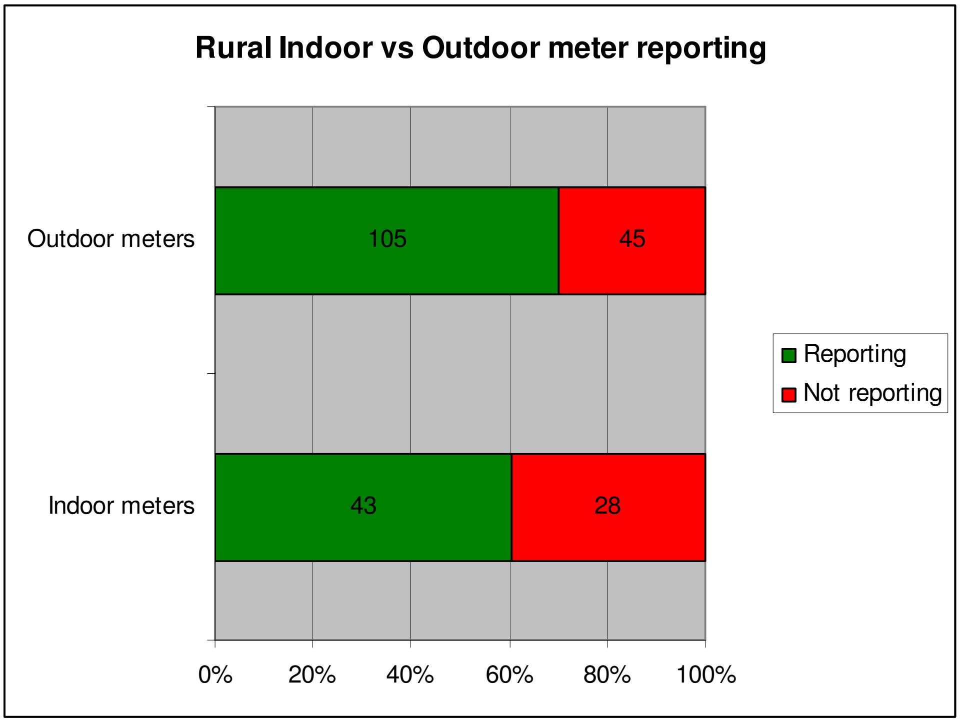


From these measurements we can assume that typical rainfall has no impact on the performance of RF Mesh.

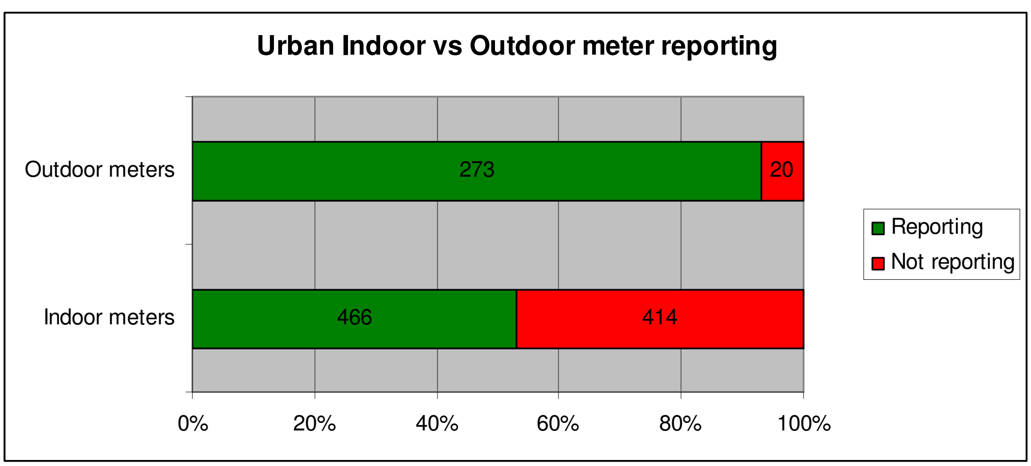
The effect of vegetation was more difficult to evaluate. The meters were installed up to December 2009 and the MeshGates shortly thereafter. The system at that time had availability of around 90% within the tuned areas and with Version 1 functionality. The availability of the system at the end of April - before the functionality Upgrades began but after a period of warm weather and vegetation growth - was still at around 90%. Although the trial area was small, there was no noticeable drop in performance.

Indoor vs. Outdoor meters

Generally outdoor meters report more reliably than indoor meters. This is to be expected. The following table and graph show the quantities of meters in the rural tuned area, and whether they are located indoors or outdoors:



Note that in the case of outdoor meters, the orientation of the meter cabinet relative to other meters determines whether the meter will mesh. Unfortunately this is entirely random and impossible to predict or model without surveying each and every meter location



5.2.7 Key Learning's from the RF Trial

Notwithstanding the European regulatory restrictions on the 2.4GHz band and the system problems encountered, the performance measured gives evidence of the potential for an RF solution.

A solution with greater transmit power and an operating frequency more conducive to propagation in the Irish environment would offer much greater potential to meet the anticipated roll out requirements.

In cities, towns and villages, where the population density is high and meter locations form a natural mesh, 2.4GHz mesh appears to offer an effective Smart Metering Technology. However in rural areas with current regulatory restrictions, with sparse or ribbon development, it is difficult for any mesh to form.

It is safe to conclude that 'weak links' due to building construction methods and location of meters (indoors) coupled with the higher quantities of data required for a DLMS/COSEM' implementation impact on the performance of the system.

While no noticeable interference was observed there is little protection from interference in the unlicensed 2.4GHz band, which is becoming increasingly congested.

An RF mesh solution in the sub-1GHz range based on dedicated spectrum would appear to offer a better possibility of meeting the need in the Irish rural context. It is clear that the market for RF solutions is driven from North America and that most of the innovation and standardisation initiatives are being carried out there. Most existing systems operate in the sub-1Ghz range, in licence exempt spectrum between 902MHz and 928MHz. The propagation characteristics of solutions in this range offer greater effective link length and building penetration. These are essential in the Irish rural environment. The American systems also operate at transmit EIRP of 1W, once again improving the performance of the system, these characteristics coupled with the Meshing capability of some of the systems maximise the performance and capability of the systems, giving good coverage, capacity, latency and availability.

Most RF technologies are proprietary in nature. This is a significant drawback. A drive towards standardisation is required to make the technologies more globally acceptable and improve confidence in their ability to provide a solution.

5.3 GPRS Trial

5.3.1 Brief overview of technology

GPRS stands for the **General Packet Radio Service**. It is a packet-based wireless communications service, based on **GSM** (which is circuit based) communication, and is recognised in the business as the best platform for mobile data networking services. GPRS is an upgrade or a smooth add-on to integrate into existing networks and can be thought of as an overlay network onto a second-generation GSM network. GPRS integrates GSM and **IP** technologies to provide wireless data services and it offers instant data connections to data networks, such as the Internet, ISP's and corporate Intranets.

GPRS is a technology that is used globally. It is not restricted location wise really, in the sense that it can reach anywhere that current GSM networks can reach. The ordinary person can use it on their mobile phones to access e-mail and the internet, and businesses can use it to access the office server of for M2M deployments.

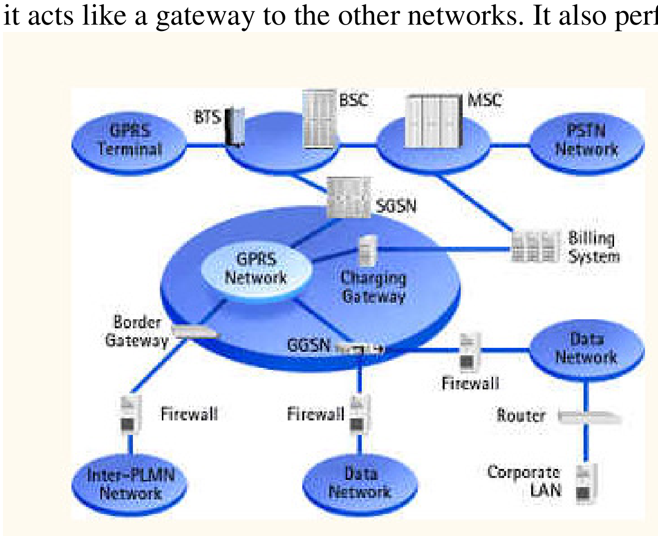
5.3.2 GPRS Network

For the core GSM network to handle packet traffic two new components, called GPRS Support Nodes, are added:

- Serving GPRS Support Node (SGSN)
- Gateway GPRS Support Node (GGSN)

The SGSN is a network element that converts protocols between the IP core and the radio network (it assigns IP addresses). It also performs mobility management functions and location management (it tracks the movement of the user to know where to send packets). It also ensures a secure connection.

The GGSN connects the GPRS network to the Internet, ISP's and corporate Intranets, it acts like a gateway to the other networks. It also performs address mapping.



A low level view of the GPRS network

GPRS Meter Deployment

GPRS was the technology chosen for the Customer Behaviour Trials (CBT). This technology was chosen due to its ubiquity, allowing for connection of meters selected at random without the need to install network infrastructure and because of its high level of standardisation, based on GSM 2+, an accepted world wide telecommunications standard.

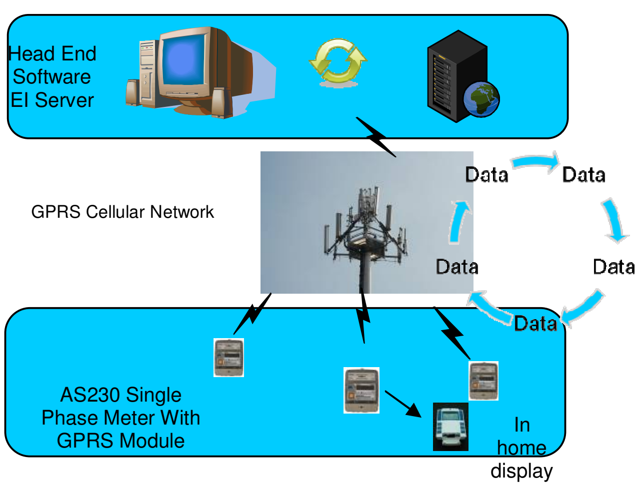
In order to deliver the solution requirements for the CBT, ESB Networks installed AS230 single phase Smart Meters from Elster Metering Limited, with an integrated GSM/GPRS Modem module. In the cases where there was a requirement for three phase measurement an A1140 Meter was deployed with a similar GSM/GPRS modem.

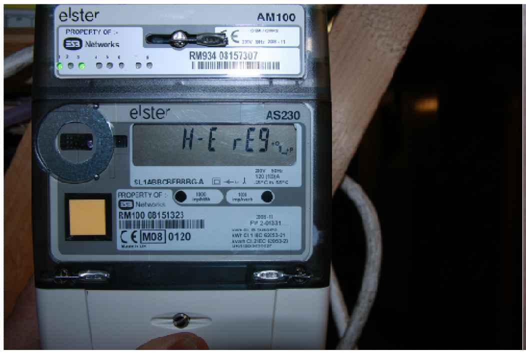
Approximately 6,500 point-to-point meters were installed for the Customer Behaviour Trial. Automatic meter registration with the EICT EIServer head-end was implemented and an always-on connection solution was deployed meaning that the meters were constantly connected to the head end and meter polling did not require any call setup time.

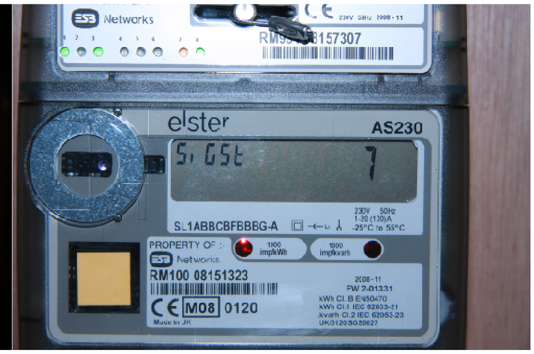
All of the locations, which were randomly chosen, were first tested for GSM signal strength. A threshold signal level, for installation, was set. If the signal level at the location was outside this threshold the installation was abandoned and an alternate location was used. This was done to ensure that maximum success rates were achieved for meter polling.

The solution collected 30 minute interval data from these meters and 24hr, Day and Night register values.

The figure below outlines at a high level the CBT infrastructure.







GPRS Meter Registered to head end GPRS Meter showing Signal Strength

5.3.3 Summary of GPRS performance.

GPRS coverage was found to be very good. 5% of locations were excluded from the trial due to signal levels being below the set threshold. It is believed that this would rise to 97% were a less exacting threshold level used.

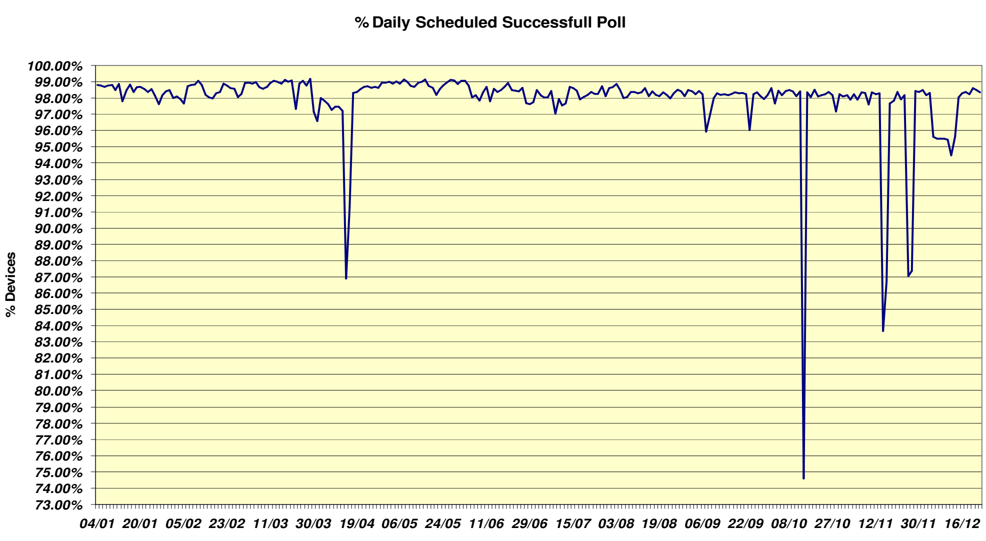
Auto deployment/self registration

Auto deployment/self registration of meters worked in 99% of cases.

Daily collection of profile data

Daily collection of profile data was found to be very good, with a success rate of 97.89% first time reads. The majority of failures were accounted by 4 individual short duration incidents. When not including the four polling incidents, the average daily success rate following the scheduled poll was 98.25%, with the highest success rate being 99.17%.

The average success rate rose to 99.1% by the end of the day. The graph below is the result of the Daily Scheduled Successful Poll over a twelve month period from January 2010 to December 2010



Daily collection of register data was as per the collection of interval reads.

Events and alarms

Events and alarms are stored on the meter and collected daily when the meter is polled. This is a function of the meter design and some alarms and events could be programmed in the meter to be instantaneous.

On demand tasks

On demand reads were 99% successful at first attempt and took on average 90secs to complete for a full daily profile.
Remote operation was measured to work on average within 30 seconds of issuing a command from the head end.

Firmware upgrade

Remote firmware upgrades worked on a meter by meter basis. GPRS is a point to point technology and broadcast and multicast are not supported. This would be a significant issue for a full roll out.

5.3.4 Key Learning's on GPRS

GPRS proved to be a very effective and reliable technology during the course of the trial.

- GPRS worked well and was very reliable for the 95% of customers that were covered.
- The meters were easy to deploy, the auto registration process was very effective.
- It is essential to work closely with the Mobile Network Operators' to ensure compatibility of modems and determine optimal configuration
- CBT design will have to be changed for larger for out as always-on connections unlikely to be allowed
- GPRS is an open standards technology. There are many vendors who will support a GPRS solution.
- Issues of Mobile Network lock-in need to be resolved if a mobile network based solution is to be considered as a viable long term solution for a full roll out.
- There is an issue for mass upgrade or mass on demand activity as the system is point to point and lacks a broadcast/multicast capability. This will be restrictive for some future potential smart metering services.
- Visibility into the MNO's device management platforms is essential

- While GPRS worked for the trial there is an issue over how long this technology will continue to be supported on all mobile operators network particularly considering the anticipated lifetime of the smart metering system, which could last up to 2032.

6 Desktop Studies

Two technologies offered at the time of the procurement process were also of interest to us. We undertook two desktop studies with vendors to help develop an understanding of how their technologies work and of their capabilities. Any figures quoted for these technologies are theoretical in the Irish context, are based on models and examples provided by the vendors and have not been verified in the field, in Irish conditions.

6.1 PLC Desktop Study.

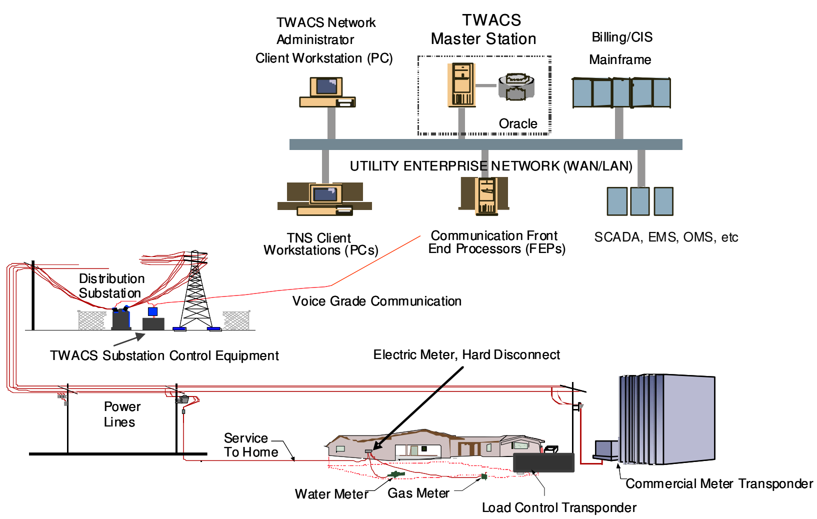
The PLC desktop study was carried out with Aclara and was based on their TWACS technology. A full trial was not possible as a suitably approved meter for Europe was not available in the timeframe of the trial.

6.1.1 Brief overview of Technology

Aclara's patented **T**wo-**W**ay **A**utomated **C**ommunications **S**ystem (TWACS) employs a system architecture composed of three layers:

- Computer Communication Equipment (CCE), the Master Station or head-end system;
- Substation Communication Equipment (SCE), and
- Remote Communication Equipment (RCE), end-point devices or TWACS transponders.

Figure 1 provides a graphical illustration of a typical TWACS® Technology implementation



Outbound signalling is communication from the substation to the end-point devices and inbound signalling for end-point device communication detected at the substation. This is a low bandwidth technology that reliance on clever use of concurrency techniques to deliver its service. This is a proprietary technology.

Desktop Study

Aclara carried out desktop studies and physical surveys at two substation locations (Balbriggan and Loughshinny) and on a number of MV feeders. Their study indicated that TWACS could be capable of delivering the meter reading requirements, including the scheduled delivery of profile data.

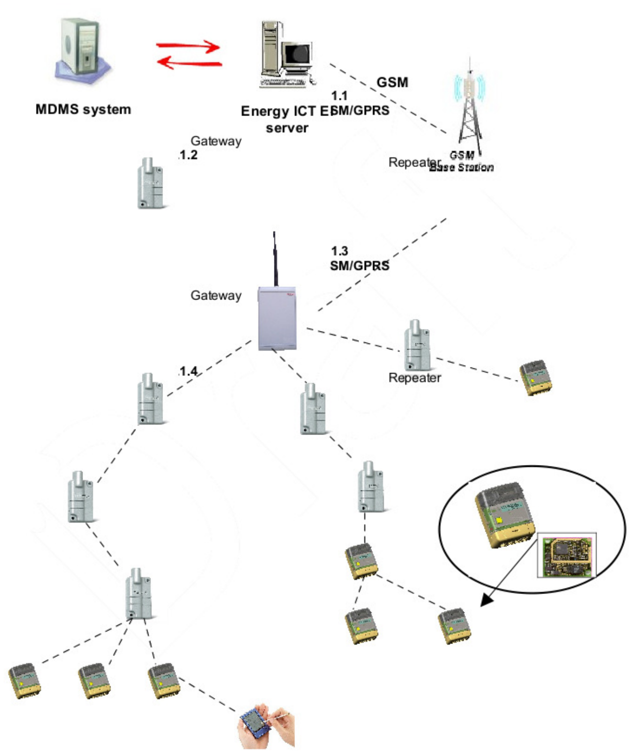
We are concerned that the performance levels required for higher level AMI functionality, including real time two way communications and speedy deployment of meter firmware upgrades and security patches may not be met by this technology. In the absence of a real deployment of significant numbers of meters, these concerns remain.

6.2 868 MHz RF Technology.

The 868MHz desktop study was carried out with Elster/Coronis and was based on their Wavenis technology

6.2.1 Brief overview of Technology

The proposed infrastructure for a fixed RF network is based on the Wavenis RF solution from Coronis and GPRS. Each meter is linked to a data concentrator (RTU+) using short-range radio (868MHz frequency), which is itself linked to a server using the GPRS network. The radio proposed is an adaptation of a Wavenis based radio currently used for water metering in France. A version of the system for the electrical network environment was not available during the timescale of the trial.



The key components of the solution are:

- Meter: Elster AS230
- Comms Module - RF: AM600
- Repeaters – Mains Powered
- Data Concentrator: (RTU+)
- Head-end Server: EIserver

The network topology proposed is not a mesh but a radial trunk and branch network, per cell. The meter radio module power is limited to 25mW by regulation and therefore has limited range.

Transmission speed is set to 19.2Kbps, the usual data communication rate selection for metering applications.

As the meters are polled by the DC only one meter can transmit at a time, per cell, this should minimise intra- and inter-cell interference.

6.2.2 Key Learning's on 868 RF Technology solution.

- The technology has not yet been adapted for the Electricity market and no large scale deployment exists.
- The technology utilises the unlicensed 868MHz band, which is limited to 2MHz of bandwidth, divided into smaller sub-bands.
- The technology does not yet have meshing, repeating or self healing capability.
- Wavenis is a published protocol and a Wavenis forum has been established which is open to meter and communications system vendors and to utilities. This reduces the risks associated with lock-in due to proprietary technologies.
- Concerns exist over the range of the 25mW radio module. This is based on studies carried out by ESB Networks using similar radios. therefore large numbers of repeaters will be required, both in Urban and Rural environments
- Network planning and design is based on averages, estimates and experience.
- We are concerned that the performance levels required for higher level AMI functionality, including real time two way communications and speedy deployment of meter firmware upgrades and security patches may not be met by this technology. In the absence of a real deployment of significant numbers of meters, these concerns remain.

7 Meter

The main focus during each of the trials was to collect scheduled interval data, registers and events reads on a daily basis from the installed smart meters. Most of the other smart functionalities within the meters themselves were actually trialled in a controlled test environment, to minimise disruption to customers.

- In all cases the remote operation of the switch in the meter worked well.
- The Trilliant comms module on the Iskraemeko meter was able to provide a last gasp message in the event of a loss of network supply. This demonstrated one of the benefits of wireless mesh.
- The Elster 1-phase meter also had very significant and useful power quality information.

Smart meters by their nature are complex devices with considerable processing power on board. However, there were some hardware and software issues with some of the meters. These included spurious alarms and events and some electronic component issues. None of these impacted on the metrological component which was rigorously tested.

Tests carried out to determine the viability of carrying out remote firmware upgrades (non-metrology) for meters, modems and data concentrators were eventually successful. This proved much easier to implement on LAN based rather that point to point technology. This functionality will be an essential feature of any full rollout.

Even with a clear focus on the use of open standards and well tested systems, it is widely recognised that the combination of the different Energy Market requirements within each of the EU jurisdictions, and the complexities in any Smart Metering implementation, will, of necessity, require a significant level of customisation for any smart metering rollout

From the perspective of all components of the meter there is a clear need for sufficient soak time during a smart metering system tendering and evaluation process, whereby meters could be fully configured and their full remote manageability verified within a proper end-to-end implementation. Major security testing should also take place at this time.

A number of the meters available for the trials were based fully or partly around DLMS / COSEM data objects, and as this is the way EU standardisation may direct us, it was a good learning exercise. However, the range of OBIS codes will need to be expanded slightly to minimise the number of Vendor-defined codes in use.

During 2009, a Smart Metering Coordination Group (SMCG) was set up by three of the main standards organisations in Europe, CEN, CENELEC and ETSI, in response to EU mandate M/441. One of the outputs of this exercise is a proposal to specify range of possible smart Additional Functionalities that should be considered by EU countries as they work towards the mandatory rollout of Smart Metering by 2020. ESB Networks' initial metering system specification has proved to be very closely aligned with the functionalities subsequently defined by the SMCG, so the experience gained during the pilot will be very beneficial in progressing towards a possible full rollout.

8 Testing

The testing approach adopted involved comprehensive, integrated test of the meter, telecommunications, newly configured ESB IT systems and all associated legacy systems. The programme test process included vendor testing, IT system testing, meter installation testing and data integrity testing. There were a number of stages of testing, from unit testing & vendor unit testing, through system integration test and user acceptance test. A final deployment acceptance test took place as a deployment ramp up.

9 Security and data protection

9.1 Procedures for trial

Customer privacy and the security of the metering data collected were key considerations during the design, testing and operational phases of the Smart Metering Trials. The security mechanisms available in the solutions selected for the trials were fully implemented according to each vendors best practice guidelines. Prior to deploying any of the technologies offered for the trials, a risk analysis was carried out to access the security services available within each solution. This analysis focussed on whether metering data could be exposed to unauthorised individuals. It also considered if such an exposure would allow the data to be modified or would allow the customer to be identified. The risk analysis concluded that the technologies were acceptable for deployment in a trial context.

The security services available for each trial were then fully tested prior to implementation and any implementation issues identified were fully rectified. A Penetration Test was also carried out by an external Security Company on the Meters, In-Home Displays, GPRS Network solution and head end solution deployed for the CBT trial. The recommendations from this Penetration Test were implemented where possible (some recommendations could not be implemented as they would have required hardware changes in devices).

The detailed consumption data collected during the trials was stored in secure head end systems. Access to these systems and the access rights of individuals on these systems were tightly controlled and audited. The data in these systems was handled in strict compliance with the requirements of the Data Protection Act.

The detailed consumption data from the CBT trial was securely delivered to Suppliers and CER Statisticians via encrypted files. Controls were put in place to ensure that each Supplier only received the data for their own customers. The data provided to CER Statisticians was anonymized so that the individual customers could not be identified. Data Transfer Agreements were signed between ESB Networks and the Statisticians in accordance with Data Protection Act requirements. These agreements described the purpose for which the data was provided and how it should be securely handled.

9.2 Full roll out issues

From a security perspective the following lessons were learned from the both direct experience in the trials and from information from other smart metering stakeholders. These are general opinions and should not be considered as applying fully to any one system deployed in the trial:

- The mechanisms for securing the smart metering infrastructure vary considerably from vendor to vendor. Where metering vendors have considered security, they have tended to focus mainly on encryption of data while in transit. However, they also need to put the same emphasis on how devices securely join the network, how data is securely stored on devices and how firmware and configuration updates are securely downloaded to devices.

- The supply chain leading up to the manufacture and delivery of devices to utility customers and their software development lifecycles need to include processes and protections to ensure that the hardware and software cannot be compromised prior to delivery to the utility.
- Many vendors use proprietary security mechanisms at present. This is generally a consequence of the proprietary networking protocols being used. Ideally, the Internet Protocol should be used at the networking layer for all smart metering solutions and the well understood and standardised security mechanisms adopted by other security sensitive industries (such as banking) should be deployed. This appears to be happening as more of the traditional networking vendors begin to deliver smart metering products.
- The computing power and memory constraints of smart meters limit the types of security solutions which can be deployed. This is also a significant consideration for battery powered devices used in the home. As the level of integration between the smart meter and other devices used in the home increases, the level of security required at the interface between the smart meter and in-home devices increases accordingly.
- If pubic networks are used to deliver all or portions of the smart metering communications infrastructure, this highlights the need for application level security as the utility does not have control of the processing of network traffic while it traverses these public networks. Device authentication and end-to-end application layer encryption become very necessary in these scenarios. The DLMS/COSEM metering standard provides for suitable authentication and encryption services.
- Role based access to devices and systems is available to a limited extent in current smart metering solutions. However, much more granular definition of roles and associated access rights is required.
- The impact of natural disasters, terrorism, and human error must also be considered when deploying solutions, particularly if these infrastructures are to be expanded to deliver Smart Grid functionality and must be highly available. A holistic approach to the design of the solution which takes into account the People and Process dimensions in addition to the Technology dimension is required.
- Logging and auditing of all activity on the infrastructure is also important. The next generation of smart metering solutions must support automatic facilities for analysing activity within the entire system to detect non-typical activities (similar to Intrusion Detection Systems and Zero-Day Virus/Worm Protection solutions deployed for Internet services today).
- As with all aspects of business, the cost of providing a secure infrastructure must be balanced against the value to someone else of exposing the risk being protected against. It has to be recognised that no infrastructure can ever be 100% secure indefinitely. Circumstances change and security processes must be constantly reviewed and improved.

10 Deployment and installation

During the Trials ESB Networks gathered a significant amount of information at the wiring interface between the meter and the customer's premises. ESB Networks network technicians were requested to complete a short questionnaire at each customer's premises in the GPRS based trial as these were randomly selected representative customers. Where at all possible, we strived to replace the meter and leave a safety letter in situations where there were issues with aspects of a customer's electrical installation. However, there were also circumstances where the NT did not carry out any work due to problems encountered or the state of the customer's electrical installation. In these situations the call was cancelled and an explanatory letter was left with the customer.

There are a number of key areas at the technical customer interface identified which will have to be rectified as part of a full roll out program. These will impact on the cost of a full roll out;

- 1.5% of all installations had missing or damaged meter box doors
- 0.4% of all installations were found to have poor or inaccessible meter locations or space problems for the meters.
- 0.2 % of external meter boxes had moisture ingress problems
- 0.4% of installations had old legacy metering arrangements with multiple metering
- 0.6% of all installations had issues wiring immediate beyond the meter. . In the case of these installations there may be substantial cost on the customer side.
- Approximately 10% of the installations required their main fuses to be replaced. The assumption is that these will be replaced as part of the cut-out replacement program.

11 Related Projects

ESB Networks are also involved in a number of other areas of work as part of the current smart metering trials. These areas include a dual fuel trial with BGN where we are looking at the concept of the smart electricity meter being used to provide a communications link to and from a smart gas meter. We are also undertaking a trial with ESB Electric Ireland on examining how smart meters could support prepay services for the customer.

12 Possible Future Work

Ongoing developments in standardisation, technology and telecommunications regulation are continually enhancing and adding to the options available and their capability. The more recent entry of major communications systems vendors into the market is accelerating the availability of IP based solutions as credible options which require detailed investigation

Technologies to be kept under review include (but are not limited to) OFDM based PLC, and emerging RF solutions in the sub 1GHz band.

The trials utilised GPRS as the designated WAN technology. This was done to facilitate flexibility, speed and ease of deployment and due to the lack of a readily available and ubiquitous alternative. Before engaging in a full roll out suitable available WAN technologies should be assessed.

13 Conclusions

Smart metering is a complex program. The experience in the trial and that of other utilities who have undertaken smart metering deployment reinforces this view.

Smart metering is the start of something bigger, it isn't just an IT project, and it introduces change across the organization and industry. In addition the program can be up to 7 years duration with almost half the time required before full deployment begins. Often the biggest risks are with devices in the field and therefore you need an extensive test program. The overall program would have a number of key phases these phases include:

- Definition of requirements, design, planning and specification and procurement. At the end of this phase we will have selected the solutions for the full roll out.
- Detailed design test and installation of all new IT systems including integration testing to meters.
- Roll out of communications infrastructure and installation of meters and any other devices.

The smart metering technologies trialled need improvement to enable a feasible smart metering rollout. This reflects the fact that smart metering is still an immature technology where significant components of many available solutions are proprietary. However upcoming developments in standardisation, technology and telecommunications regulation should enhance the options available and their capability. Based on assumptions on the timetable we could be deciding in late 2012 on the full roll out solution.

The following overall high level conclusions can be drawn from the technology trials.

- Trialled LAN technologies are not sufficiently developed for immediate full roll out based on <u>anticipated</u> high level functional and demanding performance requirements
- The proprietary nature of some offerings also presents significant commercial and technology risk. This risk will be mitigated by the specification of internationally accepted standards for all technology choices.
- Ideally, the Internet Protocol should be used at the networking layer for all smart metering solutions and the well understood and standardised security mechanisms adopted by other security sensitive industries (such as banking) should be deployed.
- Working with vendors all solutions can be improved.
- Taking into account the timetable above and the issues identified in the trial next generation PLC would appear to offer best prospects for an urban solution. This is focus of activity in Europe.
- Existing national and European regulations on spectrum availability means that currently available wireless technologies all have issues leaving GPRS/3G as the leading option for almost 700k rural customers
- Mesh systems, deployed outside of Europe, operating in the sub-1Ghz range and at relatively higher transmit power appear to address many of these issues.

We believe that more suitable wireless spectrum should be made available in the sub 1GHz area.

- If required to roll out some smart meters on an ad-hoc basis in the near term then we should develop an interim solution based on GPRS with a DLMS/COSEM meter.