Design and Development of a SMART Pressure Tester

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Abstract

Tightness testing newly laid or altered gas service connections is traditionally carried out using a manometer, commonly referred to as a water gauge. The instrument itself is subject to interpretation and does not give an accurately calibrated reading. Wales and West Utilities set about digitising the test data within their existing mobile phone app. The engineer enters the pressure value in to the phone using the touchscreen and takes a photograph of the gauge as evidence. The opportunity for error is still great and the need for quality assurance intervention and oversight is high. Among other GDNs, similar practices are in place; manually recording analogue readings.

Fig 1. Manometer "Water gauge"

The development of a SMART pressure tester enables not just Wales and West Utilities, but all of the UK GDN's to accurately record truly digital test data. A secondary benefit to the system has been the ability to demonstrate conformance with industry standards and European directives. A purpose built mobile phone app and web server stand alongside the test instrument to harness the power of the connected world and cope with the rigors of the worksite.

Designing a system of such complexity from the ground up was a 2 year project that required a multi-discipline team co-ordinating with third-party developers and negotiating steep learning curves. During the embryonic phases of the project, I carried out all development in-house which provided a deeper understanding of the demands I later placed upon outside contractors.

Background

Bluetooth™ is key to the functionality of this device. It has become an industry standard, trusted and implemented globally. Every mobile phone, tablet or laptop has Bluetooth built in and that means we can communicate with each of them. Importing live readings from a Bluetooth pressure sensor directly in to the mobile phone app, circumvents the human error found in existing methods. Adopting the technology for this application has been without question a smart move.

Measuring gas pressure comes with some different challenges. Methane is a corrosive gas and can catalyse with silicone within the sensor. The sensing element must be protected from contact with the hostile media. A group of pressure transducers that meet this requirement already exist, they are known as "media isolated" sensors.

Data capture is a function of testing that Wales and West engineers are trained to carry out. The quality of the data gathered depends on the accuracy of the test equipment and the ease by which

valid data can be entered. Auditing data to ensure the quality of it is best performed on standardised data sets, reducing confusion and duplication.

Proof of Concept

In order to understand the key technologies required to deliver the project, I undertook to design a simple Bluetooth pressure gauge. If successful, the instrument would transmit a pressure reading to a mobile phone via Bluetooth.

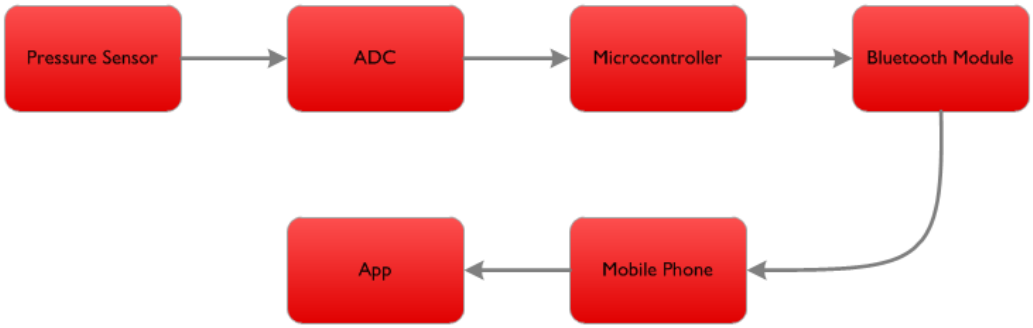

Fig 2. Data flow in proof of concept

An analogue pressure sensor was used to provide an output between 0.24 and 4.55V. This reading could be translated in to a digital value using an Analogue to Digital Converter. The ADC provided a value between 0 and 1023 counts, with zero mbar translating to about 88 counts and 539mbar to about 1020 counts. With a set ratio between the pressure at the sensor and the output from the ADC, digital data could be transmitted to the phone. A simple equation converted the digital value in to mbar.

Fig 3. Proof of concept

It was immediately apparent that the speed and simplicity with which the data was received by the phone would make the transition to business as usual far easier than expected. There was no need to pair the phone to the Bluetooth module, or to send any initiating commands. Wales and West Utilities were invited to see the progress and the list of potential features was assessed against the scope of the project. The importance of delivering the project on time and within scope was far greater than exhausting the potential of the technology. The concept was proven.

Learning

During development meetings with WWU, a key statement reoccurred; “This needs to replace the water gauge”. The performance objectives of the project were set to answer this call.

Early conceptual designs sought to produce an instrument that displayed readings with clear status indicators. The initial prototype included an LCD display and ring of tri-colour LEDs displaying pressure and test duration. This configuration relies heavily on rechargeable batteries and duplicates the information that would be displayed in an app.

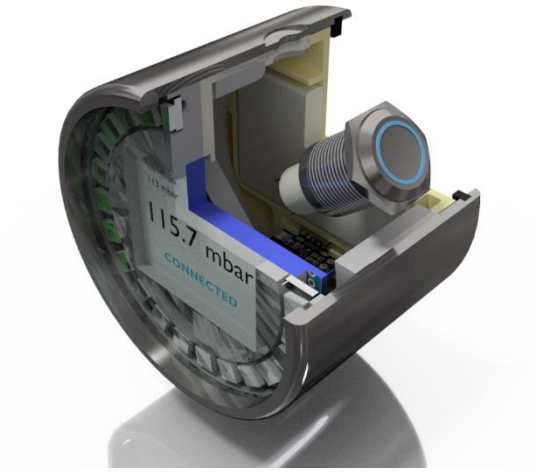

Fig 4. Prototype Bluetooth dial gauge

After further examination, some functions were deemed redundant or unnecessary. Having the ability to carry out more than one type of test became a key feature. A revision to the scope of the project was made to include tests carried out downstream of the emergency control valve. This change would require a flexibility in the test structure and behaviour to suit different test regimes.

The existing work platform was the Wales and West mobile phone app. The intention had been to replace the manual data entry phase by using the data from the Bluetooth module, that way the minimum amount of retraining and on-boarding would be required. The existing app would remain the same, aside from the method of pressure data entry. By including additional test criteria and work sequences, a new app need to be added to the list of deliverables.

Iteration

Taking guidance from the PRINCE2 method of project management, the project was divided into products: Case, Firmware, App and Webserver. Each with their own complex and differing demands, having interdependencies and design specifications that crossed with one and other.

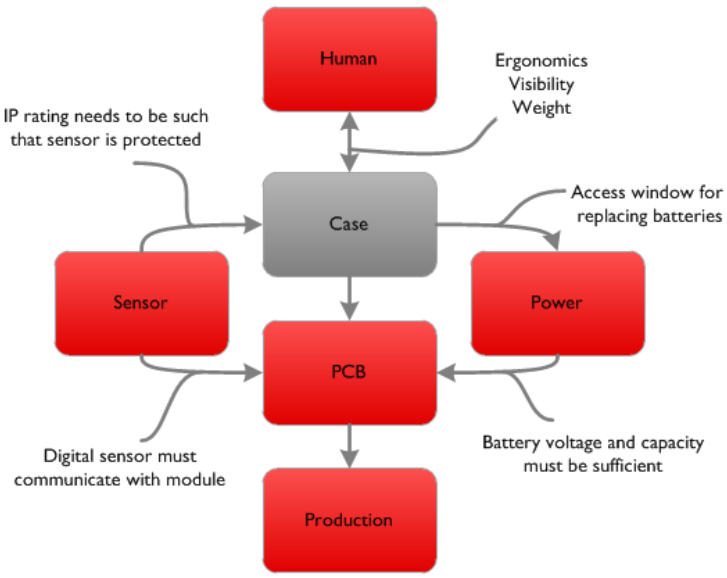

Fig 5. Product description – Case

To satisfy the new specification, the case was completely remodelled. All of the design work was carried out in-house and a working prototype was produced using an SLA 3D printer. The design uses two different materials to give both comfort in the hand and robustness. Further developments have seen the progression towards a more symmetrical handset with a lanyard anchor and waterproof seal.

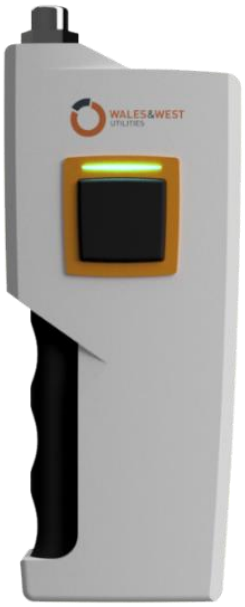

Fig 6. Case – Prototype 3D render

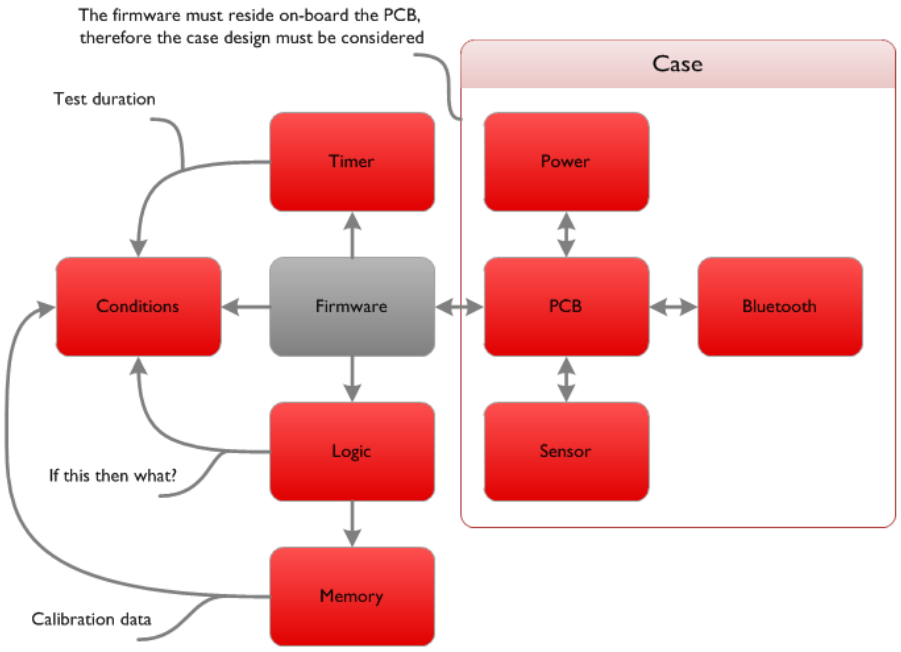

Fig 7. Product description – Firmware

The firmware that I had originally written to control an LCD display, was now responsible for transmitting pressure data and controlling the behaviour of the device. Calibration information is stored in non-volatile memory so that every time the device connects to a mobile phone, the calibration date can be checked. In order to bring the quality of the product up to commercial standards, I engaged a third-party developer to re-write the firmware in the native language of the chipset. Having established the required performance and logic sequences, transposing the functionality in to a different language proved quite straight forward.

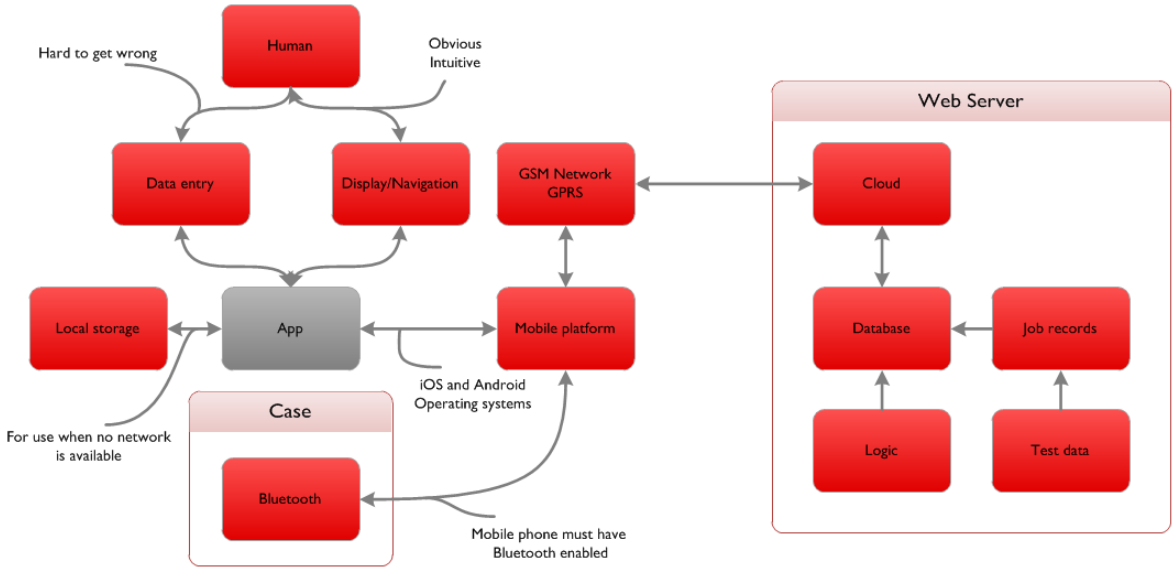

Fig 8. Product description – App

The app provides the human interface and the access to the data. The display must be obvious and intuitive and the integration with the operating system, seamless. Thousands of hours of testing have ensured that the software is stable and the information is displayed in a way that requires no second guessing.

Two systems were experimented with during the field trials, one that relied on a very rigid workflow system and another that was ad-hoc. The predictability of the test regime helps enormously with a rigid workflow and the IGEM guidance is very clear about what order activities are to be performed in. The ad-hoc version was developed to allow simultaneous activities to take place. For example, the engineer can fill in address details or geo-locate the test point while the pressure test is being carried out in the background. Long term, this is ideally suited to situations where engineers are also expected to carry out surveys, i.e. Smart meter installation. The design allows for maintenance of the test specification. When a new version of TD4 is published, the policy engineer simply adds the new logic to the Web Server and it becomes instantly available in the field.

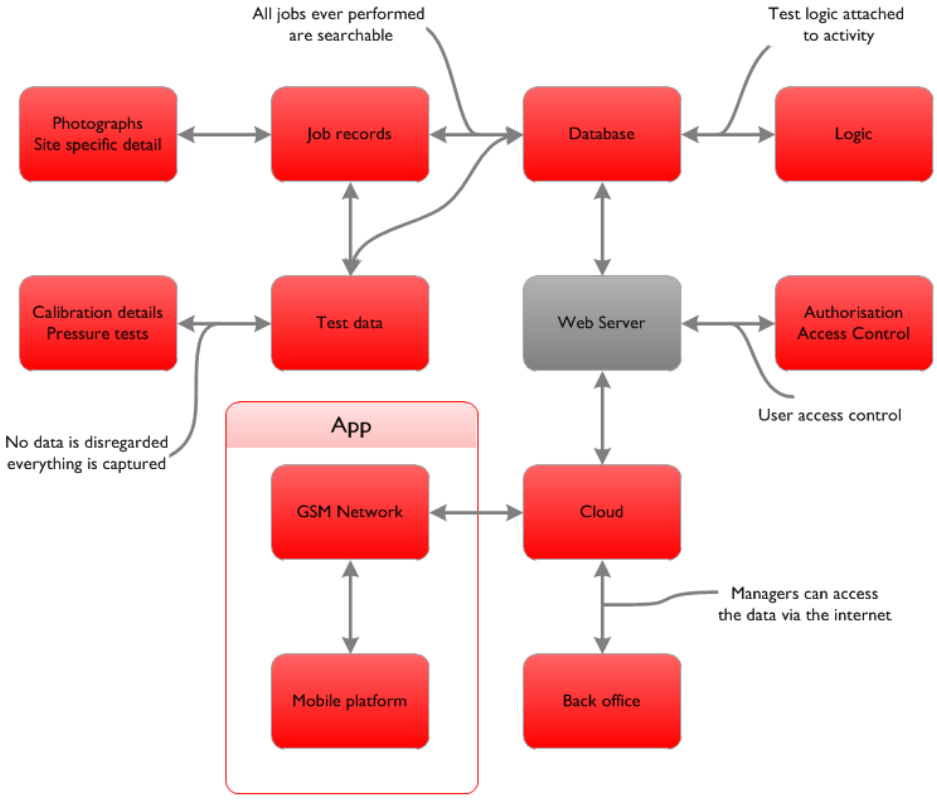

Fig 9. Product description – Web Server

Cloud computing describes the ability to access a central repository of features and information from any terminal attached to the internet. This is the service we modelled the administrative portal around. Wales and West Utilities required a platform through which planned job details could be entered. This would serve to provide the field trial with live and relevant information and also to demonstrate that the system could co-habit with the existing business processes. Data can be securely uploaded to the Web Server, where it is then disseminated to engineers across the network. So that the quality and functionality was properly delivered, we engaged a third-party developer to consult and write the App and Web Server code.

Conclusion

Without a display, the SMARTester isn't all that smart, it relies entirely on the phone in your pocket. However, it makes more sense to view things the other way round. Now your phone has a high accuracy gas pressure sensor to go with the 5" touchscreen, battery charger, GPS, connection to the internet, memory, speakers and a camera etc.

The feedback during the field trial was indicative of an appetite for change. Engineers are used to using their mobile phones for complex important tasks. With minute-by-minute accounting of activity on the ground, improved scheduling will be one of the biggest unexpected business benefits of this system. The moment a service is commissioned, the business can react and deploy purge and relight crews to a known location. Metrics describing network activity will go to improving performance and safety. In the future, developments in to high pressure testing and leak path modelling will expand the functionality of the system.

The project concluded on-time, on-budget and on specification, delivering a complete system handling data from test point to test report. Without the help and support of the design team at Steve Vick and the many dedicated suppliers, none of the above would have been possible. Managing a strong team, committed to delivering quality workmanship has been fulfilling and exciting.