Institiúid Teicneolaíochta Cheatharlach
INSTITUTE of TECHNOLOGY CARLOW

Home Operating System

Research Manual

Project Name:	PiLYNK Home OS
Student Name:	Keith Byrne
Student ID:	C00170460
Class Group:	Software Development
Supervisor:	Joseph Kehoe
Document:	Research Manual

Table of Contents

1. Purpose

The aim of this research manual is to identify areas of research conducted prior to the development of the Pi LYNK Home Operating System (Home-OS) for remote administration of appliances and lighting from anywhere in the world and extended automation of aforementioned appliances and lighting.

This document will provide an audit trail of technologies considered, evaluated and possibly tested in some cases. Subsequently, a choice of the most ideal technologies that will be used in the development of the project will be made. Furthermore, any further research made into previously overlooked technologies will be included thereafter and details of such technologies will be detailed as encountered and researched.

2. Introduction

2.1 Overview

With the rising costs of electricity due to the dwindling supply of finite resources that provide a large portion of the world's energy supply, making small changes to our daily behaviour can have a large, positive impact on energy conservation. Many of us in our daily pursuits leave our homes without a care as to what unnecessary energy consumption is actually doing to the physical state of planet. For example, leaving appliances on because it's more convenient to simply leave them on, (phone chargers, standby's, microwave idle control, etc.) rather than going through the effort of turning it off and back on when it's ultimately necessary.

It is true that people have very hectic schedules and simply may not have the time available to be concerned about these seemingly trivial issues. However, upon analysing the actual costs of unnecessary power consumption, even with a small number of idle phone chargers, laptop chargers, one can understand the need for a change in how people view this issue. As these electrical items are still active and drawing a current.

The following points are a brief overview of the impact that even leaving the house for two hours can have:

- The increase of the carbon footprint and pollution of the ecosystem.
- Higher cost of living and inorganic demand on energy suppliers.
- Maintenance costs of appliances and increases in waste disposal.

The project idea aims to help people in reducing this impact by creating a system that makes it easy to control what's on and what's not, even when that person is not even in the home and also help inform and habituate homeowners to more sensible conversation tactics. Furthermore, to allow householders to monitor activity in an effort to cut costs of the electricity bill (appliance by appliance basis) and potentially regulate usage of certain systems, such as TV's after hours for children.

3. An Overview of Home Operating Systems

Modern homes can be viewed much like a fully functioning computer system, much like a desktop computer, laptop or smart phone. Homes are typically occupied with components that serve particular functions for home owners, ranging from toasters to thermostats, analogous to soundcards and ram modules or CPU's and PSU's. This leads to a new form of thinking in how we go about our daily lives and how our homes can work for us, and us for our homes. To achieve this almost symbiotic harmony, the following statement from Colin Dixon and co-authors certainly holds true:

"The home needs an operating system..." [1].

Generally speaking, we view the home as a heterogeneous group of appliances, lighting options, heating components, etc. Subsequently, we argue that heterogeneity is hindering technological innovation in the home—homes differ in terms of their devices and how those devices are connected and used. To abstract these differences, a technical medium or bridge must be proposed.

The concept of smart, IoT connected homes has been around for well over twenty-something years. Pertaining to this vision is the concept of users being able to easily perform tasks that involve diverse sets of household devices in their home without needing to wade through a technical minefield of configuration, connectivity and the relevant programming requirements.

It may become common place in twenty years from now that all new homes will come smart home equipped. In which case, the need for such systems to be of a high standard is absolutely certain.

4. Similar Existing Technologies

4.1 Belkin WeMo

The Belkin Wi-Fi enabled WeMo Switch lets you turn electronic devices on or off from anywhere. The WeMo Switch uses your existing home Wi-Fi network to provide wireless control of TVs, lamps, stereos, heaters, fans and more. Simply download the free WeMo App from the Google Play Store or the Apple App store, plug the switch into an outlet in your home, and plug any device into the switch. You'll be able to turn that device on or off using your smartphone or tablet (running Android 4.0 and later or iOS 5 or higher). You can set schedules for your devices and control them remotely using a mobile internet connection. You can also add additional switches to your home to control more devices [2].

The WeMo range is completely modular and stands out as the best currently marketed product in this line of Home Operating System services. However, the technology comes at a considerable price tag. A single Belkin WeMo Automation Switch current retails at sixty U.S dollars [2] [3], as seen in in Figure 4.a.

Figure 4.a - Belkin WeMo Automation Switch [3]

4.2 Light Wave RF

Light Wave RF is a wide scale Home-OS service manufacturer. Light Wave produce modular technologies for appliances, heating, energy, sensors and lighting [4]. In addition to this, Light Wave RF also provide high end products for commercial/corporate customers for offices, warehouses and other interior settings. Due to the larger scale building management solutions options, Light Wave RF is an unattainable benchmark. However, in terms of this projects scope, a small subset of their services can be used for inspiration.

Light Wave RF allows users to connect with a suite of various remote access devices such as smartphone and tablet for controlling the central hub of the Light Wave RF systems. Due to this, users are connected no matter where they are currently located. Light Wave RF products are sold through Maplin, due to this, prices are not static.

Figure 4.b - Light Wave RF Device Suite [4].

4.3 ADT Security Automation

ADT Security offer a very complex range of home automation systems ranging from: ADT Pulse Features - Security, Burglary, Fire & Flood Alarms security, fire alarms, carbon monoxide air monitoring systems, video surveillance, temperature control, locks and garage door automation, lighting, flood monitoring and voice automation services [5].

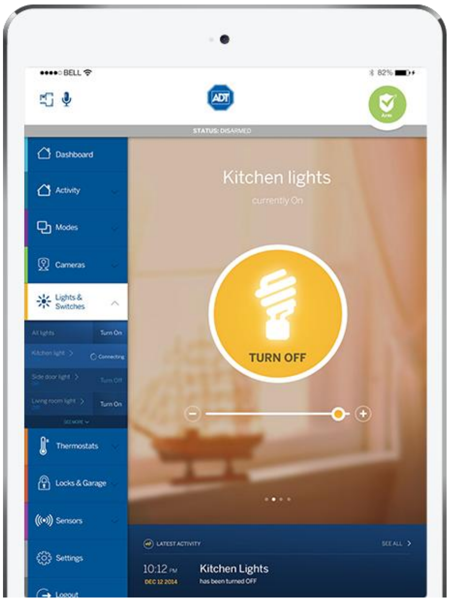

Figure 4.c - ADT Security Application Dashboard [5].

Although very specialist in nature compared to the nature of this project, the concept is similar.

Automated security is also becoming an increasingly hot topic as trust in conventional services such as door triggered alarms relies on the intervention of policing authorities to have the systems maximum effect.

4.4 Philips Hue

Figure 4.d - Hue Bulb & Hub [6]

Philips Hue is a home automation system developed by Philips. This series of automation technology focuses on highly specialised lighting for homes. The technology offers home owners ambient, sensual and mood lighting via the use of Hue modules (Hue bulbs) that are controlled using a Hue hub [6] as illustrated in Figure 4.d. Hue also offers a series of very interesting features with the Hue, such as audio tempo controlled variable lighting and a lighting array containing sixteen million colours. Philips Hue currently has control integration with Apple HomeKit [7].

5. Main Board Technology Options

For the system to be small enough to be hidden, quiet and reliable yet powerful enough to operate as a central hub and receive network requests, two options were considered:

- Small-scale m-ATX Form Factor desktop system.
- Single Board Computer System.

5.1 Small Scale Desktop Server System

This option faced many obvious downsides before research even began. The main downside of course being – cost. The system would perform its duties without any performance issues, downtime concerns or heating issues. Nevertheless, a barebones system would rack up a base price tag of anywhere between €300 and €600, depending on what dedicated hardware is to be included before any other critical components are even considered. Cheaper options are available, however this comes at the risk of high failure rates and damage to other components from typical usage.

5.2 Single Board Server System

A single-board computer (SBC) is a complete computer built on a simple foundation - single circuit board, with the necessary microprocessor(s), memory components, input/output (I/O) components and other various features required of a functional computer.

Single-board computers are typically aimed at demonstration or development systems, for educational systems, or for use as embedded computer controllers. Many types of home computer or portable computer integrated all their functions onto a single printed circuit board.

Unlike many desktop personal computer, single board computers often did not rely on expansion slots for peripheral functions or expansion. Single board computers have been built using a wide range of microprocessors. Simple designs, such as built by computer hobbyists, often use static RAM and low-cost 8 or 16 bit processors. Other types, such as blade servers, include all the memory and processor performance of a server computer in a compact space-saving format. In the next section, various options will be explored.

5.3 Deciding Factors

It was concluded early on that the system should be as cost effective as possible. But this isn't the only weighted factor in deciding which option to choose. Other factors such as cost of operation on a daily basis, space consumption, heat emission, available processing vs required processing.

6. Single Board Server Technologies

Because of the benefits ranging from size, minimal power consumption and general flexibility of single board computers, this option was decided and agreed upon at a very early stage. Much research into various board developers and specifications relating to both soon followed. Two of the biggest contenders were: Intel's Galileo and Raspberry Pi. The following sections will drill down on the features and considerations for each of the boards.

7. Intel Galileo

Galileo is a microcontroller board based on the Intel® Quark SoC X1000 Application Processor, a 32-bit Intel Pentium-class system on a chip. It's the first board based on Intel® architecture designed to be hardware and software pin-compatible with Arduino shields designed for the Uno R3. Digital pins 0 to 13 (and the adjacent AREF and GND pins), Analog inputs 0 to 5, the power header, ICSP header, and the UART port pins (0 and 1), are all in the same locations as on the Arduino Uno R3. This is also known as the Arduino 1.0 pinout [8]. The board is illustrated below in Figure 6.a and Figure 6.b

Figure 7.b - Intel Galileo (Front) [8]

Figure 7.a - Intel Galileo (Back) [8]

7.1 Relevant Features

One of the strongest advantages of the Galileo boards is the compatibility with the Arduino Software Environment, this allows users to become familiar with functionality and potential uses very quickly. In addition to Arduino hardware and software compatibility, the Galileo board has several PC industry standard I/O ports and features to expand native usage and capabilities beyond the Arduino shield ecosystem. A full sized mini-PCI Express slot, 100Mb Ethernet port, Micro-SD slot, RS-232 serial port, USB Host port, USB Client port, and 8MByte NOR flash come standard on the board [8].

7.2 Galileo Architecture

Certain important points can be considered from viewing the high level architecture of the board itself. The General Purpose Input/Output (GPIO) arrangement and availability is a factor as regardless which board is selected.

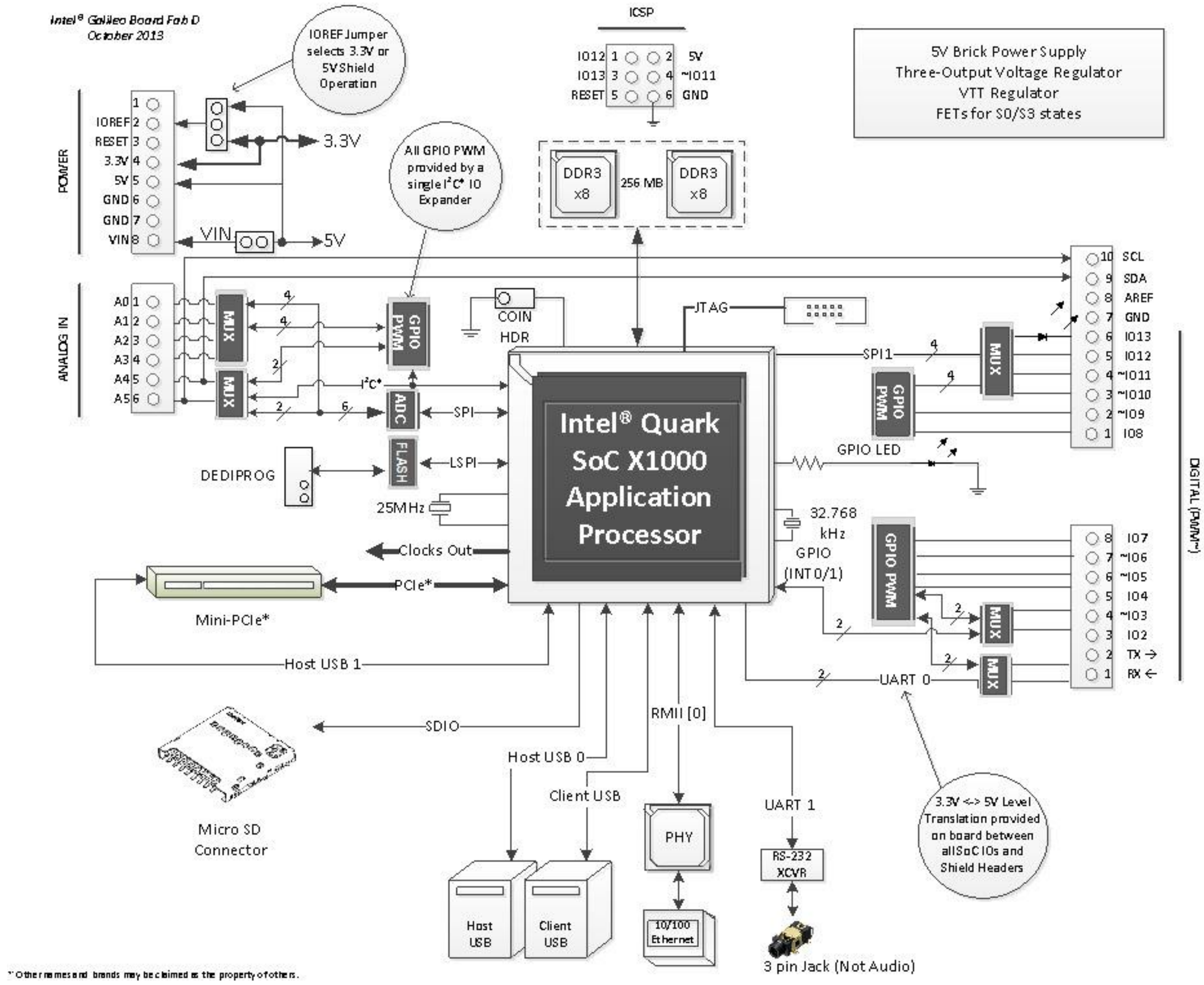

Figure 7.c - Intel Galileo Architecture

8. Raspberry Pi

The Raspberry Pi is a low cost, credit-card sized computer that plugs into a computer monitor or TV and uses a standard keyboard and mouse. It is a capable little device that enables people of all ages to explore computing, and to learn how to program in languages like Scratch and Python. It's capable of doing everything you'd expect a desktop computer to do, from browsing the internet and playing high-definition video, to making spreadsheets, word-processing, and playing games [9].

The Raspberry Pi has gained much traction since its early inception and now many models are available for hobbyists, inventors, educators etc. all offering specific specifications to suit various needs.

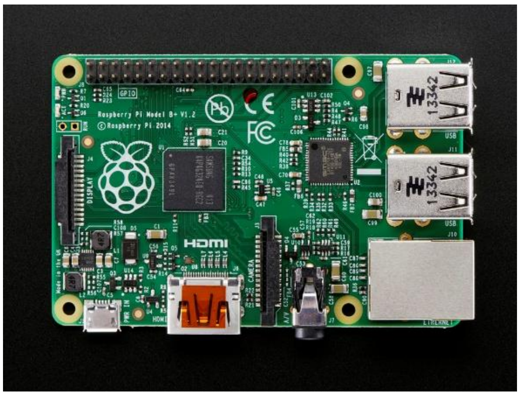
Figure 8.b - Raspberry Pi B+ (Front)

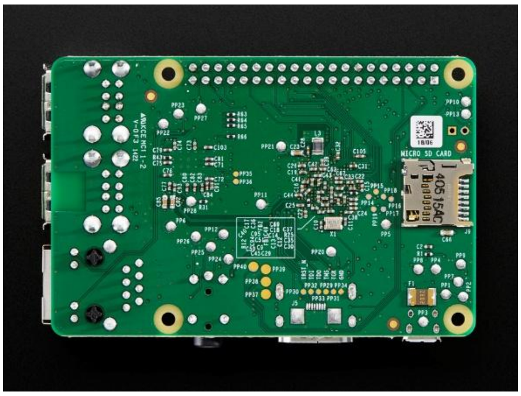
Figure 8.a - Raspberry Pi B+ (Rear)

8.1 Raspberry Pi Model Table

As of October, 2015, the following models are available for standard retail:

	R-Pi 1 Model A	**R-Pi 1 Model A+**	**R-Pi 1 Model B**	**R-Pi 1 Model B+**	**R-Pi 2 Model B**
Release Date:	*Feb 2012*	*Nov 2014*	*N/A*	*July 2014*	*Feb 2015*
Target price:	*US $25*	*US $20*	*US $35*	*US $25*	*US $35*

Note: *For the sake of efficient research, the Raspberry Pi B+ model was selected due to availability and the lower price tag.*

8.2 Relevant Features

- More GPIO. The GPIO header has grown to 40 pins, while retaining the same pinout for the first 26 pins as the Model A and B.
- More USB. We now have 4 USB 2.0 ports, compared to 2 on the Model B, and better hot plug and overcurrent behaviour.
- Micro SD. The old friction-fit SD card socket has been replaced with a much nicer push-push micro SD version.
- Lower power consumption. By replacing linear regulators with switching ones we've reduced power consumption by between 0.5W and 1W.
- Better audio. The audio circuit incorporates a dedicated low-noise power supply.
- Neater form factor. Aligned the USB connectors with the board edge, moved composite video onto the 3.5mm jack and added four squarely-placed mounting holes.

8.3 R-Pi B+ Architecture

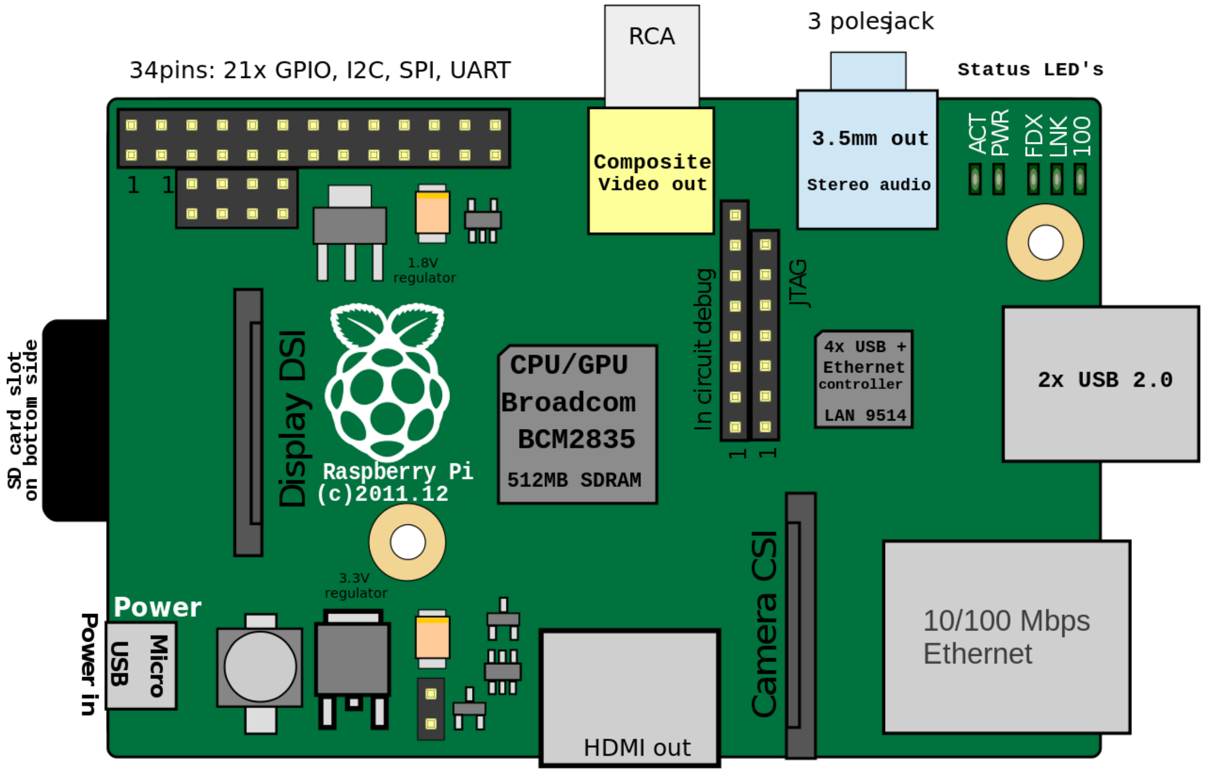

Figure 8.c - Raspberry Pi B+ Architecture

9. Intel Galileo vs Raspberry Pi B+

After considering all positive and negative points for both boards. It was decided that the Raspberry Pi B+ was to be the system's server board. However, first it must be noted that the Raspberry Pi and Arduino based boards are not aimed to achieve the same results. Both boards are good at their indented roles with diverging specialities at certain points. The decision was made due to following points:

9.1 Cost

The Raspberry Pi (~€20) comes in at almost a third of the price of a Galileo (~€70) board and can be acquired through domestic distributors and also delivered in less than a week [10] [11].

9.2 Initial Setup

The Raspberry Pi can be setup and operational in less than thirty minutes providing the available requirements are on hand. This includes an SD Card for the operating system and a 5V micro USB power supply.

9.3 Community & Development Options

The Pi comes ready to run with a large array of various libraries built using Python that can be used for a number of exciting Pi related projects [12].

9.4 Recommended Choice

Initial feedback from the Pi community, academic advice and professional opinion suggest the Pi is the better choice due to familiarity with past projects and knowledge of the Pi itself. This will reduce major downtimes due to potential common errors should they occur, as knowledge exists in regards to remedying the problem.

10. Raspberry Pi Operating Systems

Raspberry comes built ready to run a selection of down sized, existing operating systems.

10.1 NOOBS

The NOOBS [13] installer allows a user to install from a pre-set list of operating systems including:

- Arch Linux ARM
- OpenELEC
- Pidora
- Puppy Linux
- Raspbmc including XBMC
- RISC OC
- Raspbian (Recommended OS for Pi 1 models)

This is not an exhaustive list however. Several forks also exist but are not available using the NOOBS installer. These forks are special purpose built for specific tasks, such as Ark OS for website and email self-hosting. Many of these forks may or may not have uses on this project. However the best potential candidates for the project are; ***Raspbian***, ***Snappy Ubuntu***, ***Pidora*** and ***Windows 10 IOT Core***.

10.1.1 Raspbian Pi

At present, initial setup, testing and familiarisation with Raspbian showed that it is suitable for the project and offers expansion options and easy upgrades to revised systems in the further. In addition to this, Raspbian is the recommended operating system for general use and the officially supported operating system by the Raspberry Pi Foundation [13], meaning optimisations can be made within the system. Two kernel versions of Raspbian are currently available:

- Raspbian Jessie (Kernel 4.1)
- Raspbian Wheezy (Kernel 3.18)

If any changes in the operating system are decided on, details on this changes will be detail herein.

10.1.2 Snappy Ubuntu Core

Snappy Ubuntu a specially optimised operating system for clouds and small devices. "*Snappy Ubuntu Core is a new rendition of Ubuntu with transactional updates - a minimal server image with the same libraries as today's Ubuntu, but applications are provided through a simpler mechanism.*

The snappy approach is faster, more reliable, and lets us provide stronger security guarantees for apps and users — that's why we call them "snappy" applications." [14]

11. Raspberry Pi Projects

In this section, various Raspberry Pi projects designed and developed by the Pi community will be reviewed to further understand the potential of the Pi and how a simple single chip computer can become so much more.

11.1 Pi in the Sky

This project is an extension project for Raspberry Pi's GPIO break out pins. This add on board acts a GPS receiver and radio transmitter designed for tracking high altitude balloon flights. The board utilises an ultra-high frequency transmitter which is license-free in Europe. Together with the supplied, open-source software it embodies the experience of over 50 successful flights, about half of which have used the Raspberry Pi. The general features of the board include:

- Efficient built-in power regulator providing run time of over 20 hours from 4 AA cells
- Highly sensitive UBlox GPS receiver approved for altitudes up to 50km
- Temperature compensated, frequency agile, Radiometrix 434MHz radio transmitter
- Temperature sensor
- Battery voltage monitoring
- Sockets for external i2c devices, analog input, external temperature sensor
- Allows use of Raspberry Pi camera
- Mounting holes and spacers for a solid connection to the Pi

Open source software also enables a wide range of additional functionality that can further utilise data recorded using the on board sensors [14].

Figure 11.a - Pi in the Sky Board

11.2 Glasgow Raspberry Pi Cloud

The University of Glasgow Raspberry Pi Cloud project is a teaching and research project focused around the construction of a "scale-model" of a warehouse-sized computer using only Raspberry Pi devices. The project is based in the School of Computing Science and is led by SICSA Research Fellows Dr David R. White and Dr Posco Tso [15].

The project continues to progress. The physical build is complete, and one of the students has spent months building a nice RESTful API to monitor and control the PiCloud through a web interface.

According to the recent updates from the project, LXC virtualisation has also been used and furthering building a software stack on top of that. Posco has also been experimenting with Hadoop and Software Defined Networking (SDN).

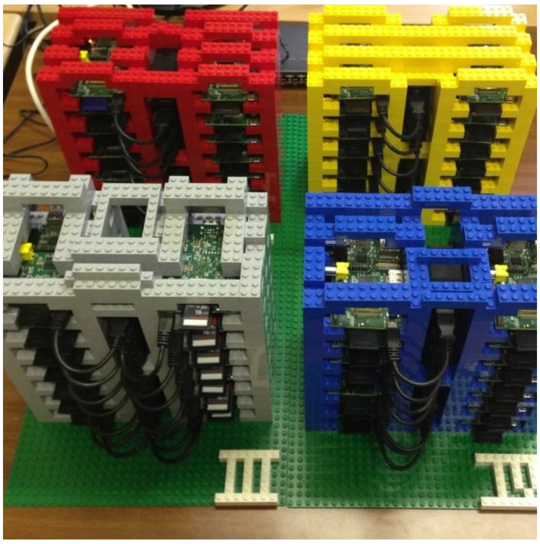

Figure 11.b - Glasgow R-Pi Cloud Housed in Lego

This project is an example that the Pi can achieve immense results, given the size and cost of materials, example shown in Figure 11.b where Lego is used as a construction bed.

11.3

12. Device Control

To achieve control of devices and lighting in the home, the system will need to be able to communicate with these devices and transmit protocol codes to control their status. This can be achieved using several different methods ranging from various complexities and prices. This section will cover a series of suitable technologies deemed suitable without in depth knowledge of electronics and advanced circuitry.

12.1 Static 433 MHz Sockets

This method of controlling devices relies entirely on being able to break a flow of electricity using an intermediate socket device with an internal switch that responds to a particular frequency, typically transmitted using a ~433.82 MHz remote control interface. 433 MHz is a pseudo industry standard used for this type of device.

Figure 13 – Energenie example socket component

The type of socket is placed between a mains outlet and the device plug itself. Using the given remote interface, a user can switch individual plugs on and off or all using the group protocol transmitter programmed onto the remotes microcontroller. Although these devices are useful, they lack the ability to automate at set times during the day and further extension requires a different remote configuration.

12.2 433 MHz Receiver

To further understand the explicit nature of the codes being transmitted from the remotes themselves, it is necessary to read and interpret the RF transmission. For this, a simple low cost ~433 MHz receiver module is required. These units are incredibly inexpensive. They can be found for at a cost typically between €1 and €5, depending on reliability and build integrity. Signals can be caught using a variety of different methods, these will be covered at a later stage.

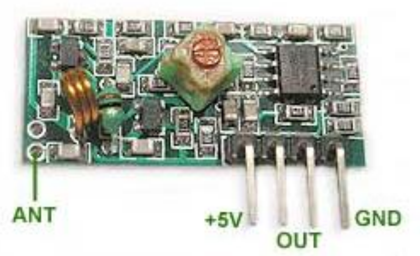

Figure 14 - 433 MHz Receiver

12.3 433 MHz Transmitter

This device allows for signals within the 433 MHz range to be transmitted. Like the receiver module, they can placed onto a breadboard for testing and work incredibly well with micro computing devices such as the Raspberry Pi and Arduino. Typically the receiver and transmitter work in pairs to allow for two way communication. These devices are also quite low in cost however and as a result are indiscriminate and will receive a fair amount of noise due to their simplicity and low cost construction.

Figure 15 - 433 MHz Radio Transmitter Module

The project will rely more on the transmission of codes than the interception of codes from source remotes. Subsequently, attention must be given to how the system will deal with the embedded codes retrieved from source devices. With a transmitter such as this, it's possible to communicate with and directly control the sockets mentioned above once the signals have been captured.

12.4 X10 Experimental

12.5 Inline Relay Control

12.6 Third Party Bridge (Hue, LightwaveRF)

13. Front End Technologies

14. Back End Technologies

15. References

[1] R. M. S. A. A. B. B. L. S. S. V. B. Colin Dixon, "The Home Needs an Operating System (And an App Store)," Microsoft Research University of Washington, Washington, 2010.

[2] Belkin, "Belkin WeMo Products," 20 September 2015. [Online]. Available: http://www.belkin.com/us/Products/home-automation/c/wemo-home-automation/.

[3] Belkin, "Belkin WeMo Switch," Belkin, [Online]. Available: http://www.belkin.com/us/F7C029-Belkin/p/P-F7C029/. [Accessed 27 October 2015].

[4] L. W. R. PLC, "Light Wave RF," Light Wave RF, 5 May 2015. [Online]. Available: http://lightwaverf.com/. [Accessed 2 October 2015].

[5] ADT, "ADT Security Specialists," 2015 ADT LLC DBA ADT Security Services, 2015. [Online]. Available: http://www.adt.com/. [Accessed 1 October 2015].

[6] Philips, "Meet Hue," Philips, 2015. [Online]. Available: http://www2.meethue.com/en-gb/about-hue/what-hue-does/. [Accessed 2 October 2015].

[7] Philips, "Philips Apple HomeKit," Philips, 2015. [Online]. Available: http://www2.meethue.com/en-gb/friends-of-hue/apple-homekit/. [Accessed 2 October 2015].

[8] Intel, "Intel Galileo," Intel, 2015. [Online]. Available: https://www.arduino.cc/en/ArduinoCertified/IntelGalileo. [Accessed 15 September 2015].

[9] R. P. Foundation, "What is a Raspberry Pi," Raspberry Pi Foundation, 2015. [Online]. Available: https://www.raspberrypi.org/help/what-is-a-raspberry-pi/. [Accessed 10 September 2015].

[10] A. Fruit, "Raspberry Pi B+ Model," Ada Fruit, 2015. [Online]. Available: https://www.adafruit.com/products/1914. [Accessed 5 September 2015].

[11] A. Retail, "Intel Galileo," Amazon, 2015. [Online]. Available: http://www.amazon.co.uk/Intel-Galileo-Gen-400MHz-Motherboard/dp/B00MTKHIFE. [Accessed 1 October 2015].

[12] R. P. Foundation, "Python Pi," Raspberry Pi Foundation, 2015. [Online]. Available: https://www.raspberrypi.org/documentation/usage/python/. [Accessed 1 October 2015].

[13] R. P. Foundation, “Raspberry Pi Downloads,” Raspberry Pi Foundation, 2015. [Online]. Available: https://www.raspberrypi.org/downloads/. [Accessed 15 September 2015].

[14] WeMo, “WeMo,” 1 October 2015. [Online]. Available: http://www.wemo.com/.

[15] R. M. S. A. A. B. B. L. S. S. a. P. B. Colin Dixon, “An Operating System for the Home,” USENIX, N/A, 2015.

[16] T. Radar, “Tech Radar Computing Components,” Tech Radar, 2015. [Online]. Available: http://www.techradar.com/news/computing-components/motherboards/8-best-micro-atx-and-mini-itx-motherboards-923069. [Accessed 1 October 2015].

[17] R. P. Foundation, “Raspberry Pi Features,” Raspberry Pi Foundation, 2015. [Online]. Available: https://www.raspberrypi.org/products/model-b-plus/. [Accessed 1 October 2015].