Honours
Literature Review

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1 Abstract

This report will review the literature surrounding sensor networks, embedded devices, network topologies and sensors used.

2 Background

The current system for monitoring rivers and bodies of water involves building small concrete huts that record and store data locally. The cost of building these huts makes them prohibitive and is inefficient with today's technology. A person is sent periodically to collect this information manually. Figure I shows one of these monitoring stations found along the River Beauly.

Figure 1: SEPA Monitoring Station [Wallace, 2012]

In 2005 the WFD reported 285 type 1a and 1b at risk bodies of water. [SEPA, 2007] By 2006 253 stations such as the one pictured in Figure 1 were in place across Scotland representing 10% of the countrys total water bodies and 26% of the 989 at risk rivers as of 2009. [SEPA, 2009]

Figure 2: Monitoring Stations in Scotland [SEPA, 2006]

The reason for this can be attributed to the cost of these monitoring stations, with the solution proposed in this paper cost could be greatly reduced to a fraction of this. [SEPA, 2016] Alternatives to this using more modern technology are still highly expensive and cost prohibitive [The IoT Marketplace, 2015]

3 Endpoint Devices

The Internet of Things (IoT) is a burgeoning field that has seen a massive boom in the Smart Devices market. [Lueth, 2018] IoT devices are defined by their low cost and low power and their ability to communicate with each other on the same LAN and have a degree of interoperability. [Vujovic et al., 2014]. With the ever increasing rise of such devices the availability of low cost SoC (System On a Chip) devices increases with it. Many vendors have begun targeting the SoC devices after the Raspberry Pi Foundation unveiled the Raspberry Pi 1. Today there exists a myriad of low cost SoCs with differing qualities for differing use cases. [Larabel, 2018] Many System On a Chips are available in the current market. Two of the largest names include Raspberry Pi from the Non Profit Raspberry Pi Foundation and the Arduino board from Arduino LLC.

3.1 Raspberry Pi

The Raspberry Pi Zero W (RPi0), the Non W (Wireless) is pictured below, is a nice fit for our endpoint controller. Its availability and its wide range of support makes it an appealing choice for the controller. The RPi0 is an excellent fit for our project as at idle it will only draw a maximum average of 100mA [Alex, 2017] with further tweaks reducing it. On a relatively low cost battery we can expect this to last a day. Many of the current SEPA stations use solar power to power the electronics inside the shed. [SEPA, 2007] Our sensors will also be battery powered leveraging a solar panel to ensure charge is maintained.

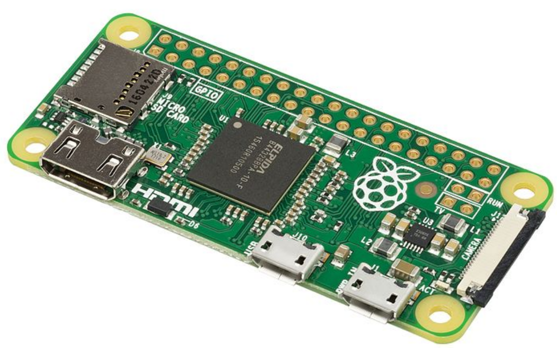

Figure 3: Raspberry Pi Zero [Amos, 2016]

The Raspberry Pi 3B+ on the other hand is a much better fit for a server/command and control device. [Leccese et al., 2014] With it's more powerful CPU increasing the power draw to an idle of 500mA [RaspberryPiFoundation, 2018a] powering this from a battery wouldn't be ideal. Instead it should be used to connecting a LTE adapter or Ethernet cable to connect the endpoints to the larger LAN or WAN for sending information back to a central server.

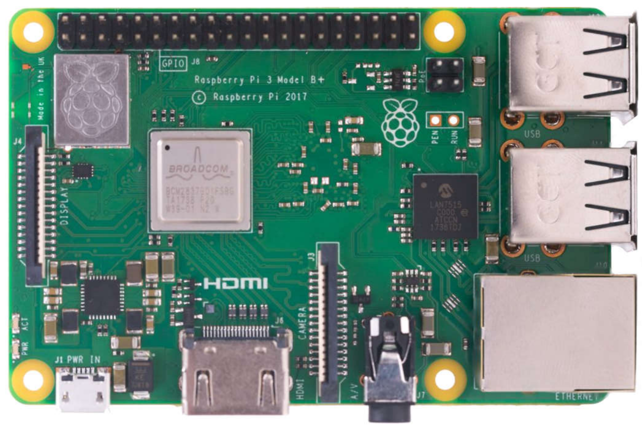

Figure 4: Raspberry Pi 3B+ [RaspberryPiFoundation, 2018b]

3.2 Arduino

The Arduino is a compelling choice as its Arduino Nano product, pictured below, uses the ATmega328 microcontroller. This is a controller with a miniscule power draw of only 19mA. [ArduinoLLC, 2010] This can be further improved to reach as low as 54 A (0.054 mA). This would enable us to run on a minimal power source such as a 9V battery cell for periods of years. [Madcoffee, 2018] Further the arduino features a smaller SoC size for both the Nano and the full-size Uno device [ArduinoLLC, 2010] making it more versatile.

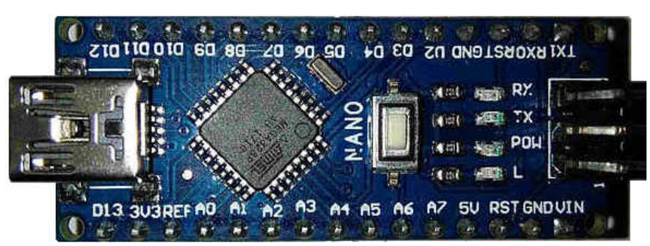

Figure 5: Arduino Nano [Mellis, 2010]

3.3 Other

Many other SoCs include the ASUS tinker board and BeagleBoard among many others. Other SoC's target features found lacking in the Raspberry Pi, namely Gigabit Ethernet and increased RAM or reducing power consumption and SoC size. These make them compelling choices in scenario's where size or bandwidth etc. are essential however these other board's are often more expensive and even more difficult to source.

3.4 Comparison

	Uno Rev 3	Nano	Pi 3B+	Pi Zero W	BeagleBone	TinkerBoard
Cost ()	15	15	35	15	50	55
Power Draw Idle	0.225 W	0.01 W	2 W	0.5 W	1.75 W	2 W
WiFI	N/A	N/A	802.11 b/g/n	802.11 b/g/n	802.11 b/g/n	802.11 b/g/n
Bluetooth	N/A	N/A	4.2	4.1	4.1	4.0
CPU Arch	AVR	AVR	ARMv8	ARMv6	ARMv8	ARMv7
Clock Speed	16 MHz	16 Mhz	1.4 GHz	1 GHz	1 GHz	1.8 GHz
Core Count	1	1	4	1	1	4
RAM	32 KB	32 KB	1 GB	512 MB	512 MB	2 GB
OS	N/A	N/A	Linux	Linux	Linux	TinkerOS

Figure 6: Comparison of devices [ArduinoLLC, 2010], [ArduinoLLC, 2008], [RaspberryPiFoundation, 2018a], [RaspberryPiFoundation, 2017], [BeagleBoard, 2017], [Asus, 2917]

The advantage afforded to the RPi0 is its availability, low cost, support but more importantly familiarity. It is important to ensure the barrier for entry, both cost and technical ability, is kept to a minimal for anyone who wishes to deploy one or more of these. Additionally by using the RPi0 we can leverage technologies already created for the device. From the graph above we can see that the pi3 and pi0 fit nicely into the middle of the graph offering good hardware and low power consumption.

4 Server

A server is defined as a device that can serve one or more "client" devices. This will usually be a powerful device that clients can send raw data to and have the server do any computation required before returning a result. [Raymond, 2003]

A number of operating systems exist to target the server. This is achieved by first stripping the system of as many superfluous systems as possible, such as a graphics stack. [Canonical, 2013] The configuration is therefore handled primarily though the shell, under Linux this is usually Bash (Bourne Again Shell). Windows Server's do not abide by this however and usually a graphical stack is used to perform most configuration [Microsoft Corporation, 2017a]. Due to this, a Linux server is best placed due to its far lower system requirements to run.

	Raspbian Lite	**Ubuntu Server**	**Microsoft Server**
CPU	1 GHz	1 GHz	1.4 GHz
RAM	128 MB	384 MB	512 MB
Storage	2 GB	1.5 GB	32 GB

Figure 7: Comparison of operating systems [Debian, 2018], [Canonical, 2013], [Windows IT Pro Center, 2017]

To ensure that costs are kept low small SD Cards are ideal which somewhat rules out the Windows option. In addition hardware support for Windows on Raspberry Pi is limited to Windows S [Microsoft Corporation, 2017c] which would require any software to be written as a UWP [Microsoft Corporation, 2017b] which would hinder performance.

5 Sensors

The collection of the river data will be the trickiest part of the project. To collect water level currently a wire is laid across the river and a buoy attached to the middle, the sag in the wire can then be used to calculate depth. [SEPA, 2016] An alternative solution involves using an ultrasonic sensor to judge the distance between the sensor and the water. [Aravind Jayan, 2016] This method has the advantage of being a low physical footprint solution to monitoring.

Figure 8: HC SR04 Ultrasonic Sensor [Mouser Electronics and OSEPP Electronics, 2016]

Types of sensors that could be used. Elements that need to be detected.

6 Sensor Networks

Table 1. ZigBee vs. some other wireless network.

ZigBee Pi 3 WiFi Pi 0 W Wi-Fi Bluetooth IEEE 802.15.04 802.11 g/b 802.11 b/g/n 802.15.1* Frequency (GHz) 2.4 2.4 2.4 / 5 2.4 Main Application Smart Devices WLAN WLAN Low Bitrate Streams Bit Rate 250 kbps 54 mbps 600 mbps

Range

Battery Life

Previous implementations of sensor network and IoT control networks.

7 Network Protocols & Topologies

The network protocols used previously and new possibilities. Bluetooth vs WiFi, Ad-hoc, hub and spoke, master slave and other technologies like zigbee. How to send the data most efficiently over the network.

Web portal How best to present data for users. Outlier notifications i.e. if flooding occurs (will need to find the thresholds for that).

References

Alex. How much power does Pi Zero W use?, 2017. URL https://raspi.tv/2017/how-much-power-does-pi-zero-w-use.

Evan Amos. Raspberry Pi Zero W, 2016. URL https://en.m.wikipedia.org/wiki/File:Raspberry-Pi-Zero-FL.jpg.

Aravind Jayan. How to Make a Water-Level Indicator With Arduino, 2016. URL https://maker.pro/arduino/projects/ultrasonic-arduino-water-level-indicator.

ArduinoLLC. Arduno Nano, 2008. URL https://store.arduino.cc/arduino-nano.

ArduinoLLC. Arduino Uno Rev 3, 2010. URL https://store.arduino.cc/arduino-uno-rev3.

Asus. Asus TinkerBoard, 2917. URL https://www.asus.com/uk/Single-Board-Computer/Tinker-Board/.

BeagleBoard. BeagleBone Black Wireless, 2017. URL https://beagleboard.org/black-wireless.

Canonical. Installing Ubuntu Server. *Methods*, page 416, 2013. URL https://help.ubuntu.com/lts/serverguide/serverguide.pdf.

Debian. Debian System Requirments, 2018. URL https://www.debian.org/releases/stable/amd64/ch03s04.html.en.

Michael Larabel. The Current Linux Performance With 16 ARM Boards, 2018. URL https://www.phoronix.com/scan.php?page=article{\&}item=16-armlinux-sep2018.

Fabio Leccese, Marco Cagnetti, and Daniele Trinca. A smart city application: A fully controlled street lighting isle based on Raspberry-Pi card, a ZigBee sensor network and WiMAX. *Sensors (Switzerland)*, 14(12):24408–24424, 2014. ISSN 14248220. doi: 10.3390/s141224408.

Knud Lasse Lueth. State of the IoT 2018: Number of IoT devices now at 7B Market accelerating. *IoT Anal. Mark. Insights Internet Things*, 2018. URL https://iot-analytics.com/state-of-the-iot-update-q1-q2-2018-number-of-iot-devices-now-7b/.

Madcoffee. Arduino Low Power - How To Run ATMEGA328P For A Year On Coin Cell Battery, 2018. URL http://www.home-automation-community.com/arduino-low-power-how-to-run-atmega328p-for-a-year-on-coin-cell-battery/.

David Mellis. Arduino Nano, 2010. URL https://commons.wikimedia.org/wiki/File:Arduino{_}Nano.jpg.

Microsoft Corporation. Windows Server Nano, 2017a. URL https://docs.microsoft.com/en-gb/windows-server/get-started/getting-started-with-nano-server.

Microsoft Corporation. Windows S, 2017b. URL https://www.microsoft.com/en-gb/windows/s-mode.

Microsoft Corporation. Windows 10 IoT Core for Raspberry Pi 2 / 3, 2017c. URL https://www.microsoft.com/en-us/download/details.aspx?id=55029.

Mouser Electronics and OSEPP Electronics. HC-SR04 Sensor, 2016. URL https://www.mouser.co.uk/ProductDetail/OSEPP-Electronics/HC-SR04?qs=sGAEpiMZZMu8c2wsui{\%}252biYud73BL9dHAk5B2HDuQZqCU=.

RaspberryPiFoundation. Raspberry Pi Zero W, 2017. URL https://www.raspberrypi.org/products/raspberry-pi-zero-w/.

RaspberryPiFoundation. Raspberry Pi 3 Model B+, 2018a. URL https://static.raspberrypi.org/files/product-briefs/Raspberry-Pi-Model-Bplus-Product-Brief.pdf.

RaspberryPiFoundation. RaspberryPi3B+, 2018b. URL https://www.raspberrypi.org/products/raspberry-pi-3-model-b-plus/.

Eric Raymond. Server, 2003. URL http://www.catb.org/jargon/html/S/server.html.

SEPA. WFD Operational and Surveillance RIver Monitoring Points in Scotland, 2006.

SEPA. An introduction to the significant water management issues in the Scotland river basin district. 2007.

SEPA. Scotland ' s WFD aquatic monitoring strategy. pages 1–14, 2009.

SEPA. River Gauging Stations, 2016. URL https://www.saa.gov.uk/blog/document-search/river-gauging-stations/.

The IoT Marketplace. Libelium Smart Water IoT Vertical Kit, 2015. URL https://www.the-iot-marketplace.com/smart-water-iot-vertical-kit.

Vladimir Vujovic, Mirjana Maksimović, Vladimir Vujović, Nikola Davidović, Vladimir Milošević, and Branko Perišić. Raspberry Pi as Internet of Things hardware : Performances and Constraints Raspberry Pi as Internet of Things hardware : Performances and Constraints. *Des. Issues*, 3(JUNE):8, 2014.

Craig Wallace. SEPA gauging station by the River Beauly, 2012. URL https://www.geograph.org.uk/photo/2754945.

Windows IT Pro Center. Windows Server 2016 System Requirements, 2017. URL https://docs.microsoft.com/en-us/windows-server/get-started/system-requirements{\#}network-adapter-requirements.