SMART AIR CONDITIONING SYSTEM FOR COLIN REEVES BUILDING

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Contents

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Introduction

Importance of IoT

The Internet of Things (IoT) can be interpreted as a far-reaching vision with technological and societal implications (International Telecommunications Union (ITU), 2012).

IoT's are considered very important as they provide connectivity, allowing anyone to connect to anything, anywhere at any time (Khan, et al., 2010). In modern society, people rely on internet connectivity to perform basic tasks such as arranging business meetings, sharing information, etc. Connectivity in this manner means that large amounts of data is shared between different people and devices, which allows consumers, businesses and cities to run more efficiently (Becker, 2013). However, large data collection means that there are concerns regarding privacy and security and it is down to manufacturers to protect and preserve data in the best way that they can.

Smart Cities

Another implementation is the idea of smart urban management, which falls under the umbrella of 'Smart Cities'. IBM defines a smart city as "one that makes optimal use of all the interconnected information available today to better understand and control its operations and optimize the use of limited resource" (Cosgrove, et al., 2011, cited in (Centre for Cities, 2014)). A smart city has 3 main focuses which are quality of life, sustainable development and economic development. These 3 areas mean that smart cities rely on interconnected telecommunication and software architecture, which is the foundation for developing citizen-oriented applications (Budde, 2014).

Urban-based IoTs are designed to support the vision of smart cities (Zanella, et al., 2014), however businesses that exist within smart cities have difficulty taking off and often run short of their potential (Dohler, et al., 2011).

Proposal

This project will look at how the IoT can be used for smart temperature control in the Colin Reeves building at Keele. From experience, it appears that the air conditioning system for the main three labs on the ground floor only activates if the average temperature of all the labs reaches a certain level which means that one lab could be full and others empty, and the air conditioning will not activate. This means that electricity is wasted by cooling down empty labs. There are systems available such as the Hive Active Heating system (Hive, 2018) which can be used can be used for temperature control as part of the implementation of the architecture.

Literature Review

The idea of smart air conditioning systems is one that has been explored before. A residential heating and air conditioning control system has been patented in the United States by Glenn Foster and Charlie Moses (Foster & Moses, 1993). Their idea is for a temperature control system that maintains programmed temperature setpoints for specific periods in zoned areas. Their system has 3 modes that are hold, override and vacation, which can temporarily alter the programmed temperature and time periods for individual zones or all zones until the next programmed time, or release of temporary modes.

Foster and Moses explain that conventional residential air conditioning systems of the time are typically controlled by a single thermostat, meaning that there is one setpoint causing the temperature of the area near the thermostat to controlled, with other areas of a residence having varying temperatures due to external factors such as windows, areas of shade, heat generated by electronic devices, etc. This means that certain places in a building need different temperature control to others. Some rooms are also only required to be controlled at certain times of the day such as bedrooms. Also, areas where there is a large amount of glass present, create larger problems for temperature control as they are likely to have exposure to direct sunlight during certain hours of the day. With a single thermostat, it is impossible to achieve an optimal temperature in all rooms always (Foster & Moses, 1993). By introducing the idea of zones, you can achieve optimal temperatures in individual areas.

The objectives of Foster and Moses' invention are to provide improved zonal temperature control, allowing for the temperature in a single area to be overridden for a period of a schedule, by reprogramming the original schedule. Also, they hope that their method will allow for the desired temperature of each zone to be held at a common set point for an unlimited period of time, allowing for the return to the original schedule without the need to reprogram the controller (Foster & Moses, 1993).

System Architecture

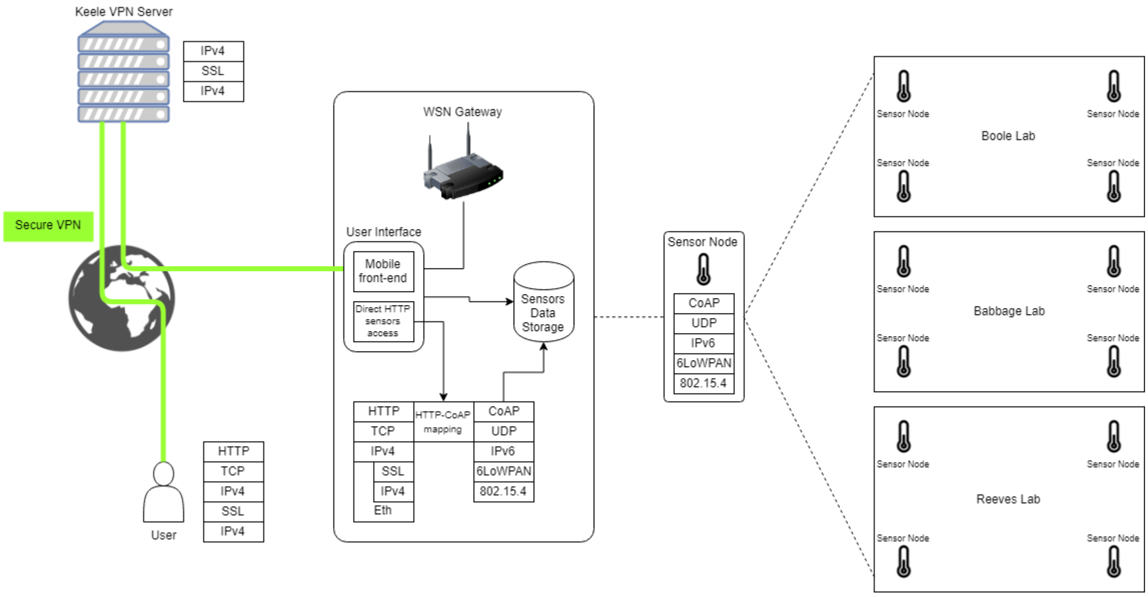

Figure 1: (Proposed) Colin Reeves Air Conditioning Architecture

IoT Devices

As can be seen in figure 1, the data with be gathered using sensors. These temperature sensors will be placed in different areas of each lab to obtain an average temperature reading to base decision making on. In terms of converting the data sent from the constrained devices to the server, a WSN (Wireless Sensor Network) gateway is required. A WSN gateway acts as the network coordinator in charge of various tasks such as node authentication and creating a bridge between the IEEE 802.15.4 wireless networks, to the wired Ethernet network (National Instruments, 2011).

Network Protocols

The protocols used at each layer differ between the outer network and the WSN. On the outer architecture, the HTTP has been used as most traffic that crosses the internet is carried at the application layer using this protocol, over a TCP transport layer protocol (Zanella, et al., 2014). However, Zanella explains that due to the complexity of HTTP, it is unsuitable to be directly deployed to constrained IoT devices, in this case, the temperature sensors, as it does not scale well onto these devices, resulting in poor performance for small data flows in lossy environments. To combat this, the CoAP protocol has been used at the application layer of the constrained devices as it proposes a binary format. In terms of transfer in the transport layer, UDP has been used as it only handles the required retransmission of data to provide a reliable service. HTTP and CoAP work together in this case as they can easily interoperate ReST methods of HTTP (Rest API Tutorial, n.d.). This allows for the IoT sensor nodes to send data seamlessly at frequent intervals, allowing for a constant monitoring of temperature.

At the network layer, IPv4 has been used on the outer network. Although it is common knowledge that IPv4 address blocks will soon be exhausted, it has been used on the outer network in this case as only a small fraction of the web has switched over to IPv6 and many routers and serves don't support it. In addition, IPv6 is still very new and contains a lot of bugs and security issues that still need to be fixed (Parr, 2011), meaning that if it was used on the outer network, there is a chance these weaknesses could be exploited or cause the system to crash. On the WSN, IPv6 has been used as its 128-bit address field means that it is possible to assign a unique address to any node in the network (Zanella, et al., 2014), allowing for expansion in the future.

At the link layer, Secure Socket Layer (SSL) has been used on the outer network. SSL will combat the security issue discussed earlier as it is used for sending confidential data over the internet by creating a secure connection via encryption between a web browser and the server. Although it is possible for unauthorized parties to intercept data, SSL makes changes to the data meaning that it cannot be read (Ward, 2014). For the WSN, 6LoWPAN has been used. This overcomes the problem with IPv6 introducing overheads that are not compatible with the limited capabilities of the constrained nodes. 6LoWPAN is an established compression format for IPv6 and UDP headers over low-power constrained networks (Zanella, et al., 2014).

Since constrained physical and link layer technologies are considered as utilizing a low energy consumption, a prominent solution is to use IEEE 802.15.4. As well as other implementations such as the basis for ZigBee, this protocol ties in the use of IPv6 and 6LoWPAN. Generally, physical IEEE 802.15.4 connections only support frames of up to 127 bytes, however the use of 6LoWPAN provides fragmentation schemes to support larger network layer packets (Wikipedia, 2018).

IoT Services

In terms of data storage, the Keele SEND project utilises cloud-based storage mediums. The benefits of using cloud platforms include the flexibility where users can scale services to fit their individual needs, and efficiency where enterprise users can get applications to market without having to worry about infrastructure or maintenance. The DNS servers that are located on the cloud can be programmed so that when a DNS request is issued (Figure 2 & 3), the IPv4 address of an HTTP-CoAP cross proxy is contacted, allowing access to the IoT node. Once the proxy has been addressed, it requires the domain name contained in the HTTP Host header to the IPv6 DNS server, which will reply with the IPv6 address, identifying the IoT node involved in the request (Zanella, et al., 2014).

```
Hypertext Transfer Protocol
> GET /weather.php HTTP/1.1\r\n
  Host: www.astro.keele.ac.uk\r\n
  Connection: keep-alive\r\n
  Cache-Control: max-age=0\r\n
  Upgrade-Insecure-Requests: 1\r\n
  User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/66.0.3359.117 Safari/537.36\r\n
  Accept: text/html,application/xhtml+xml,application/xml;q=0.9,image/webp,image/apng,*/*;q=0.8\r\n
  Accept-Encoding: gzip, deflate\r\n
  Accept-Language: en-GB,en-US;q=0.9,en;q=0.8\r\n
```

Figure 2: Example HTTP message request

```
Hypertext Transfer Protocol
> HTTP/1.1 200 OK\r\n
  Date: Fri, 20 Apr 2018 09:42:26 GMT\r\n
  Server: Apache/2.4.6 (Scientific Linux) OpenSSL/1.0.2k-fips PHP/5.4.16\r\n
  X-Powered-By: PHP/5.4.16\r\n
> Content-Length: 833\r\n
  Keep-Alive: timeout=5, max=100\r\n
  Connection: Keep-Alive\r\n
  Content-Type: text/html; charset=UTF-8\r\n
  \r\n
  [HTTP response 1/2]
  [Time since request: 0.043767000 seconds]
  [Request in frame: 170]
  [Next request in frame: 175]
  [Next response in frame: 184]
  File Data: 833 bytes
```

Figure 3: Example HTTP response message from server

Conclusion

The proposed design looks to overcome a problem that has been identified by many students and staff alike in Colin Reeves that the air conditioning system appears to function using ideologies that do not match the needs and requirements of those who use the labs. There have been numerous times where computer labs have been full, with most of the computers going and the air conditioning system has not activated and vice versa. Not only does this waste energy which could be used elsewhere but makes the experience for the students uncomfortable which can have an adverse effect on their studies.

Introducing a smart, zone-based air conditioning system, building on the work of Foster and Moses (Foster & Moses, 1993), allows for the temperature of each lab to be evaluated and adjusted individually to achieve an optimal temperature that is both energy efficient and comfortable for those using the labs. The use of IoT temperature sensors allows for a completely wireless network which can link to the cloud servers of the SEND project, whilst the various protocols implemented allows for a seamless, smooth and secure transmission of data and information between IoT devices and servers.

This design can be adjusted and expanded to work in a range of other scenarios. For example, a typical office block may have a different number of people in a room at different times. By expanding this system to consider a larger area, the principles discussed, and the technologies implemented could provide an effective solution.

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