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Comparison of Power Consumption of WiFi Inbuilt Internet of Things Device with Bluetooth Low Energy

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***Abstract*—**The Internet of things (IoT) is currently a highly researched topic, especially within the context of the smart home. These are small sensors that are capable of gathering data and transmitting it to a server. The majority of smart home products use protocols such as ZigBee or Bluetooth Low Energy (BLE). As these small sensors are increasing in number, the need to implement these with much more capable and ubiquitous transmission technology is necessary. The high power consumption is the reason that holds these small sensors back from using other protocols such as the most ubiquitous form of communication, WiFi. Comparing the power consumption of existing transmission technologies to one with WiFi inbuilt, would provide a better understanding for choosing between these technologies. We have developed a small IoT device with WiFi capability and proven that it is much more efficient than the first protocol, 433 MHz. We extend our work in this paper and compare WiFi power consumption with the other most widely used protocol BLE. The experimental results in this paper would conclude whether the developed prototype is capable in terms of power consumption to replace the existing protocol BLE with WiFi.

***Keywords*—**Bluetooth, internet of things, power consumption, WiFi.

I. Introduction

THE IoT is currently one of the most researched areas, especially within the context of 'Smart Home' [11] and 'Smart Cities' [12]. IoT is a network of devices which is capable of communicating through wireless protocols such as WiFi, BLE, and ZigBee [10]. These devices, when implemented with sensors, can be seen as being 'smart'; the idea behind IoT. According to Cisco and Gartner, the number of these small devices being used in 2016 would be 16 billion [3] with an expected rise to 50 billion by 2020 [9]. The majority of these devices will be battery powered and expected to last for many years. In agreement with Lattice Semiconductor, power efficiency is one of the main challenges that constrains the advancements of IoT devices [16]. Since power efficiency is desired, a power hungry protocol such as WiFi is undesirable. However, with the majority of homes, cities, transport stations, and airports already supporting WiFi, a low energy WiFi solution could be favored over Bluetooth, Zigbee or 433MHz.

The first protocol 433 MHz is power efficient and popular compared to the other existing protocols. Lower powered protocols with reduced data rates such as 433 Mhz and BLE are the industry standard today. Although 433 MHz is effective for short range communication, it is incapable of supporting long distance transmission. The range offered by BLE is far greater than 433 MHz and it is capable of supporting up to 20 devices. Although WiFi is ubiquitous with more range and device coverage than BLE and 433 MHz, the power consumption restrains it from being implemented into IoT sensor devices.

In previous paper [18], we have developed a low-cost WiFi inbuilt device capable of providing much less power consumption than 433 MHz. Later, the same device was modified with a low power MSP430 to further reduce the power consumption [17]. In this paper, we will focus on the comparison of our WiFi inbuilt device with a BLE device to determine whether WiFi can be a suitable substitute for IoT over BLE. Table I represents a comparison of the main protocols being used in this paper: WiFi and BLE.

TABLE I
WiFi vs. BLE

	WiFi	BLE
Frequency / GHz	2.4, 5	2.4
Range / meters	32-95	77
Power Consumption	High	Very Low
Latency / ms	150	150
Bit Rate / Mbps	600	1

Table I shows that WiFi is capable of operating in more frequencies than BLE and has a much higher data rate. With the range and latency almost equal, the defining factor between these two protocols comes down to power consumption. Since IoT devices need to be very power efficient in order to have long life spans, BLE has been favoured over WiFi. However, if the low powered WiFi module we have created can rival the power consumption of that of the BLE, we can take advantage of WiFi's high data rates and multiple frequency bands.

The paper is organized as follows: Section I provides a brief introduction with subsections discussing BLE and WiFi. Section II provides an overview of the experiments carried out followed by Section III discussing the experiment scenario in detail. Section IV discusses the results obtained through the experiments with Section V concluding the paper.

A. BLE

BLE, also known as Bluetooth Smart, is an enhancement of the existing Bluetooth protocol [8]. BLE has reduced power

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consumption when compared with classic Bluetooth [7]. It is supported by the majority of smart phones and tablets, making it more appealing for IoT devices [14]. It is currently being used for applications in the health [19] and fitness sector and within industry related applications.

BLE is capable of supporting up to 20 devices compared with classic Bluetooth which offered less than half of that. The range of BLE devices can reach up to 77 meters. Again, this is more than double that of classic Bluetooth with has a total coverage between 5-30 meters. However, classic Bluetooth had a higher data rate than BLE sending 1-3 Mbit/s whereas BLE transmits 1 Mbit/s. BLE consumes much less power than classic Bluetooth and is more secure when transmitting data.

BLE uses 128-bit AES encryption with Counter Mode CBC-MAC whereas classic bluetooth uses 56/128 bit encryption. The connection times between BLE and its devices takes around 1 ms. Standard Bluetooth could take up to 100 ms to establish a connection between a device. The power consumption when establishing a connection between modules and devices is reduced in the BLE.

B. WiFi

WiFi is an IEEE 802.11 standard [15] that was developed to compliment IEEE 802.3. WiFi offers a full TCP/IP stack when connecting to the Internet. Ever since WiFi was introduced, it has been very popular among users. Almost all of today's technology: Laptops, smart phones, tablets, and TVs come integrated with WiFi. It is this integration that has made it become a well established standard. The majority of WiFi networks operate at the 2.4 GHz band. When higher data rates are needed, WiFi is capable of operating in the 5 GHz band providing a clearer signal with more channel space. However, the range of 5 GHz radios is shorter than 2.4 GHz which is why the 2.4 GHz band is often used within homes. Enterprise applications often favour the 5 GHz band over 2.4 GHz because it is better at serving multiple access points.

Power consumption has always been an issue for WiFi [20] making it extremely inefficient for IoT devices and therefore avoided by consumers and researchers. However, having looked into this, we have discovered that these issues become negligible when the WiFi module is combined with a powerful microprocessor. Based on the results [17], the new WiFi device is capable of consuming less power than other protocols such as the 433 MHz. This paper is an extension of that work by comparing the WiFi inbuilt IoT device to the currently most popular protocol: BLE.

The next section looks into the experiments carried out for this paper.

II. Experiment

In comparison to WiFi inbuilt IoT devices, BLE devices are popular within IoT devices in terms of lower power consumption [13]. For this paper, we compare the power consumption of two IoT devices: WiFi and BLE. The description and methodology in implementing the low cost WiFi module for these small sensor devices is provided in [17]. The power consumption results are discussed in detail within [17]. As the previous paper looked into the transmission of temperature data to a remote destination using WiFi, we recreate the same scenarios with BLE for comparison within this paper. The BLE module used for the experiment is an ADAFRUIT UART FRIEND [6]. A DS18S20 temperature sensor [1] is used throughout the experiments.

The experiment is as follows: Bluetooth transmission of the temperature data obtained through the processor, MSP430.

III. Bluetooth Transmission with MSP430 and DS18S20

In this scenario, the MSP430 [4] microcontroller would receive the temperature data from the DS18S20 sensor and using the BLE module, transmit it to a user's mobile device using Bluetooth. An MSP430 processor is used in this experiment with the BLE used as a slave device. The processor is necessary as the results will be compared with the WiFi IoT device which used the same processor in the previous paper [17]. In this experiment, a MSP430 microcontroller was used to supply power to the devices.

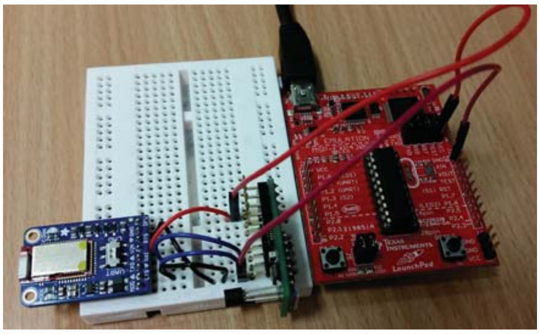

Fig. 1 Experiment Setup

The code is set up such that the BLE module transmits temperature data to the user when the user inputs a specific character command. This command acts as a flag in order to control when the data is transmitted. After the device has received the character, the temperature data is transmitted by the MSP430 + DS18S20 sensor via Bluetooth to the users mobile device. Fig. 2 shows the MSP430 processor and the sensor on the IoT WiFi inbuilt device that we have designed. In order to get as accurate power measurements as possible, the Portapow is used to record to power consumption for each device [5]. This particular method of transmission was chosen in order to monitor the power consumption. If the BLE module is constantly transmitting data, it would be impossible to have a clear measurement of the power consumption. Constantly transmitting data is impractical for IoT devices which solely rely on battery packs as their source of power because the BLE consumes power at a much higher rate when transmitting. By choosing to only transmit data when the user requires it, we can reduce the overall power being consumed thus increasing the life span of the small sensors. We use this method to replicate and compare the power consumption of sleep mode in WiFi modules.

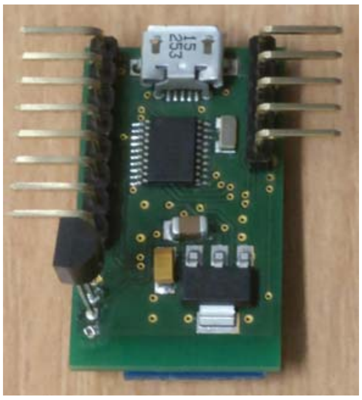

Fig. 2 Prototype [17]

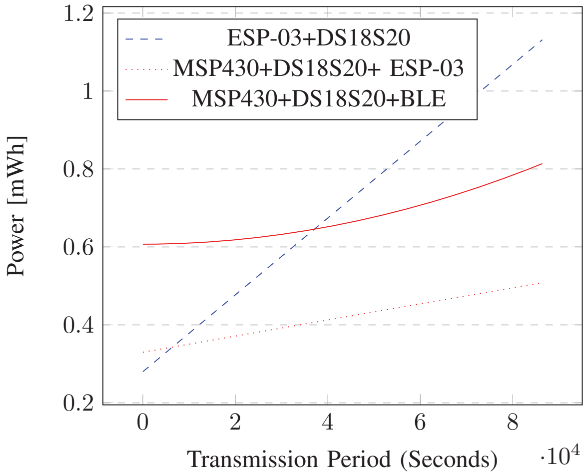

Fig. 3 Comparison Graph

When a WiFi module enters sleep mode, all connections remain established between devices. When the BLE wants to reduce the power consumption over a long period of time, the user must disconnect the device and reconnect when the data are needed. When a connection has been established and maintained by the BLE module and device, the BLE module consumes more power than when having no devices attached. In light of this, all devices are disconnected from the BLE module to ensure the module consumes as little power as possible.

The next section discusses the results of the experiment in more detail.

IV. Discussion of Results

The BLE results gathered are compared with two other scenarios from [18], [17]. A WiFi only module, ESP03 [2] and a WiFi module with a MSP430 processor are compared against the BLE results with MSP430 processor. All modules are equipped with a DS18S20 temperature sensor. The WiFi module with a MSP430 processor is the IoT device we have mentioned throughout the paper. The solo WiFi module is used to support our claim that the WiFi module is more power efficient with a powerful microprocessor attached. The same processor was used with the BLE module so the results are as accurate as possible. The power consumption was monitored over a long period of time with similar scenarios being performed on the BLE device that where performed on the WiFi module in [18], [17].

TABLE II
Energy Use per Transmission

Transmission every	BLE (mWh)	ESP (mWh)	ESP+MSP (mWh)
10 minutes	0.607	0.285	0.331
30 minutes	0.607	0.297	0.333
1 Hour	0.608	0.315	0.337
2 Hour	0.610	0.350	0.344
3 Hour	0.612	0.421	0.359
4 Hour	0.616	0.563	0.389
1 Day	0.813	1.131	0.508

The graph of results illustrates the three different power consumption scenarios. With the WiFi only module, the power consumption is higher than the BLE after 27 transmissions. In the beginning, however, the BLE's power consumption is higher. In the long term, BLE is more efficient in terms of power consumption. While comparing the BLE module to the WiFi inbuilt device we have developed, it can be seen that the power consumption of the BLE is higher in both the short and long terms. This is due to the extra power being consumed by the devices, when establishing and de-establishing connections between the BLE when transmitting date.

In our device, the WiFi module goes into sleep mode retaining all previous connections with the user. Therefore, each time the WiFi module awakens, a new connection does not need to be established. Overall, this results in less power being consumed by the WiFi inbuilt IoT device. Table II provides a overview of the graph's results over a long period of time.

V. Conclusion

Based on the results from this paper, the WiFi inbuilt IoT device we have developed consumes less power than the BLE module. These devices are tested under the same conditions with use of a microcontroller such as the MSP430. Although, if the ESP03 WiFi module is used on its own i.e. without a microprocessor, the power consumption is shown to be low only for short period of time. In this case, the BLE module is much better than the WiFi module.

If the BLE module is capable of operating as a master device, then the need for an external microprocessor would be unnecessary. This not only reduces the complexity of the system but also provides less power consumption. However, many designs require an additional microprocessor in any case.

When the WiFi module is coupled with the processor, the power consumption is much lower than the BLE module and therefore could be considered as a substitute within IoT devices over BLE in terms of power consumption alone.

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