Design and Implementation of an Interactive Quiz System using IoT-enabled Wireless Buttons

Chuang Tuan Ming Matthew
Computing Science Joint Degree Programme, Singapore Institute of Technology - University of Glasgow,
2101903@sit.singaporetech.edu.sg

Koh Ding Yuan
Computing Science Joint Degree Programme, Singapore Institute of Technology - University of Glasgow,
2100609@sit.singaporetech.edu.sg

Cheo Cheang Ming
Computing Science Joint Degree Programme, Singapore Institute of Technology - University of Glasgow,
2100965@sit.singaporetech.edu.sg

Byun Min Sik (Roy)
Computing Science Joint Degree Programme, Singapore Institute of Technology - University of Glasgow,
2102150@sit.singaporetech.edu.sg

Koh Hui Ting Jonalyn
Computing Science Joint Degree Programme, Singapore Institute of Technology - University of Glasgow,
2101932@sit.singaporetech.edu.sg

Abstract – Amid the COVID-19 pandemic, online education has witnessed a surge in popularity. While tools like Kahoot have been successful in conducting quizzes, they exclude students who lack smartphones or face physical constraints. In this paper, a wireless button system is proposed to address these issues. The system will be designed to be user-friendly and ensure equal participation among students irrespective of physical abilities or financial constraints. Additionally, the performance of the system was evaluated over Wi-Fi and BLE star network topologies, revealing Wi-Fi to have the smallest latency regardless of distance.

Keywords – IoT, Wi-Fi, BLE, Wireless Button System, Zigbee, Z-Wave, M5 C plus stick, Raspberry Pi, MQTT, HTTP, REST APIs

1. Introduction

During this digital age, technology has transformed the way individuals go about their daily lives and work. This transformation is credited to a wide variety of tools and inventions that have greatly improved our overall existence. One of these ground-breaking innovations is the Internet of Things (IoT), providing an unparalleled degree of connectivity and efficiency by allowing computer devices embedded within everyday items to communicate with each other via the internet. By doing so, it creates a network consisting entirely of intelligent gadgets that can be controlled remotely while enhancing people's productivity levels.

1.1 Background

Due to the COVID-19 pandemic, online education has become increasingly common. However, conventional ways of administering online quizzes in a classroom or virtual environment may not provide students with the same level of interactivity and immediate feedback that they find stimulating. As a result, their participation and engagement levels may decrease which can ultimately lead to poor academic results. Therefore, alternative approaches are necessary for enhancing student involvement in remote learning settings during these challenging times.

Although Kahoot and similar solutions can boost student participation in online quizzes, they come with a drawback: students need to have smartphones. Unfortunately, this is not viable for those residing in developing countries or individuals who face physical challenges that prevent them from using a smartphone. To overcome these limitations and create an inclusive learning environment that caters to everyone's needs regardless of financial constraints or disabilities, we must seek innovative solutions.

1.2 Motivation

To enhance students' involvement and interaction during online quizzes, the team’s proposed solution intends to introduce a wireless button system that utilizes IoT technology. This will facilitate real-time communication with the web server, thereby providing an interactive quiz experience for all participants. The user-friendly design of these buttons ensures equal participation among students irrespective of their physical abilities or financial limitations.

The key objective of this project is to create a dependable and productive wireless communication solution that can be effectively utilized across diverse environments and settings. Its application will not only benefit academic institutions like schools but also residential localities. Furthermore, the project seeks to enhance student engagement and learning outcomes in both virtual and physical education setups and ultimately improve academic performance while enhancing overall satisfaction with the educational process.

2. Literature Review

2.1 Key Consideration Factors

2.1.1 Data Rate

In the context of the wireless IoT button project, data rate plays a crucial role in determining the amount of data that can be transmitted over a wireless network in each time frame. A higher data rate allows for the transmission of more information, such as button presses or audio, in real time to the server. This improves the responsiveness of the system, providing a more engaging user experience for students.

However, a low data rate can result in delays in transmitting data, causing the wireless button system to operate slowly and negatively impacting user engagement and participation. Furthermore, a low data rate can result in latency issues and delays in transmitting data, impairing the system's ability to accurately identify the first player to press the button, which is essential for determining the winner of the quiz. Therefore, selecting a communication protocol with a high data rate can enhance the performance of the wireless IoT button system and provide a more seamless and engaging quiz experience for students.

2.1.2 Affordability

In emerging economy countries, the cost of implementing the wireless IoT button system is a crucial factor to consider, as schools in these regions may have limited budgets for technology investments. Therefore, the system must be designed with cost-effectiveness in mind, to ensure that it can be implemented within the school's budget and provide a viable solution for enhancing student engagement and participation. Therefore, the communication protocols and hardware selected must be widely available and cost-effective in the local market.

2.1.3 Scalability

Scalability is a critical factor to consider when designing the wireless IoT button system, as it must be able to adapt to varying class sizes and the number of students participating in the quiz. To achieve this, the system must be designed to support a high number of concurrent connections and be able to handle large volumes of data from multiple devices in real time. Additionally, the system must be flexible enough to adapt to different educational settings and be able to grow with the needs of the schools. To achieve scalability, the communication protocols for the wireless IoT button system must be capable of supporting a large number of concurrent connections, while maintaining a high level of performance and reliability.

2.1.4 Power efficiency

Efficient power consumption is a critical consideration in the design of the wireless button system for extended and frequent use. To ensure the system operates reliably without frequent battery replacements or recharging, power efficiency is essential. In this context, the wireless button system for schools does not require a system that consistently conserves energy, but rather a system that can function for a reasonable period without needing replacement or recharging of the battery. The design of the system must consider the power consumption of the system and ensure that it is balanced with the need for reliability and user experience.

2.2 Available communication protocols

In this section, the team discusses commonly used wireless communication protocols. Examples of such wireless communication protocols include Wi-Fi, Bluetooth, Zigbee, and Z-Wave.

2.3 Discussion of Communication Protocols

2.3.1 Wireless Fidelity (Wi-Fi)

Wi-Fi uses high-frequency radio waves for wireless data transmission, with high data rates of megabits to gigabits per second [1], and medium to high power consumption [2] based on the Wi-Fi standard used. Scalability is also high with the use of access points to add more devices and range to the network [3]. However, the costs of Wi-Fi implementation vary based on equipment and network size [4, 15].

Advantages	Disadvantages
High data rate	High power consumption
High scalability	Varying costs (medium-high)

2.3.2 Bluetooth

Bluetooth uses high-frequency radio waves for wireless data transmission, with medium data rates ranging from hundreds of kilobits to megabits per second [5]. It has low power consumption [6, 16], but is limited to medium scalability, supporting from up to seven devices to twenty or more based on the standard of Bluetooth used [7]. Implementation costs for Bluetooth are low [8].

Advantages	Disadvantages
Acceptable data rate	Medium scalability
Low costs	-
Low power consumption	-

2.3.3 Zigbee

Zigbee is a low-power, wireless technology that uses high-frequency radio waves for data transmission, with low data rates ranging from tens to hundreds of kilobits per second [9]. It's highly scalable [10], with low implementation costs [1]

Advantages	Disadvantages
High scalability	Low data rates
Low costs	-
Low power consumption	-

2.3.4 Z-Wave

Z-Wave is a low-power, wireless technology that uses high-frequency radio waves for data transmission, with low data rates ranging from thousands of bits to tens of kilobits [11]. It's highly scalable, supporting up to 232 concurrent devices [13], however, is more expensive than Zigbee [12] to implement [14].

Advantages	Disadvantages
High scalability	Low data rates
Low costs	-

3. Related Works

The purpose of this section is to discuss and examine similar works of wireless buttons that have been implemented using IoT technology.

3.1 Kahoot

3.1.1 Description

Due to the rise in home-based learning, Kahoot has become a popular tool for teachers to engage with students and encourage their participation during class. Kahoot is an online web application that allows teachers to host quizzes for their students. Students are provided with a set time limit to answer multiple-choice questions, and points are awarded to the fastest student who correctly answers each question. Kahoot does not require any physical buttons and can be answered with a click of a button on the web application.

3.1.2 Communication Protocol

Kahoot uses several wireless communication technologies, the main wireless protocol being used in Kahoot is Wi-Fi. Kahoot connects participants to the game and shows it on a bigger screen using two different kinds of technology. Wi-Fi is used to link participants' devices to the game's control centre. Players can connect to the game using Wi-Fi by inputting a game PIN on their device to participate. Players use their devices to input their answers as the central device displays the questions and correct answers.

3.1.3 Benefits and Drawbacks of Kahoot's Wi-Fi-Based Quiz System Using Wireless Buttons

While Kahoot is a widely used quiz platform among teachers and students, it has both advantages and disadvantages. Specifically, there are both benefits and drawbacks to using Wi-Fi as a wireless communication protocol for the platform. The following section outlines these advantages and disadvantages in more detail.

Benefits	Reason
Increased Interactivity	As the platform uses IoT technology such as Wi-Fi, this creates an interactive learning activity where teachers and students can engage with each other in real time.
Accessibility	Utilizing IoT technologies, Kahoot is compatible and works with a wide range of devices, such as smartphones, laptops, etc. As long as the student has an internet connection, they can access it from any device. [24]

Drawbacks	Reason
Dependent on IoT technology	As the platform is heavily reliant on IoT technology, the platform may be unstable if the technology were to fail
Weak Security	Wi-Fi is susceptible to cyber-attacks, as the platform is heavily reliant on IoT technology such as Wi-Fi, this makes it susceptible to cyber-attacks as well, which puts them at risk of data breaches or any other cyber security attacks.

3.2 QuizXpress Wireless Buzzer System

3.2.1 Description

QuizXpress Wireless Buzzer System is a wireless interactive game and quiz software that allows participants to answer questions using wireless buzzers. It is designed to create an engaging and interactive experience for the audience and contestants during game shows and events. This system consists of a host computer installed with QuizXpress software, a receiver which is connected to the computer through a USB port, and wireless buzzers [22].

3.2.2 Radio Frequency (RF) communication technology

QuizXpress Wireless Buzzer System use radio frequency (RF) communication technology, typically 2.4GHz band, to interact between the wireless buzzers and the receiver connected to the host computer. RF communication is commonly used in wireless devices as it provides good range and signal strength, making it ideal for quiz and game show systems where quick and reliable communication is essential [23].

3.2.3 Benefits & Drawbacks of QuizXpress's Implementation

QuizXpress is a popular tool used in game shows and contests to engage many participants. It supports a range of useful features that are attractive to customers. However, the system has some drawbacks as well. The following sections outlines these advantages and disadvantages in more detail.

Benefits	Reason
Number of participants	The QuizXpress Wireless Buzzer System has the advantage of being able to support a few hundred to thousands of devices at once, making it suitable for large events or audiences.
Freedom of movement	QuizXpress Wireless Buzzer System can operate with battery power, which provides greater freedom of movement and flexibility for participants.

Drawbacks	Reason
External Devices	The external devices required by the QuizXpress system include additional software and an external RF receiver that must be connected to the computer to receive signals from the wireless buzzer devices.
Cost	Due to additional devices and software, the cost of the QuizXpress system is significantly higher.

3.3 Wireless Pagers at Chili's Restaurant Chain

3.3.1 Description

Although Chili's restaurant chain employs a wireless pager instead of a wireless button, their wireless paging system shares similarities with the concept that we are exploring. The Chili's pager uses Bluetooth technology to facilitate communication between users and staff members. Customers are given a small wireless pager to request assistance or call a waiter. To signal for attention, the user presses the button on the pager, which sends an alert to a staff member's mobile device for prompt response.

3.3.2 Communication Protocol

Chili's restaurant chain's paging system uses Bluetooth Low Energy (BLE) technology with a frequency range of 2.4GHz, it provides a longer battery life and improved range as compared to the traditional Bluetooth technology. As a result, the pagers used by customers and the mobile devices carried by staff can communicate over longer distances without quickly draining the batteries. Additionally, BLE is specifically designed to work in environments with significant wireless interferences, such as busy restaurants, ensuring that Chili's paging system is reliable and dependable.

3.3.3 Benefits & Drawbacks of using BLE Technology in Wireless Pager

While BLE technology is widely used, it has its own advantages and disadvantages, that should be considered before implementing into a system. As for Chili's restaurant chain, the benefits and drawbacks of implementing BLE technology into their wireless pager are as follows:

Benefits	Reason
Extended Battery Life	As compared to the traditional Bluetooth technology, the battery life of the device would last longer as it has lower power consumption
Reliability	Using BLE technology ensures that all customers are attended to promptly, especially during peak hours, as it offers optimal reliability in environments with high levels of wireless interference [25]

Disadvantages	Reason
Compatibility	BLE technology may not be compatible with all mobile devices, this could prevent staff members from receiving alerts and attending to customers promptly
Cost	Implementing a BLE-based paging system might require a higher cost as compared to traditional paging systems as BLE technology may require specialized hardware and software, it also provides additional benefits that a traditional paging system lacks

4. Methodology

Communication Protocols	Data rate	Scalability	Affordability	Power Consumption
Wireless Fidelity	Mbps - Gbps	High	Medium	High
Bluetooth	Kbps - Mbps	Medium	High	Low
Zigbee	Kbps	High	High	Low
Z-Wave	< Kbps	High	Low	Low

The table above provides an overview of these wireless communication protocols against the key consideration factors mentioned in the previous section.

4.1 Proposed Communication Protocols

This section aims to compare the available communication protocols such as Wi-Fi, Bluetooth, Zigbee and Z-Wave based on the different key consideration factors such as data rate, scalability, affordability, and costs which were discussed within the literature review.

The system's data rate is of utmost importance since a low data rate can adversely affect communication, particularly those requiring rapid responses to auditory cues. Wi-Fi has a high data rate ranging from 2.0 megabits to 9.6 gigabits per second, depending on the Wi-Fi standard [1]. In contrast, Bluetooth has a moderate data rate of 732.2 kilobits to 50 megabits per second, depending on the Bluetooth standard used [5]. Zigbee and Z-Wave, on the other hand, have low data rates of 20 to 250 kilobits per second and less than 100 kilobits per second, respectively. Consequently, the team decided to remove Zigbee and Z-Wave from consideration due to their inadequate data rates.

The system's affordability is also an important consideration, particularly since schools may have limited budgets for such systems. Bluetooth is the more affordable option, with per-unit costs of under $10 [8]. On the other hand, Wi-Fi's affordability varies, depending on the equipment and network size [4], with a range from medium to high. Monthly maintenance expenses for equipment and broadband service could bring the cost up to approximately $85 per month [15]. In terms of cost, Bluetooth is a more cost-effective solution compared to Wi-Fi.

The system's ability to accommodate numerous students utilizing wireless button devices concurrently in a classroom environment is crucial, making scalability a critical factor. According to sources [3][7], Wi-Fi can handle communication from hundreds of devices, while Bluetooth can handle communication from over twenty devices. However, since both Wi-Fi and Bluetooth can support the use of wireless button devices for an entire classroom, scalability is not a concern. Wi-Fi can handle communication from a larger group of students compared to Bluetooth.

Ensuring reliable device operation without frequent battery replacements or recharging is crucial, and power consumption is a key factor in achieving this. According to Bluetooth standards [16], Bluetooth's power consumption ranges from 10 milliwatts to a watt, while Wi-Fi has a higher power consumption of approximately 6 watts [17], which is significantly more than Bluetooth. Nevertheless, the team decided to disregard this factor since the power consumption of the device should be sufficient for it to function for a reasonable period. Additionally, with easy access to electricity within the school environment for recharging, energy conservation over extended periods was not deemed necessary.

Based on the reasons and evidence gathered so far, the team felt that BLE fits the case better. In comparison to Wi-Fi, it has lower power consumption, and lower costs for implementation while having sufficient data rates and scalability to perform the required use case of implementing a wireless button-clicking system within a classroom setting. To investigate this further, the team will put Wi-Fi and BLE to the test in a controlled environment to compare them before concluding on the communication protocol to propose.

4.2 Discussion of Network Topology

The selection of a suitable network topology was crucial for the design of a wireless button-clicking system that requires high data rates, scalability, affordability, and power efficiency. While mesh networks were known for their simple scalability and self-healing capabilities [18], star network topologies were considered a better choice due to their higher data rates and scalability [19].

Star topology networks provide centralised hubs, that efficiently manage network traffic, ensuring high data rates within the network [19]. These centralised hubs can also be used to add more devices to the network [20], making it highly scalable and easy to set up. While mesh networks offer several benefits such as simplicity in scaling and self-healing [18], they may experience latency issues due to the multiple hops required to transmit data between devices, leading to lower data rates than star topology networks [18]. Setup costs for mesh networks also may be higher than star topology networks [19].

With these considerations in mind, the team decided to use a star network topology approach for the implementation of communication protocols within the wireless button-clicking system.

4.3 System Architecture

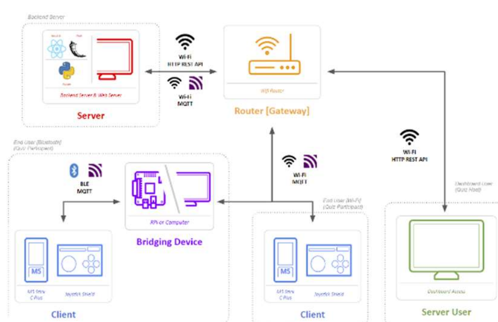

Figure 1. Proposed System Architecture

The proposed system architecture, illustrated in Figure 1, comprises three key elements: a backend server, M5 C plus stick paired with a joystick shield and a router. The team has designed the architecture using a star topological pattern where the router acts as the central point. This configuration offers scalability by allowing for additional router connections and makes it possible to operate across multiple networks.

In the system architecture, quiz participants will communicate with the backend server using Message

Queuing Telemetry Transport (MQTT) over a local network connection. On the other hand, REST APIs will enable the quiz host to access the solution's dashboard. In future development or implementations, an internet based MQTT broker could be included for clients to connect solely through Internet access to the backend server's network, eliminating the need for being on the same network as the backend server.

Although Bluetooth is an option for clients, it requires a connection to another computing device to expand beyond its immediate range and operate at higher levels within the Wi-Fi network. Clients have the choice of using either Wi-Fi or Bluetooth when they are close by; however, if they opt for Bluetooth, they will need an intermediary device to increase their connectivity capabilities.

4.4 Limitations Faced

The team encountered a significant drawback in their project when they realized that the backend server was originally intended to run on a Raspberry Pi. Unfortunately, the provided device did not possess sufficient specifications to operate effectively. Since managing quizzes was an essential part of the solution, addressing potential racing conditions became imperative. However, this required real-time handling and optimal system speeds – which were beyond what the given Raspberry Pi could deliver

Therefore, the team has chosen to utilize a computer as the backend server instead. Their development procedures involve implementing Python, which is a versatile programming language that can also be implemented on Raspberry Pi if necessary.

5. Results

The team conducted experiments to establish the average latency experienced by messages transmitted from the M5 stick to the backend server through both BLE and Wi-Fi mediums, across distances ranging from 1m to 20m. The findings are presented in **Figure 2** and **Figure 3** below.

The results of BLE have shown a much higher latency as compared to Wi-Fi. A problem faced by the team was that the team could not establish a reliable connection between the two devices to get significant latency reading after the distance of 10m, hence latency values are only projected up to 10m.

Whereas the latency values for Wi-Fi depict that it provides a much more reliable connection over the range while maintaining an optimal latency.

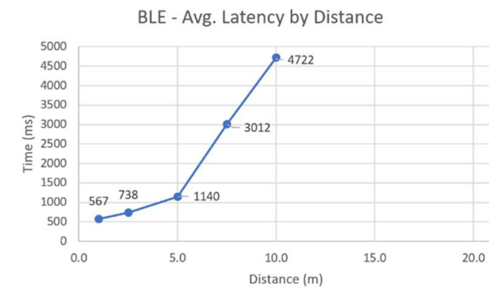

Figure 2. BLE Average Latency by Distance.

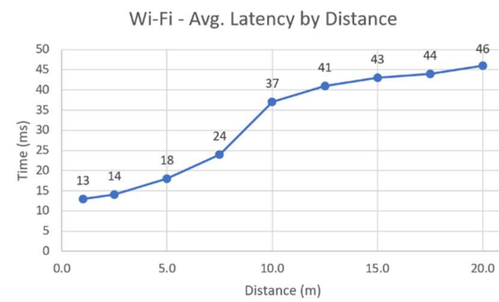

Figure 3. Wi-Fi Average Latency by Distance.

6. Conclusion

The outbreak of COVID-19 has resulted in a shift from traditional teaching methods to remote learning, posing difficulties in keeping students engaged. Although tools like Kahoot and QuizXpress can assist with conducting quizzes and virtual classes, they may not cater to individuals without smartphones or those who cannot operate them physically. To address this issue inclusively, the suggestion is to implement a wireless button-clicking system as an alternative solution.

The team introduced an IoT-based approach to enhance the management of real-time quizzes. This involved utilizing devices like M5 along with a backend server for logic processing and communication protocols such as MQTT and HTTP. BLE and Wi-Fi were used as mediums, and after assessing performance over both channels it was determined that Wi-Fi provided better latency and reliability even at longer distances compared to BLE.

To summarize, the study demonstrates that a wireless button-clicking system using Wi-Fi and BLE star network topologies can be implemented in a classroom environment to enhance remote learning student participation. However, due to limited resources, the team could not fully evaluate the system's effectiveness with other networks or explore its performance if utilized via mesh network topologies. Future research should concentrate on analyzing whether mesh network topology is feasible under comparable conditions.

7. References

[1] Encyclopædia Britannica, inc. (n.d.). *Wi-Fi Networking Technology*. Encyclopædia Britannica. Retrieved March 31, 2023, from https://www.britannica.com/technology/Wi-Fi

[2] Maclay, W. (2021, October 22). *Wireless Communication Choices for IoT Designs*. Voler systems. Retrieved March 31, 2023, from https://www.volersystems.com/blog/wireless-communication-choices-for-iot-designs

[3] Geier, E. (2021, September 7). *How to scale a wi-fi network*. Network World. Retrieved March 31, 2023, from https://www.networkworld.com/article/3632144/how-to-scale-a-wi-fi-network.html#:~:text=Scaling%20up%20a%20Wi%2DFi,clients%20in%20the%20same%20area

[4] M. Zhang and R. S. Wolff, "Using Wi-Fi for cost-effective broadband wireless access in rural and remote areas," *2004 IEEE Wireless Communications and Networking Conference (IEEE Cat. No.04TH8733)*, Atlanta, GA, USA, 2004, pp. 1347-1352 Vol.3, doi: 10.1109/WCNC.2004.1311638.

[5] Cadence PCB Solutions. (2022, October 13). *Transmission rate vs. bandwidth in bluetooth technology*. Retrieved March 31, 2023, from https://resources.pcb.cadence.com/blog/2022-transmission-rate-vs-bandwidth-in-bluetooth-technology

[6] *Bluetooth technology overview*. Bluetooth® Technology Website. (n.d.). Retrieved March 31, 2023, from https://www.bluetooth.com/learn-about-bluetooth/tech-overview/#:~:text=The%20Bluetooth%20Classic%20radio%2C%20also,medical%20(ISM)%20frequency%20band

[7] *How many devices we can connect to bluetooth 5*. Stack Overflow. (n.d.). Retrieved March 31, 2023, from https://stackoverflow.com/questions/48418427/how-many-devices-we-can-connect-to-bluetooth-5#:~:text=For%20classic%20Bluetooth%20the%20limitation,on%20the%20hardware's%2Fstack's%20capabilities

[8] K. V. S. S. S. S. Sairam, N. Gunasekaran and S. R. Redd, "Bluetooth in wireless communication," in IEEE Communications Magazine, vol. 40, no. 6, pp. 90-96, June 2002, doi: 10.1109/MCOM.2002.1007414.

[9] *(PDF) study on Zigbee Technology - Researchgate*. (n.d.). Retrieved March 31, 2023, from https://www.researchgate.net/publication/261497749_Study_on_ZigBee_technology

[10] *Intelligent Management of hydroponic systems based on IOT for agrifood ...* (n.d.). Retrieved March 31, 2023, from https://www.researchgate.net/publication/366230369_Intelligent_Management_of_Hydroponic_Systems_Based_on_IoT_for_Agrifood_Processes

[11] *What's the difference between Zigbee and Z-wave? - electronic design*. (n.d.). Retrieved March 31, 2023, from https://www.electronicdesign.com/technologies/communications/article/21796052/whats-the-difference-between-zigbee-and-zwave

[12] *Z-wave hits 4,000 certified Smart Home Devices*. The Ambient. (2022, June 16). Retrieved March 31, 2023, from https://www.the-ambient.com/news/z-wave-hits-4000-certified-smart-home-devices-2895

[13] Seitz, D. A. (2020, January 22). *What is Z-wave? what you need to know about the smart home standard*. Lifewire. Retrieved March 31, 2023, from https://www.lifewire.com/what-is-z-wave-4588924

[14] Griffith, Y., Jackson, T., Perry, T., & Henry. (2022, January 26). *Why are Z-wave smart devices just so expensive?* Smart Home Point. Retrieved March 31, 2023, from https://www.smarthomepoint.com/why-z-wave-so-expensive

[15] Noori, R. (2023, March 23). *How much does WIFI installation cost? price guide*. Network Installers. Retrieved March 31, 2023, from https://thenetworkinstallers.com/blog/how-much-does-wifi-installation-cost/#:~:text=The%20minimum%20equipment%20you%20need,you%20can%20purchase%20your%20own

[16] Bloechl, M. (n.d.). *Power Consumption & IOT: Bluetooth & Zigbee: Blog: Link labs*. Blog | Link Labs. Retrieved March 31, 2023, from https://www.link-labs.com/blog/bluetooth-zigbee-comparison#:~:text=Traditional%20Bluetooth%20design%20recommends%20one,Bluetooth%20recommends%20you%20design%20for.

[17] *Electricity usage of a Wi-Fi Router*. Electricity usage of a Wi-Fi Router - Energy Use Calculator. (n.d.). Retrieved March 31, 2023, from https://energyusecalculator.com/electricity_wifirouter.htm#:~:text=We%20estimate%20that%20a%20Wi,a%20day%20%40%20%240.10%20per%20kWh.&text=Power%20Use%20(Watts)%3A%20Enter,of%20the%20device%20in%20watts.

[18] *Mesh topology advantages and disadvantages - javatpoint*. www.javatpoint.com. (n.d.). Retrieved

March 31, 2023, from https://www.javatpoint.com/mesh-topology-advantages-and-disadvantages

[19] GeeksforGeeks. (2022, September 1). *Advantages and disadvantages of Star Topology*. GeeksforGeeks. Retrieved March 31, 2023, from https://www.geeksforgeeks.org/advantages-and-disadvantages-of-star-topology/

[20] Mayur. (2023, March 17). *Best 7 characteristics of Star topology networking in computer*. Computer Basic Tutorials. Retrieved March 31, 2023, from https://www.chtips.com/networking/characteristics-of-star-topology/#Disadvantages_of_Star_Topologies_in_Points

Star topology advantages and disadvantages - javatpoint. www.javatpoint.com. (n.d.). Retrieved March 31, 2023, from https://www.javatpoint.com/star-topology-advantages-and-disadvantages [21]

[22] *Game Show buzzers*. QuizXpress. (2022, September 13). Retrieved March 31, 2023, from https://www.quizxpress.com/game-show-buzzers/

[23] *Game Show Software • Create and host your gameshow with QuizXpress QuizXpress*. QuizXpress. (2021, November 29). Retrieved March 31, 2023, from https://www.quizxpress.com/

[24] Kaur, M. (2021, March 13). *Kahoot what is it: Features, advantages, disadvantages, and faqs.* techprevue. Retrieved March 31, 2023, from https://www.techprevue.com/kahoot/

[25] *Staff & Server Restaurant Paging Systems*: JTECH. JTECH, An HME Company. (n.d.). Retrieved March 31, 2023, from https://www.jtech.com/server-pagers