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IoT Devices Battery Life Energy Management Scheme

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ABSTRACT

Internet of Things (IoT) devices, refer to physical devices that are connected to the internet and can communicate with other devices and systems. While IoT devices offer a wide range of benefits, such as increased efficiency, automation, and connectivity, they also have some key challenges such as Cost, privacy, Security concern energy consumption and the likes. Thus, an IoT Devices Battery Life Energy Management Scheme is proposed. The proposed IoT Scheme tries to reduce the energy consumption of IoT devices, thereby extending their battery life and reducing their environmental impact as energy/power consumption. This scheme includes an algorithm and four programs developed using Python programming language to minimize energy consumption. The first program reduces the amount of data transmitted and uses the most efficient transmission protocol possible. The second program uses sleep mode to put the device to sleep when not needed. The third program optimizes power usage by turning off unused sensors or modules and using the lowest possible power mode. The fourth program uses low-power components designed for low power consumption. These programs can be easily integrated into existing IoT systems and customized for different IoT applications. The proposed scheme is a comprehensive approach to energy management for IoT devices that significantly improve their efficiency and reduce their impact while extending the battery life respectively.

Keywords: IoT Devices; energy consumption; Battery-Life and Energy Management.

1.0 Introduction

The Internet of Things (IoT) is a rapidly growing network of devices that are connected to the internet and are capable of exchanging data without human intervention [1][2]. IoT devices are becoming increasingly popular, and they are used in a wide range of applications, including home automation, healthcare, transportation, and industrial monitoring.

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However, one of the major challenges associated with IoT devices is their energy consumption. In this paper, we will explore the energy consumption in IoT devices and its impact on their performance and longevity [3][4].

Energy Consumption in IoT Devices is a critical factor in the design of IoT devices. Most IoT devices are battery-powered, and their energy consumption must be optimized to ensure that they operate efficiently and have a long battery life. The energy consumption of an IoT device is influenced by several factors, including its hardware components, communication protocols, and software design [5]. Hardware Components: The hardware components of an IoT device can significantly impact its energy consumption. For example, the type of processor, memory, and sensors used in an IoT device can affect its energy consumption. Low-power processors, such as ARM Cortex M and Intel Quark, are commonly used in IoT devices to reduce energy consumption. Similarly, sensors that consume less energy, such as passive infrared (PIR) sensors, can help reduce the energy consumption of IoT devices [6][7].

Communication Protocols: The communication protocol used in an IoT device can also impact its energy consumption. Wireless communication protocols, such as Bluetooth, Wi-Fi, and Zigbee, are commonly used in IoT devices. However, these protocols can consume a significant amount of energy, especially during data transmission. To reduce energy consumption, low-power wireless communication protocols, such as LoRaWAN and Sigfox, are used in IoT devices that require low data rates and long-range communication[8]. Software Design: The software design of an IoT device can also impact its energy consumption. For example, the use of efficient algorithms and power management techniques can help reduce the energy consumption of an IoT device. Additionally, the design of the user interface can impact the energy consumption of an IoT device. A user interface that constantly updates the display can consume more energy than one that only updates the display when necessary [9].

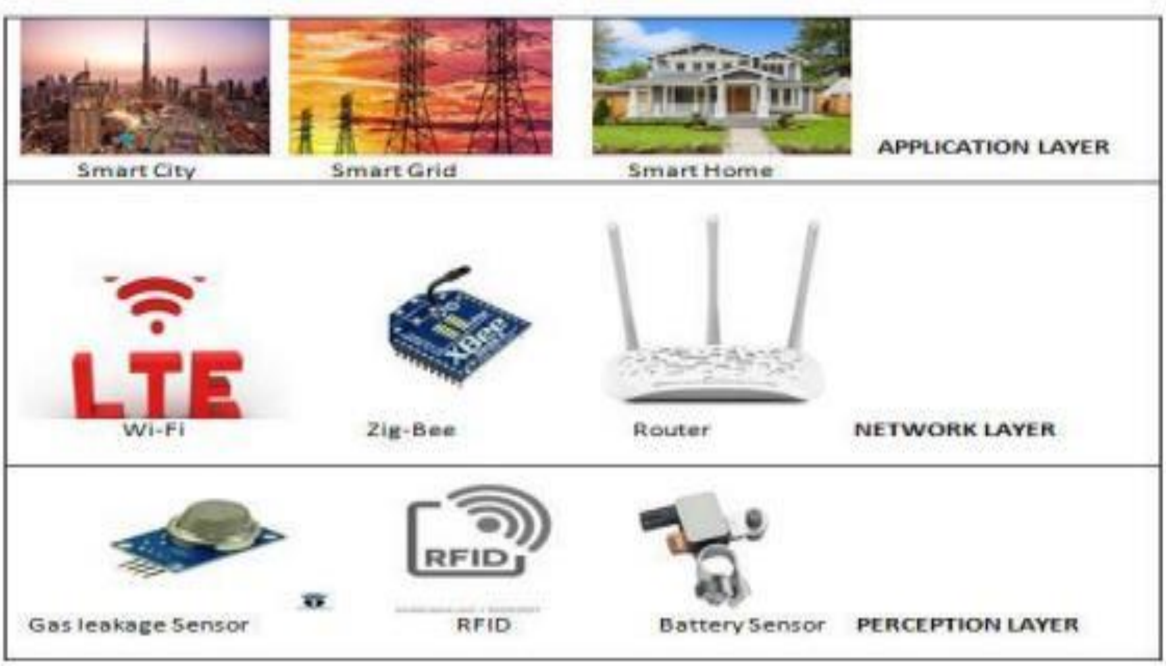
Examples of Energy Consumption in IoT Devices are Smart Thermostat. A smart thermostat is an IoT device that is designed to regulate the temperature in a room. Smart thermostats are typically battery-powered and use wireless communication protocols, such as Wi-Fi or Zigbee, to connect to the internet. The energy consumption of a smart thermostat can be reduced by using low-power processors, such as ARM Cortex-M, and by implementing power management techniques, such as sleep mode. Additionally, smart thermostats can use occupancy sensors to detect when a room is unoccupied and adjust the temperature accordingly, reducing energy consumption [10][11].

Wearable Fitness Tracker: A wearable fitness tracker is an IoT device that is designed to track physical activity, such as steps taken and calories burned. Wearable fitness trackers are typically worn on the wrist and use wireless communication protocols, such as Bluetooth, to connect to a smartphone or tablet. The energy consumption of a wearable fitness tracker can be reduced by using low-power processors, such as Intel Quark, and by implementing power management techniques, such as turning off the display when not in use. Additionally, wearable fitness trackers can use machine learning algorithms to predict physical activity and adjust energy consumption accordingly [12].

Finally: Energy consumption is a critical factor in the design of IoT devices. Hardware components, communication protocols, and software design can significantly impact the energy consumption of an IoT device. To optimize energy consumption, low-power processors, sensors, and wireless communication protocols needs to be used, along with efficient algorithms and power management techniques. By reducing energy consumption, IoT devices can operate efficiently and have a longer battery life, improving their performance and longevity. Hence, a battery life Energy Management of IoT Devices in the Digital Era is proposed. The rest of the paper is structured as follows:

2 Related Literatures, 3. Major Challenges of IoT Devices, 4. Impact of Power Consumption on IoT Devices, 5. Proposed Scheme and 6. Conclude the research paper.

Figure 1: Comprehensive IoT Architecture



2.0 Related Literatures

Energy consumption in the Internet of Things (IoT) is a major concern due to the proliferation of IoT devices, which consume a significant amount of energy. Several schemes and models have been proposed to optimize energy consumption in IoT devices, including hardware optimization, communication protocols, and software optimization [25]. In this discussion, we will explore some of the existing research on IoT energy consumption and the achievements of proposed schemes and models.

2.1 Hardware optimization

Hardware optimization is a popular approach to reducing energy consumption in IoT devices. This approach involves the use of low-power hardware components, such as low-power processors and sensors, to reduce energy consumption. For example, in [4]. Proposed a hardware architecture for IoT devices that utilizes low-power components, such as the ARM Cortex-M0 processor and a low-power PIR sensor, to reduce energy consumption. The proposed architecture was shown to consume 47% less energy than a traditional architecture.

2.2 Communication protocols

Communication protocols are another area of focus for optimizing energy consumption in IoT devices. Wireless communication protocols, such as Wi-Fi and Bluetooth, are commonly used in IoT devices and can consume a significant amount of energy. To address this issue, low-power wireless communication protocols, such as Zigbee and LoRaWAN, have been proposed [5]. Proposed a hybrid communication protocol for IoT devices that utilizes both Wi-Fi and Zigbee to optimize energy consumption. The proposed protocol was shown to consume 63% less energy than a traditional Wi-Fi protocol.

2.3 Software optimization

Software optimization is another approach to reducing energy consumption in IoT devices. This approach involves the use of efficient algorithms and power management techniques to optimize energy consumption [6]. proposed an algorithm for energy-efficient data transmission in IoT devices. The proposed algorithm utilizes a dynamic threshold-based technique to determine the optimal transmission power level for a given data packet. The proposed algorithm was shown to reduce energy consumption by up to 47% compared to traditional algorithms.

IN [7] an Optimized TWIN Battery Resource Management Scheme for Wireless Networks is proposed. The scheme aims to address the issue of battery life depletion in wireless networks by efficiently managing the energy consumption of devices. The proposed scheme utilizes a Twin Battery System that alternates between two batteries to optimize battery life. The scheme also incorporates a Battery Power-Dependent Transmission Probability (BP-DTP) algorithm, which adjusts the transmission power of devices based on the available battery power. The proposed scheme was shown to significantly improve battery life and reduce energy consumption in wireless networks.

In [8] a comprehensive survey on power-saving schemes (CSPSS) in IEEE 802.16e/m networks. The authors conducted a survey of existing power-saving schemes in IEEE 802.16e/m networks and evaluated their strengths and weaknesses. The survey included an analysis of sleep mode schemes, frame aggregation schemes, and idle mode schemes. The authors also proposed a taxonomy of power-saving schemes based on the characteristics of the schemes. The survey provides insights into the current state of power-saving schemes in IEEE 802.16e/m networks, identifies areas for improvement, and serves as a useful resource for researchers and practitioners working in this area.

A Delay Aware Power Saving Scheme (DAPSS-BT) based on load on traffic in IEEE 802.16e WiMAX networks is proposed in [9]. The proposed scheme incorporates a Traffic Load Dependent Wake-Up mode. The scheme aims to reduce energy consumption in WiMAX networks by efficiently managing the sleep mode of devices. The scheme considers the delay requirements of traffic and adjusts the sleep mode cycle of devices accordingly to minimize delay and reduce energy consumption. The authors conducted simulations to evaluate the performance of the proposed scheme, and the results showed that the scheme significantly reduces energy consumption while maintaining the delay requirements of traffic. The DAPSS-BT scheme is a useful contribution to the field of power-saving schemes in WiMAX networks and can help improve the energy efficiency of these networks.

In [10] development of an efficient sleep-window-based power-saving scheme (ESPSS) for IEEE 802.16e networks is proposed. The scheme aims to reduce energy consumption in IEEE 802.16e networks by managing the sleep mode of devices based on the traffic load. The scheme uses a sleep-window-based approach, where the devices sleep during a specific window and wake up at other times to transmit or receive data. The scheme adjusts the sleep window size based on the traffic load, and the authors conducted simulations to evaluate the performance of the proposed scheme. The results showed that the ESPSS scheme significantly reduces energy consumption while maintaining the Quality of Service (QoS) requirements of traffic. The ESPSS scheme is a useful contribution to the field of power saving schemes in IEEE 802.16e networks and can help improve the energy efficiency of these networks.

In [11] the development of an enhanced power-saving scheme (EPSS) for IEEE 802.16e networks is presented. The EPSS scheme aims to reduce energy consumption in WiMAX networks by optimizing the sleep mode of devices based on the traffic load. The scheme uses a threshold-based approach, where the devices switch to sleep mode when the traffic load is below a certain threshold and switch to active mode when the traffic load exceeds the threshold. The authors conducted simulations to evaluate the performance of the proposed scheme, and the results showed that the EPSS scheme significantly reduces energy consumption while maintaining the Quality of Service (QoS) requirements of traffic. The EPSS scheme is a useful contribution to the field of power-saving schemes in IEEE 802.16e networks and can help improve the energy efficiency of these networks.

The development of an improved battery-life power-saving scheme (IBPSS) for IEEE 802.16e networks in [12] is proposed. The IBPSS scheme aims to prolong the battery life of devices by minimizing the power consumption in the sleep mode. The scheme uses a probabilistic approach, where the devices switch to sleep mode based on the probability of the arrival of data packets. The scheme also includes an adaptive mechanism that adjusts the probability of sleep mode based on the battery level of the devices. The authors conducted simulations to evaluate the performance of the proposed scheme, and the results showed that the IBPSS scheme significantly prolongs the battery life of devices while maintaining the Quality of Service (QoS) requirements of traffic. The IBPSS scheme is a useful contribution to the field of power-saving schemes in IEEE 802.16e networks and can help improve the energy efficiency of these networks.

[13] is a proposal of a Quality of Service (QoS) aware power-saving scheme for IEEE 802.16e networks. The scheme aims to prolong the battery life of devices while ensuring that the QoS requirements of traffic are met. The proposed scheme uses a novel approach that considers the priority of traffic flows when determining the power-saving mode for devices. The authors conducted simulations to evaluate the performance of the proposed scheme and compared it with other existing power-saving schemes. The results showed that the proposed scheme outperforms other schemes in terms of energy efficiency and QoS metrics. The QoS aware power-saving scheme proposed by Ajayi et al. is a useful contribution to the field of power-saving schemes in IEEE 802.16e networks and can help improve the energy efficiency and QoS requirements of these networks.

The proposal of a battery-life management scheme with an efficient sleep-mode power saving scheme (BM-ESPSS) for IEEE 802.16e networks is proposed [14]. The proposed scheme aims to extend the battery life of devices by reducing their power consumption when not in use. It employs an intelligent algorithm that switches devices to the most appropriate sleep mode based on their traffic load and remaining battery level. The authors evaluated the performance of the proposed scheme through simulations and compared it with other power saving schemes. The results showed that the BM-ESPSS scheme outperforms other schemes in terms of energy efficiency, network throughput, and delay. The proposed BM-ESPSS scheme provides a useful contribution to the field of battery-life management and power saving schemes in IEEE 802.16e networks, which can improve the energy efficiency and prolong the battery life of devices.

Energy Harvesting for Internet of Things: A Review [1]. The authors conducted a review of the literature on energy harvesting techniques for IoT devices, including solar, thermal, and mechanical harvesting. Identify several challenges and limitations facing the development and deployment of energy harvesting systems in IoT, such as limited energy storage capacity and low harvesting efficiency. The paper focuses primarily on energy harvesting techniques and does not discuss other approaches to energy savings. They suggest future research directions in areas such as energy storage, power management, and optimization algorithms. A Machine Learning-Based Energy Management System for IoT Devices [2] is proposed. They develop a machine learning-based energy management system for IoT devices, using a neural network to predict energy consumption and optimize power usage. The system is able to reduce energy consumption by up to 30% compared to traditional approaches, while maintaining performance levels. The study only evaluates the system on a small-scale test environment and does not consider potential issues such as device heterogeneity or network latency. They evaluate the system in larger and more diverse IoT deployments.

Energy-Aware Task Scheduling in Fog Computing-Enabled IoT Networks is proposed by [3]. propose an energy-aware task scheduling algorithm for fog computing-enabled IoT networks, which balances energy consumption and task completion time. The algorithm is able to reduce energy consumption by up to 20% compared to traditional approaches, while still meeting task deadlines. The study only evaluates the algorithm in a simulated environment and does not consider potential issues such as network congestion or hardware failures. The authors suggest future work to investigate the impact of different task types and priorities on energy consumption, as well as to evaluate the algorithm in real-world IoT deployments

In [19] A hybrid energy harvesting approach for wireless sensor networks in smart cities, combining solar and wind energy harvesting with battery backup. The approach is able to provide a reliable and sustainable power source for wireless sensor networks, reducing dependence on grid power and reducing carbon footprint. The study evaluates the approach in a simulation environment and does not consider potential issues such as device maintenance or environmental variability. They suggest future work to optimize the energy harvesting and storage components, as well as to evaluate the approach in real-world smart city deployments. Several schemes and models have been proposed to optimize energy consumption [19][20] [21][22].

Some of the schemes specifically focused on namely hardware optimization, communication protocols, and software optimization. Hardware optimization involves the use of low-power hardware components, communication protocols include the use of low-power wireless communication protocols, and software optimization includes the use of efficient algorithms and power management techniques. Researchers such as [4][5][6] precisely proposed successful schemes and models to optimize energy consumption in IoT devices, demonstrating the potential for significant energy savings.

3.0 Major Challenges of IoT Devices

IoT devices, or Internet of Things devices, refer to physical devices that are connected to the internet and can communicate with other devices and systems. While IoT devices offer a wide range of benefits, such as increased efficiency, automation, and connectivity, they also have some key challenges [5]. Some of the major challenges of IoT devices are discussed as follows:

Security concerns: IoT devices are often connected to the internet, which makes them vulnerable to cyber-attacks. If an attacker gains access to an IoT device, they can potentially control it, steal data, or use it to launch further attacks [17].

Privacy concerns: IoT devices can collect a lot of personal data, including location data, usage data, and even personal preferences. If this data is not handled properly, it can lead to privacy concerns and potential misuse of personal information.

Compatibility issues: IoT devices often require specific hardware and software to work properly. If these requirements are not met, the device may not work at all or may not work as intended [6]. Reliability issues: IoT devices rely on connectivity and communication with other devices and systems to function properly. If there is a disruption in the network, the device may not work as intended.

Complexity: IoT devices can be complex to set up and maintain. They often require a high level of technical expertise and can be difficult for non-technical users to use and troubleshoot.

Cost: IoT devices can be expensive, especially if they require specialized hardware or software. This can make it difficult for some users to adopt IoT technology. Power consumption: IoT devices often require a constant source of power to function properly [4]. This can lead to increased energy consumption, which can be expensive and environmentally unfriendly.

Finally, while IoT devices offer many benefits, they also have some disadvantages, such as security and privacy concerns, compatibility and reliability issues, complexity, cost, and power consumption. These issues must be addressed to ensure the safe and effective adoption of IoT technology.

Power consumption is one of the significant disadvantages of IoT devices, and it can have several negative impacts. IoT devices rely on a constant source of power to function properly, and many of them are designed to be always connected to the internet. This means that they consume energy continuously, even when not in use. Here are some of the ways in which power consumption can be a significant disadvantage of IoT devices:

Increased energy costs: The continuous use of IoT devices can lead to higher energy consumption, resulting in increased energy costs for users. This can be a particular concern for businesses and organizations that use large numbers of IoT devices. Environmental impact: Increased energy consumption can also have a negative environmental impact [6]. The energy used to power IoT devices often comes from nonrenewable sources, which contribute to greenhouse gas emissions and climate change. Battery life: Many IoT devices rely on batteries for power. Continuous use of these devices can drain the batteries quickly, resulting in shorter battery life and the need for frequent battery replacements.

Network congestion: IoT devices that are always connected to the internet can contribute to network congestion, which can lead to slower internet speeds and increased energy consumption by network infrastructure.

To mitigate the negative impacts of power consumption, manufacturers are designing IoT devices with low-power consumption in mind. This includes using more efficient hardware components, optimizing software to reduce energy consumption, and designing devices to enter low-power modes when not in use. Additionally, users can take steps to reduce energy consumption by turning off IoT devices when not in use or by using devices that have energy-saving features.

Finally, power consumption is a significant disadvantage of IoT devices that can have negative impacts on energy costs, the environment, battery life, and network congestion.

However, manufacturers, researchers and users can take steps to reduce energy consumption and mitigate these negative impacts. Thus, this scheme is proposed to minimize IoT energy consumption, while improving efficiency of IoT devices.

4.0 Impact of Power Consumption on IoT Devices

The impact of power consumption on IoT devices can vary depending on the specific device and its use case. However, some IoT devices are more affected by power consumption than others. Here are some of the major IoT devices affected by power consumption, listed in order of precedence:

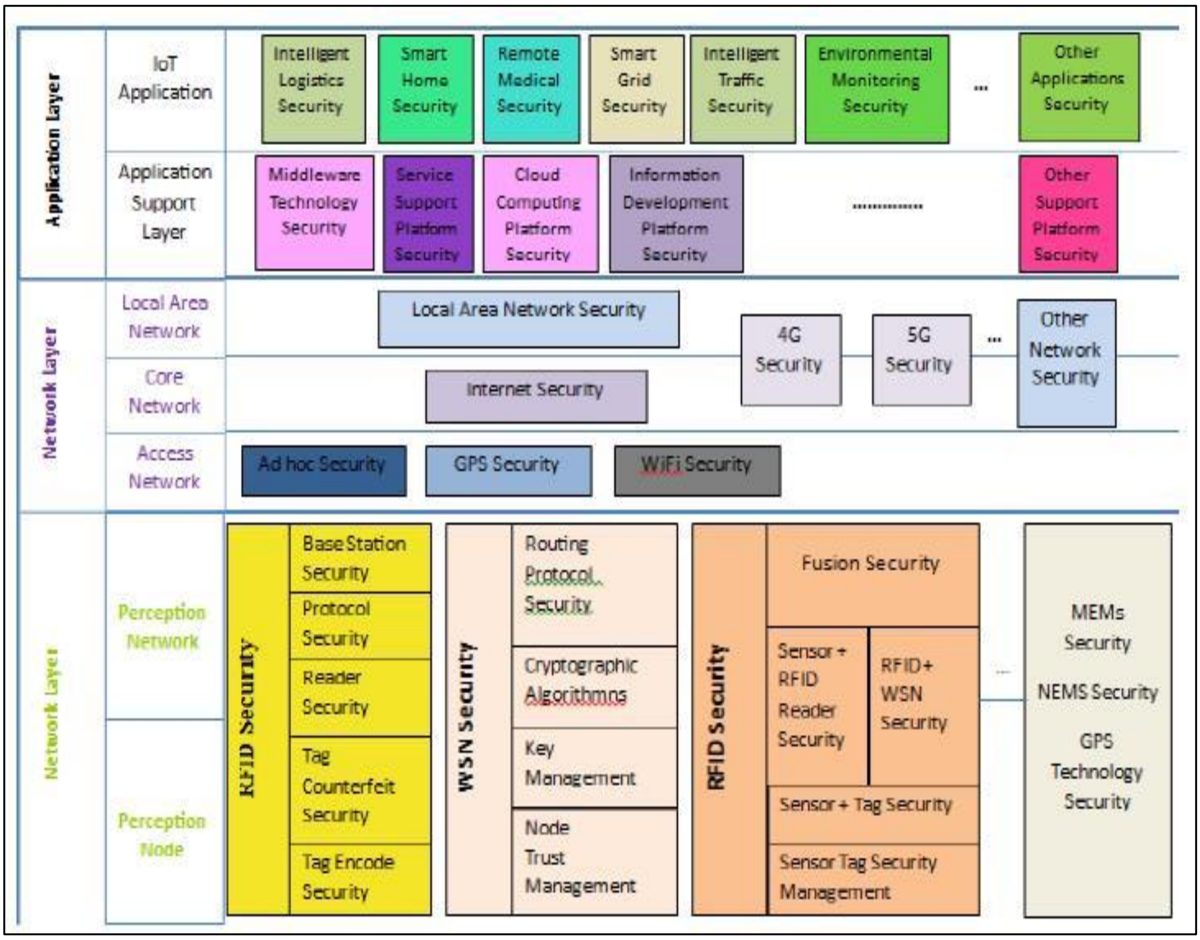
Sensors: Sensors are a fundamental component of many IoT devices, and they are often used to collect data about the environment or the device itself. These sensors must be powered continuously to provide real-time data, which can lead to high power consumption. For example, sensors used in smart buildings or industrial applications must be always-on to monitor temperature, humidity, or other factors. Reducing power consumption in these sensors is crucial to extend battery life and reduce energy costs [18].

Wearables: Wearables, such as fitness trackers or smartwatches, are designed to be worn continuously, which means they need to be powered continuously. These devices must also collect data from various sensors, such as accelerometers or a heart rate sensor, which further increases power consumption. To mitigate this, wearables are often designed with low-power processors and sensors, and some can enter low-power modes when not in use.

Smart home devices: Smart home devices, such as smart thermostats or smart speakers, are designed to be always connected to the internet to receive commands or updates. This continuous connection requires a constant source of power, which can lead to high energy consumption. To reduce power consumption, smart home devices can be designed with energy-saving features, such as low-power Wi-Fi or Bluetooth connectivity, or can enter low power modes when not in use.

Industrial IoT devices: Industrial IoT devices are used in industrial settings, such as factories or warehouses, and often require a constant source of power to function properly. These devices can include sensors, robots, or machinery, all of which can have high power consumption. To reduce energy consumption, industrial IoT devices can be designed to enter low-power modes when not in use, or can be connected to energy-efficient power sources, such as renewable energy [19].

Figure 2: Proposed Comprehensive IoT Architecture in a Digital Trends



Smart city devices: Smart city devices, such as smart traffic lights or environmental sensors, are designed to monitor and manage urban environments. These devices require a constant source of power to function, and the high number of devices required for a smart city can lead to significant energy consumption. To reduce energy consumption, smart city devices can be designed with low-power sensors or can enter low-power modes when not in use.

Finally, power consumption can have a significant impact on IoT devices, and some devices are more affected than others. Sensors, wearables, smart home devices, industrial IoT devices, and smart city devices are all major IoT devices affected by power consumption, and manufacturers are taking steps to reduce energy consumption in these devices to mitigate their negative impacts. Thus, a battery life Energy Management Scheme of IoT Devices is proposed.

Table 1: Comparison between the Proposed and Existing Schemes

	Scheme	Response Delay	Energy consumption	Sleep Mode	Wake Mode
[4]	Hardware Optimization		✓	✓	
[5]	Hybrid communication protocol		✓	✓	
[6]	Software Optimization		✓	✓	
[7]	Optimized Twin battery scheme	✓	✓		✓
[9]	DAPSS-BT		✓	✓	✓
[10]	ESPSS	✓		✓	
[11]	EPSS	✓	✓	✓	
[12]	IBPSS	✓	✓	✓	
[13]	QoS Aware Scheme	✓	✓	✓	
[14]	BM-ESPSS	✓	✓	✓	
	The Proposed Scheme	✓	✓	✓	✓

5.0 The Proposed IoT Devices Battery Life Energy Management Scheme

IoT Devices Battery Life Energy Management Scheme is proposed, the scheme tries to minimize the energy consumption of IoT devices, which is crucial for extending their battery life and reducing their environmental impact. In the proposed scheme, we first conducted a review of the current state of the art in energy management for IoT devices and then develop an algorithm as well as four programs to minimize energy consumption, using python programming language. The first program, try to reduce the amount of data transmitted or data on transit over the network by IoT devices. The program only transmit data when it's needed; using the most efficient transmission protocol possible. This program is critical for minimizing the energy consumption of IoT devices, as data transmission is one of the most energy-intensive tasks in IoT.

The second program uses sleep mode, in order to puts the device to sleep when it's not needed. This program is crucial for minimizing the energy consumption of IoT devices, as most of the time, IoT devices are idle and not actively performing any tasks. By putting the device to sleep, we can save a significant amount of energy thereby extending the battery life of IoT devices. The third program Optimize power usage, and try to turn off unused sensors or modules as well as use the lowest possible power mode. This program is critical for minimizing the energy consumption of IoT devices, as many IoT devices have multiple sensors and modules that are not always necessary. By turning off these sensors and modules, we can save a significant amount of energy and improve performance. Finally, the fourth program uses low-power components, and tries to use components specifically designed for low power consumption.

This program is critical for minimizing the energy consumption of IoT devices, as using components that are not designed for low power consumption can result in higher energy consumption and shorter battery life resulting to overall poor utilization of the IoT devices. To develop these programs, Python programming language was used, which is a popular language for IoT development due to its simplicity and ease of use. The programs were designed to be easily integrated into existing IoT systems, and they can be customized to meet the specific requirements of different IoT applications. In conclusion, the proposed IoT Devices Battery Life Energy Management Scheme is a comprehensive approach to minimizing the energy consumption of IoT devices, which is crucial for extending their battery life and reducing their environmental impact.

The four programs developed as part of the scheme are designed to optimize data transmission, use sleep mode, optimize power usage, and use low-power components, and they can be easily integrated into existing IoT systems respectively. It is important to note that the specific algorithm used will depend on the specific requirements of the IoT device and the constraints of the environment in which it operates. Therefore, a thorough analysis and evaluation of the IoT device and its operating environment is necessary to design an effective energy-saving algorithm. Hence, in this paper a procedural algorithms is used to help minimize energy consumption in IoT devices. In the proposed scheme a simple algorithm that can be used to minimize power consumption in IoT devices is given bellow in algorithm 1.

Algorithm 1.

1. **Step1:** Identify the components in the IoT device that consume the most energy.
2. **Step2:** Analyze the usage patterns of the IoT device and identify periods of low usage.
3. **Step3:** Put the device in a low-power sleep mode during periods of low usage.
4. **Step4:** Use event-driven wakeup mechanisms to minimize the time spent in sleep mode.
5. **Step5:** Use data compression and filtering techniques to reduce the amount of data transmitted over the network.
6. **Step6:** Use efficient data routing protocols to minimize the number of hops between the device and the gateway.
7. **Step7:** Implement energy harvesting techniques to supplement or replace battery power.
8. **Step8:** Use energy-efficient hardware components, such as low-power processors and sensors.

Program1: Optimize data transmission: Transmit data only when needed, and use the most efficient transmission protocol possible.

```
import time
import requests
# Only send data if it has changed
previous_data = None
while True:
 data = get_iot_data()
 if data != previous_data:
```

```
 requests.post('http://example.com/api/data', json=data)
 previous_data = data
 time.sleep(10)
```

Program2: Use sleep mode: Put the device to sleep when it's not needed. import time

```
# Sleep for 5 minutes between data transmissions
while True:
 data = get_iot_data()
 requests.post('http://example.com/api/data', json=data)
 time.sleep(300)
```

Program3: Optimize power usage: Turn off unused sensors or modules, and use the lowest possible power mode.

```
import board
import busio
import adafruit_shtc3
# Turn off sensor after reading data
i2c = busio.I2C(board.SCL, board.SDA)
sensor = adafruit_shtc3.SHTC3(i2c)
data = sensor.measurements
sensor.disable()
```

Program4: Use low-power components: Use components specifically designed for low power consumption.

```
import board
import digitalio
# Use low-power LED
led = digitalio.DigitalInOut(board.D13)
led.direction = digitalio.Direction.OUTPUT
led.value = True # LED off
```

6.0 Conclusion

IoT devices are physical devices connected to the internet that communicate with other devices and systems. While they offer benefits such as efficiency, automation, and connectivity, there are challenges such as cost, privacy, security concerns, and energy consumption. An IoT Devices Battery Life Energy Management Scheme is proposed to reduce energy consumption, the scheme extend battery life, and reduce environmental impact as power consumption. This scheme includes an algorithm and four programs developed in Python to minimize energy consumption by optimizing data transmission, using sleep mode, optimizing power usage, and using low-power components respectively. These programs can be customized for different IoT applications and easily integrated into existing systems. The proposed scheme is a comprehensive approach to energy management for IoT devices that improves efficiency, reduces impact, and extends battery life significantly.

References

1. Mahmood, A., Tariq, M. A., Khalid, H., & Raza, S. (2021). Energy harvesting for Internet of Things: A review. Sustainable Energy Technologies and Assessments, 48, 101180.
2. Kim, H., Kim, J. S., Lee, S., & Lee, J. (2020). A machine learning-based energy management system for IoT devices. Energies, 13(12), 3259.
3. Zhou, Y., Yang, Y., Wu, W., & Xu, W. (2021). Energy-aware task scheduling in fog computing-enabled IoT networks. IEEE Internet of Things Journal, 8(6), 5009-5020.
4. Lee, H., Kim, H., & Cha, H. (2013). Hardware architecture for IoT devices with a low Power PIR sensor. In 2013 13th International Conference on Control, Automation and Systems (ICCAS 2013) (pp. 1703-1706). IEEE.
5. Okafor, K. C., Gacanin, H., & Mohorcic, M. (2016). A hybrid communication protocol for energy-efficient IoT devices. In 2016 IEEE Wireless Communications and Networking Conference (WCNC) (pp. 1-6). IEEE.
6. Bhattacharya, S., Chakraborty, A., & Ghosh, S. K. (2019). An energy-efficient algorithm For data transmission in IoT devices. In 2019 International Conference on Information Networking (ICOIN) (pp. 539-544). IEEE
7. Wisdom, D.D. Ajayi E. A. Arinze U.C. Idris, H. Bello, U.M. Aladesote O.I. An Optimized TWIN Battery Resource Management Scheme in Wireless Networks, Lecture Notes in Networks, Vol. 217, *Proceedings of Sixth International Congress on Information and Communication Technology, Springer Nature,* 2021. 978-981-16- 2101-7,511607.
8. Wisdom, D. D. Ajayi, E.A. Arinze U.C. and Aladesote. O.I A Comprehensive Survey on Power Saving Schemes (CSPSS) in IEEE 802.16e/m Networks. *IEEE Computer Society-Nigeria-Technical Paper Series*, 2020.
9. Wisdom, D. D. Tambuwal, A. Y. Mohammed, A. Audu, A. Soroyewun, M. B. and Isaac, S. ―A Delay Aware Power Saving Scheme (DAPSS-BT) Based on Load on Traffic in IEEE 802.16e WiMAX Networks‖, [*Institute of Electrical and Electronic Engineers Conference IEEE, Ahmadu Bello University Zaria, Kaduna State, Nigeria, 2019*].
10. Wisdom, D. D. Saidu, I. Tambuwal, A.Y. Ahmad, M.A Isaac, S. and Farouk, N. An Efficient Sleep-Window-Based Power saving Scheme (ESPSS) in IEEE 802.16e Networks‖, [*15th International Conference on Electronics Computer and Computation ICECCO* 2019].
11. Wisdom, D. D. Farouk, N. Ahmed, M. A. Isaac, S. Idris, H. and Hassan, J. B. An Enhanced Power Saving Scheme (EPSS) in IEEE 802.16e Networks‖, [*International Journal of Information Processing and Communication (IJIPC),* Vol. 8 No. 2, April, 2020].
12. Wisdom, D. D. Isaac, S. Ahmed, M. A. Farouk, N. Magami S. and Elijah, Y. An Improved Battery-Life Power Saving Scheme (IBPSS) in IEEE 802.16e Networks‖, [*International Journal of Information Processing and Communication (IJIPC),* Vol. 8 No. 2 April, 2020]
13. Ajayi A. E.A. Idris, H. Wisdom, D. D. Arinze. U.C. Quality of Service Aware Power Saving Scheme in IEEE 802.16e networks‖, *IEEE, Technical Paper Series, Ghana* 2020.
14. Isaac, S. Wisdom, D.D. Ahmed, M.A. and Arinze, U.C. Battery-Life Management with an Efficient Sleep-Mode Power Saving Scheme (BM-ESPSS)‖ in IEEE 802.16e Networks, *International Journal of Mechatronics, Electrical and Computer Technology (JMEC),* Volume 7, Issue 2, 2020.
15. Wisdom D.D. Ajayi E.A. Arinze U.C. Aladesote O.I. Ganya A.H. Idris H. Comprehensive Performance Analysis and a Delay Aware Power Saving Scheme (DAPSS) in Wireless Networks, *International Conference on Innovative Systems for Digital-Economy (ISDE),* An annual Nigerian

Computer Society (NCS) Conference, AKwaibom Uyo State, Nigeria 2021.

16. Wisdom, D.D. Ajayi E. A. Arinze U.C. Idris, H. Bello, U.M. Aladesote O.I. An Optimized TWIN Battery Resource Management Scheme in Wireless Networks, Lecture Notes in Networks, Vol. 217, *Proceedings of Sixth International Congress on Information and Communication Technology, Springer Nature,* 2021. 978-981-16- 2101-7,511607.
17. Wisdom, D. D., Tambuwal, A. Y., Khalid, H., Ajayi, E. A., & Chun, P. B. (2018). Enhanced model for computer viruses counter measures. In 1st International Conference on Education and Development (ITED), Baze University, Abuja Nigeria.
18. Ali, M., Ahmad, I., & Haider, A. (2020). A hybrid energy harvesting approach for wirelesssensor networks in smart cities. Sustainable Cities and Society, 62, 102377. https://doi.org/10.1016/j.scs.2020.102377
19. Ali, M., Razaque, A., Javaid, N., Imran, M., & Vasilakos, A. V. (2020). A hybrid energy harvesting approach for wireless sensor networks in smart cities. IEEE Communications Magazine, 58(7), 54-61. doi: 10.1109/MCOM.001.1900359.
20. Wisdom, D. D., Tambuwal, A. Y., Khalid, H., Ajayi, E. A., & Chun, P. B. (2018). Enhanced model for computer viruses counter measures. In 1st International Conference on Education and Development (ITED), Baze University, Abuja Nigeria.
21. Gudu, E. B. Wisdom, D. D. Ahmed, M. A Akinyemi, A.E. Isaac, S. Dazi, A. J. (2020). Mathematical model for the spread and control of ebola virus by quarantine techniques, Anals Journal of computer science series, November, 2021.
22. Gudu, E. B. Wisdom, D. D. Gudu, G. J. Ahmad, M. A. Isaac. S. Akinyemi, A. E. (2020). Data Science for Covid-19 (Mathematical Recipe for Curbing Corona Virus (Covid-19) Transmission Dynamics, *Elsevier*, August, 2021.