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Battery Lifetime Analysis of XBee Sensor Using Transmission Power and Period Approaches: A Case of Server Room Monitoring System

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Abstract

In the server room, it is necessary to monitor the appropriate temperature for the efficient use of electricity. Especially in hot regions and seasons. For example, April is the summer in Thailand where the temperature is about 35-40 ^{O}C every year, but the optimum temperature for the server room is about 20-22 ^{O}C. This paper presents the measurement of a wireless temperature system through the use of XBee sensors to monitor the real-time server room temperature. The system consists of an XBee sensor node, Gateway (GW), and IoT cloud server. In addition, the measuring device can use a wireless sensor, it is convenient and easy to install as well. Therefore, when choosing a wireless sensor device, it is necessary to test its performance in terms of both the period and the power transmission of the device. Such parameters affect the battery lifetime. The results of the measurement of the sensor's energy efficiency measured the voltage drop of the device by adjusting the power transmitter and period of the XBee sensors. These parameters directly affect the battery power output and are expected to benefit users in the future.

Keywords: battery lifetime; ZigBee; Server room; IoT.

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1. Introduction

Wireless sensor network (WSN) can be connected to the internet via a gateway (GW) that supports internet technology [1]. Moreover, another technology that is gaining increased attention in new research is the low power wide area network (LPWAN) technology that can be connected to base stations of existing telephone systems. Its lower cost structure has prompted embedded system developers to become more interested in the technology and enable them to explore additional solutions that can meet a long range of applications in data communications that are both convenient and secure [2]. Another important issue is regarding IoT networks becoming a gateway to launch attacks on the internet server system and pose a threat to the entire network system [3]. System developers need to distinguish between the core service and the IoT networks to avoid direct system attacks by which the network can be physically and logically separated [4]. The ZigBee WSN for developing a range of expertise has developed significantly. ZigBee is an evolution of short-range wireless networking standards, low-data rate, low cost, and low power. It is well-suited for wireless technology due to its vital networking, identity functionality, and enhanced security [5]. A battery lifetime investigation is essential for system deployment [6]. The first method optimizes the trade-off in the WSN using the data transmission period. The second alternative creates two power-saving modes during computationally cyclic periods: active mode and sleep-power mode [7].

In [8], The experimental data and analyses demonstrate the energy using a Time Division Multiple Access (TDMA) communication schedule for efficient power consumption. In addition, the power consumption estimates in [9] the 2000 mAh battery lifetime for the rechargeable batteries Xbee sensor nodes obtained from Digi International Company to be 1.5 years if the sensor update time for 10 minutes time sampling. Furthermore, the power usage in [10] evaluated the ZigBee device at different transmission power levels and found that the type of antenna consumes different power. As the authors reviewed previous research, it is found that both period and power transmission significantly affected energy consumption. Therefore, this paper presents the measurement of a wireless sensor device base on the XBee application that communicates according to the ZigBee protocol. The monitoring devices can be connected to the internet via the NB-IoT network, which isolates the network from the room's main server network. Additionally, the effect of the battery power consumption was also studied in which both the power transmitter and time variables were used in the experiment to determine the efficiency and power constraints of the sensor node. The results of the study are expected to be used to determine the appropriate energy consumption.

2. Proposed system

The temperature monitoring system developed in this research consists of an XBee sensor, GW, and an IoT cloud server, which was deployed in the server room to monitor the temperature where the air-conditioner was operating continuously on a 24-hour basis. The system begins with the XBee sensor that monitors the temperature and transmits the data wirelessly to the GW via the Zigbee protocol. Subsequently, the GW will read the temperature data and convert it into a format, and communicate it to the NB-IoT network to transmit and record the results on the IoT cloud platform. The monitoring system is not interconnected with the server room's system. The system architecture is shown in Figure 1.

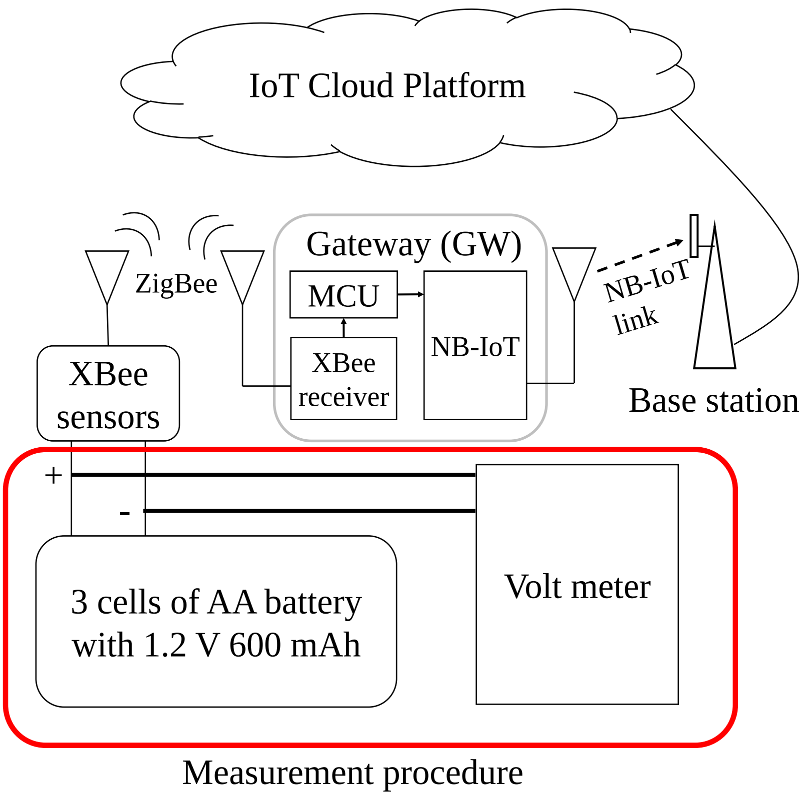

Figure 1: System architecture

2.1. XBee sensor configuration

Digi's XBee sensors, which monitor temperature, relative humidity, and light, were applied in this research as the wireless sensor device. The XBee sensors require roughly 0.28 milliamperes in cyclic sleep mode when reading and transmitting data wirelessly, and microamperes in sleep mode. In the setting up of the XBee device, the X-CTU program was used to configure the variables. Figure 2 illustrates the XBee end device node sensors and the other one, which is set up to be a coordinator.

Figure 2: XBee sensor device configuration

Figure 2 demonstrates the components of point-to-point wireless XBee communication. Namely, the XBee sensor device, which can be configured to measure temperature parameters. The received input from a node sensor is an analog signal installed within the enclosure and connected to the XBee. End device node XBee is able to measure and transmit information data to the XBee coordinator.

Moreover, the link between the XBee sensors and the coordinator can be assigned numbering within the network through the use of a personal area network identifier or PAN ID to support connections within the same network. However, they will not be able to be linked together on different networks. In addition, variables that are related to lowering the battery power can be set by configuring up to five power levels as shown in Table 1. Another important variable in the device's energy efficiency is the cyclic sleep mode setting. The different time settings are shown in Table 2.

Table 1: Power level configuration of XBee device

Power level setting	Transmitter power [dBm]
Lowest (0)	-2
Low (1)	2
Medium (2)	4
High (3)	6
Highest (4)	8

Table 2: Time sampling with cyclic sleep method of XBee device

Testing Parameters	Value setting
Cyclic sleep period (SP)	7D0
Sleep mode (SM)	Cyclic sleep (4)
Time before sleep (ST)	3E8
Sleep Option (SO)	4
Number of cyclic sleep periods (SN)	1,5,10, and 20 for 1,5,10, and 20 minutes, respectively

2.2. Gateway connectivity

As for the GW connectivity, it starts the program by connecting to the XBee and NB-IoT devices. Once the connection has been made, the GW is then ready to receive the data packet from the XBee sensor and perform packet parsing to calculate the temperature. Thereafter, the GW will then organize the data into the JSON format and send it to the server via the NB-IoT network to further record the temperature data. The hardware used is shown in Figure 3.

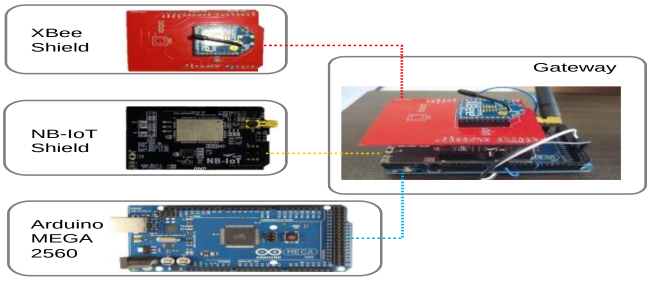

Figure 3: Gateway connection diagram

3. Experimental and results

In the experiment, the temperature data was recorded through the use of XBee sensors and transmitted to the server via the NB-IoT to save it for further analysis. The experiment was divided into two parts: the server room test and the energy efficiency test of the XBee sensors.

3.1. Temperature data collection testing

In the temperature recording in the server room at the office of National Broadcasting and Telecommunications Commission (NBTC) Region 4, Songkhla, Thailand, which had the related equipment to the control of communications within the region, such as office internet equipment, Radio over Internet Protocol (ROIP) system, an uninterruptible power supply (UPS), and a CCTV system. The server room is shown in Figure 1. The room installs an air conditioner that helps maintain the coolness of the communication equipment. The recorded temperature is a result of the environment outside the room and the condition of the materials inside the room, including the glass in the server room that allows sunlight to enter during the afternoon.

Figure 4: Configuration of testing system

Figure 5 graphs the server room temperatures whereby monitoring by the proposed NBTC system. The data was collected for 24 hours of 5 days from 10 to 14 April 2021. The results of the temperature data measurements from the server room indicated that the temperature ranged between 18-26 ^{o}C, where the low-temperature range was recorded between 5.00-6.00 am., while the high-temperature range was from 3.00-4.00 pm.

Figure 5: Temperature sensing data in a server room

Additionally, the authors also recorded data on the voltage drop. The voltage was monitored every 3 hours to ensure the correct voltage, because when the XBee sensors started operating until the battery ran out, it recorded an error in the sensor reading, with the distortion showing that the temperature reading tends to drop sharply.

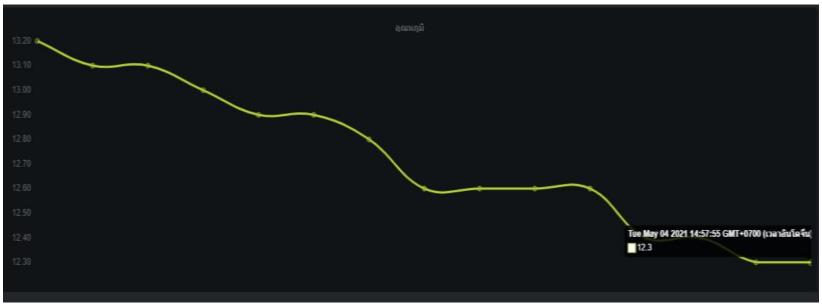

Figure 6: An example of wrong temperature values according to the power supply voltage dropped

Figure 6 demonstrates in case the battery voltage is going to drop from the acceptable voltage, which about 3.5 V to supply the XBee node. Then, in case the battery levels below 3.5 volts are displayed as “off” and data transmission has been stopped when the battery of the XBee node reaches 2.00 volts. The different battery capacities in the previous work had a longer working load. For the reason for choosing a battery for this research. The authors chose the smallest capacity in the market at 600 mAh. It is acerate the voltage dropping time according to the next section. In addition, the temperature dropped to 12°C and the XBee sensors stopped transmitting data at a voltage of 2.0 V. Data of the voltage drop is shown in Table 3. Moreover, the specification of the XBee sensor usually works accordingly where the state of the battery can be set to indicate the meter availability by allowing the GW to determine the state of the battery and should then notify the user accordingly.

Table 3 shows the measurement results of the battery status based on individual temperature monitoring. The testing has been repeated in the previous research [9] using alkaline batteries and the present study used a Ni-MH rechargeable battery with 600 mAh, which received the monitored temperature at similar levels.

Table 3: Previous and current work comparison of XBee sensor in cases: voltage dropped and status battery

Operation time [hrs]	Previous work with alkaline battery type with Panasonic brand [9]		Current work with Ni-MH rechargeable battery with 600 mAh	
	Voltage [V]	Battery status	Voltage [V]	Battery status
0	5.10	On	4.10	On
3	5.00	On	3.84	On
6	4.90	On	3.78	On
9	4.85	On	3.70	On
12	4.81	On	3.65	On
15	4.75	On	3.54	On
18	4.70	On	2.10	Off
19	4.60	On	2.00	Off and stopped
19-55	4.60-3.50	On	-	-
55-65	3.50-2.00	Off and stopped	-	-

3.2. Voltage drop test in power level and time period cases

The objective of this experiment was to investigate the effect of voltage drop from the effect of the XBee power level and time period setting, which can be useful for configuring both parameters for practical applications.

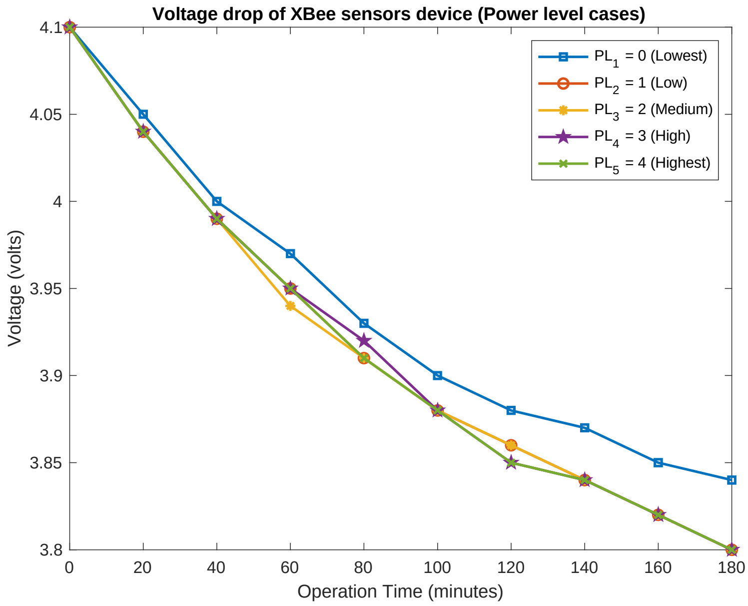

Figure 7: Voltage drops with power level cases

Figure 7 shows the comparison of the measurement of voltage drop for different power levels (LV0 – LV4). The time period for data transmission was set for every 1 second, to which the entire experiment covered 180 minutes. The results revealed that when the power level is 0, the voltage drop is at the lowest level based on the starting voltage of 4.1 V up to 3.84 V. When the power levels are at 1, 2, 3, and 4, the voltage drop rates tend to be similar.

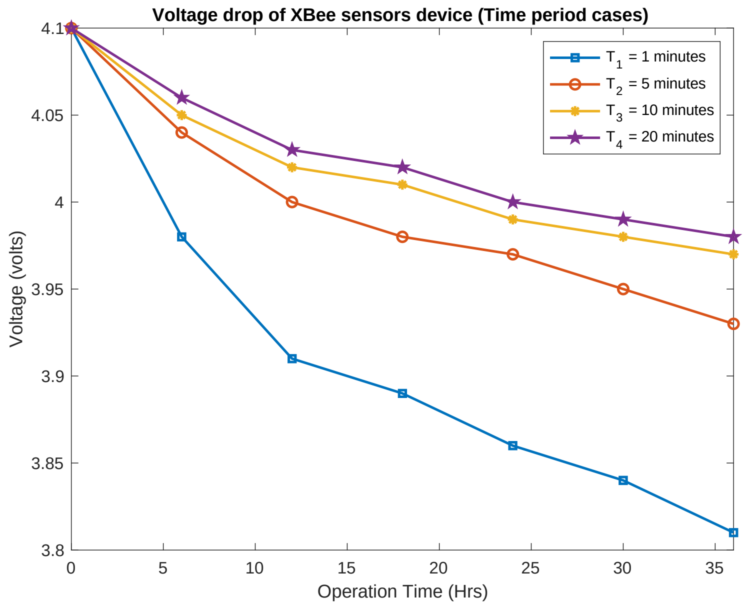

Figure 8: Voltage drops with time period cases

Figure 8, shows the results of another experiment based on time period cases for different times (when T equals 1, 5, 10, and 20 minutes) and set a power level of 4 for the fastest decrease in voltage unit. This experiment covered 36 hours. The results of each period when the XBee sensors were started from 4.1 V, and its voltage drop reduced to 3.81 V (in the case where T equals 1 min.), which amounted to approximately 2160 packet transmissions, and in the case of T of 5, 10, 20 minutes, there were approximately 432, 216, and 108 packets being transmitted, respectively. Therefore, it may be significantly concluded that the lower the number of transmitted data will result in significant battery savings as the time period increases.

4. Conclusion

This study presents the results of the development of a temperature monitoring system through the use of XBee wireless sensors, which are connected to the internet via the NB-IoT communication network. The benefit received from this research is that it can monitor the necessary server room temperature by separating the IoT network from the primary network servicing in the server room. In addition, the battery power efficiency test was conducted by setting the power levels and time periods of the XBee sensors to determine the optimal choice for actual use in subsequent projects. All of this concept is to consider a solid-battery supply and include high-safety batteries in other solutions in future works. This is because to make the stability of data monitoring system performance in high efficiency and also the low power consumption accessories to include in a design system.

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