# An Optimized Temperature Sensing Period for Battery Lifetime in Wireless Sensor Network

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***Abstract*— The battery lifetime is the most important issue in a wireless sensor network (WSN). As the battery lifetime is restrictive in WSN, energy efficiency is very important. In case of outdoor monitoring, the data of temperature has a feature which changes slowly. If the value of temperature does not change constantly, the network communication has to extend sensing period because it is the most energy consuming aspect of the battery. In this paper, we propose optimized temperature sensing period (OTSP) for efficient energy consumption. The main ideas of OTSP are that the network communication find successive stable section through proposed algorithm and the network communication reduce the wireless temperature network period in stable section. We experimented on OTSP in the rooftop of the building in order to remain unaffected by environments. The result of experiment indicates that OTSP reduces the energy consumption and extends the battery lifetime as compared with temperature sensing system.**

***Keywords- battery lifetime; energy consumption; wireless sensor network; temperature sensor***

## I. INTRODUCTION

WSN is used to monitor the various areas of the environment for implementing an IoT-based technology as used for the purpose of collecting and transmitting the data. Applications of WSN are used in the domain ecology, climate, environment, industry, transport, fire monitoring.

Most of these measurement of the wireless network environment is supplied with power through the battery. However, current battery technology cannot sufficiently supply the power in WSN. In addition, wireless communication constantly needs to consume the battery. As a result, research was done to minimize the WSN period, because the network communication approximately 20 percent of the battery's total energy consumption.

The data in WSN is divided into two types of feature, that is, the discontinuous and the continuous type of data. The discontinuous type of data is unstable, and the continuous type of data is stable. If the outdoor temperature is stable for a long time, the data in WSN is useless as we need to gather information about various data to optimize services. However, existing WSN system gathers all information although it is useless. To handle this problems, WSN has to minimize in stable section.

In this paper, we proposed the system to maximize the battery lifetime using OTSP. The wireless temperature sensor network has both types of unstable feature and stable feature.

This paper is organized as follows: in Section II, we discuss the works related to existing WSN; in Section III, We present the algorithm and important schemes; in Section IV, we show the implement and the results; finally, some concluding remarks and directions for future work are given in Section V.

## II. RELATED WORK

WSN is required to extend battery lifetime. Improved battery lifetime in WSN has been proposed in several papers.

### *A. Study on management of energy consumption to improve battery lifetime in WSN*

One of the energy management solution in WSN is network communication control, which is able to improve battery lifetime by analyzing data pattern. Wenguo et al [1] introduced the relationship between the energy utilization rate and the maximal network hop number. Akshay et al [2] used various models of the alkaline battery for maximizing its utilization and its lifetime. Suh et al [3] Software-based self-test has emerged as an effective strategy for online testing of processors integrated in bad-safety critical applications. However, these studies mostly focus on energy saving without utilizing the information on the accuracy.

### *B. Study on sleep mode to manage energy consumption in WSN*

As a similar method used in this paper, studies using sleep mode in WSN are performed [4]. Several studies use sleep mode for energy management. Two terminal reliability of WSN is calculated, using Monte Carlo Simulations. Then via simulation results the effects of sleep probability on consumed energy and network reliability are considered [5]. However, sleep mode introduced in these studies has not been applied in environment monitoring system in WSN. Therefore, to improve battery lifetime in WSN, network communication control using sleep mode is needed

## III. AN OPTIMIZED TEMPERATURE SENSING PERIOD

The proposed paper designs the OTSP system with temperature sensor and wireless communication interface. Before presenting the proposed system with system algorithm


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and important scheme, the proposed paper discusses the problem of temperature sensing systems.

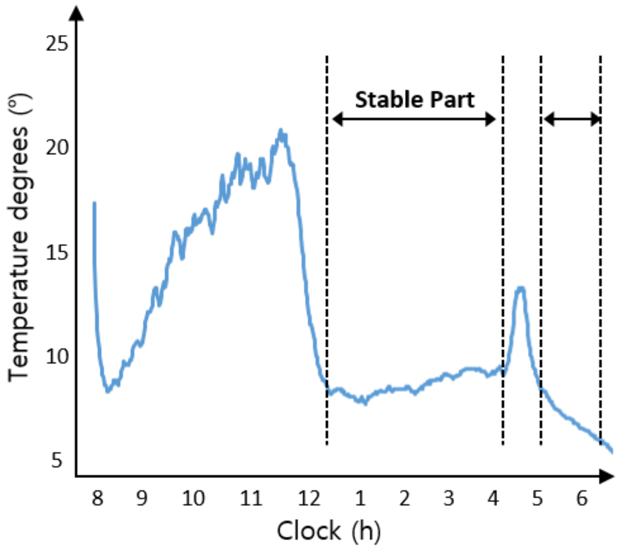


Figure 1. Data of temperature graph for daytime

The proposed system controls the network communication to minimize sensing period. The value of temperature is changed into environments (e.g., sunrise, sunset, wind, clouds, etc.) during daytime. The temperature variation during a certain period can be divided into two types. One type is much temperature variation, which is important to apply service models. The other type is little temperature variation, which is useless if it maintains for a long time. As shown in Fig. 1, the temperature graph for daytime has little temperature variation which is called stable part. If sensing period extends to sleep mode for stable part, it can get improved battery lifetime by saving network communication in WSN. Therefore, it is necessary to properly set the value according to temperature characteristics.

### A. *An optimized temperature sensing period Algorithm*

Fig. 2 illustrates a flowchart of an optimized temperature sensing period algorithm. Low data change is received from temperature degrees through embedded system per proposed method. The successive stable section denotes that the current data is stable state.

The proposed optimized sensing period algorithm adjusts sensing period based on the successive stable section of temperature, which are inputted via embedded systems. The value of temperature degrees at the latest is $x_{Temp.n}$, the value of sensing time intervals that is a gap between previous sensing time is $\Delta x$, the value of temperature variation that has been changed differences degrees at the latest is $a_{Temp.n}$, the time that has been aggregate successive stable section is $S_{a.n}$. The procedures are composed of three steps.

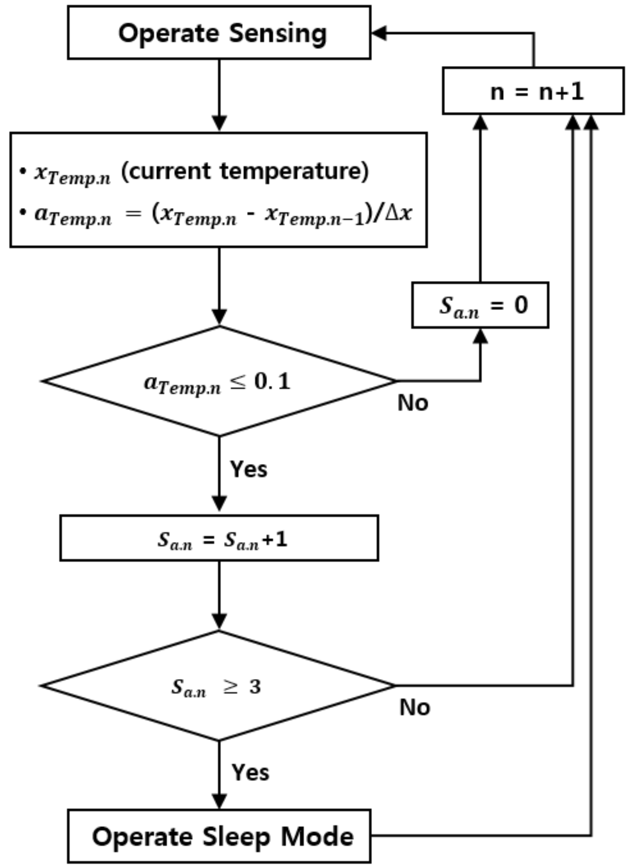


Figure 2. A flowchart an optimized temperature sensing period algorithm.

Step 1. A value of current temperature degrees through sensor is $x_{Temp.n}$. Then, calculates $\Delta x$ which is sensing time intervals at the latest and $a_{Temp.n}$ which is temperature variation.

Step 2. Check whether $|a_{Temp.n}|$ is less than or equal to 0.1 that a measure effects of little temperature variation and wind and clouds, than class stable section and add 1 point in $S_{a.n}$. If $|a_{Temp.n}|$ is greater than 0.1, than initialize $S_{a.n}$ and operate sensing.

Step 3. Check whether $S_{a.n}$ is greater than or equal to 3, then operate sleep mode. If $S_{a.n}$ is less than 3, then operate sensing.

It is possible to derive the optimized sensing period, which can save energy at the maximum without useless sensing section through the proposed algorithm.

The proposed system can reduce energy consumption via interaction with the information about temperature variation.

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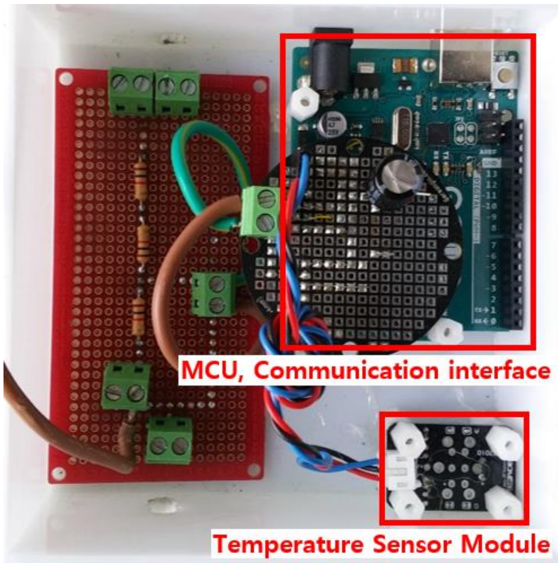


Figure 3. A prototype of an optimized temperature sensing period.

## IV. Implementation and Experimental Results

### A. *Hardware of an optimized temperature sensing period*

Fig. 3 shows a prototype of an optimized temperature sensing period. The main processor is a 16-bit micro controller unit (MCU). It is used for performing the main tasks such as complex event processing, processing of priority based scheduling algorithm, the provision of sensing period, pattern generation, and situation analysis. A ZigBee transceiver is used for communication with other networked devices. We used a 250 kbps/2.4 GHz ZigBee transceiver of Arduino Module. The metering circuit plays a role in measurement of the temperature degrees. The system is composed of temperature sensor module, MCU and communication interface. We operate parallel two systems, which are temperature sensing system and OTSP system in order to compare energy efficient system.

### B. *Experiment*

We deployed OTSP system on the rooftop of the building in order to remain unaffected by environments. We analyzed proposed system according to two different methods. The results presented in the following were collected from 8:00 A.M to 6:00 P.M for four days.

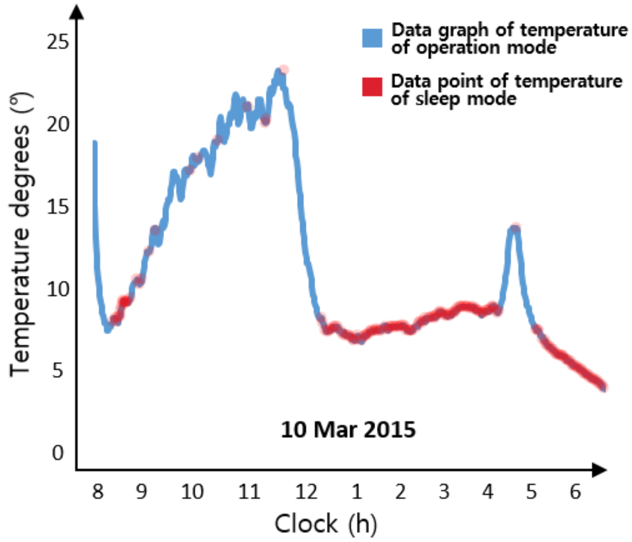


Figure 4. Daytime temperature graph from 8 A.M to 6 P.M and point of sleep mode in stable section.

We conducted experiment with two different systems that are the temperature sensing system and OTSP system. The temperature sensing system performs sensing of remaining 1 minute period. The OTSP system performs scheduling of operation mode/sleep mode according to previous temperature variation. The sensing period on sleep mode is remaining 2 minutes. Fig. 4 shows the sleep mode using OTSP in stable sections. The result show that almost point of sleep mode lie at stable section. Therefore, the OTSP system has little effect of services.

### C. *Result of an optimized temperature sensing period*

Figs. 5 and 6 show the sensing counts for four days. As shown in Fig. 6, the value of network communication is reduced by 30.1 percent through OTSP system.

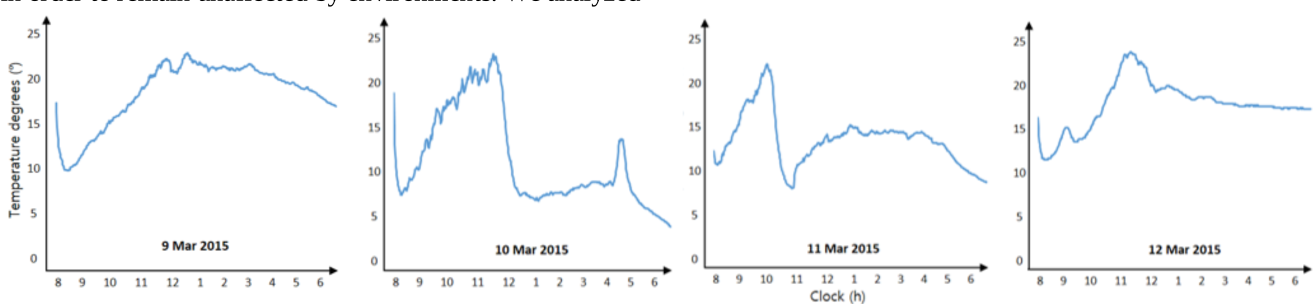


Figure 5. Daytime temperature graph from 8 A.M to 6 P.M for four days

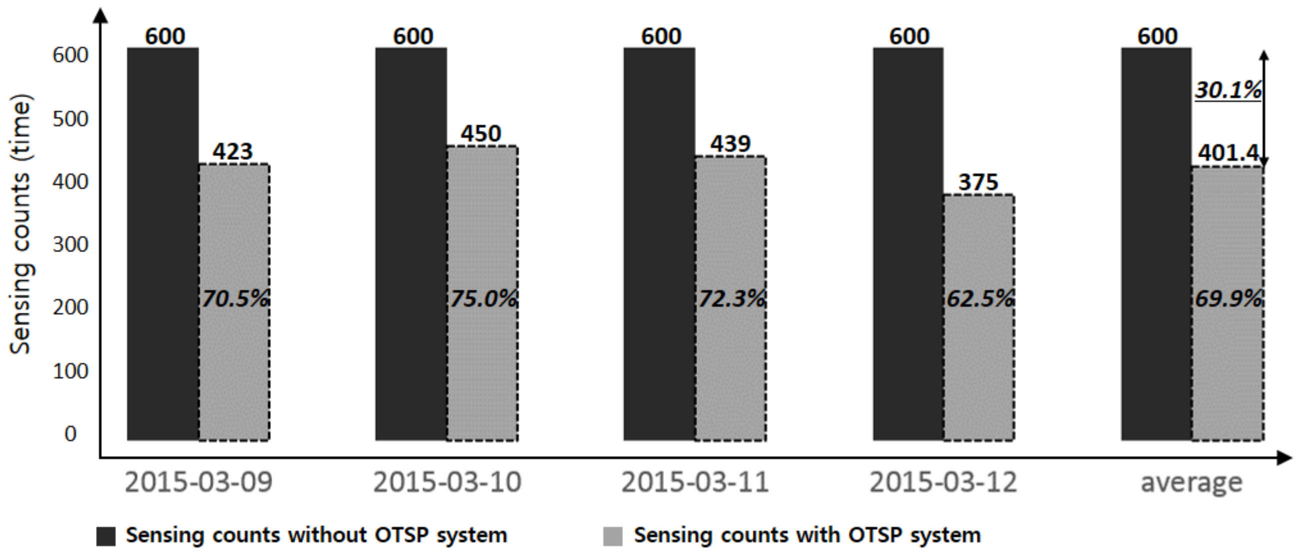


Figure 6. Comparison of system sensing counts for four days

Fig. 6 shows the sensing counts for four days. The result shows that the average sensing counts of temperature reduce.

*D. Result of Battery Lifetime*

*1) Average sensing counts for 1 day*

- Sensing counts without OTSP : 600 times/day
- Sensing counts with OTSP : 419.28 times/day

Simple experiment was performed to evaluate the above optimized temperature sensing period for improved battery lifetime. The performance of the proposed OTSP depends on average sensing counts during four days.

Therefore, the effectiveness of the above an optimized temperature sensing period can be evaluated by analyzing the improvement of battery lifetime of WSN using (1) to (4).

$$S_d = C_o \times C_S \times T_o \quad (1)$$

Where $S_d$ is the sensing consumption current for 1 day (Ah/day); $C_o$ is the operation current; $C_S$ is sensing counts (/day); and $T_o$ is the operation time (h).

$$S_y = C_o \times C_S \times T_o \times 365 \quad (2)$$
$$= S_d \times 365 \quad (3)$$

Where $S_y$ is the sensing consumption current for 1 year (Ah/year).

$$S = C_n + C_m \quad (4)$$

Where $C_n$ is the network node current; and $C_m$ is the MCU spending current.

$$L_B = C_B \,/\, S_y \quad (5)$$

Where $L_B$ is the battery lifetime (year); and $C_B$ is the battery capacity;

*a) Average Current Consumption on Operation Modes*

- Transceiver Module : 50mA (0.6sec per 1 time)
- MCU : 81.33mAh/year

*2) Sensing consumption current without OTSP for 1 year*

*a) consumption current of network node current*

- Operating time : 0.6sec
- $S_d$ = 50mA × 600 time/day × 0.6sec = 5mAh/day (6)
- $S_y$ = 5mAh × 365day = 1825mAh/year (7)

*b) Sensing consumption current*

- $S$ = 1825mAh/year + 81.33mAh/year (8)
  = 1906.33mAh/year

*c) Battery lifetime*

- $L_B = 2200mAh$ / 1906.33 = 1.154 year (9)

*3) Sensing consumption current with OTSP for 1 year*

*a) consumption current of network node current*

- Operating time : 0.6sec
- $S_d$ = 50mA × 401 time/day × 0.6sec (10)
  = 3.34mAh/day
- $S_y$ = 3.34mAh × 365day = 1219.7mAh/year (11)

*b) Sensing consumption current*

- $S$ = 1219.71mAh/year + 81.33mAh/year (12)
  = 1301.04mAh/year

*c) Battery lifetime*

- $L_B = 2200mAh$ / 1301.04 = 1.691 year (13)

*4) Benefit of battery lifetime using OTSP.*

*a) Compared with battery lifetime*

- $\mathrm{n(year)} = 1.691 - 1.154 = 0.537\mathrm{year} = 196\ \mathrm{day}$ (14)

As a result, the proposed OTSP improve the total battery lifetime by 196 days.

## V. Conclusion

Saving energy has become one of the most important issues in WSN. The network communication approximately 20 percent of the battery's total energy consumption. The main ideas of OTSP are that the network communication find successive stable section through proposed algorithm and the network communication reduce the wireless temperature network period in stable section. An optimized temperature sensing period algorithm was proposed. The proposed OTSP can be easily modified and cost effectively implemented. We deployed OTSP system on the rooftop of the building in order to remain unaffected by environments, and measured the sensing counts to evaluate the performance of battery lifetime. The proposed OTSP improves the total battery lifetime by 196 days. It is expected that this work will contribute to providing guidance on the development of WSN.

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