The Reduction Method of Power Consumption for the Wireless Sensor Network System

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Abstract

The most basic components of the WSN system are the sensor node and the power consumption reduction method of sensor nodes is important. When the RF communication is done each sensor node during the WSN systems operating, power consumption is greatest. So we proposed the reduction method of power consumption and the same time to avoid data omission for the WSN system. Proposed method is the Network with the RF communication module that turn on/off periodically, power consumption less than operating the module all the time without it toggles. At the same time, we proposed the counter synchronization, the tag node algorithm, base station algorithm to prevent data omission. Experimental results show that the proposed method was no data omissions and the life time can be 12 times longer than existing WSN system.

Keywords: *Power consumption reduction method, WSN, Sensor node, Toggle, Counter synchronization*

1. Introduction

With WSN technology, not only small applications such as smart house but also in the larger society such as environmental, military, health and commercial applications. More and more we see the importance of WSN technology. To make human life become more convenience we should apply development technologies [1, 4-6].

Important components of the WSN system are the sensor nodes and the base station. So the WSN system is designed to combine two elements: Tag node and Programming. The tag node collects near the environmental information and sends this information to administer is called sensor node. The tag nod has senor for measuring external environmental information, CPU for storage and processing information from the sensor and RF module for sending stored data or receiving. The tag node for WSN is demanded computing power of appropriate level, small size and long life (operating time) in many applications area. Presently, performance of the MCU for the sensor network is enough or develops over. The tag node that is made small size as possible can only use the battery because of limitation of installed location and cost saving. Life of this tag node is decided by size of battery capacity and power consumption. So we will use battery of high capacity or design it for low power consumption in order that increase life of the tag node. However, battery capacity is limited. So low power design of tag node is the most important for operating life [2, 3, 9]. Until now many researcher have studied about tag node for reducing power consumption and they have designed new tag node hardware and new algorithm [5-10]. However, no one have handled the RF module where consumes the greatest power during the WSN system operation. So we can expect decrease in power consumption if we handle it.

And next we check the programming for WSN system. The WSN system use TinyOS for programming. TinyOS is a free and open source component-based operating system and platform targeting wireless sensor networks. TinyOS is an embedded operating system which is written by nesC programming language as a set of cooperating tasks and processes [2][5]. When the RF communication is done each tag node during the WSN systems operating, power consumption is greatest.

In this paper proposed the method of low power consumption for WSN system. The proposed method is to control RF module with turning on and off it periodically. However, if RF module toggle, the data may be lost, because the tag node can’t receive and transmit any data during RF communication. So we save power and consider the data loss together.

In order to verify the effectiveness of the proposed system, we performed experiments on the counter synchronization, data loss, and power consumption. In various tag nodes, this paper using K-mote based on Telos. The Telos hardware use MSP430 of Texas Instruments for MCU and CC2420 ZigBee chip of Chipcon for RF module, and we use TinyOS for programming.

2. Low power system for WSN

2.1. WSN

WSN consists of the sensor node, router, sink node (base station), internet, server, and manager. The most basic components of the WSN technique are sensor nodes. The sensor node consists of sensors, communication module, memory, processor, and batteries, the following conditions are required [1, 3].

① moderate level of computing power

② small size

③ long life (operate time)

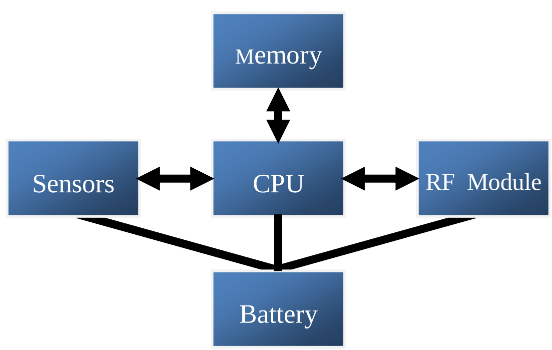

Figure 1. The Block Diagram of Sensor Node

And next part is software part. In the field of sensor networks, the actual implementation and the application most widely is the TinyOS. TinyOS is a free and open source component-based operating system and platform targeting wireless sensor networks. It started as collaboration between the University of California, Berkeley in co-operation with Intel Research and Crossbow Technology, and has since grown to be an international consortium, the TinyOS Alliance [5]. Especially we use TinyOs -1.x version for stable development. The above version has been developed for a long time so more stabilized than TinyOs-2.x version. TinyOS is an embedded operating system which is written by nesC programming language as a set of cooperating tasks and processes [5].

It is a kind way of the pre-processor. The nesC is a component-based and syntax is similar to the C programming language. The nesC compiler convert source code into C program file and this file is responsible compile and link through the GCC (GNU Compiler Collection) compiler [6]. Figure 2 shows the nesC compiler process.

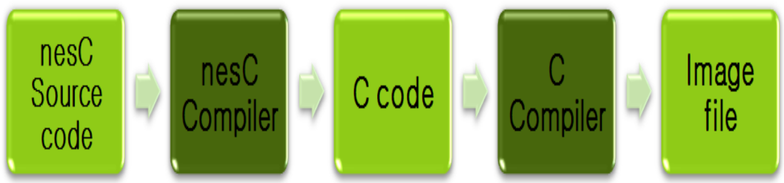

Figure 2. The nesC compiler process

With population of C programming language, Use TinyOS will avoid some mistakes when we program, implement and troubleshoot this system. Update for system will be easier [4].

2.2. Low power consumption method

To minimize the power consumption of sensor nodes is hardware or software methods. The hardware method for the reducing power consumption of sensor nodes can be designed MCU, RF modules, sensors, and in addition to the additional circuitry.

Figure 3 is the block diagram of the circuit of hardware method for sensor nodes of low power configuration [9-10].

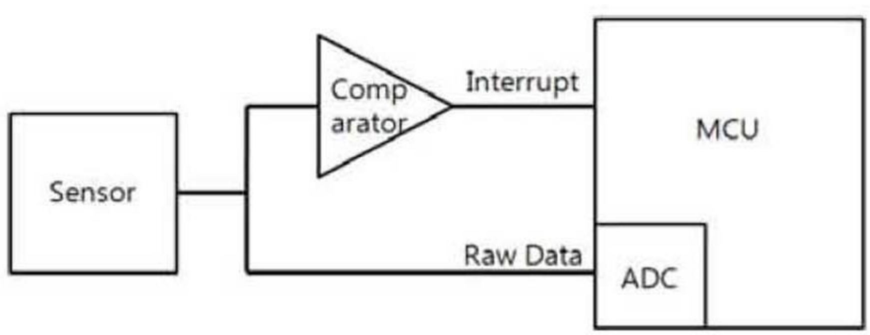

Figure 3. The block diagram of hardware method for low power consumption

The method of software for low power system has developed various algorithms such as clustering network, election of cluster head, selection of optimum route in multi hop sensor network, and so on. These algorithms optimize used each application system and are saved power consumption. Figure 4 shows the block diagram of software method for low power consumption [7].

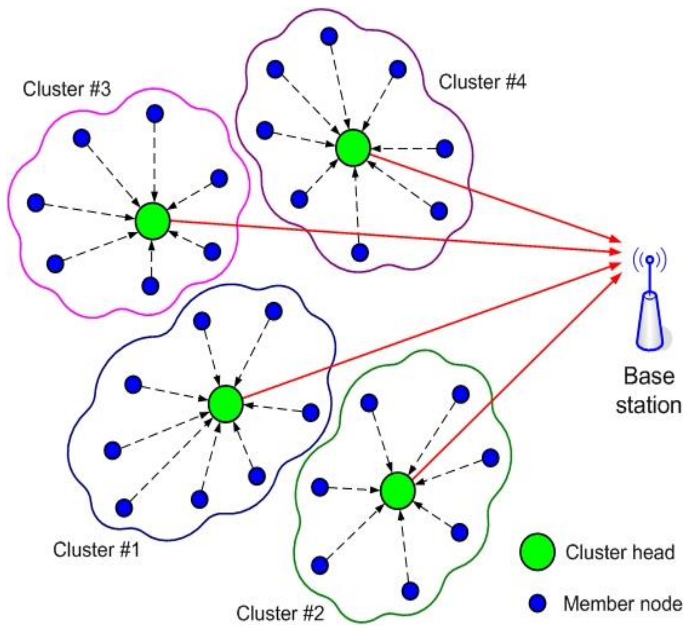

Figure 4. The block diagram of software method for low power consumption

Each tag node transmits the data to base station. But in this system, some each tag node is same like the base station and receives data from around the tag node. This tag nod such as base station is cluster head and around tag nod is member node. Member nodes begin sleep mode after transmit itself data. Thus the tag that more stays sleep mode saves power consumption [7].

3. Proposed low power system

In this paper, we used K-mote based on Telos for sensor node. The Telos hardware use MSP430 of Texas Instruments for MCU and CC2420 ZigBee chip of Chipcon for RF module and it uses two AA-size batteries. Figure 5 and Table 1 each shows the picture of K-mote [4] and power consumption of CC2420.

Figure 5. K-mote

Table 1. Power consumption of CC2420 according to operating mode [3]

Kind of operating mode	Power consumption(mW)
Active power (MCU active)	3
Sleep power (MCU sleep)	0.015
RX power (MCU-RF module active)	38
TX power (MCU-RF module active)	35

According to Table 1, we can find that there is the greatest power consumption in RX(Receiver X-tal) and TX(Transmitter X-tal) power mode. Therefore, if we handle the RF module, we will save the power in WSN system. We should not be only handled RF module on/off because the tag node can't receive data when the RF module off cycle. It can causes data loss, so we must consider the prevention about data loss and RF module handling for low power system together. This paper suggests the new low power system for WSN handling the RF module and using new algorithm according to state for prevention data loss.

3.1. RF module On/Off cycle

The RF module always turns on, while the tag node operates. The RF module not only transmits the data in the tag node, also receives data from another tag node, so it must ready for communication. However RF module operation is greatest power consumption more than 10 times CPU operation. So we need to handle the RF module for save power. We control the RF module cycle such as Figure 6.

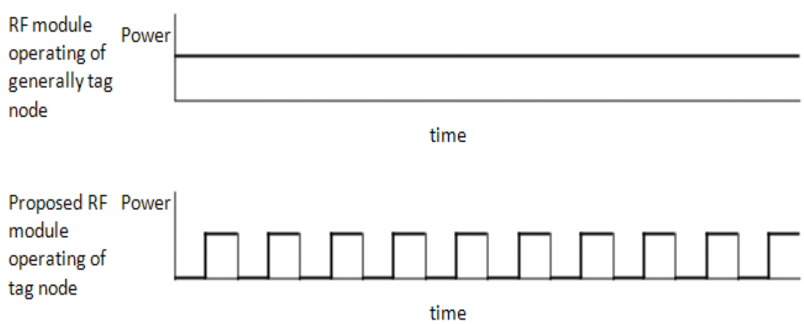

Figure 6. Compare RF module operating period

Generally RF module is always turned on. But proposed system is toggled states on/off. The RF module turn on minimize time for transmission, turn off for saving power, turn on minimize time for reception data and turn off for saving power periodically. Using toggled states, we expect reduction of power as number of RF module is turned off. However this system causes data loss. So we need to prevention for it. We have to consider RF module on/off cycle. The tag node transmits or receives data, while the RF module operates. But power consumption is highest. So we need to minimize the RF module on cycle.

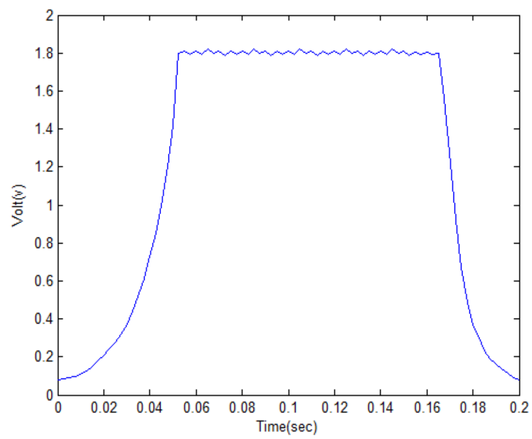

Figure 7. RF module Toggle output graph

The Figure 7 is output volt graph when the RF module operates 2 second. The RF module doesn't operate as soon as turn on such as Figure 7. Besides the RF module stop action is also. So we decide the RF module on/off cycle, considering operation margin time.

$$V = 1.778 * 10^7 * t^5 - 1.73 * 10^6 * t^4 + 6.577 * 10^4 * t^3 - 758.2 * t^2 + 6.17 * t + 0.07502 \qquad (1)$$

$$V = -1.864 * 10^{10} * t^6 + 2.322 * 10^9 * t^5 - 1.115 * 10^8 * t^4 + 2.502 * 10^6 * t^3 (2) 2.263 * 10^4 * t^2 - 45.77 * t + 1.797$$

Through the graph of Figure 7, we can derive the equation (1) and (2) for calculation on/off margin time. The equation (1) is operation margin time function when the RF module turns on. The equation (2) is stop margin time function when the RF module turns off. Through these two equations, this paper calculates the operation margin time and stop margin time as follow.

① Operation margin time : 0.0527 second

② Stop margin time : 0.037 second

We have to run the RF module 0.0897 second to the RF module normally operate according to margin time. So this paper decides minimum RF module operation time at 0.0897 second. Then we need to decide RF module stop action time. This part we must decide carefully. While the RF module stops, the tag node can't transmit and receive any data. It can cause data loss. So we check this part in next Section 3.2 about prevention data loss.

Next, Coding the WSN source code, we can realize RF module on/off periodically operation. Typically, we use the function StdControl when we code the WSN algorithm. It acts the each basic component of tag node. This basic component also includes the RF module action.

Generally, the function StdControl is declared front, this coding can't control the RF module. So we must extract the element of RF module in function StdControl.

If we extract the function Commcontrol in function StdControl, we can control the RF module on/off. Also we can control the RF module action cycle, using the function Timer.

3.2 Preventing data omission

3.2.1. Counter synchronization: The tag node have counter for action standard. It operates sensing, saving, processing, transmitting and receiving according to the counter. When we administrate many tag node, the counter synchronization of these is very important. If we don't do counter synchronization, the tag node will each different act and can't transmit-receive data. These things lead to data loss. So we must control the counter for synchronization.

The counter starts when the each tag node is turned on. So we have to determine the counter criteria node and time for the counter synchronization. The counter criteria node must center of communication between the each tag node and can be excluded for power reduction target. The tag node that satisfies these conditions is base station node. The base station node is linked each node and communicate the data. It also is powered in the center of the device. Therefore we select the base station node for counter criteria node. Next we will check about synchronization time. The counter starts when the each tag node is turned on as before. Then, if the counter synchronization at base station node starts when each tag node turn on, we can control each tag node at the same time more simple and easy. It also prevents the data loss occurring different counter in each tag node.

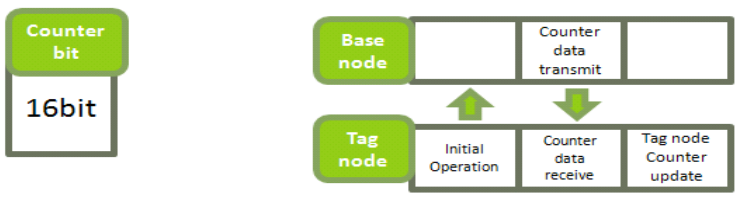

Figure 8. Counter of the tag node update in initial operation

The tag node has 16bit as counter bit and using this bit, operate system. This counter bit controls the cycle of RF module on/off. On the basis of the counter bit of the base station, the counter bit of the tag node update. The tag node counter bit update in initial operation such as Figure 8. It requests the counter bit data to base station and base station transmit itself counter bit data to the tag node. This counter synchronization not only initial operate but also operate every transmission and receipt between the tag node and the base station. This counter synchronization can reduce loss data between tag node and base station.

3.2.2. Tag node Algorithm: The tag nodes are all the nodes except the base station. These perform work such as sensing information, saving data and transmitting data to base station. These tag nodes are the target for reducing the power consumption. Therefore this paper proposed the tag node algorithm to reduce the power consumption and data omission prevention. We just check the RF module on/off margin time in Section 3.1. And next we select the on/off cycle. We have to determine how long the RF module operates and stops.

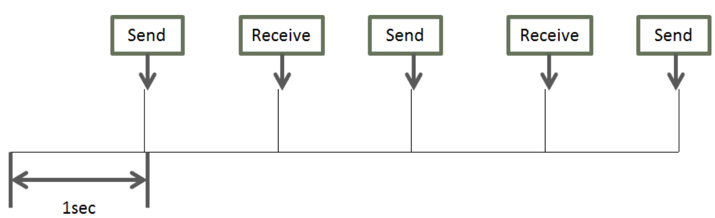

Figure 9. RF module of the tag node on/off cycle

Such as Figure 9, this paper's proposed tag node has cycle of on/off RF module power. This RF module of the tag node operates 0.0897 second. It is minimum operation time according to Section 3.1. And RF module turns off during 1 second. This time is correct for catching and sending data to the other node and saving the power. When the RF module operates, the tag node has two conditions that are send condition and receive condition. It operates send or receives data periodically in 2 second. Using this algorithm, we can prevention data loss and save power together.

3.2.3. Base station Algorithm: The base station mainly receives the data from the tag node and processes it. However, sometimes the base station sends the data to the tag nodes for transmission command. If the base station unilaterally receives the data from tag nodes, the data loss should not occur. But it's not. We can say about not occulting data loss when the tag nodes all receive the data from the base station. So we need to check the reception data in tag node. But we can't check this by the usual way. Therefore this paper proposed base station algorithm for prevention data loss checking the data reception in tag nodes.

This algorithm uses two kinds of bit (Mode bit and Check bit). The mode bit use diving three modes at the base station such as Table 2. And the check bit checks the receipt data from the base station at the tag node such as Table 3.

Table 1. The mode according to mode bit

Mode bit	Mode
0	Receive mode
1	Transmit and Receive mode
2	Transition mode

Table 2. The satus according to check bit

Check bit	States
0	Normal
1	Receive data from base station

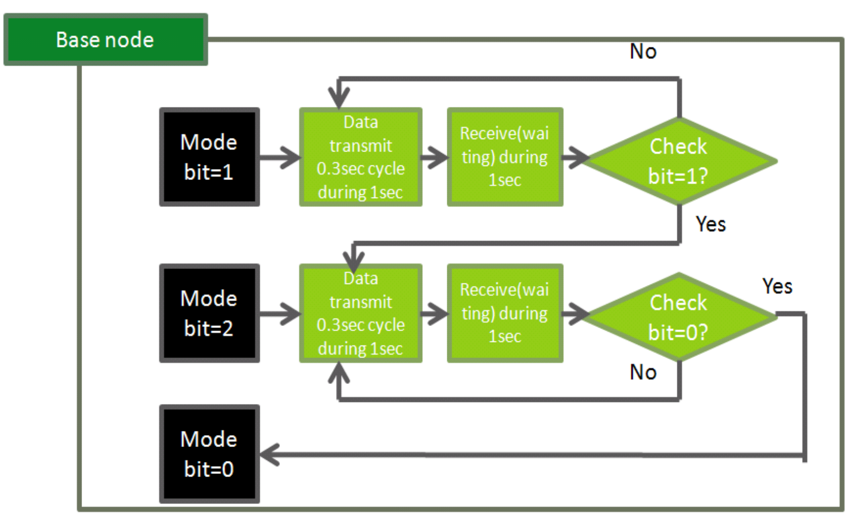

Figure 10. The Base station algorithm flowchart

The base station usually only receives data. However when it will transmit the data, not only receive the data, to the tag node, it special operate such as Figure 10. We check the meaning of mode bit and check bit. This system use these bit and communicate between the tag node and the base station without loss data. It has two cycles (Data transmit cycle and Receive cycle). The base station transmits itself data and checks the tag node data during 1sec. We can save power without data loss using this algorithm.

4. Experiment

4.1. Counter synchronization experiment

First we must check the counter synchronization the tag node with the base station. The counter synchronization prevents data loss as a discordance of on/off period between the tag node and the base station.

Figure 11 is experiment about counter synchronization using LED. This experiment uses red and blue LEDs. These two LEDs toggle in consecutive order. We can easily check the counter synchronization to see the LEDs. However this experiment is not correct. So this paper uses Listen command in Linux such as Figure 12.

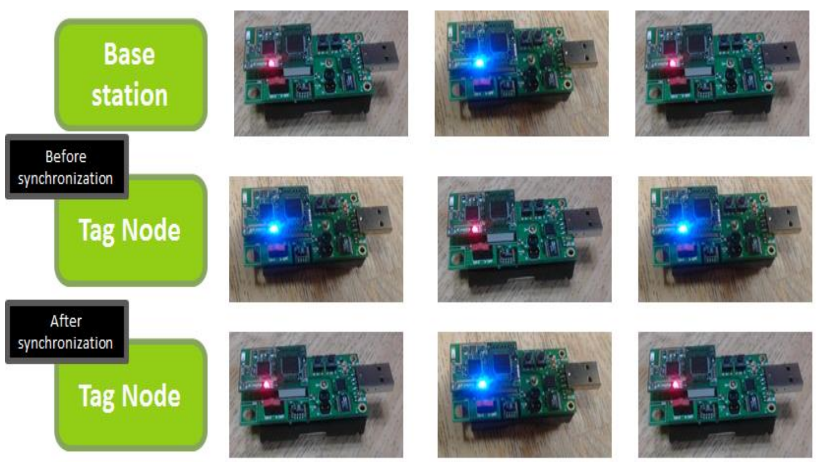

Figure 11. Counter synchronization experiment using LED

We can find that counter bit add one when the base station output the data packet in Linux window. In the middle of Linux window, we can see the “00 00” counter bit. This counter bit is not the base station’s counter bit. It’s tag node’s counter bit that start the tag node as initial condition. The tag node’s counter bit soon change 00 04 by base station’s counter bit. We can know the counter synchronization occurrence by this one.

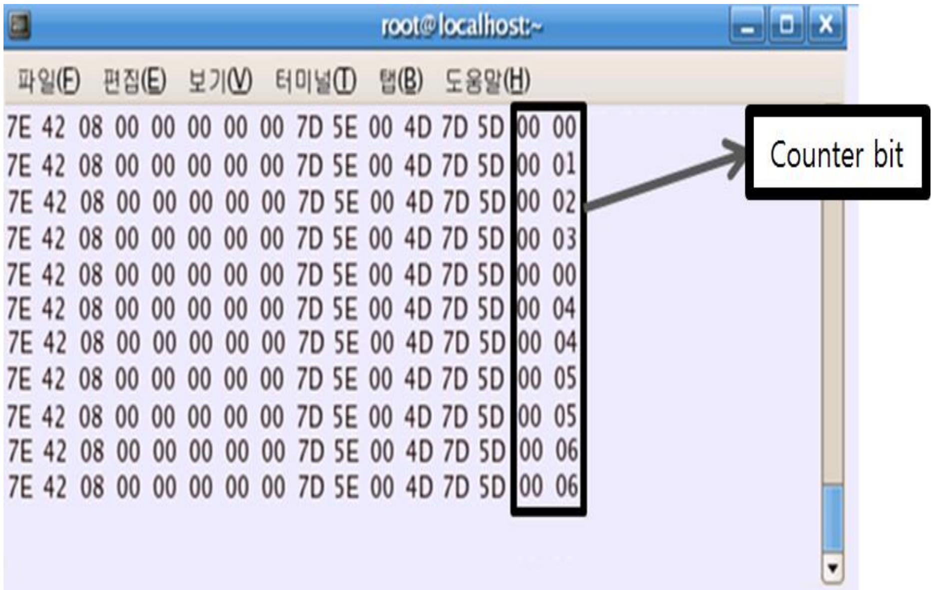

Figure 12. Counter synchronization experiment using Listen command

Table 4 is success rate of counter synchronization. The experiment carries out 30th times and the distance between the tag node and base station is changed. The experimental environment is sunny morning in open place.

Table 3. Success rate of counter sysnchronization experiment

Distance between the tag node and the base station	Success rate(30th times)
5m	100%
10m	100%
15m	100%
20m	100%
25m	83%

Following this experimental result data, we can be sure this system doesn't occur data omision due to counter synchronization in 25m radius.

4.2. Data omission experiment

We check the data omission when the tag nodes communicate the each other in this section. Table 5 is result of suceeded receive rate between the tag nodes. This experiment repeat 30th times and the number of tag nodes and the distance between the each tag nodes is changed. This experiment carries out sunny day in open place and we can find the data loss through this experiment.

Table 5. Data receive rate experiment result

Number of the tag node	Distance	Data receive rate(30th times)
5	5m	100%
10		100%
5	10m	100%
10		100%
5	15m	100%
10		100%
5	20m	100%
10		100%
5	25m	100%
10		100%
5	30m	100%
10		100%

Through the data receive rate experiment result, we can see that data loss doen't occur when the each nodes communicate. The delay time form receive mode to transmit and receive mode during the communication is different each distance even if the data receive is 100%. Table 6 is delay time experiment result. This experimental environment is same the data receive rate experiment.

Table 6. Delay time experiment result

Number of the tag node	Distance	Delay time(30th times)
5	5m	2.3 second
10		2.2 second
5	10m	2.2 second
10		2.4 second
5	15m	2.4 second
10		2.3 second
5	20m	3.2 second
10		3.5 second
5	25m	3.5 second
10		3.9 second
5	30m	5.2 second
10		6.2 second

The delay time is almost same bout 2.2 second between the each tag nodes in 15m radius. But the delay time increase at 3 second in 20m radius and extremely increase in 30m radius. This paper use K-mote based on Telos of device for designing low power system. The K-mote has CC2420 chip for RF module. The 25m is the radius of the trust receives by this chip. Therefore we can predict the extremely increment about delay time in 30m radius.

4.3. Power consumption experiment

Experiment was a clear day, the distance between the base station and the tag nodes were measured at 10m. Power supply of 1.5V 2800mAh AA size batteries was used.
Figure 13 is output volt versus time graph. We check the applied algorithm in tag node in Section 3.2.2. The RF module minimum operates and stops during 1 second.
Through the graph, we can calculate the life of ta node in various application areas. Table 7 is the comparing data between the existing system and the proposed system. The life of proposed system is calculated through the graph.

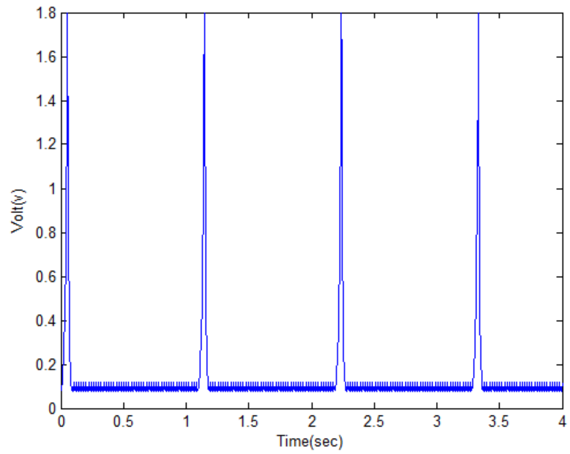

Figure 13. Power consumption graph

Table 7. Life Expectancy

Whether to use the proposed algorithm	Life expectancy
Don’t use	5 days 12 hours
Use	62 days 1 hours

We can find the excellence of proposed system according to Table 4-4 and the proposed system is 12 times longger than existing system.

5. Conclusion

When applied to several applications each sensor node used in the WSN technology, small size and behavior for a long time should be. Firstly, it is necessary to design a small size, the power supply used by the sensor nodes, the use of having a limited capacity, such as a small battery. Node, such as a long period of time in a limited capacity to work should be managed to minimize the power consumed by it. Therefore we study about long life of sensor node for applied various application area.

In this paper proposed the reduced method of power consumption for WSN system. The proposed method is to control RF module with turning on and off it periodically. However, if RF module toggle, the data may be lost, becase the tag node can’t receive and transmit any data during RF communication. So we save power and consider the data loss together. In order to verify the effectiveness of proposed method, we have done the experiment and it confirmed as follows.

① Operating cycle: RF module of the tag node minimum operates 0.0897 second. And RF module turns off during 1 second. When the RF module operates, the tag node has two conditions that are send condition and receive condition. It operates send or receives data periodically in 2 second.

② The base station has three conditions: reception condition, transmission-reception condition and transition condition.

③ Counter synchronization of each tag nodes.

④ No data omissions during RF communication

⑤ Extended life time of 12 times longer than existing WSN system.

Acknowledgements

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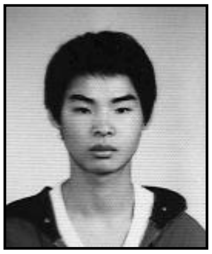

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