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WBAN 환경에서 효율적인 라우팅을 위한 3차원 좌표 주소할당 기법의 적용

이준혁*

요 약

WBAN은 인체 내부 및 외부에 부착한 디바이스를 무선으로 연결하여 통신하는 근거리 무선통신 기술로 IEEE 802.15.6 TG BAN을 중심으로 물리, 데이터 링크, 네트워크, 응용계층에서 표준화가 진행되고 있다. WBAN 기술은 전력제한 및 생체특성을 반영하여 센서와 지그비 디바이스를 사용하여 에너지 효율적으로 구성한다. 무선 센서 네트워크는 다수의 센서노드와 센서노드가 전송하는 센싱 데이터를 수집하는 싱크노드로 구성된다. 센서노드는 넓은 지역에 정해진 형태없이 배치되어 프로토콜에 의해 자가구성 능력을 가진다. 본 논문에서는 WBAN 환경에서 적용되고 있는 ZigBee 무선 통신 환경의 주소 지정 방식과 라우팅 알고리즘의 성능을 향상시키기 위한 새로운 좌표 값 알고리즘을 제안하였다. 기존 $Cskip$ 알고리즘을 이용한 분산 주소 할당 기법의 낭비되는 주소공간의 문제를 해결하기 위해 (x,y,z) 3개의 좌표 축을 제안하여 16bit 주소공간을 분할하여 사용한다. 각 노드에서 라우팅 시 좌표 값을 이용하여 적은 비트별 연산이 수행되며 멀티 홉을 감소시킬 수 있다. 이에 대한 성능 분석으로 제안한 알고리즘은 수학적 분석 모델을 사용하였고 ZigBee 무선 통신 환경의 계층적 라우팅에서 사용하는 경로 벡터를 사용하여 센서 노드의 멀티 홉 카운트 결과를 도출하였다. 수학적 분석 결과 ZigBee 분산 주소 할당 기법과 기존 알고리즘에 비해 평균 멀티 홉의 수가 감소함으로써 에너지 효율이 향상됨을 입증하였다.

키워드 : 무선센서 네트워크, 지그비 디바이스, 라우팅 알고리즘

A Distributed address allocation scheme based on three-dimensional coordinate for efficient routing in WBAN

Jun-Hyuk Lee*

Abstract

The WBAN technology means a short distance wireless network which provides each device interactive communication by connecting devices inside and outside of body. Standardization on the physical layer, data link layer, network layer and application layer is in progress by IEEE 802.15.6 TG BAN. Wireless body area network is usually configured in energy efficient using sensor and zigbee device due to the power limitation and the characteristics of human body. Wireless sensor network consist of sensor field and sink node. Sensor field are composed a lot of sensor node and sink node collect sensing data. Wireless sensor network has capacity of the self constitution by protocol where placed in large area without fixed position. In this paper, we proposed the efficient addressing scheme for improving the performance of routing algorithm by using ZigBee in WBAN environment. A distributed address allocation scheme used an existing algorithm that has wasted in address space. Therefore proposing x, y and z coordinate axes from divided address space of 16 bit to solve this problems. Each node was reduced not only bitwise but also multi hop using the coordinate axes while routing than $Cskip$ algorithm. I compared the performance between the standard and the proposed mechanism through the numerical analysis. Simulation verified performance about decrease averaging multi hop count that compare proposing algorithm and another. The numerical analysis results show that proposed algorithm reduced the multi hop better than ZigBee distributed address assignment

Keywords : WBAN, WSN, ZigBee, routing

1. Introduction

U-healthacre technology makes available for the chronic patients, livingalone seniors, recovering patients, or post-operation patients to measure and monitor their physical conditions and receive expert service instantly in their daily lives based on wired communication and wireless networks(Bluetooth, ZigBee, UWB, WLAN)[1].

Wireless sensor network consist of sensor field and sink node. Sensor fields are composed a lot of sensor node and sink node connects the sensor field and external network. Sensor nodes transmit data to sink nodes according to the event generation in the sensor field or sensor nodes transmit data to sink nodes by the request message of sink nodes[2].

ZigBee is one of the representative techniques of long distance wireless sensor network with low power, low price, and availability. It builds on PHY layor and MAC layor and upper layor, Network, APL layors are defined in ZigBee Specification.

ZigBee wireless communication is the standard technique for Healthcare, HB, and data network with low transmission speed. It can collect and control viral reaction sensor rates everywhere, and it can be usefully and diversely used with the telephone communication through the Internet[3][4][5].

The logically formed network, however, has a disadvantage of increasing the wasting address space when the sensor is arranged in reality[6].

In this study, when the node transmits data, in order to have better multi-hop than the existing ZigBee distributed address allocation and solve the problem of wasting address spaces, I propose an algorithm using three coordination values(x,y,z).

This thesis is structured as followings. Chapter II described about WBAN, routing algorithm, existing distributed address allocations algorithm, and proposing effective address allocations algorithm.

In addition, it explained the proposing algorithm in terms of distance vector and route vector.

Chater III compared and analyzed performance evaluation about the routing applying proposing algorithm. Lastly, Chapter IV described the conclusion and the suggestion for future research.

2. Related Research

2.1 summary of WBAN

WBAN consists of one sink coordinator and numerous sensor devices around the human.

WBAN device is attached or implanted into the body by applying like (Figure 1), and it is used for the entertainment application for the viral information or its collection. Coordinator composes topology with devices around it and provides bidirectional communication. And it controls devices and transmit collected data to sink.

Coordinator also provides multimedia services to the users with the form of personal portable terminal, and allows them to gather, analyze, and control their health information.

※ Corresponding Author : Jun-Hyuk Lee
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Accepted : December 20, 2014
* Sahmyook Health University College, Department of Medical Information System
Tel: +82-2-3407-8674, Fax: +82-2-3407-8679
email: jhlee@shu.ac.kr
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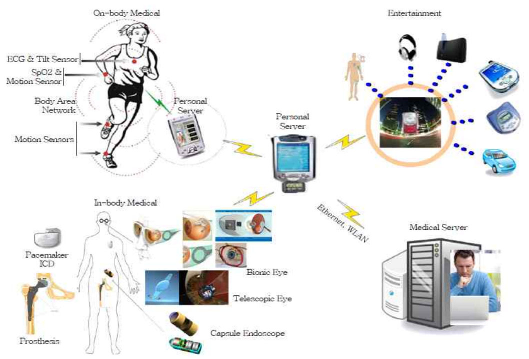
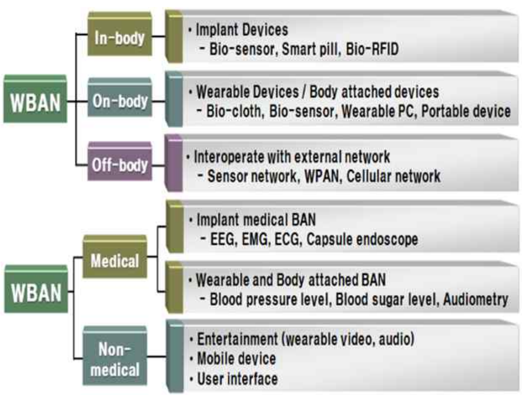


(Figure 1) WBAN concept

WBAN is divided into the medical and nonmedical service according to the kinds of application services.

The medical service is divided into the implantable and wearable device and the nonmedical service provides entertainment service such as sending voice, video, data stream, etc.

In order to provide these services, as WBAN device is implanted into the body and has a function of transmitting personal medical information reliably, it requires the characteristics such as latency. low-power, error rate, and loss factor[6][7][8].



(Figure 2) WBAN application service

2.2 ZigBee Network

The nodes consisting ZigBee network are divided into the coordinator having the routing function and the end device that does not have the routing function.

Coordinator has a function of routing and a role of starting the network..

Since router has a routing function, it has a role of intermediate node and it can possess child-node.

On the other hand, the end device does not have the function of routing, it cannot possess child-node and has a function of reducing energy consumption with its sleep mode.

As a routing algorithm that is established in ZigBee standard, tree routing skill is used when IEEE 802.15.4 MAC is beacon-enable mode, and mesh routing skill is used when it is non-beacon mode.

ZibBee tree routing network consists of tree construction by the parent-child relationship.

Firstly, the coordinator is designated as a top parent node and other lower nodes are located from the closer child-nodes of the coordinator while forming a radial shape. Basically the tree routing skill is activated by distributed address allocation.

Coordinator and router can allocate 16bit of address to the new node asking their access to the network, thus can allocate 2^{16}=65536 of nodes.

This address can be the only address for routing within the network. The coordinator and router that enable the address allocation to their child node have the range of address for the allocation according to their depth of network. This can be calculated with $Cskip$ algorithm.

$$Cskip(d) = \begin{cases} 1 + C_m \times (L_m - d - 1) & ,\text{if } R_m = 1 \\ \dfrac{1 + C_m - R_m - C_m \times R_m^{L_m - d - 1}}{1 - R_m} & ,otherwise \end{cases}$$

(1)

The variables about the formula(1) can be tabulated as in <Table 1>

Variable	Description
$Cskip(d)$	the range of block address that each node can allocate
C_m	The maximal number of child nodes each node can have
L_m	Maximal depth of network
R_m	The maximal number of routers that can have as child
d	Their own network depth

<Table 1> Variables for Equation (1)

Using the above $Cskip$ algorithm, we find the range of block address. Then, the top parent-node that accepts the access of new node allocates addresses of newly added nodes using the formula(2). When we find the range of block address that the node can allocate using the $Cskip$ algorithm., the parent-node that accepts the access of new node allocates addresses using the formula (2)[9].

$$A_n = A_{parent} + Cskip(d) \times m + 1 \qquad (2)$$

Variable	Description
A_n	Address allocating for new nodes
A_{parent}	Parent-address allocation address
m	The number of routers Parent-nodes has at the moment.

<Table 2> Variables for Equation (2)

The variables about the formula(2) can be tabulated as in <Table 2>

When the depth and the maximal number of cnild-nodes and routers are determined, newly added nodes' addresses can be distributed using the formula(1) and (2). ZigBee Tree routing algorithm is a method to send data using simple calculating formula and distribute address allocation skills without any separate routing table.

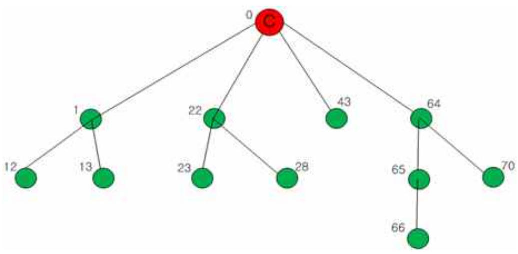
This method, however, has a problem in that it only transmit data to parent-nodes or child-nodes.

After the address allocation using the formula(2), when one of routers receives the destination address it wishes to communicate, it transmits this data to other child-nodes if formula(3) is valid, and it transmits to parent-node if not valid[8].

The parent-node receiving this data repeats these process, thus makes tree routing.

$$A_r < D < A_r + Cskip(d-1) \qquad (3)$$

A_r means the router's own address, and D means destination address. The parent-node receiving the data repeats these process, thus makes tree routing.



(Figure 3) Address allocation when C_m=R_m=4and L_m= 3

D	$Cskip(d)$
0	21
1	5
2	1
3	0

<Table 3> $Cskip(d)$ when C_m=R_m= 4, L_m= 3

(Figure 3) reveals that the each node's maximal number of child-nodes are 4, the child node's maximum routers are 4, and the example of address allocation when the maximal depth of network is 3.

According to this example, when the current d is 0 the value of $Cskip(0)$ is 21 by the formula(1).

When the coordinator allocated address 0 and allocagtes. Then add the value of second child address to the value of $Cskip(0)$, 21

Like this way of allocating address value of second depth, we use the value of $Cskip(1)$ to allocate the node address of first depth.

Although we allocate the 21 address scopes for each node, however, it creates the waste of address space if one router's numbers of sensor-nodes are not allocated as much as the address block scopes.

Thus, in order to solve the space waste problem, new address allocation method is proposed.

2.3 Route search

In network hierarchy, finding the appropriate route for sending data frame to the destination is the first priority. ZigBee spec provides two route search algorithms, hierarchical routing and route search, and these algorithm has its benefits and drawbacks. The standard recommend using two algorithms depending on appropriate situations.

2.3.1 Hierarchical routing

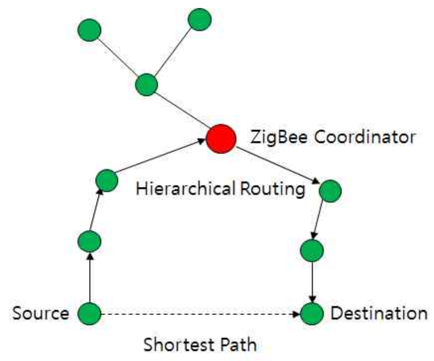
ZigBee hierarchical routing is possible as ZigBee address is hierarchically allocated.

Thanks to the 16bit addresses allocated by logical formula, node can check the destination 16bit addresses of data frame and find out whether the destination exists within its own address block scope.

If the destination address A is smaller than the value of $Cskip(d-1)$ plus its address, it means that the destination is one of its own childs.

Node applies these calculations to its childs and send data frame to the nodes that supposed to have the destination as childs. Hierarchical routing does not consume the additional resource such as routing table, and consists of simple algorithm.

However, the hierarchical routing algorithm reveals the shortest path problem like the (Figure 4) the node within one-hop has to pass several nodes inefficiently.



(Figure 4) Shortest path problem in hierarchical routing

2.3.2 Route search algorithm

In order to solve the shortest path problem in hierarchical routing, ZigBee provides route search algorithm. Route search is the On-demand routing protocol that search for the route when it is required for sending data go the destination. And it has a characteristic of distance vector routing that each node has the next route for the destination.

ZigBee cordinator and ZigBee routers with the ability of router have Route table that save the destination and relations of around nodes. The network hierarchy find the route to the destination based on this table for sending data.

<Table 4> shows the routing table fields used for path navigation.

Field Name	Size	Description
Destination address	2 Bytes	Network Address for Destination 16bits
Status	3 bits	Route Status
Next-hop address	2 Bytes	Next Node for for Destination 16bits

<Table 4> Routing tables fields used for path navigation

If there is no information about destination address of data frame in the route table, ZigBee network hierarchy gives order of route response to the destination address. This frame is flooding until it finds the response nodes that know the destination or the route to the destination

As passing through nodes, the route request frame calculate the expense of rink between nodes and save it. The response node choose the cheapest route among the received several route request frames and send the route request frame to the first node. All the nodes between the first nodes and response nodes make new entry to the route request frame of route search table and save the information.

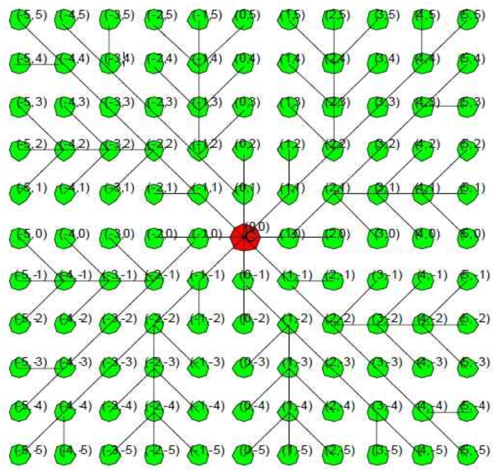
The entry of route search table disappears after a period of time but the route information of route table exists and is used for the next route request.

2.4 Address allocation using (x,y) coordinates

Unlike the existing address allocation method, this algorithm takes the concept of coordinate plane. Centered on the coordinator in coordinates, the addresses are allocated in order.

When expressing the address, it formulates 8 bits each in x and y. By so doing, we can have the number of 2^{16}=65536 address values as a result of combination from (0,0) to (255,255)

In order to have the coordinate value of (0, 0) with the coordinator as the center of the coordinate, the range from (-128, -128) to (128, 128) is expressed.



(Figure 5) (x, y) coordinates using a routing path

In (Figure 5) the sensors spread out centered coordinator in the coordinate. Generally, the address value of 16bit shows only the ID value of sensor node. Using these coordinate values, however, we can express the address, find the distance to the coordinator, and can transmit to the closest value to the coordinate (0,0) in tree routing.

In addition, if we allocate the address as the value of coordinate plane and make the distance between each sensors about 30 meter, the maximal depth of the network is 127 and the distance between the coordinator and the laster sensor is 30×127=3810m. Thus, by placing sensors about 3.8km apart around four directions, the values of each sensor can be read. Since these ZigBee sensor is structured hierarchically, we should set the communication route.

In order to do that, the administrator randomly puts FFD(Full Function Device) that has both functions of routing and sensing on regular nodes and puts RFD(Reduced Function Device) that has only sensing function on other nodes.

In this case, however, the problem happens about where put the router functioned device.

When constructing sensor network in the

building or apartment, it is not proper to apply the plane coordinates value address allocation method because it becomes 3-dimensional space with some floors.

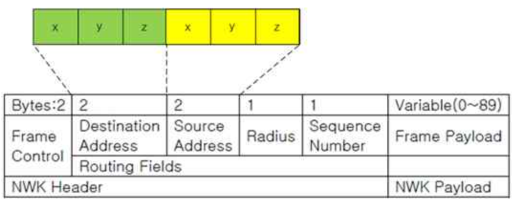
Due to the tendency that sensor nodes should be placed close together, the number of child-nodes is limited. That can be considered as a drawback.

2.5 Supposed Address allocation algorithm

2.5.1 Coordinates plane Address allocation

In Smart Grid environment that can be applied in various areas, three dimensional space should be considered as well as the plane space.

The address field used in ZigBee network allocates and use 2Bytes each to Destination Address and Source Address. Thus, as in (Figure 4) Destination and Source nodes have 16bits of address scopes each and can allocate 65536 of nodes. However, the ingredient of the space in wireless communication environment should be considered sufficiently. And when 65536 of allocated nodes are not met, it cause a waste of address space



(Figure 6) The network layer frame format of the proposed

To solve these problems, this thesis gives 3 different coordinate values (x, y, z) and divides 16bits of space address as seen in (Figure 6).

Since the administrator previously knows the location of each sensor nodes in fixed network, he can allocate fluidly the coordinate values according to each sensor. Routing decisions flow of suggesting algorithm is as in (Figure 7)

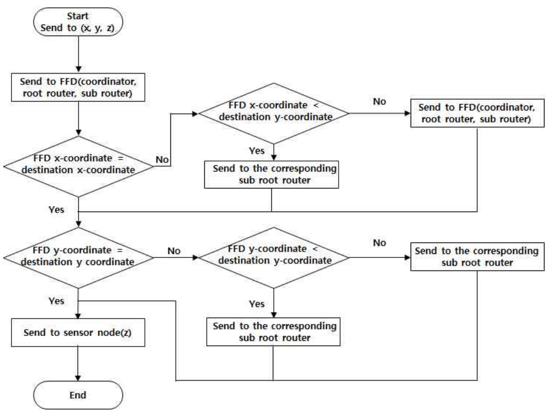
Sensor node that happened event firstly transmits data to the upper FFD device and calculates the value for (x, y, z) coordinates, then sets the routing route according to that.

FFD that received data frist compares the values for x-coordinate and sends data to the related upper/lower route router.

In the FFD device that matched the value for x-coordinate, it compares the values for y-coordinates. And if the values for y-coordinate are the same, it is its own child node and can be transmitted using the value for z-coordinate.

On the other hand, in case that the x-coordinates are not the same, it sends data to the upper route router having same value. And when its value is smaller than the destination address, it sends data to the lower route router.

The value for y-coordinate is also used for comparing and it sends to the appropriate sub-routers and finishes data transmission to the value for z -coordinate that has the same value for final sub-routers.



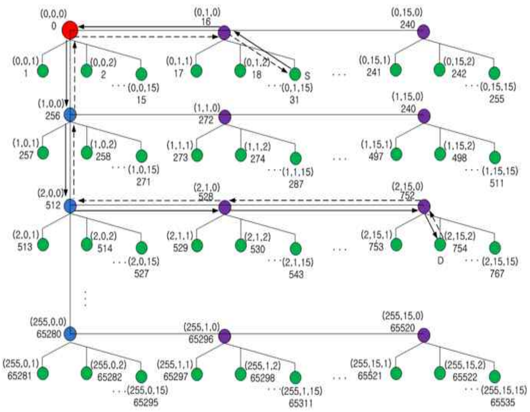
(Figure 7) (x, y, z) coordinates routing decisions Flow

(Figure 8) shows the (x, y, z) a coordinate axis over the coordinate plane.

As a coordinator as a axis, x-axis shows route router and y-axis represents sub router and each of FFD device will administer sensor nodes.

For example, if it sends data from source node(0, 1, 15) to the destination node(2, 15, 0), it starts routing by sending data as packet data unit to the upper sub-router.

Sub-router that received data from the lower node compares its own address and the value for x-coordinate, and as it is larger than its own value, it sends to the upper coordinator. Then the coordinator sends data to the route-router that has the same value for x-coordinate.



(Figure 8) (x,y,z) routing over the coordinate plane

Route-router that received data forwards it again to the sub-router having same y-coordinate value, and compares the value of z-coordinate in the sub-router having the address value of (2, 15, 0), then send to the second sensor-node (2, 15, 2).

In verifying the destination address, it does not calculate all the 16bit addresses, but does it with one coordinate value among coordinates in 3 axis coordinates.

By so doing, we can have faster and more efficient hop -count.

3. Performance Evaluation

3.1 Evaluation

I compared the proposing address allocation method applying the value for (x, y, z) coordinate to the C_{skip} algorithm, ZigBee distribute address allocation method, and the differences of the average number of multi hope using the existing the value for (x, y) coordinate.

In order to simulate the performance evaluation algorithm, I set up the number of maximal hop that can be the same by the number of nodes.

C_{skip} algorithm supposes two network parameter as C_m and R_m.

For the unbiased comparisons, I modified the network parameters and compare the same number of maximal hop counts, same number of close nodes, and the multi hops when the number of maximal network size node is 65536 and when it reduces to 255.

The number of hop count means the route between two random nodes and the average hop count is the sum of all the hop counts from one random node to the another random node.

In initial design of the building, the administrator previously allocates the location information about the sensor nodes to the appropriate value of (x, y, z) coordinate.

The allocated bit means the route-router in x-axis, the sub-router in y-axis, and the value of general sensor nodes in z-axis, and it constructs the equipment following the formula(4).

$$\begin{aligned} &2^x - 1 : \textit{the number of the root router};\\ &2^x \times (2^y - 1) : \textit{the number of the subrouter};\\ &2^x \times 2^y \times (2^z - 1) : \textit{the number of the sensor node}; \end{aligned} \quad (4)$$

In order to calculate the average hope, use the formula(5) when Z=0

$$|x_d - x_s| + |y_d - y_s| = hop\ count \quad (5)$$

When $Z \neq 0$, follow the formula(6)

$$|x_d - x_s| + |y_d - y_s| + |1| = hop\ count \quad (6)$$

x_s indicates source address and x_d, destination address. And when the calculated the whole hop count sum through formula(5) and formula(6) is divided by the number of allocated nodes, we can calculate the average hop count following formula(7).

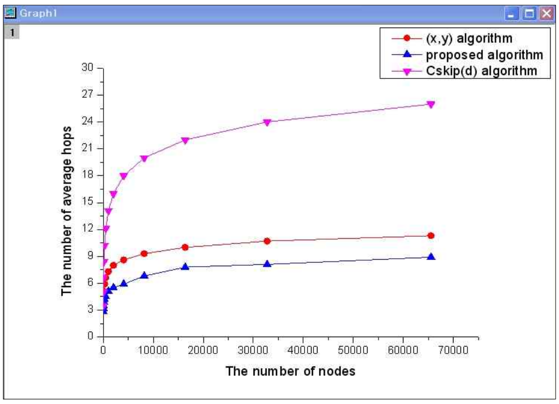
$$Average\ hops = \frac{Total\ hop\ count}{Maximum\ vmber\ of\ senser\ node} \quad (7)$$

3.2. Result Analysis

These are the comparisons of the average hopes after the arrangement of the maximum 65536 nodes

Nodes Number	Cskip Average Hop of Algorithm	coordinates(x,y) Average Hop	coordinates(x,y,z) Average Hop
1023	14.1	7.3	5.1
2047	16.0	8.0	5.5
4095	18.0	8.6	5.9
8191	20.0	9.3	6.8
16383	22.0	10.0	7.8
32767	24.0	10.7	8.1
65535	26.0	11.3	8.9

<Table 5> The comparison table of the average hops(node 65535)



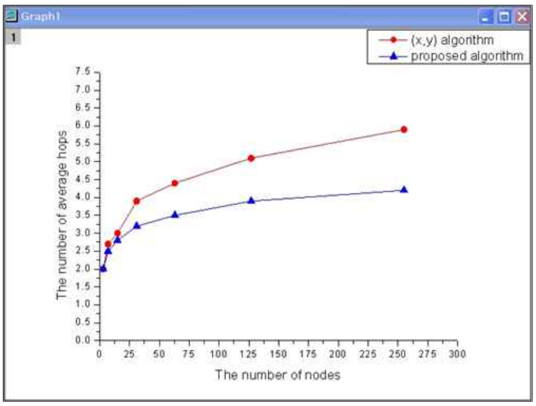
(Figure 9) (8, 4, 4) coordinate the total node 65,536

In (Figure 9) the proposed algorithm shows significant decline in the number of multi hop compared to the C_{skip} algorithm of ZigBee distribute address allocation.

Also, it is decreased keeping regular gap comparing with the existing (x, y) distribute. it's shows the difference of the actual average hops between the existing (x, y) coordinate and the proposed algorithm, in 255 of maximal nodes.

Nodes Number	coordinates(x,y) Average Hop	coordinates(x,y,z) Average Hop
3	2	2
7	2.7	2.5
15	3	2.8
31	3.9	3.2
63	4.4	3.5
127	5.1	3.9
255	5.9	4.2

<Table 6> The comparison table of the average hops(node 255)>



(Figure 10) (4, 2, 2) coordinate the total node 255

(Figure10) shows the difference when reducing the number of maximal nodes. Compared to the existing (x, y) algorithm, the proposed algorithm shows the decline of 1.7 in average in 255 of maximal nodes.

As seen in the comparison result, the proposed address allocation algorithm shows the decline of multi hop according to the allocated coordinate value, compared to the existing algorithm .

Decreasing hops in sensor network means reducing the necessary expenses as much.

Thus, in terms of effectiveness of network, the discussion of the sensor network and address allocation method is determined by the average number of multi hops by compared to the other parameters.

4. Conclusion

In this paper, we proposed the efficient addressing scheme for improving the performance of routing algorithm by using ZigBee in WBAN environment.

The allocated 16 bits address fields of ZigBEe network frame is divided and allocated into x, y, and z coordinate axes.

By allocating the address values to the three variables, x, y, and z, the smaller calculation of bits for routing is performed. And it can has the shorter transmittion path, thus reduce node's energy and the network traffic.

By using both route vector of hierarchical routing and distance vector of route search algorithm to devide x, y, and z coordinate axes, the value of coordinate in evaluation of address value from one node to the destination reduces the number of hop count as a result.

In wireless sensor network, reducing the number of hop means saving the necessary expenses as much and reducing energy consumption.

When applying it in Healthcare environment, the sensor nodes can be located appropriately using the coordinate axes proposed by the administrator.

By so doing, it uses the distance vector and routing vector appropriately to the given environment and can do the efficient routing.

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이 준 혁

1997년 : 광운대학교 대학원 (공학석사)
2009년 : 광운대학교 대학원 (공학박사)

2003년～2013년: 한국정보통신기능대학 정보통신설비과 교수
2014년～현 재: 삼육보건대학교 의료정보시스템과 교수
관심분야 : 통신망 관리, 병원네트워크