Efficient Data Gathering Mechanism for Mobile Sink node in ZigBee Network

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Abstract— **In wireless sensor network, sensors distributed at specific regions sense some data, and a sink node collects data from source nodes. The sink node can be one or** few. **By supporting mobility, the sink node can stay in different sensor networks, and can gather specific data that is needed. Recently, many researchers and companies like IEEE 802.15.4 working group and ZigBee alliance are trying to implement sensor networks to apply it to real world. However, the selection mechanism of sink nodes supporting mobility to gather sensed data has not been addressed sufficiently. In this paper, we design a mobile sink node selection mechanism which can collect data sensed in ZigBee-based network for processing information.**

I. Introduction

The concept about wireless sensor network is introduced to sense and to deal with the change of specific phenomenon in wide region, as the industry of ubiquitous computing proceed actively, so there are many researchers working in this field[1].

Currently, relating to wireless sensor network, IEEE 802.15.4 [2][3] by IEEE Standard, has defined Physical and MAC layer. Similarly, ZigBee[4][5] by ZigBee Alliance has defined Network layer and Application Layer and some optional functions, such as security. Each specification describes detail requirements for sensor network implementation. In ZigBee network, however, the operation for mobile sink node is not described. Thus, in order to specify the operations of a sink node supporting mobility, existing specification need to be modified.

In this paper, the procedure that mobile sink node enters into a ZigBee network and collects data from all nodes in the network efficiently. A mobile sink node enters into ZigBee network, associates any router selected by the mobile sink node, and then sends request message to all nodes via the router as a Sink Agent. As a response, each node sends the data recorded to the sink node via the Sink Agent. For such procedures, required frame format and each field have to be modified and added. Also additional procedures are required for mobile sink node.

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II. Related Work

A. Research about a sink node mobility

Two prominent works: 'Directed diffusion [6] and LEACH (Low-Energy Adaptive Clustering Hierarchy) [7], define the operation of data gathering in sensor network. However they work fine under for a sensor network with static sinks.

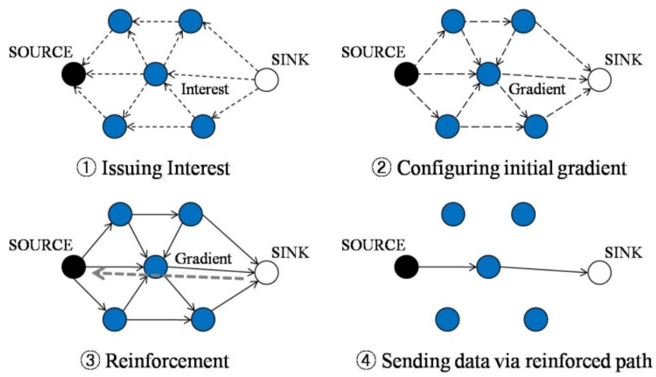

Fig.1 Directed Diffusion

Directed diffusion is data-centric and flat routing. A sink node sends its interest messages to the neighbour nodes. After that the gradient is configured in response to the interest. The sink node requests data to all nodes via multi-hop configured by such scheme. After that optimal paths are reinforced and the data are sent via these paths. This method is efficient if there are many requests from a sink node in the network. But, if the sink node moves frequently, it's not efficient and the message overlapping problem can be occurred because of a lot of flooding, which causes battery to be drained quickly. Because when the sensor node starts the transmission, the battery consumption of the node is increased more than other work, such as data receipt or data processing [8].

LEACH (Low-Energy Adaptive Clustering Hierarchy) is hierarchical and cluster routing, to distribute energy consumption fairly among all nodes in the network. The role of cluster head with highest energy consumption rate is taken over to another node randomly. Each cluster gathers data and sends them to the node on higher layer, the sink node can gather all data through this node. LEACH can solve the message overlapping problem of Directed diffusion, but the data or messages have to pass only the parent or child nodes on the way to destination, which reduces the effectiveness of this scheme.

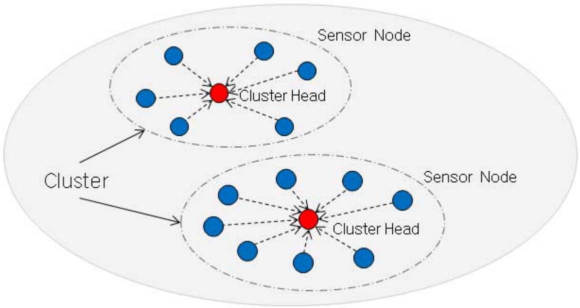

Fig.2 LEACH

B. IEEE 802.15.4

1) Association procedure

In order to associate with other nodes, the node which wants to join the network, searches near routers, and selects a suitable router for request association.

The Fig. 3 shows the association procedure between a general node and a Coordinator.

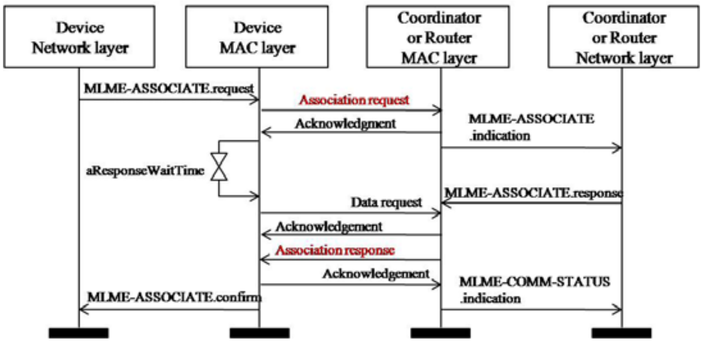

Fig. 3 Message sequence chart for association

Table 1 shows General MAC frame format used in IEEE 802.15.4.

TABLE I
GENERAL MAC FRAME FORMAT

Octet:2	1	0/2	0/2/8
Frame control	Sequence number	Destination PAN identifier	Destination address
		Addressing fields	
MHR			
0/2	0/2/8	Variable	2
Source PAN Identifier	Source address	Frame payload	FCS
Addressing fields			
MHR		MAC payload	MFR

C. ZigBee

1) Address assignment

16-bit address used by MAC layer is assigned by network layer in ZigBee. When a new ZigBee device joins ZigBee network, the parent node of this node assigns the 16-bit address by using specific calculation, called distributed address assignment mechanism. If the node is ZigBee Coordinator or ZigBee Router, the node can assign the 16-bit address to their children. This 16-bit address is unique in a ZigBee network. Following variables and formula are for distributed address assignment mechanism.

- C_m : the number of maximum children
- L_m : maximum depth of network tree
- R_m : the number of maximum router as child
- d : the depth of current node
- Cskip(d) : the child address range of the node of depth d
- n : the order of node joining the network
- A_{parent} : the address of a parent node
- A_n : the address of nth child

We can calculate Cskip(d) as below

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

And by using Cskip(d), we can calculate the address of a node

$$A_n = A_{parent} + Cskip(d) \cdot Rm + n$$

Where $1 \le n \le (Cm - Rm)$ and A_{parent} represents the address of the parent.

The following example in Fig. 4 shows the short address assignment in ZigBee networks when $C_m = 4$, $R_m = 4$ and Lm = 3. The table in Fig. 4 shows that Cskip(d) depends on the network depth. By using Cskip(d) value a ZigBee coordinater can select child nodes. These child nodes then can be selected as a parent for other nodes.

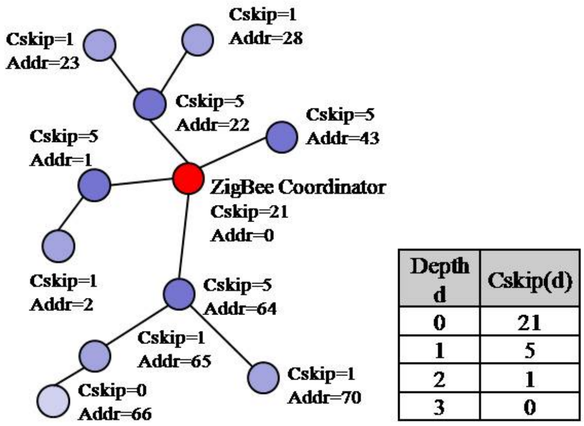

Fig. 4 Example of distributed address assignment mechanizm

2) Routing in ZigBee

There are three types of ZigBee devices. They are ZigBee Coordinator establishing the new network, ZigBee Router allowing children to join it, and ZigBee End Device which has no children. Routing protocol in ZigBee uses both hierarchical routing and AODV [9] as flat routing. Tree topology is used basically and ZigBee Routers can use AODV by using their neighbour table. ZigBee nodes can send their data via the shortest path by AODV. If the ZigBee node cannot find the shortest path, it can send the data by hierarchical routing flexibly. But, if AODV is used, many massages for route discovery have to be sent to other nodes. So this situation incurs the cost of battery life reduction of the sensor nodes.

III. Proposed Scheme

A. *Operation of a mobile sink node for ZigBee network*

1) *Association Procedure between a zigbee node and a sink node*

When mobile sink node based in ZigBee enters into the network, it has to associate with any router. Then the sink node sends advertisement message to the routers in frequency range to notify its existence. And the nodes receiving the ADV (ADVertisement) message, sends the REQ (REQuest) message to the sink node including energy consumption of the nodes. Both messages are of same concept with the communication messages in SPIN protocol [10]. By comparing the energy consumption of each node, the router having the lowest energy consumption associates with the sink node. Then this router becomes Sink Agent. The Sink Agent can gather data from other nodes in ZigBee network instead of mobile sink node. Fig. 5 shows the overall architecture.

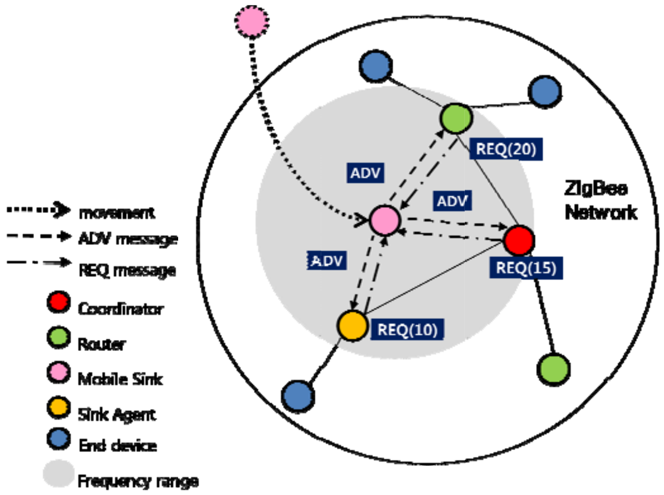

Fig. 5 Association procedure between a Sink node and a ZigBee Router

In order to associate with a sink node, all ZigBee routers record their energy consumption by using the number of their transmission, reception, and data processing.

Energy consumption can be calculated by using the attribute values in TABLE II.

TABLE II
ADDITIONAL MAC PIB ATTRIBUTE

Attribute	Identifier	Type	Range	Description	Default
macTxCnt	0x77	Integer	Variable	The number of transmission	0x00
macRxCnt	0x78	Integer	Variable	The number of receipt	0x00
macPcCnt	0x79	Integer	Variable	The number of processing	0x00

E_{trx} = macTxCnt
E_{rcv} = macRxCnt
E_{prc} = macPcCnt
$E_{csp} = 0.6E_{trx} + 0.3E_{rcv} + 0.1E_{prc}$

When a router is selected as a Sink Agent, the sink node broadcasts the message to notify all ZigBee nodes of its existence. In this situation, tree routing has to be used to avoid problem with message overlapping.

For sink node operations, in network layer, the attributes given in TABLE III have to be added in ZigBee specification. The router elected as a Sink Agent has to set its IsSink nodeAgent attribute to true.

TABLE III
ADDITIONAL NETWORK IB ATTRIBUTE

Attribute	Identi fier	Type	Range	Description	Default
IsSink nodeAgent	0x9B	Boolean	TRUE or FALSE	If TRUE, the node is connected with a Mobile Sink node. Otherwise, it's not.	FALSE
Sink nodeAgent-Address	0x9C	Integer	0x0000-0xfffe	The network address of Sink node-Agent	0x0000

B. Data Gathering Operation of a Sink Node

1) *Data Request*

A sink node sends Data Request Message via the Sink Agent to gather data of all ZigBee nodes. Data Request Message has to be sent to all nodes, and tree routing is not used to avoid problem with message overlapping. Fig. 6 shows the procedure of data request.

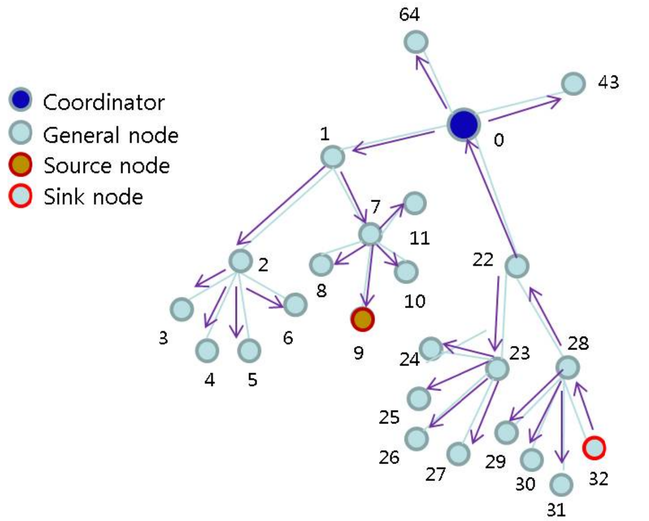

Fig. 6 Sending data request message to all nodes

2) Data Response

When the nodes receiving Data Request Message send Data Response Message to a Sink Agent, the shortest path has to be used. Each node manages neighbour table. This table contains neighbour node information, group ID, Depth. The address of each neighbour node and the address of their highest parent node except Coordinator are also stored. This address of parent node is logical group ID in the network. This operation uses 16-bit short address assignment mechanism in ZigBee. The group ID is the address of child nodes of coordinator. Each group ID is assigned by Cskip(0). By using this, each node can know their group. The nodes at boundary of each group know that some neighbour nodes are in different group and other nodes are in the same group. The source node sending Data Response Message first finds out that its neighbour nodes in different group or in the same group. The source node sends the data to neighbour node. Then the data transmission can be more efficient by avoiding unnecessary transmission.

The table and Fig. 7 show the procedure of transmission of Data Response Message.

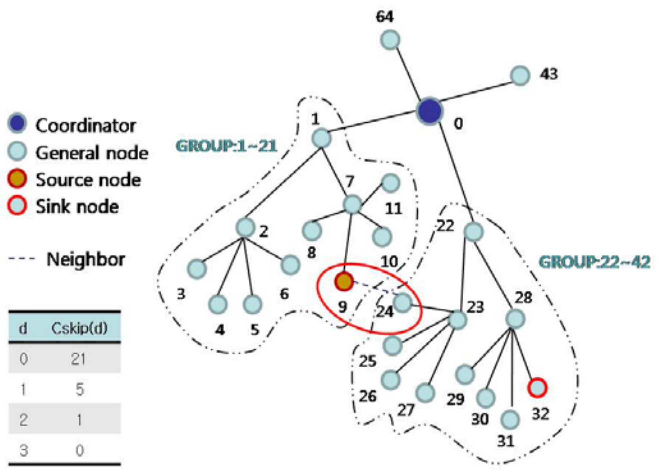

Fig. 7 Finding out the neighbour node in different group.

If node 6, node 8, node 10, and node 24 are in frequency range of node 9, they are neighbours of node 9. And node 9 can form its neighbour table like TABLE IV. Relation field is the relationship between neighbour nodes and node 9. For example, if a neighbour node is the parent of node 9, the relation is 'parent node'. Group ID is the address of the highest parent node of each group. And the highest parent node is direct child node of ZigBee coordinator.

TABLE IV
Example of neighbour table of node 9

16bits address	relation	Group ID	depth
6	Sibling	1	3
7	Parent	1	2
8	Sibling	1	3
10	Sibling	1	3
24	Sibling	23	3

By using this information in neighbour table, the source node sends the data to its neighbour node which is in same group with the group including the destination node as in Fig. 8. But, if the group of destination node is different with the group including the source node, the source node cannot use the shortest path by using depth.

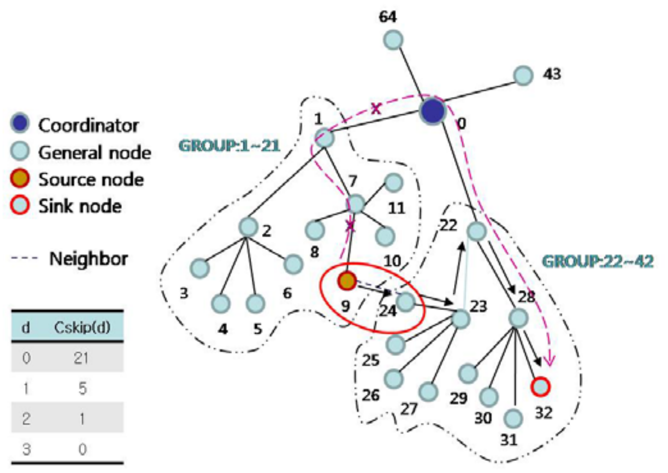

Fig. 8 Sending the data to destination by using the shortest path.

When data is sent to the highest node, some source nodes know that they are much more far from the highest nodes than their neighbour by comparing the depth of their nodes with the depth of their neighbour node. Then the source nodes send the data to their neighbour node which is closer than source. Fig. 9 shows the method to use the shortest path by using depth.

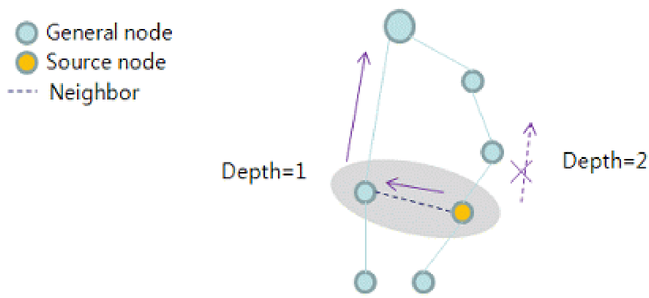

Fig. 9 The method to the shortest path by using depth.

IV. Performance

In the following, we will measure the life time of a node depanding on Energy Consumption by using E_{csp}. Through this measurement, we can verify that E_{csp} value represents node lifetime. We will compare the performance of the proposed routing using depth with AODV in ZigBee network.

We analysis the lifetime of a node depanding on Energy Consumption. Energy consumption depends on the number of transmissions, the number of receipt, and the number of data processing. As you can see in Fig. 10, the more the energy consumption, the shorter the life time of a node.

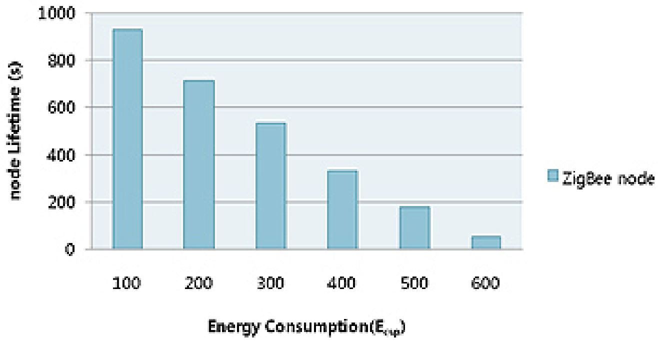

Fig. 10 Node Lifetime depanding on Energy Consumption

We analyze the performance of our proposed routing protocol, using depth. Fig. 11 shows that the nodes using proposed routing can keep their lifetime more than the nodes using AODV. Because AODV uses more message transmissions, such as RREQ and RREP.

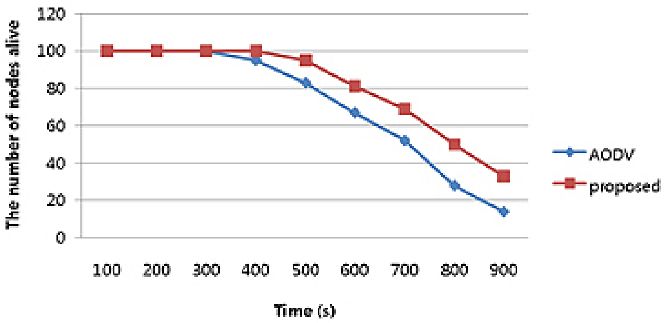

Fig. 11 The number of nodes alive of AODV and proposed scheme

We also compared proposed routing with Tree routing. As in Fig. 12 that for 100 nodes in ZigBee networks, the tree routing is used more number of nodes.

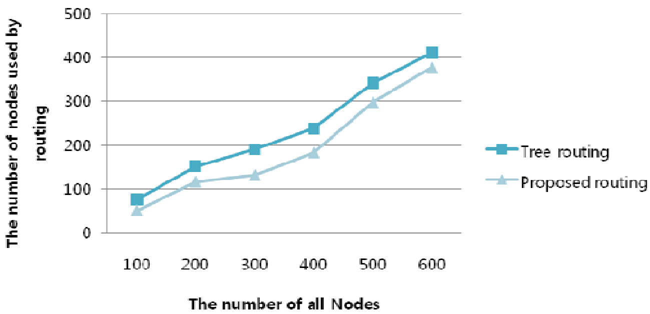

Fig. 12 The number of node used by tree routing and proposed routing

If the proposed routing is used, the number of nodes used by routing is reduced. Because many parent nodes don't need to use as routing path. As in Fig. 12, we can know that the proposed routing mechanism is more efficient than tree routing.

V. CONCLUSIONS

In this paper, we proposed the mechanism for selecting Sink Agent which can gather data instead of mobile sink node and for sending the data efficiently by using the depth of nodes.

The mobile sink node select its Sink Agent by finding out the energy consumption of the routers in frequency range of mobile sink node, and then the connection with ZigBee can be maintained longer. When the battery of sensor node cannot keep their lifetime longer, the lifetime issue of sensor network needs to be improved.

By using the depth of nodes, the source ZigBee node send the data to the Sink Agent efficiently. But the nodes in boundary of each group are more useful than other nodes to use this mechanism. So we should consider more efficient mechanism by using depth for all nodes.

By realizing our proposal as specific application, ubiquitous health care system or Home network can be realized and used by all people. And the research for realizing efficient sensor network should be studied by improving the contents of specification and by proposing various applications of sensor network.

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