

A Joining Mechanism for Efficient Address Management in Low-rate WPAN Mesh

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Abstract— The IEEE 802.15.5 standard is operated in mesh topology. In order to simply forward via mesh sublayer, this network assigns address of devices using block address scheme. However, this scheme has a weak point that is lack of address. To overcome this weakness, we suggest a new mechanism of joining process that makes a tree level minimized. After the network is completed, each node checks periodically status of neighbour nodes to make unbiased tree topology. The proposed scheme can overcome the problem of short of address. We explain some process in detail through several case studies. We can make an efficient address management using a proposed joining mechanism.

Keywords— IEEE 802.15.5; WPAN mesh; Mesh-under routing; Mesh Topology Routing; WSN

I. INTRODUCTION

The IEEE 802.15.5 (WPAN mesh) is a member of the Wireless Personal Area Network (WPAN) standard family [1]. This standard supports a sensor network to operate mesh networks. The purpose of WPAN mesh is to facilitate wireless mesh topologies optimized for IEEE 802.15 WPANs. Mesh topology provides extension of network coverage without increasing the transmit power or the receiver sensitivity, enlargement of reliability without any layer-3 router. The standard consists of two parts; the low-rate WPAN mesh that is developed based on IEEE 802.15.4-2006 MAC and PHY layer specifications [2] and the high-rate WPAN mesh that is developed based on IEEE 802.15.3-2005 MAC and PHY layer specifications [3]. In this paper, we focus only on the LR-WPAN mesh standard.

In the Wireless Sensor Networks (WSN), we need new routing methods to support mesh-under routing. When some data are forwarded via mesh sublayer in limited-resource networks, it should be considered about its physical memory size and battery life. To overcome this weakness, some schemes such as Adaptive Block Addressing (ABA) scheme and Distributed Link State (DLS) scheme already has been proposed [4]. By binding logic addresses to the network topology, routing can be carried out without going through route discovery. This eliminates the initial route discovery latency, saves storage space otherwise needed for routing table, and reduces the communication overhead and energy consumption. Because the ABA scheme pre-assigns an address to each device in the network topology and it prefers

16-bit address to 64-bit, however, a device runs out of addresses. Besides, if there is a substantial change of the device number or network topology, which cannot be handled locally, the network is allowed to go through the address assigning procedure again.

In this paper, to solve inefficient addressing schemes, we propose a new mechanism of tree management for Low-rate Wireless Personal Area Networks (LR-WPAN). According to this proposed mechanism, a new node considers not only Link Quality Indicator (LQI) but also tree level at its potential parents during joining process.

The rest of the paper is organized as follows. In Section II, some works related to the proposed method and their problems is briefly reviewed. Then, we will explain our proposed in Section III and we will show some case study in Section IV. Finally, we conclude this paper.

II. RELATED WORKS

A. The Low-rate WPAN mesh

The Low-rate WPAN mesh (LR-WPAN mesh) standard, as illustrated in Figure 1, is developed based on IEEE 802.15.4-2006 MAC layer and PHY specifications. Although the IEEE 802.15.4 standard was designed to support mesh networking, however, the tasks of defining and implementing the mesh networking functions are out of the scope.

The Low-rate WPAN mesh provides an architectural framework that enables low-power, low-rate WPAN devices to promote interoperable, stable, and scalable wireless mesh topologies. First of all, mesh network topologies allow devices to extend the network coverage without increasing the transmission power or the receiver sensitivity. Another key advantage of the mesh network is the enhanced reliability via route redundancy [1].

Mesh Sub-layer	IEEE 802.15.5 –WPAN mesh						
MAC/PHY Layers	LR-WPAN					HR-WPAN	
	15.4	15.4a	15.4c	15.4d	15.4e	15.3	15.3c

Figure 1. The WPAN mesh and 802.15 family standards

B. Joining a mesh network

The joining process into a mesh network usually contains following two steps:

- Discovering existing channels and networks
- Selecting a channel and network and parent device to join

The first thing a non-MC (non-Mesh Coordinator) device should do is to detect whether there are WPAN networks operating in its vicinity. The next higher layer of the device will issue a MHME-DISCOVER.request to its mesh sublayer. The mesh sublayer will attempt to discover networks operating within the device's operating area by performing an active scan over the channels specified in the MHME-DISCOVER.request primitive. This scan is performed by issuing the MLME-SCAN.request primitive to the MAC layer of the device [1].

When the MLME-SCAN.confirm primitive comes back from the MAC layer, the mesh sublayer of the device will gather a list of networks operating in its neighborhood. The mesh sublayer will then issue an MHME-DISCOVER.confirm primitive containing the information about the discovered networks with a Status parameter value equal to that returned with the MLME-SCAN.confirm to the next higher layer [1].

Upon receiving the MHME-DISCOVER.confirm primitive, the next higher layer is able to start the joining process. This is done by the AME (Application Management Entity) issuing an MHME-JOIN.request to the MHME (Mesh Sublayer Management Entity). The mesh sublayer will try to find the best neighbor device to join, if multiple candidates are available. After determining the neighbor device to join, the device issues an MLME-ASSOCIATE.request primitive to its MAC layer. If the device joins the network as an end device, the device can start performing its task after transmitting the MHME-JOIN.confirm primitive to AME [1]. This joining process is illustrated in Figure 2.

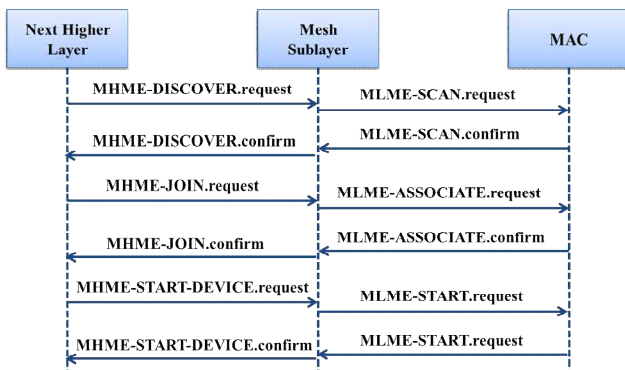


Figure 2. The joining process into a mesh network

C. Address Assignment and Forwarding

By binding logical addresses to the network topology, routing can be carried out without going through route discovery. Address assignment consists of association and address assigning process.

1) Association: During the association stage, beginning from the root, devices gradually join the network and a tree is formed. In this process, each device calculates its child devices and it accept according to its capability and other factors.

2) Address Assigning: After a branch reaches its bottom, that is, no more devices wait for joining the network (a suitable timer and meshChildNbReportTime can be used for this purpose), a bottom-up procedure shall be used to calculate the number of devices along each branch, as shown in Figure 3. The numbers in square brackets indicate the numbers of devices within branches below a certain device [1].

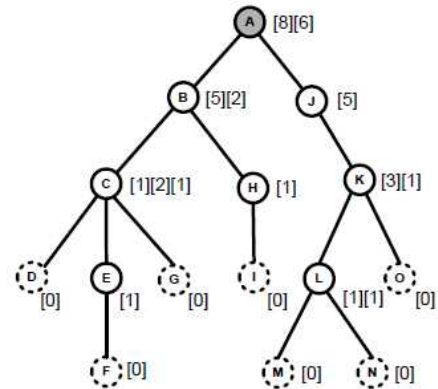


Figure 3. Calculation of number of devices along each branch [1]

III. TREE TOPOLOGY MANAGEMENT SCHEME

In this section, we propose a new tree management scheme to overcome weakness of block address. This block address scheme proposed by IEEE 802.15.5 standard has advantages that is eliminating route discovery and reducing route tables. In practice, however, there are some problems when a device runs out of addresses. For instance, a device can request more addresses from its parent. If the parent does not have enough addresses, it may either request additional addresses from its parent or adjust address assignment among its children. If there is a substantial change of the device number or network topology, which cannot be handled locally, the network is allowed to go through the address assigning procedure again. Moreover, in the mobility environment, all addresses might be reassigned because of frequent joining process.

There are two parts of this problem: increase of tree level and biased tree topology. First, the increase of tree level occur lack of address. Fortunately, the LR-WPAN is sufficient to assign addresses to a large number of devices because it uses 16-bit address. In tree topology networks using block address scheme, however, the number of 16-bit addresses is not enough because each device can acquire address block according to own level.

This following formula as in (1) can be proved easily. This formula shows that the increase in the level of the tree exponentially reduces the number of addresses.

$$\varepsilon = \alpha / \beta^{\delta}. \quad (1)$$

- ε : the number of addresses capable of assigning at specific tree level
- α : the number of total addresses capable of assigning in the network
- β : the number of average nodes at specific tree level
- δ : the specific tree level

Second, the biased tree topology means specific node has a lot of child nodes compared to other nodes as shown Figure 4. In this figure, a node C has two child nodes and a node H and a node K have nothing. If each siblings have the same number of addresses in the tree topology, the node have a lot of children might run out of address. For instance, if same addresses are assigned in each node, node C is not enough address 20% compared to node H. To overcome this problem, the root node initially assigns the differential number of address blocks. As time goes by, however, this network needs to reassign address because we consider mobility environment. After all, this network totally generates an amount of control message for reassigning address.

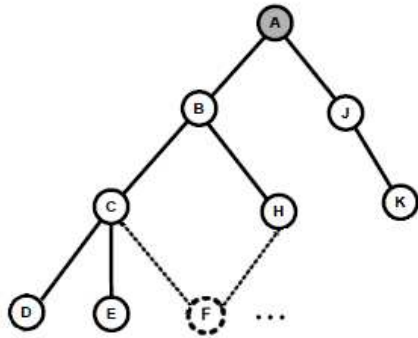


Figure 4. Biased Tree Topology

To solve this outstanding problem, we propose a new mechanism of managing tree topology. When a new node can joins to two or more nodes, this node should join to parent node of lower tree level. If available parent nodes have same level, the node should select parent node that has the lowest offspring. We are suggesting a new mechanism which is made up a join phase and adjustment phase.

A. Joining a Mesh Network

In this section, we propose a new mechanism of joining a mesh network at first to protect lack of address. When a node initially joins a network, the higher layer issues MHME-JOIN.request primitive to mesh sublayer and select a parent node. If there are two more devices in the range of new device, the node should select only one parent with considering tree level and Link Quality Indicator (LQI). These useful values can be found in MESHDescriptor of mesh discovery table (After the mesh sublayer receives the MLME-SCAN.confirm primitive from MAC, a mesh coordinator (MC) records several values in the MDT). In this paper, we strongly

consider tree level value in order to make a low level tree. We don't think about making unbiased tree because the network didn't completely be configured yet.

As shown Figure 5, a new device performs an active scan over the channels and check the number of devices available called a potential parent node. If the number of potential nodes is two or more, a new device checks attribute of tree level in each the MESHDescriptor of potential parent nodes and select a parent in the lowest tree level. However, several nodes can have same tree level. Therefore, this mechanism is not perfect because one node has to only one parent. If the number of selected nodes still is more than two, a new device should choose a parent within the threshold. Finally, the new device becomes a child of specific parent node via MHME-JOIN.request primitive.

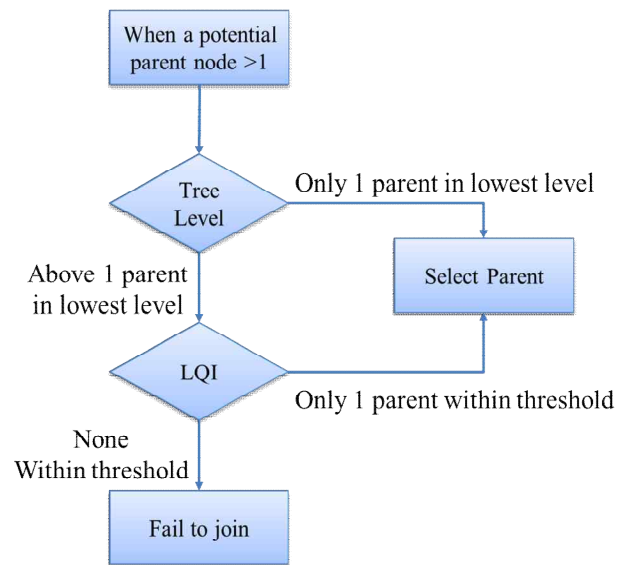


Figure 5. Joining Process with Considering Tree Level and LQI

This mechanism can reduce tree level when a new device joins a mesh network with considering tree level of parent. Consequently, it seems to solve lack of address. According to change a network topology, however, the probability of short of address is increased. Hence, completed network topology needs to appropriate adjustment

B. Adjustment of a Network Topology

In this section, we explain a way of continuous management scheme through periodical command message. After address assigning phase, appropriate address block is assigned to all nodes. Even though proper address block is assigned, this network is frequently changed. This network is inevitable to modify balance of the network topology.

To overcome this unevenness, a leaf node should periodically check ratio of total available addresses and left addresses. We make indicator for selecting appropriate parent, as shown (2).

$$\gamma = (\alpha / \kappa) * (\theta / \delta). \quad (2)$$

- γ : the indicator for selecting an appropriate parent
- α : the number of total available addresses
- κ : the number of left available addresses
- θ : link quality indicator
- δ : the specific tree level (above of one)

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The number of total available addresses is known through children number report command defined by the IEEE 802.15.5 standard. This command is used for a child device to report its number of child devices to its parent device. Also, a new node can learn the number of left available addresses through address assignment command defined by the IEEE 802.15.5 standard. This command is used for a parent device to assign an address block to its child devices. This indicator, as shown (2), is related with tree level and LQI. Therefore, a new node should modify its parent if this indicator is higher than other ones. This process reduces control messages for reassigning address because control messages are generated by only leaf nodes for modifying their parent.

IV. CASE STUDY

We will discuss how the new mechanism works better in two scenarios compared to the previous mechanism. An assumption that signal strength of the entire potential parent falls within threshold has been made in all the scenarios being discussed.

1) Initial Join Process: When a node join a mesh network without considering tree level, this network can be made up of high level tree, as illustrated in Figure 6. We assume that overall network can use 100 addresses. If a mesh coordinator (MC) has two descendants and they have the same number of own child nodes, the MC assign 50 addresses to each descendant. However, according to increasing a tree level, limited address size is assigned, as shown in Table I. In this our scheme, the node E is increasing address block about 12 times.

TABLE 1. ADDRESS ASSIGNMENT

Node ID	Attribute			
	Number of Address (Traditional Scheme)	Tree level	Number of Address (Proposed Scheme)	Tree level
A	80	1	50	1
B	20	1	50	1
C	30	2	30	2
D	10	3	25	2
E	2	4	25	2

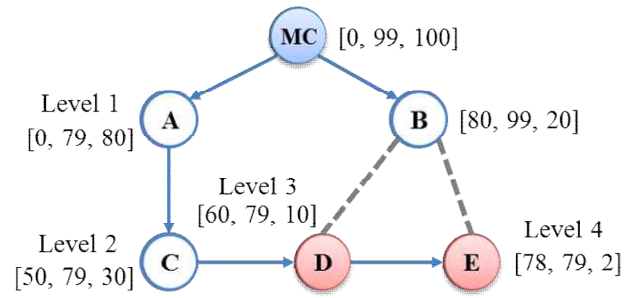


Figure 6. The Deep Level Tree Topology

2) Adjustment Phase: After the network topology is complete, each leaf node periodically checks whether its parents run out of addresses or not. In this Figure 6, we assume that node A has node C and node D and node E have a parent which is node B. Now, we can calculate defined indicator, as shown (2). For example, node D should change its parent to node A because indicator of node A is larger than node B.

V. CONCLUSION

In this paper, we proposed new mechanism of joining an existed network and management scheme of network topology. First, when a new node initially joins a mesh network, we suggest that the node select minimum tree level among some parents. This mechanism prevents a tree topology from growing deep level of tree to one side. This mechanism brings a saving address pool because deep nodes need more addresses. Second, after the network is made up, each node periodically check its neighbor node. If the proposed indicator which is made for selecting an appropriate parent is higher than current one, this node changes a parent node to a proper node. During joining process, a parent node request extra address blocks if it cannot provide address to its child node. This process leads to generate a number of messages and it brings waste of energy. However, we overcome problems using modifying a parent node when a previous parent node goes through lack of address.

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