Bias Child Node Association Avoidance Mechanism for Hierarchical Routing Protocol in 6LoWPAN

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Abstract—6LoWPAN enables IPv6 to be applied to wireless sensor network and enable end to end communication. One of the 6lopwan features is the capability of dynamic assignment of 16 bit short addresses. Using this feature a hierarchical routing protocol was designed. The designed hierarchical routing protocol focuses on the address allocation method and routing mechanism. However the routing protocol doesn't address scenario where there is more than one potential parent node. If the child nodes attaches to the first responding parent when there is more than one potential parent than this could lead to bias or uneven distribution of child node. Bias association could impact the reliability and also shorten the life span of the network. To overcome this problem a mechanism which uses current number of child node of potential parent was suggested. This mechanism displayed weakness when the responding parent node is having different depth or energy level or same number of current child. This paper reviews current hierarchical routing, highlights the issues and suggests a mechanism which avoids a bias routing hierarchical tree set up by taking into account the potential parent node's signal strength, depth and energy level.

Keywords- 6LoWPAN, routing protocol, HiLOW, WSN)

I. INTRODUCTION

In recent years vast research is being conducted in the area of Wireless Sensor Network (WSN). WSN is being applied in various applications now ranging from military application, general engineering, agriculture monitoring, environmental monitoring, health monitoring and also home and office monitoring and automation. Sensor nodes are tiny and limited in power, computational capacities and memory [1]. WSN consist of sensor nodes which communicate with each other wirelessly. WSN has one or several base station, called a sink node. The sink node's role is to collect sensing value from distributed sensor nodes.

IEEE 802.15.4 [2] standard which is a low cost, low power, and low data rate wireless personal area standard for lower (physical and link) layers is well suited for WSN. Meanwhile 6LowPAN [3, 4] is a standardization effort of IPv6 networking over IEEE 802.15.4. 6LoWPAN provides a WSN node with IP communication capabilities. One of the distinct features of 6LoWPAN is allowing dynamic configuration of the 16 bit short address in MAC layer in addition to the EUI-64 address.

The remainder of this paper is organized as follows. Section 2 reviews the hierarchical routing protocol in 6LoWPAN and works done in this area. Section 3 highlights issues in current work and suggests a mechanism to avoid a bias routing tree set up. Section 4 presents the conclusion.

II. RELATED WORKS

A hierarchical routing protocol (HiLow) for 6LoWPAN was introduced by K.Kim in 2007 [6]. HiLow is a routing protocol based on 16-bit short address of 6LoWPAN. HiLow assumes that the multi-hop routing occurs in the adaptation layer by using the 6LoWPAN Message Format [4] (Figure 1). In the rest of this section we will discuss the address allocation mechanism, routing operation and route maintenance in HiLOW and other works done to improve HiLOW as well as their weakness.

A. Address Allocation in HiLOW

The process of assigning address in HiLOW follows a sequence of activities. The activity starts when a node tries to discover an existing 6LoWPAN to join into. The node tries to discover the existing 6LoWPAN in its Personal Operation Space (POS) either by using active or passive scanning technique. In the case the node does not discover any 6LoWPAN in its POS; the node will initiate a new 6LoWPAN by becoming the coordinator and assign the short address by 0.

Meanwhile if the node discovers an existing 6LoWPAN in its POS, it will find itself a parent and try to associate with the parent at the MAC Layer, and obtain a 16 bit short address from the parent. The parent will assign a 16 bit short address to a child by following the formula as in (1). HiLOW addressing scheme needs the number of maximum child node a parent to be set.

FC : Future Child Address
MC : Maximum Allowed Child
N : Number of child node the parent has inclusive of the new node.
AP : Address of Parent Node

$$FC = MC * AP + N \; (0 < N <= MC) \qquad (1)$$

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                     1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|1 0|V|F|HopsLft| originator address, final address
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
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Figure 1. Mesh Addressing Type and Header

B. Routing Operation in HiLOW

Sensor nodes in 6LoWPAN can distinguish each other and exchange packet after being assigned the 16 bits short address. HiLOW assumes that all the nodes know its own depth of the routing tree. The receiving intermediate nodes can identify the parent's node address through the defined formula (2). The '[]' symbol represents floor operation

$$AP = [(AC-1) / MC] \tag{2}$$

AC : Address of Current Node
MC : Maximum Allowed Child

The receiving intermediate nodes can also identify whether it is either an ascendant node or a descendant node of the destination by using the above formula. When the node receives a packet, the next hop node to forward the packet will be calculated by the following three cases (3).

SA : Set of Ascendant nodes of the destination node
SD : Set of Descendant nodes of the destination node
AA(D,k): The address of the ascendant node of depth D of the node k
DC : The depth of current node
C : The current node

Case 1: C is the member of SA (3)
The next hop node is AA(DC+1, D)

Case 2: C is the member of SD
The next hop node is AA(DC-1, C)

Case 3: Otherwise
The next hop node is AA(DC-1, C)

C. Route Maintenancein HiLOW

Each node in HiLOW maintains a neighbor table which contains the information of the parent and children node. When a node loses an association with its parent, it should to re-associate with its previous parent by utilizing the information in its neighbor table. In the case the association with the parent node is able to be recovered due to situation such as parent nodes battery drained, nodes mobility, malfunction and so on, the node should try to associate with new parent in its POS [7]. Meanwhile if the current node realizes that the next-hop node regardless whether its child or parent node is not accessible for some reason, the node shall try to recover the path or to report this forwarding error to the source of the packet.

Even though a route maintenance mechanism has been defined in HiLOW, the mechanism is seen as not sufficient to maintain the routing tree. An Extended Hierarchical Routing Over 6LoWPAN which extends HiLOW was presented by C.Nam et al. in order to have better maintained routing tree [9]. They suggested two additional fields to be added to the existing routing table of HiLOW namely, Neighbour_Replace_Parent (NRP) and Neighbour_Added_Child (NAC). This NRP doesn't point to the current parent node but to another node which can be its parent if association to current parent fails. Meanwhile NAC refers to the newly added child node. More work need to be done on this mechanism on how many nodes allowed to be adapted by a parent node in addition to the defined MC and whether this mechanism will have any impact on the routing operation, however this topic is beyond the scope of this paper.

HiLOW did not define a mechanism to handle a scenario where the child node detects more than one potential parent. In [10] a mechanism to select a parent node to associate with was suggested. They highlighted that if the node selects the first detected parent and associates to it, this could lead to a bias routing tree set up. Their mechanism suggests the potential parent node to provide the new child with its existing child node count (child_number). By issuing the child_number the node could select suitable parent which has less child nodes. The suggested mechanism performs well only when the potential parent node has same depth, same energy level and has different number of existing child. Meanwhile, in scenarios where the parent node has different depth level or different energy level or same number of existing child the mechanism seems to have disadvantages and still lead to bias child association.

III. New Bias Child Node Association Avoidance Mechanism

We are suggesting a new mechanism which is able to overcome weakness displayed in previous mechanism [10] and avoid bias child association. In this mechanism we are suggesting the new child node to be provided with two data, one is the depth of the potential parent node and secondly the average amount of power the potential parent node has. The average amount of power of the potential parent node is suggested to be calculated as in (4):

Avg : Average Amount of Power
CBP : Current Battery Power of Potential Parent
CC : Current Child Node

$$Avg= CBP / (CC+2)^{*} \tag{4}$$

*Current Child node is added with 2 as 1 represents the node itself, meanwhile the other 1 will be the requesting child node. So, the average represents an average power the parent node has for itself, current nodes and future node.

In situation where there is more than 1 potential parent the child node will then make decision on which potential parent node to associate with according to steps as displayed in Fig. 2. First the child node will compare parents Link Quality Indicator (LQI) to identify whether there is any potential parent within the threshold set. LQI is selected compared to Received Signal Strength Indication (RSSI) as LQI is more accurate to measure the quality of the link and the delivery ratio especially when there are obstructions or noise [11]. In the case there is only 1 potential parent within the threshold that parent is automatically selected and process of association starts. If there is more than one parent or no parents at all within the threshold, then the child node will compare the depth of all the potential parent nodes. If there is only parent node with the lowest node, then that particular parent node is selected and process of associating with it is started. In the case there is more than 1 potential parent node with the lowest level of depth, and then the average power is compared. The child chooses the parent with the highest average power and associate with it if there is one particular potential parent with highest energy. If there is more than one parent which shares the lowest level of depth and highest level of energy, then the child node should try to establish association with the first potential parent in this category which respondent. Methods of measuring the LQI and setting up the threshold are not within the scope of this paper.

Now we will move on to discuss how the new mechanism works better in 3 scenarios compared to the previous mechanism. An assumption that all the potential parent's signal strength falls within the threshold has been made in all the scenarios being discussed.

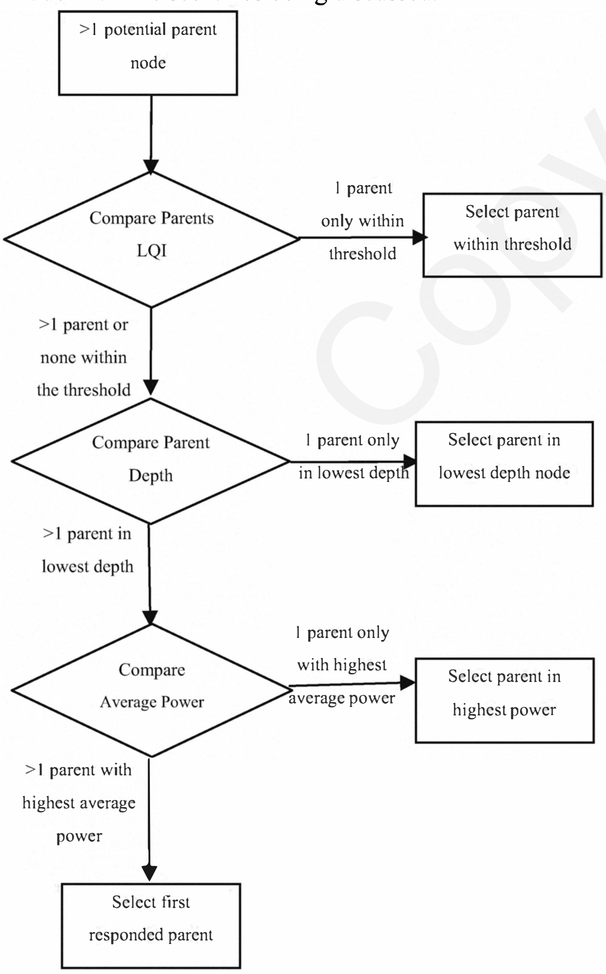

Figure 2. Suggested Mechanism

The first scenario will be described with the assistance of Fig. 3. When two potential parent node(8) and node(4) responds; according to the previous mechanism the child node should attach to parent node(8) as it has only 1 child node compared to node(4) which has 2 child node. According to our mechanism the child node will attach to node(4). Attaching to node(4) is more advantageous compared to attaching to node(8) as it only goes through 1 hop to sink node compared to 2 hops if attached to node(8). By attaching to node(4) only node(X) and node(4) energy will be used in transmitting the data to the sink node, meanwhile in the other case energy of node(X), node(8) and node(1) will be used in transmitting the data to the sink node.

The second scenario is when there are two or more potential parent nodes with different number of existing child nodes as represented in Fig. 4. According to the previous mechanism the node(X) to associate itself with node(17) as it has no child node compared to node(8) which has one child node. This association is acceptable if both node(17) and node(8) has same level of energy. In the case node(8) has abundant amount of energy compared to node(17) then this association is disadvantageous. Our mechanism suggests the node(X) to take into consideration the average amount of power the potential parent node has. In the case parent node(8) has more average power than parent node(17) then node(X) will join parent node(8). Meanwhile if the parent node(17) has more power than it will associate itself with parent node(17).

The third scenario is when all potential parents have the same number of child nodes. The previous mechanism didn't anticipate such a situation could occur. Following our mechanism node(X) will first compare potential parent depth from sink node in this case node(4), node(8) and node(17) (Fig. 3). In this case the node(X) will try to associate with node(4) as it nearer to the sink node. Meanwhile if the potential parent node which responded is only node(8) and node(17), node(X) will join the node which has highest average energy. In the case both node(8) and node(17) has the same amount of average energy it will associate itself with the first potential parent which responded.

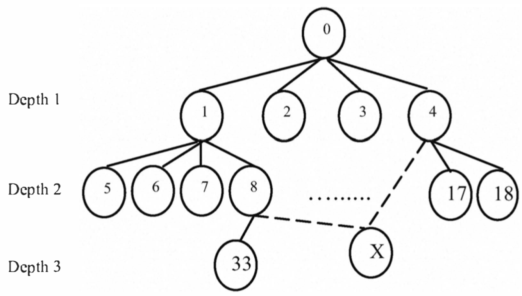

Figure 3. Potential Parent node with different depth and different number of existing child node

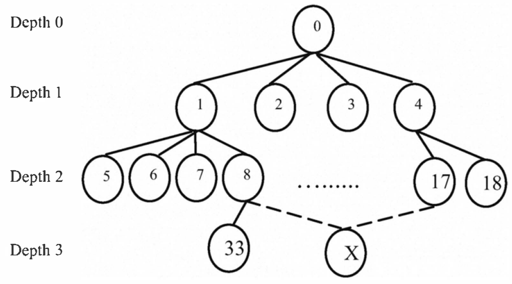

Figure 4. Potential Parent node with same depth and different number of existing child node

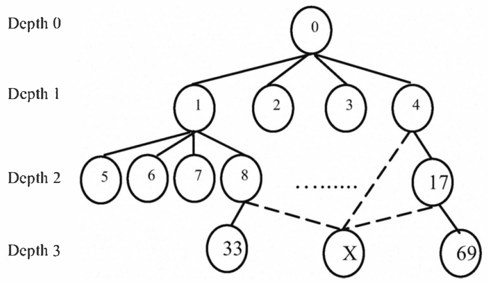

Figure 5. Potential Parent node with same number of child

IV. Conclusion

In this paper we have suggested a new mechanism to overcome bias child node association in HiLOW; bias child association could jeopardize the reliability of the network as well as shorten the life span of the network. Although a mechanism to overcome bias child node association has been introduced before. The previous mechanism seems to be not advantageous as it is not considering potential parents node signal strength, depth and energy level. The proposed new mechanism is expected to perform better in establishing a reliable network and enhance the lifetime of the network. This paper also provides review on HiLOW routing protocol, problems faced in HiLOW and other works done in improving HiLOW. Our future research will be focused on how the signal strength is going to be measured, validating the suggested mechanism as well enhancing it.

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