Transmission Power Level Selection Method Based On Binary Search Algorithm for HiLOW

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Abstract

Recently the sensor communication research has introduced an IP-based communication known as 6LoWPAN to sensor network. 6LoWPAN was introduced to give a new perspective to sensor network by enabling IPv6 to be applied to wireless sensors as well as wired sensor. Dedicated routing protocols based on 6LoWPAN was soon introduced and Hierarchical Routing Protocol for 6LoWPAN (HiLOW) is one of them. HiLOW clearly defines the routing tree setup process, address allocation technique and the data routing process but there is some shortcomings in terms of transmission power selection. HiLOW does not highlight how the suitable transmission power is being selected for sensor communication purpose and this leads to the assumption that at all time and all scenarios the sensors are using maximum transmission power. In the case the sensors are using maximum transmission power for communication even when it is not necessary then power depletion for sensors will be amplified and the network lifetime will be significantly reduced. In this paper we present a brief introduction to 6LoWPAN, a concise review on HiLOW, a highlight on issues revolving each process in HiLOW and propose a new idea on transmission power selection method for HiLOW.

Keywords: *Wireless Sensor Network, Hierarchichal Routing, 6LoWPAN, HiLOW, Transmission Power Selection.*

1. Introduction

The Wireless Sensor Network (WSN) has been getting much focus from research community in recent years due to its foreseen potential as a tool in solving many problems from day to day problems such as home monitoring [1] up to ecological problems such as mountain side monitoring to detect possible landslides. Initially WSN started a technology used and researched only for military usage for the purpose of detecting enemies, land mines and identifying own man, but WSN has been extended to home monitoring, office monitoring, environmental monitoring and many other areas. In future WSN could exist in every part of our life due to the engineering contribution. Even though enormous improvement in being observed from the hardware engineering perspective but till today WSN still faces the limitation in power and computational capacities and memory usage[2].

In WSN there are two crucial activities which take place; first is sensing activity done by the sensors then followed by communication between sensors. Radio communication for transmission is typically the most energy consuming activity [3] and the reception energy is often as high as the transmission energy. Thus the network protocol as well as the routing protocol being designed specifically for WSN needs to take into consideration the energy usage in setting up the network as well as complexity of computation during routing. Flaws in routing tree setup could increase the request of retransmission and also cause the node to use more power to reach the parent node or child node to transmit; this will lead towards energy wastage and further shorten the network life and reliability.

IPv6 over Low-Power Wireless Area Network (6LoWPAN) was introduced by Internet Engineering Task Force (IETF) as a standardization effort of IPv6 networking over IEEE 802.15.4. Prior to the introduction of 6LoWPAN many other communication protocols have been introduced to Wireless Sensor Network namely 802.15.1 Bluetooth [4], WirelessHart [5], ZWave [6], ZigBee [6] and others. 6LoWPAN[7] is significant compared to the prior communication protocols as it is the first to introduce IPv6 to be applied not only to wireless but also wired sensor network.

IPv6 was introduced to Low-Power Wireless Area Network compared to IPv4 as IPv6 is the future network. IPv6 was introduced to overcome the address depletion problem in IPv4. Thru introduction of IPv6 other weakness in IPv4 is also handled such as inefficiency of header processing, lack of standisation on mobility flow, control, security, M/c and re-configuratiion. As IPv6 will soon be the addressing scheme as well as the additional benefits it posses then the low powered sensor network is also introduced with IPv6 capability in contrary to IPv4.

6LoWPAN defines the network layer protocol as well as the transport layer protocol which can be deployed to any IEEE 802.15.4[8, 9] compliant sensors. The 6LoWPAN stack is minimum 30KB in size which is smaller compared to the named protocols above. The routing protocol for 6LoWPAN is an open area for research as it is not specifically defined. As of now, there are three prominent routing protocols which have been designed specifically for 6LoWPAN namely Hierarchical Routing Protocol (HiLOW) [11, 12], Dynamic MANET On-demand for 6LoWPAN (DYMO Low) [13] and 6LoWPAN Ad Hoc On-Demand Distance Vector Routing (LOAD) [14].

The remainder of this paper is organized as follows: Section 2 reviews the processes defined in HiLOW protocol briefly and highlights the issues pertaining the protocol and other works undertaken to improve HiLOW. Section 3 explains in detail the proposed power selection method. Section 4 presents the conclusion.

2. HiLOW Protocol and Existing Issues

A hierarchical routing protocol (HiLow) for 6LoWPAN was introduced by K. Kim in 2007 [11]. HiLOW exploits the dynamic 16-bits short address assignment capabilities of 6LoWPAN. HiLOW makes an assumption that the multi-hop routing occurs in the adaptation layer by using the 6LoWPAN Message Format. The operations in HiLOW ranging from the routing tree setup operation up to the route maintenance operation and the issues revolving each operation level will be discussed in the rest of the section.

2.1 Hilow Routing Tree Setup, Issues and Other Works done.

The process of setting up the routing tree in HiLOW consists of a sequence of activities. The process is started by a node which tries to locate an existing 6LoWPAN network to join into. The new node will either use active or passive scanning technique to identify the existing 6LoWPAN network in its Personal Operation Space (POS).

If the new node identifies an existing 6LoWPAN it will then find a parent which takes it in as a child node and obtain a 16 bit short address from the parent. Parent node is a node which is already attached to the network. The parent will assign a 16 bit short address to a child by following the formula as in (1). An important element of HiLOW is that the Maximum Allowed Child (MC) need to be fixed for every network and all the nodes in the network is only able to accept child limited to the set MC. In the case where no 6LoWPAN network is discovered by the node then it will initiate a new 6LoWPAN by becoming the coordinator and assign the short address as 0.

FC : Future Child Node's Address

MC : Maximum Allowed Child Node

N : Number of child node inclusive of the new node.

AP : Address of the Parent Node

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

Three potential issues have been identified in this process. The first issue involving this protocol is that the nodes are assumed to communicate using maximum power transmission. Using maximum power transmission to communicate to its parent's node is not advantageous. This method could lead towards enhanced power drainage of a child node. For example in a scenario that a child communicates with a parent using maximum power transmission (power level 10) even though it could communicate via lower transmission (power level 5) then its power drainage is heightened by nearly 50%. So in this paper we are proposing a power selection method during the routing tree setup by implementing binary search algorithm with LQI value as qualifier. The proposed method is expected to reduce power wastage and heighten the network lifetime.

The second issue would be when the child node gets respond from more than one potential parent. There is no clear mechanism rolled out in selecting the suitable parent to attach with. If the new node chooses to join the first responding parent node, it could be bias to the parent as some parent might be burdened with more parents meanwhile other parents which is in the same level has less child or none at all. Selecting the parent based on first responded potential parent could also lead to fast depletion of energy to certain parent causing the life span of the network to be shorter and the stability to be jeopardized. Selection of parent without considering the link quality could cause towards high retransmission rate which will consume energy from the child node as well as parent node.

In [15] a mechanism to overcome the issue was suggested. 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. Their mechanism also does not take into consideration the quality of the link established between the parent node and child node. Therefore the suggested mechanism does not solve the arising issue completely. In order to overcome the weakness in the selection method a comprehensive parent selection method that takes into consideration the link quality, the existing energy of the potential parent as well as the depth of the parent has been proposed in [16]. The paper theoretically discusses how the proposed method could overcome bias child attachment in different scenarios.

Third issue revolves around the MC value which is being fixed for all nodes. The current scenario works well in a homogenous powered sensor environment where all the sensors' power source is the same; for example all is battery powered with same type of battery or all sensors are non-battery powered and having same power source. Meanwhile in a heterogeneous power source sensor environment this method is not advantageous as sensors which are main power and affluent in energy should be assigned with more child compared to battery powered sensor. This is an open issue to be addressed in HiLOW and assumption that all nodes having same energy conservation have to be made. The activity of disseminating the MC value to joining nodes is also left in gray. This issue is not addressed in this paper.

2.2 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

AC : Address of Current Node

MC : Maximum Allowed Child

$$AP = [(AC-1) / MC] \qquad (2)$$

By using the above formula the receiving intermediate nodes can also identify whether it is either an ascendant node or a descendant node of the destination. When a node receives a packet, the node determines the next hop node to forward the packet by following the three cases (3) as shown in [10]. So far no issues have been identified in this process.

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)

2.3 Route Maintenance in HiLOW

Each node in HiLOW maintains a neighbor table which contains the information of the parent and the 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 of the association with the parent node cannot 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 [11]. 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 in [16] in order to have better maintained routing tree. 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.

3. Transmission Power Level Selection Method for HiLOW

A transmission power level selection method by implementing binary search algorithm coupled with maximum search round and LQI value as qualifier is being presented in this paper. The suggested method is able to reduce number of nodes communicating using maximum transmission power with its parent node, by doing so the energy used in transmission is reduced and network lifetime is heightened.

Binary search method coupled with maximum is selected compared to incremental search or pure binary search in order to reduce the number of rounds the nodes undergoes to search for parent. Table 1 displays the number of maximum search rounds in worst case scenario which is possible based on the different number of power levels for three different searches. From the table it can be easily deducted that Binary Search Algorithm is more efficient in worse case scenarios. Meanwhile the mechanism suggested in this paper ensures that the number of search is even more limited as the energy is very crucial for sensor nodes.

An assumption that all the nodes have mapped their Tx Power Setting to output power and the Tx Power setting is incremental by 1 from each other, for example as set by default in Atmel Raven Nodes as shown in Table 2. An assumption that different power level setting uses different battery consumption is also made for example in Atmel Raven when the output Power is 0dBm the amount of battery power is quoted to be less than 13mA and in the case of full output power (≈ -17 dBm) the battery consumed battery power is 16-17mA.

Table 1: Maximum Search Rounds in worst case scenario for three different type of search method

Power Level (N)	Incremental / Linear Search	Binary Search ($\log_2 N$)	Suggested Search (MR =4)
5	5	3	3
10	10	4	4
20	20	5	4
30	30	5	4
40	40	6	4

The transmission power selection process starts when a node starts when the node looking to join a network in it POS as shown in Fig. 1. Before starting a scan the node needs to determine and the Lowest Transmit Power (LP) and Highest Transmit Power (HP). The node then sets the Optimum Transmit Power (OP) value to be equivalent to HP. Then the Search Transmit Power (SP) value has to be determined. The SP value is determined following mathematical equation in (4). The Current Search (CR) value is also set to 0.

Table 2: Default Power Mapping in Atmel Raven Sensor Nodes [19]

TX Power Setting	Output Power[dBm]
0	3
1	2.6
2	2.1
3	1.6
4	1.1
5	0.5
6	-0.2
7	-1.2
8	-2.2
9	-3.2
10	-4.2
11	-5.2
12	-7.2
13	-9.2
14	-12.2
15	-17.2

Two values are to be set during compile time; one is Maximum Search Round (MR), the MR value has to be set for all nodes and the value should be same for all nodes. MR is basically the number of maximum search round the nodes can go through before they terminate the search. Second value is the accepted LQI value.

SP : Search Transmit Power Level

HP : Highest Transmit Power Level

LP : Lowest Transmit Power Level

$$SP = [((HP - LP)-1) / 2 \quad (4)$$

The node then will use the SP to search for the potential parent.

In the case 1: Where the node does not find any potential parent it will set the LP value to be SP value.

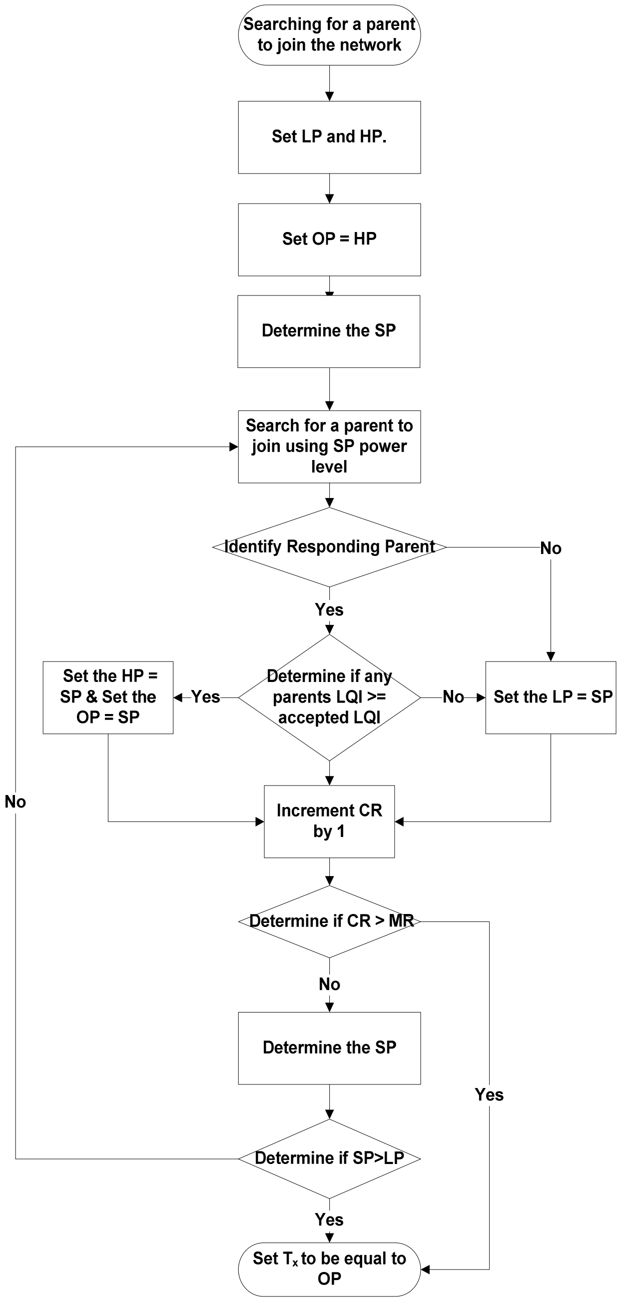

Fig. 1 Proposed power level selection method for HiLOW

In the case 2: Where the node does find a potential parent it will compare the LQI value with the accepted LQI value. In the case where the LQI value is more than accepted LQI then the HP will be set to equal with SP and OP will also be set to equal SP. In the other case the LP value will be set to SP value and the OP value remain unchanged.

Regardless which ever case the node encountered, the node will then continue to the same process which is increment CR by 1, then determine if the CR more than MR. If the condition is true then the node terminates the search process and set the transmission power level to be equivalent to OP. In the case the condition is not true then the SP is again determined, then the new SP is compared with the LP to ensure that is higher than LP if it is not then the process is also terminated and the transmission power level is set to be equivalent to OP. In the case the condition is true then the process loops back to the process for a parent using the SP power level.

4. Conclusions

In this paper review on HiLOW, issues revolving each process in HiLOW and other works done in this area are presented. A new idea on transmission power level selection method by implementing binary search algorithm coupled with maximum search round and LQI value as qualifier is presented in this paper. The presented power level selection method is believed to be able to overcome the problem of maximum power usage for every transmission; by which the network lifetime could be increased. The presented power selection method is also better than linear search method and pure binary search method as discussed in our paper as it has it exits search in fixed number of rounds compared to the latter. Even though the method is suggested for HiLOW, the method could be easily adapted to other type of hierarchical routing. Our future research will be focused on validating the suggested mechanism as well as adapting it to other routing protocols such as LEACH.

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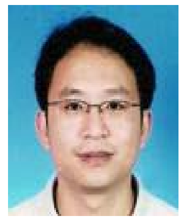

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