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Weight Ranking Mechanism of Energy Balancing Routing Metric for RPL Protocol in Smart Grid Communications

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***Abstract*—Nowadays, many protocols have been designed to support smart grid system due to the massively of transferred data, reliability and the constrained of environment. RPL protocols have been designed to support with these constrains of networks: energy, memory, power and interconnection. To improve the performance, ETX and energy balance metrics must be use in RPL networks. In this paper, we propose Weight Ranking Mechanism of energy balancing routing metric algorithm which can prolong a better life-time as compared to the conventional RPL routing metric.**

***Keywords*—RPL protocol, Energy balance, Ranking mechanism**

I. INTRODUCTION

Smart grid will become a major part in development of the human being. The used of electricity has been increasing due to the growth of human population. The traditional of electrical system would not meet the requirement in near future, e.g., the system cannot feedback to the end-user when there is a link-failure in the system. It may take many hours to maintain and re-establish the system. To satisfy the demand of using the electricity, smart grid can help to improve the efficient by enabling feedback control from device to device, data monitoring and etc.

Many smart grid applications such as smart meter and home automation require a massive of transferred data, reliability and low packet drop. To reach the requirement above, a protocol must be used in the smart grid. In present, many protocols have been designed for smart grid system, for example; GPSR, LoadNG and RPL [1-4]. In these routing protocols, routing protocol for low power and lossy networks (RPL) is more interesting than other because RPL can provide better transmission time, end to end delay and packet delivery ratio (PDR).

In [5], tree topology of RPL is created by Directed Acyclic Graphs (DAG). This topology starts from root node (or sink node) by sending objective function on DIO message to other nodes that are called child nodes. Child nodes use Rank and Expected Transmission Time (ETX) parameter in objective function for finding its candidate parents [6]. The selected parent in the candidate parents is the node with minimum ETX value. In general, child nodes usually send data to root node through their selected parent nodes. It is not surprising that the selected node will de-operate faster than others because of the conventional objective function has no energy balancing technique. In [7], they proposed energy balance for prevent this problem. This method uses both ETX and energy consumption with constant weight parameter to determine the selected parent nodes. In practical term, the selected parent nodes at lower Rank send data more frequently than the selected parent nodes at higher Rank. So, the weight parameter should adjustable follow the Rank mechanism. In this paper, we proposes a new routing metric algorithm that is Weight Ranking mechanism of energy balancing routing metric algorithm. The proposed method applies the Rank mechanism for energy balance in RPL networks.

The remaining of this paper is organized a follows. In section II, RPL overview is provided. Then, we propose a new metric in section III. The result and conclude will be in section IV and V, respectively.

II. RPL OVERVIEW

Internet Engineering Task Force Routing Over Low power and Lossy networks (IETF ROLL) working group has defined the RPL that is a specific protocol for support these constrains: energy, memory, power and network interconnection. RPL builds its own infrastructure which calls Destination Oriented DAGs (DODAGs). DODAGs makes no cycle path exist as shown in Fig.1. In order to maintain and build topology, RPL uses 3 types of control messages: DODAG Information Object (DIO), DODAG Information Solicitation (DIS) and Destination Advertisement Object (DAO) [8-9].

To construct DODAGs, the root node sends a DIO message toward to its neighbors. The neighbors have to send the acknowledgement back to their sender nodes. When the neighbors join the DODAGs, they will forward DIO messages to their own neighbors [10]. If the nodes that outside the DODAGs want to join, they will send a DIS message for

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requesting a DIO message. Child nodes response the DAO message to their selected parent after they received the DIO message. This message will contain addresses and prefixes in order to update a receiver node routing table.

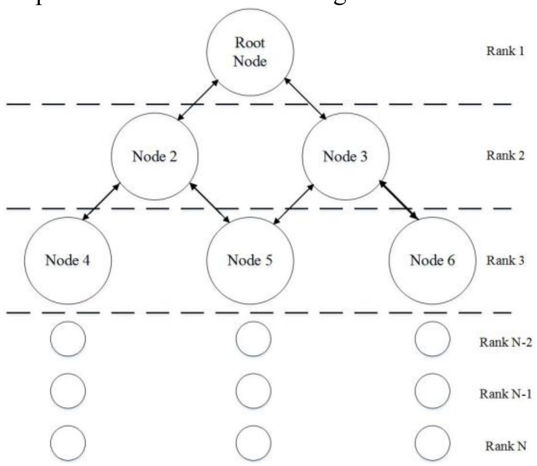

Figure 1 RPL topology

From Fig. 2, the RPL creates the link for data transmission by using ETX matric routing. For easy to understand, we will show the example of RPL creation. At node 5, this node has two candidate parents that are node 2 and node 3. Node 5 will select the link with node 2 for data transmission because this link has a better ETX than the ETX of the link with node 3. At node 2, we can see that this node responses to send the data from node 4 and node 5 to the root node. So, energy of node 2 should reduce quickly than node 3 that transmits only data from node 6. If node 2 is out of energy, node 4 and node 5 have to find their new best parents for data transmission. Fig. 2 shows that node 5 is the new best parent of node 4 and node 3 is the new best parent of node 5. The out of energy of node makes the important problem in the network such as link delay and transmission time [11]. For solve this problem, the energy balance should be applied to one of the parameters for selection the best link instead the conventional technique that considers only ETX value.

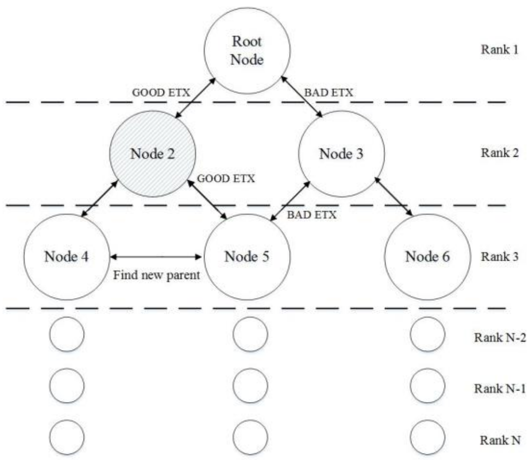

Figure 2 The conventional RPL metric selection.

III. PROPOSE SCHEME

As we discussed in section II, energy balance is very important in the RPL networks. The networks can perform a function with a low packet drop in a long term. In practical term, nodes with lower Rank have much more link to concern than any higher Rank node. This means that the lower Rank node selection must be decided in energy term than higher Rank node. Therefore, we are not only taking into account of energy consumption and ETX but we also are considering the Rank parameter in our technique.

In this paper, we introduce our new routing algorithm for making each node that can perform a better function. Our method calls Weight Ranking mechanism of energy balancing routing metric as shown eq. 1.

$$S_i = K\left(\frac{ETX}{maxETX}\right) + (1-K)\left(\frac{curEnergy}{maxEnergy}\right) \quad (1)$$

where S_i is the routing score of link i for selecting a new parent. The right side item represents ETX value in each link of all possible links. The left side of (1) is the ratio of current energy and its own maximum energy in each candidate node. The K value is our adjustable weight value as shown below

$$K = \frac{curRank}{maxRank} \quad (2)$$

where $curRank$ represents a current node Rank value and $maxRank$ is a maximum Rank value in the networks. The proposed algorithm will decide the candidate parent that has the smallest S_i value. The change of K value depends on a Rank in each node.

IV. SIMULATION RESULTS

In ours experiment, we use MATLAB running on windows 10 equipped with an Intel Core i7 7440, RAM 32 GB and CPU at 3.4 GHz for RPL simulation. Our system networks include 45 nodes that have same amount of battery as shown in Fig. 1. Fig. 3 shows the definition of link that is considered in this paper. We assign that the link of the left side node (parent A) has a good ETX. It means that this link is better quality than the link of the right side node (parent B). The left side link is used frequently to transmit data if the selection parameter is consider only the ETX value. Therefore, the energy of parent A reduces quickly than parent B.

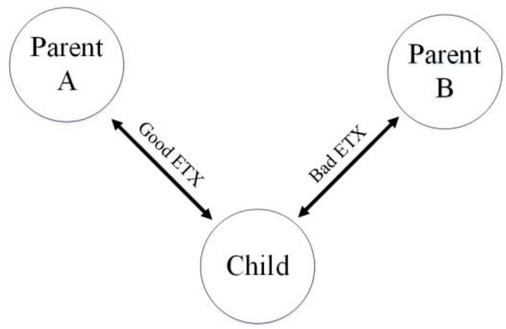

Figure 3 The parent-links.

As discussed in section II, ETX metric works in a way of choosing a better link quality metric. While energy balance metric chooses a better energy remaining or a better life-time node. Both of these parameters must combine in an appropriate way to provide a better transmission mechanism in RPL networks. In Fig. 4, we compared the energy usage per time of node 2 and 3 at weight = 0.9 and 0.1 of [6]. For weight value equals to 0.1, the energy of node 2 and 3 de-operate in the same time. It means that the best link considers for energy balance. On the other hand, if weight value is 0.9, node 2 is out of energy quickly than node 3. This means that the best link will be selected by choosing the minimum ETX value. In [6], they presents that the proportional weight = 0.5 for balancing energy metric. However, the energy balance control in each Rank should adjustable because the node at lower Rank is frequency to use for data transmission than the node at higher Rank. Therefore, the proposed method uses the Rank parameter to select the best parent. Fig. 5 shows the comparison between the previous work at weight = 0.5 and the proposed method. Simulation results show that the proposed method can control energy balance better than the previous work.

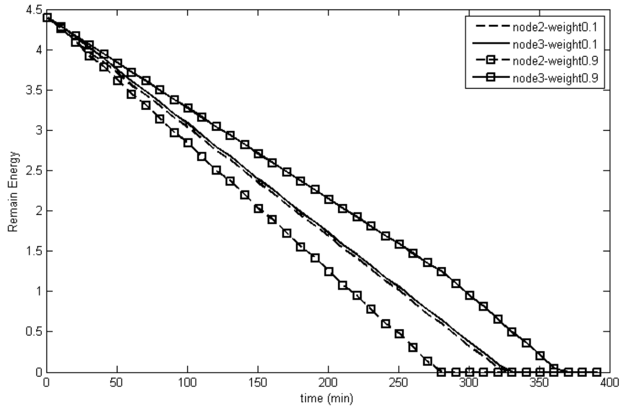

Figure 4 Energy consumption of node 2 and node 3 under two weight values: 0.1 and 0.9.

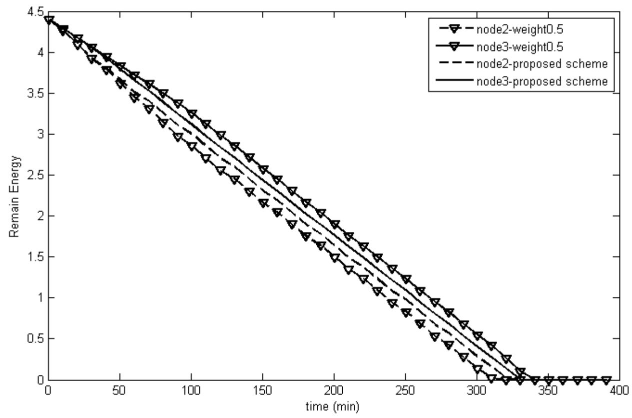

Figure 5 Energy consumption of node 2 and node 3 with weight = 0.5 and the proposed scheme.

In Fig. 6-9, we present the battery life time of parent nodes in seven Rank that consider two node at the edge of tree RPL topology (left and right node) under four weight cases. For the lower Rank nodes, for example; Rank 1 or Rank 2, battery life time is more important than the ETX because the node at lower Ranks respond to transmit data information of many child nodes. So, these nodes should have a long life time of battery. On the other hand, for the higher Rank nodes (Rank 8 or Rank 9), this Rank should has good ETX value for giving the low average PDR system. From Fig. 6, we know that this method cannot balance energy at lower Rank of RPL because the battery life time of left node is different the life time of right node. In Fig. 7-9, these techniques can control the balance energy at the lower Rank. However, at higher Rank nodes, the child should concentrate to the link that has a good ETX. So, the energy balance is not the major part at these Ranks. From simulation results, we can conclude that the proposed method has a good energy balance at lower Rank and a good link at higher Rank. Moreover, ours work can prolong lower Rank node life time by 14.13% and 10.24% as compared to the conventional work with weight 0.9 and 0.5, respectively.

For the nodes in right side, the results show that the energy consumption of node at higher Rank of all methods have the same values. On the other hand, the energy consumption of the proposed method the node at the lower Rank shown that our metric has an almost same performance as the previous work with weight 0.5 and 0.9F.

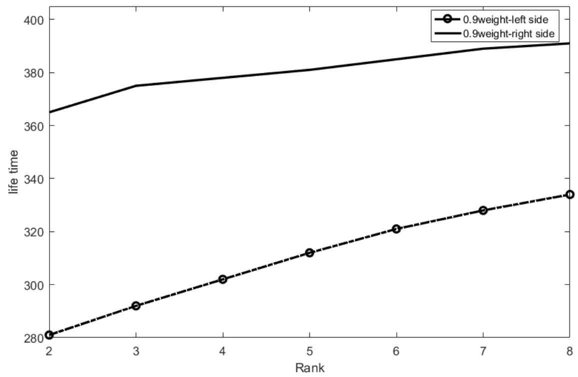

Figure 6 Life time of node in each Rank with 0.9 weight case.

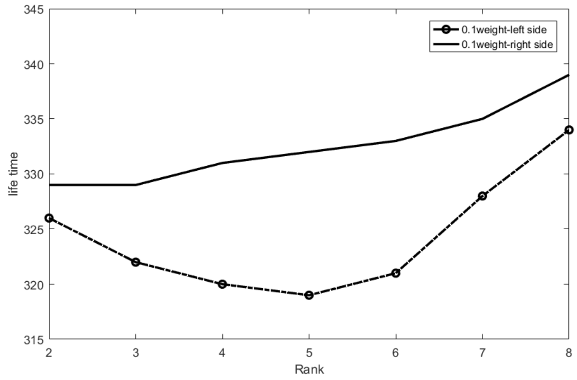

Figure 7 Life time of node in each Rank with 0.1 weight case.

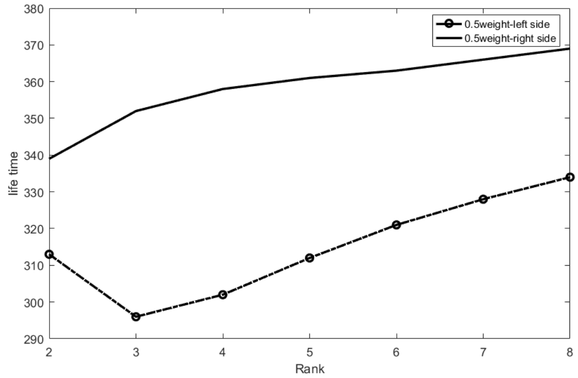

Figure 8 Life time of node in each Rank with 0.5 weight case.

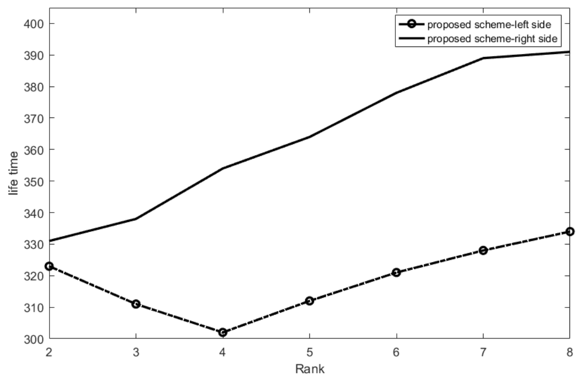

Figure 9 Life time of node in each Rank with the proposed weight case.

V. CONCULDE

In this paper, we propose Weight Ranking mechanism of energy balancing routing metric to enhance RPL routing protocol in order to provide more suitable energy balancing and prolong a network life-time. We combine 3 criteria as follow: ETX, energy consumption and Rank value. From the result, our metric can prolong the node life-time by 14.13% and 10.24% as compared to the conventional work with weight 0.9 and 0.5, respectively.

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