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An Improved ME-AODV Energy-Balanced Algorithm

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Abstract

The Internet of things is a network that based on the IEEE802.15.4 wireless communication protocol and transmit data between devices. It contains a big variety of communication technology, considering the advantages of low-power,low-cost and large-capacity, ZigBee technology becomes the best way to solve Wireless Personal Area Network portion of Internet of Things. However, due to the theoretic immaturity of this newborn technology and complexity of its hardware implementation, there are numerous problems need to be solved, such as reduce energy consumption to increase the lifetime of zigbee, this paper propose an energy-balanced algorithm which combine and balance ME-AODV(Multipath Energy Aware AODV Routing)and Cluster-Tree routing algorithms. This algorithm employs ME-AODV and Cluster-Tree routing algorithms in different energy conditions to reduce energy consumption and extend the lifetime of network. The simulation have been performed using IEEE802.15.4,ns-2moudule and simulation results show that the improved algorithm can optimize the energy consumption of ZigBee network compared with original algorithm.

Keywords*: ZigBee;Tree ; energy-balance;ME-AODV*

1. Introduction

With the development of Information technology, communication has experienced exponential growth caused by the need of connectivity in this years. The rise of Wireless Personal Area Network(WPAN) enable people to get rid of the cable shackles and realize the communication between various devices in short range. With the merits of WPAN, like low overall system cost, fastness of transmit speed, and low energy consumption, Zigbee technology targets the applications such as industrial, medical, mobile communication and smart home systems which have more throughput capacity requirements and substantially lower power consumption than current existing standard implementations[1].With the development of zigbee and perfect, its widely use will bring many convenient and material benefits for People's Daily life.

The supporters of ZigBee have established ZigBee Alliance[2]. It's responsible for making the standard, promoting the ZigBee Protocol and testing the ZigBee Product. Following the standard open Systems Interconnection (OSI) reference Model ,ZigBee's protocol stack is structured in layers.The first two layers, Physical(PHY) and media access(MAC),are defined by the IEEE802.15.4 standard.The layers above them ,NWK(Network) layer and AF(Application Framework) as well as security services are defined by the ZigBee Alliance .The ZigBee Alliance also specifies two routing protocols. The first one is a simple Cluster-Tree routing protocol. In Cluster-Tree algorithm, node calculate its next-hop through the network address of destination node. Tree routing protocol requires no broadcast to find routing path and no memory to maintain routing information. It finds the routing paths using a distributed addressing scheme based on tree topology. Although tree routing is simple and cost very low resource, it may be quite inefficient. Another routing protocol in ZigBee named AODVjr which similar to Ad-hoc

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On-demand Distance Vector Routing(AODV)[11]. When one node want to send data to destination node but do not have routing information, AODVjr will find a appropriate routing path by flooding the Route Request Command Frame(RREQ) in the network.However,routing overhead for routing discovery may often cause Network congestion and affect the overall performance.In December 2004,ZigBee Alliance passed the version 1.0 specification.

2. ZigBee Routing Mechanism

There are there different topology in ZigBee Network,star,tree and mesh.ZigBee defines three types of devices: ZigBee coordinator(ZC), ZigBee routers(ZR), and ZigBee end devices(ZED) .An reduced function device(RFD) can only be a ZigBee end device, while an full function device(FFD) can be either a ZigBee coordinator or ZigBee router.The ZigBee coordinator is responsible for starting a new network and manage the WPAN. The routers have the ability of routing while the ZigBee end devices can't participate in routing and have to rely on their corresponding ZigBee parent routers for routing which are either FFD or RFD[3]. ZigBee network layer provides functionality such as establish dynamic network , address assignment, routing and discovering one-hop neighbours. The network address is recommended to be assigned in a hierarchical tree structure. The deployed ZigBee devices automatically construct the network and then changes such as joining/leaving the devices are automatically reflected in the network configuration.

2.1. ZigBee Address Allocation Mechanism

In a Zigbee network, Zigbee equipment can structure star network or point to point network, within every Zigbee network , respectively for 16 bit short address or 64 bits long address.64 bits long address is the unique identification of the node and 16 bits address was distributed dynamically by its parent node when node joining the network.ZigBee coordinator determines maximum depth of network (Lm), maximum number of children of any potential parent (Cm),maximum number of children which can be routers (Rm).Every parent node will calculate the size of address sub block of its child nodes according to the function[4]:

$$C_{skip}(d)=\begin{cases} 1+C_m*(L_m-d-1), & R_m=1 \\ \dfrac{1+C_m-R_m-C_m*R_m^{L_m-d-1}}{1-R_m}, & otherwise \end{cases} \quad ①$$

Where d is the depth of parent node.

When Cskip(d)>0,the node was eligible for child nodes assigned address which means it allows children node to join.Specific steps are as follows:

When the coordinator establish a new network,it will assign itself a network address 0 and a network depth of Depth0=0.

When the ith route node wants to join the network and associate with node p,node p will become the father node of node i.Assumed that Ap is the network address of node p,then Ai will be assigned as the following expression:

$$A_i = A_p + C_{skip}(d)*(i-1)+1 \quad ②$$

Where $1 \le i \le R_m$

When the kth end device join the network,father node p will assign network address as follows:

$$A_k = A_p + C_{skip}(d)*R_m + k \quad ③$$

Where $1 \le k \le (C_m - R_m)$

It will certain whether the destination node is its child node by using expression

$$A \le D \le A + C_{skip}(d-1) \quad ④$$

We suppose that the network address of destination node is D,the network address and network depth of this router are equal to A and d respectively.If the logical expression ④ is true,we know that destination node is its child node,then the address of next hop can be calculated by the following expression:

$$N = \begin{cases} D, & if\ \ end\ device \\ A+1+\left[\dfrac{D-(A+1)}{C_{skip}(d)}\right] * C_{skip}(d), & otherwise \end{cases} \quad ⑤$$

If the destination node with network address D is not the descendant of router whose network address is A,the router forwards it to its parents node.

This address allocation mechanism mainly aims at a tree network ,but it also applies to medium large cluster network.By this means,these address are unique within a particular network and a router can acquire the relationship of two nodes though their network address which are assigned using a distributed address scheme. The advantage of Tree Routing is that it requires no communication overhead to find routing path and no memory to maintain routing information.It is simple and needs very less resource.However,Tree Routing may provides an inefficient routing path which consume more energy and induce more transmission delay.

2.2. ZigBee Routing Algorithm

Since Tree Routing often provides un-appropriate routing path,to overcome the problem,the ZigBee standard specifies another routing protocol AODVjr[1] to find the optimal path using route discovery.AODVjr will initiates a route discovery process to find the optimal path for the destination ,the source node firstly broadcasts a Route Request Command Frame(RREQ) to its neighbors,when the intermediate routers receives a new RREQ,it creates a new Routing Table entry and a Route Discovery Table entry for the destination,but most of the RREQ is useless,this may cause the redundancy and Consume more energy.Cluster-Tree algorithm is simple and no need memory to maintain routing information,reduces the control overhead and routing cost of routing protocols.But when the network size is too large,Tree Routing may provides an inefficient routing path ,cause too many hops and higher delay.

AODVjr and Tree Routing algorithm have their own advantages and disadvantages, although ZigBee uses a mix of Tree and AODV routing,there is no detailed specifications to show how to selection strategy by setting the corresponding parameters[10].In this paper,we introducing the concept of Node Energy Classification, according to different Node energy level, we can select different algorithms.

3. Energy-Balanced Optimization Algorithm

In this paper, we propose a routing algorithm combined ME-AODV[5] and Cluster-Tree Routing[6].When the energy of cluster head is sufficient, within the cluster to use ME - AODV, with AODV algorithm for data transmission between clusters. When the cluster head's energy is too low, within the cluster using a simple Cluster-Tree Routing algorithm.when the energy of cluster head is warning,it responds only to the situation in which it is the destination node.By this method, the optimal routing path is not only used, but also the redundancy RREQ packet is reduced.

3.1. Establishment of ME-AODV Cluster

ME-AODV utilizes ZigBee network's cluster-tree topology to divide the network into logical cluster and assigns each logical cluster a unique cluster ID.This cluster ID along with network is used to avoid the flooding of route request messages during route discovery.Nodes in cluster have 3 different roles which are cluster head,gateway and cluster members.Each cluster contains a cluster head, and the cluster head plays a role in controlling and managing.In order to form a cluster ,We make the following provisions on the formation of clusters:

(1) Only ZC and ZR have the qualification of becoming a cluster header.

(2) End devices cannot form clusters, can only be added to the parent node of the cluster.

ME-AODV consists of two stages: the construction of cluster phase and data communication phase.In the construction stage, the ZigBee network is divided into several logical clusters according to certain rules. Each cluster has a unique cluster ID, and the network nodes are divided into cluster head, gateway and cluster member nodes. The cluster head and the cluster member nodes communicate with each node in a single hop and within the same cluster nodes in Shared cluster routing information. Specific process is as follows:

1. The first cluster in the network is formed by the center coordinator as the cluster head, which is mainly composed of the nodes Within the range of center coordinator.The first cluster denoted as clusters 0. After the cluster is formed, the coordinator broadcasts the message to the nodes that has been found,if found node is not the child of coordinator ,a mesh link(dotted line) will creat between them.For example,as shown in Figure 1.(c)

2. All the nodes of cluster 0 found in step 1 above(say current) will broadcast message within their radio range to search new nodes.If the found node is a leaf node of cluster 0,then these current and found nodes will connect with a mesh link,and the sibling relationship will memorize.If the found node is new and not the child of corresponding current node,a new cluster is created and the found node is designated as new cluster header,then a mesh link is created between them.

3. All the cluster head founds in the step 2 (say current),start the discovery process again.If the newly found node is a cluster head already,and has parent-child relationship with current,then the two clusters will be merged, the parent node will become the cluster head of merged cluster.If there is no relationship between them,the node with higher connectivity will become cluster head.In case of tie,the node with less numeric value of network address will become cluster head.In our case in Figure 1.(e),node 7 has less numeric value of network address than node 8,hence only node 7will be the header of cluster. If the newly discovered node is an isolated node, not in any cluster, it will join the cluster which current belongs as cluster member,then a mesh link will establish between found node and current.

4. All the leaf nodes of new cluster found in step 3 above (say current),start the same process as in step 2.If the found node is the leaf node of cluster which parent node belongs,a mesh link will create between them.If the found node is new,the node will create a new cluster as a cluster header.Current will become the gateway for this newly cluster.

5. Steps 3 and 4 will be repeated until no new neighbors are found by any cluster leaf node.

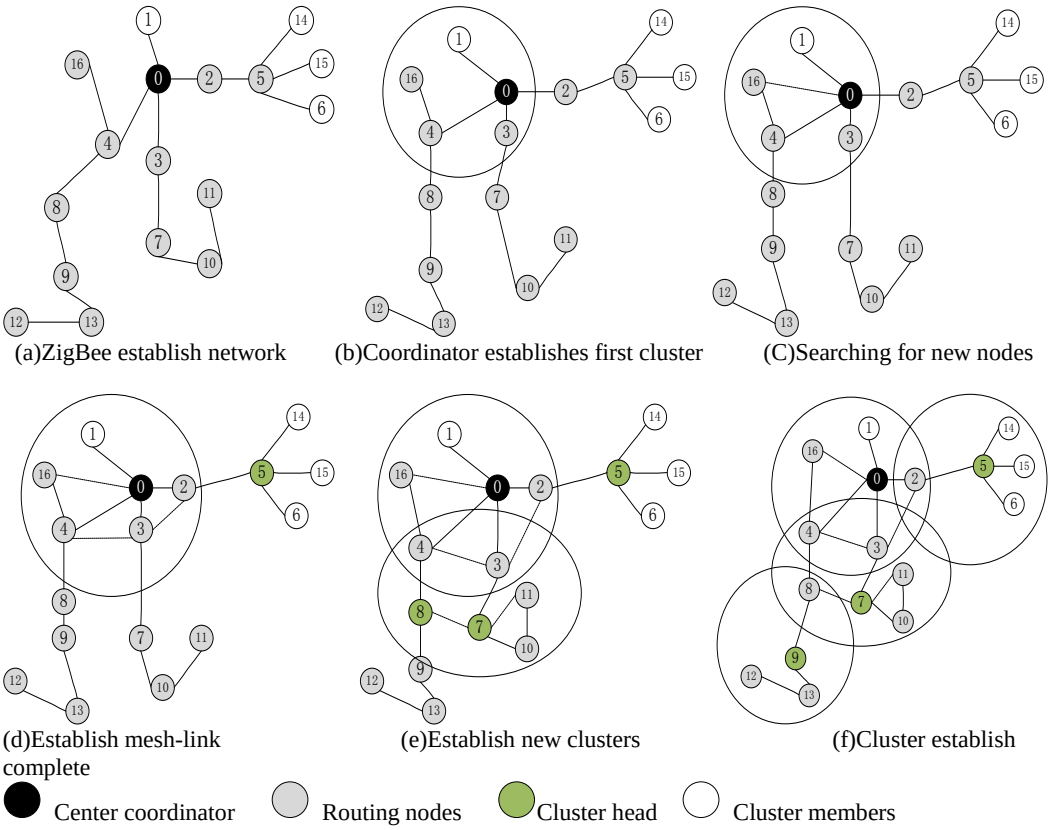

Figure 1.The Clustered Process of ME-AODV Protocol

After the completion of clustering,if one node wants Communicate with another.Firstly judge that whether the source node and destination node within the same cluster.If not, the RREQ packet will be forwarded to the traditional AODV routing process; If so, determine that whether there is mesh link between them, if yes, the data packet is sent directly to the destination node; If not, then the RREQ unicast message to the source cluster head. The node that receives RREQ message will follow the way of AODVjr to forward the message and reply RREP message.

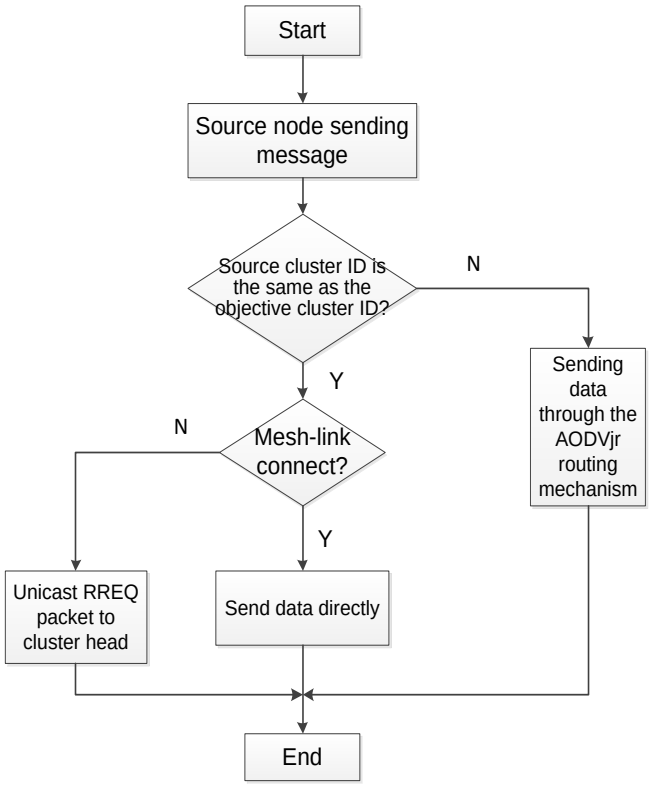

Figure 2.The Specific Data Transmission Process Of ME-AODV Protocol

3.2. Node Energy Classification

In this paper, the node energy is divided into 3 levels: sufficient, low, and warning.According to different battery energy[7],cluster head will choose different mechanism after receiving the RREQ groups. If cluster head's remaining battery capacity is sufficient, within the cluster to use ME - AODV, with AODV algorithm for data transmission between clusters.When the remaining energy of cluster head is low,Cluster-Tree routing algorithm will be used within cluster.When the energy of the cluster head is in addition of warning,It responds only to the situation itself as a destination node.If it is not the destination node, then do not respond.

The literature[8]defined different node energy value of warning, it is dynamic update so that warning nodes can restore for effective routing under some certain. But sufficient energy and low energy value is fixed,can not change with the change of network conditions,this leads to a large number of nodes in a state of low energy level and affect the routing discovery process.Literature[8][9] , warning value is a function of network running time, the longer the network running,the lower the warning value.But only set time as a variable can not describe the concrete conditions of the energy of the node adequately.In this paper,we simplify the formula in literature[8],the definition of dynamic update of the node energy is as follows:

$$Power_{Sufficient} = \alpha^N \times Power$$

$$Power_{Low} = \beta^N \times Power$$

$$Power_{Warning} = \gamma^N \times Power$$

Power is the initial energy value of node.α , β , γ are fixed factors.N is a counter for the initial value of 1.When the ratio of warning nodes and all nodes reached the threshold,value of N plus one.

3.3 Data Frame Transmission with Low Energy

Suppose that the source cluster ID is the same as objective cluster ID,but there is no mesh-link connect,RREQ packet will be unicasted to cluster head,then cluster head initiates a route discovery process to find the optimal path to the destination. Generally speaking,the cluster will not too large,within the cluster AODV algorithm can find the optimal path,but unicast will cause communication burden,what's more, excessive use of RN+ nodes may bring out RREQ redundancy and consume more energy.Cause cluster head take an important role in the network,when the energy of cluster head in a state of "PowerLow",in order to extend the lifetime of network ,Cluster-tree algorithm will be executed within the cluster instead of ME-AODV.

(1) Source node cluster

The processing flow after the nodes in source node cluster received the data frame as shown in Figure 3.

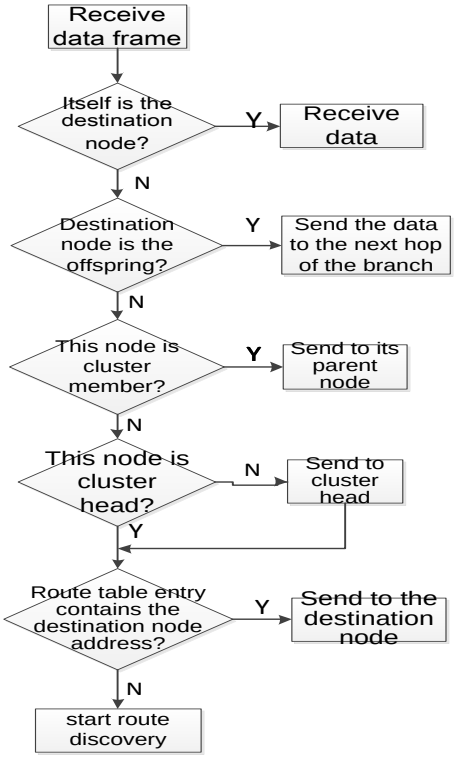

Figure 3. The Processing of the Data Frame of the Nodes in the Source Cluster

When source node desires to send data to another node,firstly it will determine whether destination node is their own offspring by formula④,If so,sent the data to the next hop of the branch.If not,determine the type of its own and take different processing procedure according to different node types.

When the members in the cluster which source node belongs receive or send data frame,it can only use Cluster-Tree algorithm and can not store routing table.Cluster member will determine whether itself is the destination node or not.If so,receive data.If not,determine whether destination node is their offspring nodes.If so,sent the data to the next hop of the branch,otherwise the node will rebroadcast data to its parent node according to Cluster-Tree algorithm and sent to cluster head eventually.

When the Gateway in cluster which source node belongs receive or send data frame,firstly determine that itself is the destination node or not.If it is,receive data. If

not,determine whether destination node is their offspring nodes.If so,sent the data to the next hop of the branch,otherwise send data frame to cluster head directly.

When the head of cluster which source node belongs receive or send data frame,firstly determine that itself is the destination node or not.If it is,receive data.If not,determine whether destination node is their offspring nodes.If so,sent the data to the next hop of the branch.If not,cluster head buffers the data packet temporary and view if the route table entry contains the destination node address,if there is ,the data frame will transmit directly to the destination in accordance with the specified path.If there is not,cluster will start a route discovery process to locate a shortest path for the destination.

(2)Destination node cluster

The processing flow after the nodes in destination node cluster received the data frame as shown in Figure 4.

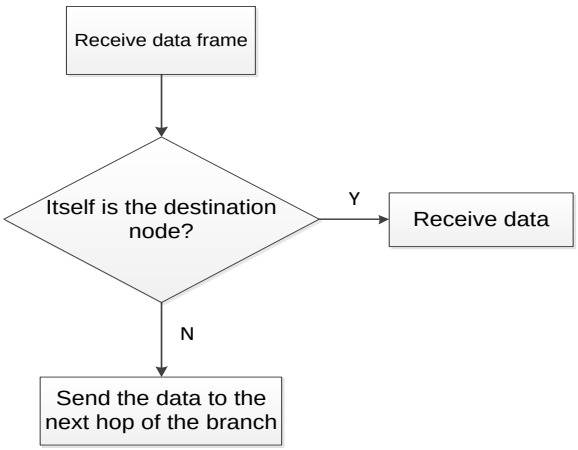

Figure 4.The Processing of the Data Frame of the Nodes in the Destination Cluster

When the information is transmitted to the cluster head of the destination cluster, the cluster head is compared to the address information of the nodes in the cluster and found the address of destination node,cluster head sent the data to the next hop of the branch,eventually reached the destination node.

4. Simulation and Analysis

This simulation experiment using NS-2[12] as the network simulation platform, the simulation experiment is carried out on the basis of the physic layer and MAC layer module.Network covering an area of 100m×100m,network number is set to 100,the initial energy of the nodes is 1000J. α , β , γ are set to 0.75,0.5,0.15 Respectively.Threshold is 0.5,The data rate is 250 KB,packet length 128bit.As shown in Figure 5,because introduced the energy classification and energy levels are dynamically changing,realized the balance of ME-AODV and Cluster-Tree. Compared to the ME-AODV,algorithm in this paper can reduce the energy consumption and prolong the network lifetime of network.Although the initial stage of the network consumption is basically the same,with the increase of network running time,algorithm in this paper is better than ME-AODV in overall energy consumption.

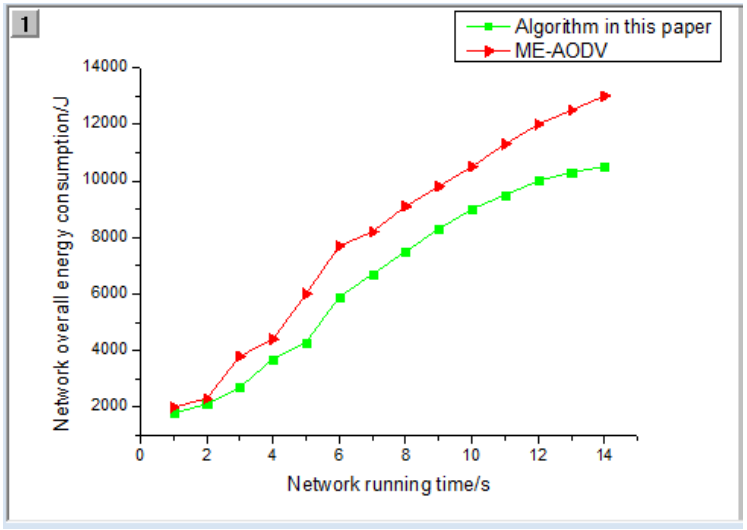

Figure 5. Network Energy Consumption

As shown in Figure 6,at the beginning ,each node's energy is sufficient,no node will "die" in two algorithms.With the running of network,some nodes which act as routers will consume a lot of energy and tend to die.In this paper,we consider the state of node energy and use Cluster-Tree while cluster head's energy is low to extend the lifetime of network.Compared with ME-AODV algorithm,the timing and number of death node are optimized.

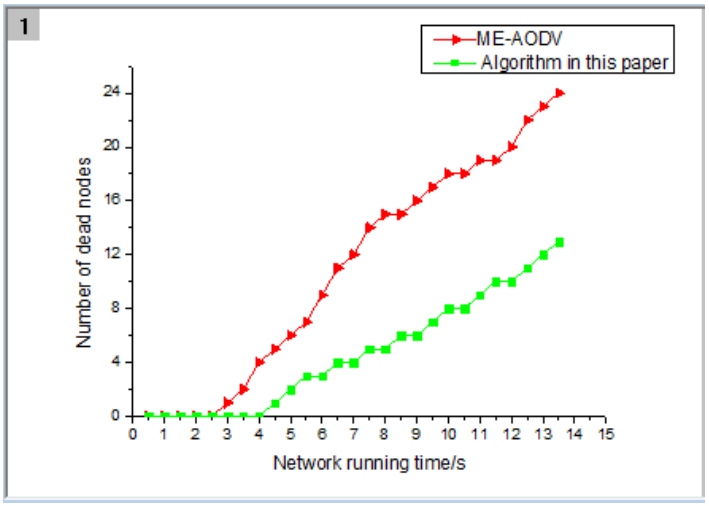

Figure 6. Number of Dead Nodes

5. Conclusion

ZigBee hierarchical network provides a simple and reliable solution for short-range, low data rate and low-cost communication.The research on ZigBee will lay a foundation for the application and development of the IOT.ZigBee technology research has been focus on the optimization of network layer.This paper is based on the research of ZigBee routing energy optimization and combines the advantages of ME-AODV and Cluster-Tree.This algorithm is based on clustering mechanism and introduces the method of energy classification.when the energy of cluster head is sufficient, within the cluster to use ME - AODV, with AODVjr algorithm for data transmission between clusters. When the node energy is too low, within the cluster using a simple Cluster-Tree Routing algorithm.By this method,the route discovery process and redundant RREQ packet is

reduced.Simulations shows that Energy-balanced optimization algorithm in this paper can optimize the energy consumption of ZigBee network and extend its lifetime.

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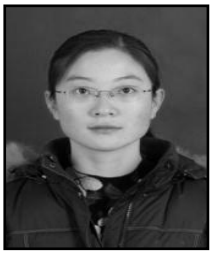

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