Street Lamp Management System Based on zigbee Technology Routing Design

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Abstract

A mixed routing strategy of AODV and Tree Routing is designed in the ZigBee specification. But there is no method designed to balance these two Routing modes in order to achieve better performance. We realized the ZigBee protocol module in NS2. Simulations had been run to analyze the ZigBee network performance. According to the analysis, a strategy of ZigBee routing selection based on data services has been proposed. The simulation results show that such routing selection strategy has excellent network performance and low energy consumption. Additionally, the power control is not much considered in ZigBee Routing specification. But for the ad hoc wireless network application, power control is the most significant issue in ZigBee. So a power control strategy is proposed to improve the ZigBee routing, the simulation results show that this power control strategy will greatly balance the node energy, avoid that nodes use up all the battery power and die too early.

Keywords

Zigbee, routing, energy-banlance.

1. Introduction

In December 2000, an IEEE 802 WPAN (Wireless Personal Area Network) group was founded to define the wireless protocol for WPAN. And a new protocol IEEE 802.15.4 [1] is released for low power and low cost wireless networking for residential and industrial environments in December 2003. To further leverage the success that 802.15.4 enjoys, the ZigBee Alliance released its first specification [2] in December 2004, based upon the physical (PHY) and medium access control (MAC) layer of IEEE 802.15.4 protocol. Recently, since the ZigBee specification and its applications is getting more and more developed, and the ZigBee products of many companies are not accordant with the specification [3]. So the applicationconfiguration, performance analysis and optimization remain further discussed [4] [5] [6]. For example, there is still no ZigBee module in the NS2 tool extensively used for the network simulation and so there is no relative analysis about the performance of the ZigBee routing. And the routing strategy and its optimization of ZigBee must also be taken into consideration. Therefore, we realized the ZigBee stack in the NS2. In this paper, the simulations have been run to evaluate the ZigBee routing method. And according to the actual application, optimizing strategies and algorithms of routing is proposed.

2. Overview of the IEEE 802.15.4 protocol and ZigBee specification

The ZigBee specification defines network layer, application layer and correlative security strategies, based upon the physical (PHY) and medium access control (MAC) layer of IEEE 802.15.4 protocol. The application layer defines the corresponding application specification for different background. Especially, it defines the service binding which means that the data service can be bound between the fixed nodes. The definition of ZigBee network layer includes network topology, network establishment, network maintenance, routing and its maintenance. ZigBee defines three types of devices: ZigBee coordinator, ZigBee router and ZigBee end device. And three network topologies are defined: star, tree and mesh topology. The star topology of ZigBee is mainly designed for the simple communication from one node to several nodes. The tree network uses a Hierarchical/Tree Routing mechanism. And the mesh network uses the mixed routing method combined with AODV and Hierarchical/Tree routing. However, the AODV used in ZigBee is a little different to the AODV in ad hoc network. The latterone is based on the sequence number, which always chooses the newest routing. The AODV of ZigBee is based on the path loss. So we use Z-AODV to represent the AODV of ZigBee for convenience.

3. Analysis of routing algorithm

3.1 Tree routing

The Tree Routing mechanism includes the configuration of tree addresses and tree addressing routing. When the coordinator establishes a new network, it will assign itself a network address 0 and a network depth of Depth0 0 . If node (i) wants to join in the network and associates with node (k), node (k) will become the father node of node (i). And then according to its own network address *A k* and network depth *Depthk* , node (k) will assign a network address *A i* and a network depth of 1 *Depth i k Depth* to node (i). The network depth means the hops from a node to the root node, that is, the PAN coordinator of the network. Figure 1 shows the tree structure of ZigBee. The parameter nwkMaxChildren(CM) represents the largest number of children nodes which can associate with a router or a coordinator. The parameter nwkMaxRouters(RM) means the number of children nodes which can be a router. And for the same network, different nodes usually have the constant CM and RM.

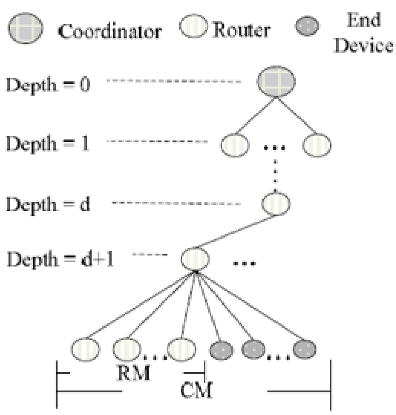

Figure 1. Tree structure of ZigBee

A new node (n) is a RFD (reduced function device), which means it has no routing ability. It is associated with a coordinator as its nth child node. According to its own depth d, parent node (k) will assign child node (n) the network address:

$$A n \qquad A k \quad Cskip(d) \quad Rm \qquad n$$

And if the new child node is a FFD (full function device) which means it has routing ability, parent node (k) will assign the network address like

$$A n \qquad A k \qquad\qquad Cskip(d) \quad (n\text{-}1)$$

And Cskip equals to:

$$Cskip = \begin{cases} 1 + Cm \cdot (Lm - d - 1) & if\ Rm = 1 \\ \dfrac{1 + Cm - Rm - Cm \cdot Rm}{1 - Rm}, & otherwise \end{cases}$$

It is supposed that a router forwards a data packet to the destination node whose network address is D. The network address and network depth of this router are equal to A and d respectively. It will first judge that whether this destination node is its child node according to the expression:

$$A \quad D \quad A \quad Cskip(d \quad 1) \,.$$

If the destination node is its child node, the address of the next hop node is

$$\mathrm{N} = \begin{cases} \mathrm{D}, \ \text{if end device} \\ \mathrm{A} + 1 + \left[\dfrac{\mathrm{D} - (\mathrm{A}+1)}{Cskip(d)}\right] \times Cskip(d), otherwise \end{cases}$$

Otherwise, the next hop node is the father node of this router.

3.2 Simulation model

We realize a ZigBee module in the NS2 in order to evaluate the performance of ZigBee routing. We use a 50×50 m^2 square simulation area, and the numbers of nodes are 11, 21, 51 respectively. And 15 meter transmission range is adopted. Packet error ratio is set to 0.2% and the data rate is 250kbps. The packet size is 70 bytes. The simulation time is 100 sec.

3.3 Simulation of Tree routing and Z-AODV

The simulation comparison of Tree Routing and Z-AODV is shown in Figure 2.

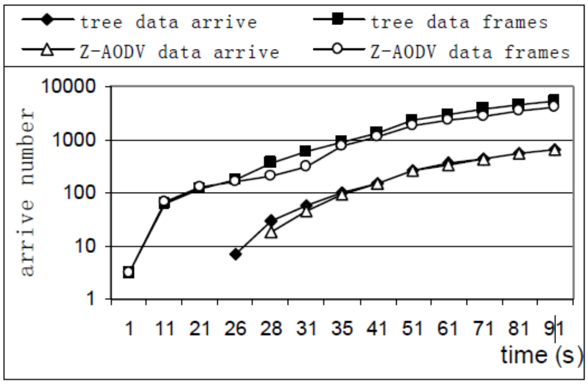

Figure 2. Tree Routing and Z-AODV

Data flow starts at 25s. We can see that Tree Routing has faster response to forward data packets since it needn't to establish routing tables. At 26s, there have already been 7 data packets arriving at the destination node. And data packets arrive at 27s because Z-AODV must initiate the routing discovery. After Z-AODV establishes its routing table, the numbers of data packets of two routing methods will tend to be the same. Z-AODV always chooses the route of less hops and Tree Routing can not usually obtain shorter route. So data frames transmitted in Tree Routing network are always 1.2 or 1.4 more than data frames transmitted in Z-AODV network. Apparently, Tree Routing of ZigBee is suitable for bursting data transmissions and Z-AODV is suitable for continuous data transmissions.

3.4 Routing based on data services

The ZigBee mesh network uses a mixed routing mechanism combined with Tree Routing and Z-AODV. The DiscoverRoute field of the data frame head is defined as the routing approach for data frames. And it can have three values as follows.

1. Suppress route discovery: it uses the routing tables that exist already. When there is no corresponding address of the destination node and the parameter nwkUseTreeRouting is equal to TRUE, the network will use Tree Routing.

2. Enable route discovery: if there is the routing address in the routing table, the routing will follow this routing table. Otherwise, the router will initiate the routing discovery. When this node has no ability to initiate the routing discovery, it will exploit the Tree Routing.

3. Force route discovery: The node has to initiate the routing discovery constrainedly no matter whether there is the corresponding routing table or not. It is not explained in ZigBee specification that how these parameters are configured in order to choose the routing strategy. According to the simulation results above, we can choose the routing strategy like this. The binding data services in the ZigBee application layer will always use “enable route discovery” routing method. The bursting data services use “suppress route discovery” routing method. This kind of routing method is called routing based on data services.

3.5 Simulation of routing based on data services

In this simulation, data flow is mixed with binding data and bursting data. The bursting data packets are under 30% of all the packets. The routing definitions in Figure 3 are shown in Table 1. And the efficiency is defined as the ratio between transmitted data bytes and the total transmitted bytes.

Table 1. Routing definitions

shortened form	routing strategy
ERD	All packets enable route discovery
BoS	routing based on data services
SRD	All packets suppress route discovery

As shown in Figure 3, when the number of bursting packets group increases, the efficiency of SRD routing is the highest and the efficiency of ERD routing is lowest. BoS has to initiate the routing discovery for the binding data flow. ERD has to do so for both the bursting data flow and binding data flow. SRD needn’t to initiate the routing discovery. So the increase of control overhead cause that the efficiency of ERD routing is low and it is sensitive to the number of the bursting data flow.

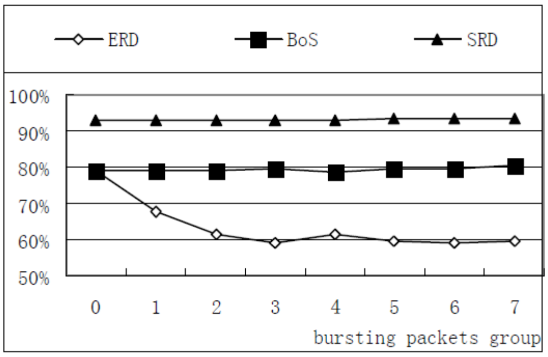

Figure 3. Comparison of routing strategies in ZigBee

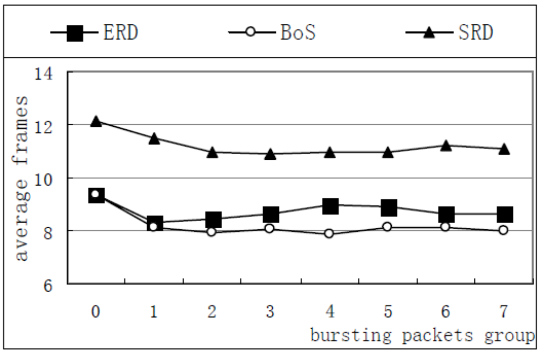

Figure 4. Z-AODV and ZigBee routing based on data services

Figure 4 shows the average transmitted frames that the three different routing strategies need respectively to transmit a data packet in the case of different bursting data. SRD transmits more frames since it sends packets through tree paths. ERD elects the shortest path, so it transmits fewer frames. The routing based on data services cuts down the consumption of routing discovery for bursting data since it uses Tree Routing. So it has the least overhead. BoS saves about 9% overhead than ERD and saves about 28% overhead than SRD. So BoS cuts down the power consumption accordingly. It is much beneficial to low-power IEEE 802.15.4 and ZigBee. In addition, the drop ratio of packets of ERD is 2.85%. The drop ratio of BoS is 1.5%. And the drop ratio of SRD is 1.03%. The main reason for ERD having large drop ratio is that it continuously initiates routing discovery for new data flows. So it needs to broadcast routing discovery frames and lots of frames collisions happen because of hidden terminal problem. SRD never broadcasts routing discovery frames and has the smallest drop ratio.

4. Energy-balance routing algorithm

The power control is not much considered in ZigBee Routing specification. But for the ad hoc wireless network, power control is very important. So a power control strategy is proposed to improve the ZigBee routing. It will avoid that nodes use up all the power and die too early. When a node wants to select a path, it will take the residual power of nodes in the path into consideration.

4.1 Energy-balance routing

The method to calculate *p l* is not mentioned in ZigBee specification. The protocol developers can define path loss according to their own demands. For example, *p l* can be calculated by LQI (link quality indication) or used a constant 7. So an energy-balance algorithm can take several factors into consideration synthetically to choose the routing. The factors are energy of adjacent nodes, energy of a node itself and link quality. The value of residual energy *local E* can be sent in the reserved field of every ZigBee frame. So every node can get the newest energy distribution about its neighbors. Furthermore, we can get the mean area energy *E avg* .

4.2 Simulations of energy-balance algorithm

We set the path loss to the constant 7. We compare the simulation results between the energy-balance algorithm and the previous algorithm that does not use the energy-balance algorithm, as shown in Figure 5. We can observe that the energy-balance algorithm has smaller standard deviation of nodes energy than constant cost algorithm. It means that energy-balance algorithm really balances nodes energy.

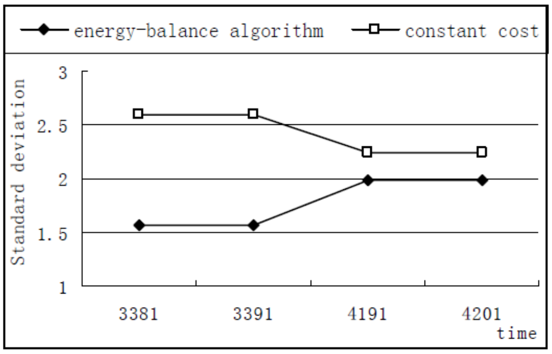

Figure 5. Comparison results

Another important simulation result is that life of nodes in energy-balance algorithm is 20% longer than in the previous algorithm in the case of the same data flow. So the energy-balance algorithm is effective.

5. Conclusion

In this paper, we introduce the mixed routing strategy of AODV and Tree Routing of ZigBee. A routing selection strategy based on data services and an energy-balance algorithm in ZigBee are proposed. Several simulations have been run using ns2 to evaluate the two enhanced algorithms. And from the results, we can see two algorithms represent better performances comparing to the previous one. In future, we will do further research in optimizing the routing of ZigBee.

References

[1] IEEE Std. 802.15.4-2003, Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks[S], 2013.
[2] ZigBee Alliance, ZigBee Specification Version 1.0, http://www.zigbee.org, December 14th, 2014.
[3] Microchip Technology Inc. Microchip Stack for the ZigBee™ Protocol Version 1.0, 2015.
[4] M. Streeton and C. Stanfield, "ZigBee: the telemetry solution?", Telemetry and Telematics, The IEEE Seminar,
2005.
[5] D. Egan, "The emergence of ZigBee in building automation and industrial control", Computing & Control Engineering Journal, 2005.
[6] N. Baker, "ZigBee and Bluetooth strengths and weaknesses for industrial applications", Computing & Control Engineering Journal, 2005.