An Approach on Optimization of ZigBee Network Routing Algorithm

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***Abstract*—ZigBee routing protocol study and optimization for the problem of the effects of flooding AODVjr algorithm RREQ packet. By introducing new coordinate parameters and other methods to control the RREQ packet forwarding. Network robustness problem and prolong the life of the network, by changing the algorithm in the case of low energy strategy. And simulation comparison to verify the effectiveness of the optimization algorithm.**

Keywords- wireless sensor networks; ZigBee; low energy; RREQ; MATLAB

1 Introduction

ZigBee network is an emerging wireless sensor networks. He built based on IEEE802.15.4 standard [1]. Combines three advantages of the topology of the network in the form of cluster tree algorithm is widely used. The ZigBee networks usually use a combination of Cluster-Tree AODVjr algorithm routing strategy. Cluster tree algorithm is static routing algorithm, node assigned numbers by the formula, the formula to calculate the path can be based on the original node and the destination node, the node is not necessary to store the routing table to reduce memory requirements, but the requirements of the path is not the optimal path , resulting in a low transmission efficiency. From AODV AODVjr algorithm evolved by sending RREP packet to find the optimal path, but AODVjr easy to form a broadcast storm, resulting in a large number of routing overhead. The ZigBee network usually Cluster-Tree + AODVjr algorithm the ZBR routing strategy, in order to make the network to meet different application requirements, and optimize network performance.

1.1 Cluster-Tree

ZigBee network nodes by the MAC layer to provide the associated process generates a logic tree. When the nodes in the network to allow a new node to join the network between the two nodes form a parent-child relationship, the distribution mechanism is as follows:

Let each parent node can connect up to Cm child node. These child nodes up Rm routing node, the maximum depth of the network as is Lm Cskip (d) represents that the network depth d father of the offset between the node address of its child nodes are assigned, the sub-node number can be as follows formula derivation:

$$C_{skip}(d)=\begin{cases}1+C_m\times(L_m-d-1) & R_m=1\\ \dfrac{1+C_m-R_m^{(L_m-d-1)}-C_m\times R_m}{1-R_m} & Rm\neq 1\end{cases} \quad (1)$$

$$A_k = A_{father} + C_{skip}(d)\times(k-1)+1 \quad (2)$$

$$A_n = A_{father} + C_{skip}(d)\times R_m + n \quad (3)$$

If the routing node Cskip(d) is greater than 0, it can receive the other node to its child nodes, and its child node network address is assigned. It will be between the first one with its associated routing nodes are assigned than their big an address, associated with the routing address of the node the offset Cskip(d) apart. Each parent node can be assigned up to Rm address. Address allocation for the terminal node for the assigned address of the routing nodes, the address for Aparnt set the parent node. Then the n-th associated terminal sub-node address An:

$$\mathrm{A_n = A_{parent} + C_{skip}(d)\times R_m + n} \quad (4)$$

Cluster-Tree algorithm, the node to calculate the packet's next hop according to the network address of the destination node, for the address for the depth d ZigBee routing node having a destination device address is d, if the following expression (1) holds, then for the childequipment.

$$\mathrm{A < D < A + C_{skip}(d\text{-}1)} \quad (5)$$

If the destination node is a descendant of the receiving node, the receiving node grouping will send one of its child nodes, at this time if:

$\mathrm{D > A + R_m \times C_{skip}(d)}$ The destination node is the receiving node of the terminal sub-node, when the next hop node address N is:

$$N = D \quad (6)$$

Otherwise, N is obtained by the equation (5):

$$N = A+1+\left[\frac{D-(A+1)}{C_{skip}(d)}\right]\times C_{skip}(d) \quad (7)$$

If the destination node is not receiving node offspring, then the packet is sent to its parent node.

1.2 Introduction to 1.2 AODVjr algorithm

The used ZigBee routing algorithm AODVjr algorithm is to streamline and improve the AODV algorithm. AODV is an on-demand routing protocol, to establish and maintain routing based on network requirements, it is a combination of DSDV (Destination-Sequenced Distance-Vector) protocol and DSR (Dynamic Source Routing) protocol. AODVjr abandon AODV target sequence and hops, only

the target node to respond first arrived RREQ signal, this strategy also called point-to-point strategy. The same time AODVjr canceled HELLO information solidification occurs, would like to The Source sent KEEP_ALIVE connection information to maintain routing on a regular basis by the destination node. AODVjr algorithm to find a shortest path, flooding addressing messages and route maintenance requires a lot of overhead.

1.3 previous attempts

At present, the domestic and foreign scholars selective forwarding attacks made certain achievements.

Predecessors from two main directions of the algorithm for optimization.

Flexibility in adjusting the node energy the route formation [4], with a low-energy node does not load excessive transmission task.

Study how to reduce the effect of flooding RREQ packet forwarding[5][6], which they use is generated according to the Cluster-Tree topology network structure. Wherein the parent-child relationship to determine the general direction of the target node. However, such an algorithm is a lot of limitations.

(1)there is likely to miss the actual shortest path. Figure 1, for example from H to send information to the A method in accordance with the previous from H A is not H, the child nodes of the child nodes of H I does not forward the RREQ packet, but the actual optimal path is indeed HIA this route.

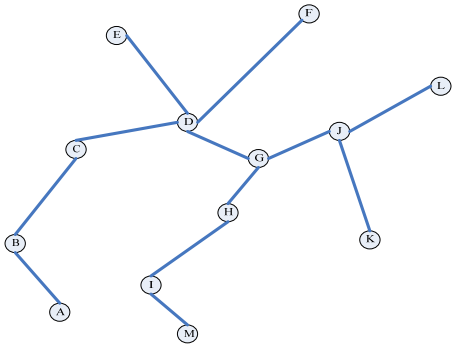

Figure 1 topology case diagram

(2)Energy exhausted in the beginning of the network node, the node starts successively death to many path will disappear, and all the reduction of the RREQ forwarding packets are actually reduce the possible paths from the original node to the destination node, although these paths may not bethe shortest path. Sufficient energy of this algorithm is very effective, but the node after the death of so many original shortest path disappeared. In the original AODVjr same algorithm can find the path, there may not be able to find these path optimization algorithm.

2 Improved ZigBee ideas and algorithms

The Cluter-Tree, and AODVjr algorithm combines the benefits of ZigBee routing compared AODVjr reduce the routing overhead, but will still be in the process of finding a path to generate a lot of redundant control packets, these routing control packet also participate in the route discovery, but no apparent help to find the optimal path. So if through the optimization algorithm limits the useless the RREQ packet generation and forwarding, the network will be able to effectively reduce the routing overhead. The other direction is to enhance the robustness of the network, improve network transfer success rate in the low-energy environment.

For this analysis, these two aspects limit RREQ packet forwarding.

2.1 limit the packet forwarding RREQ

(1) discarding RREQ packets hop count is too long

ZigBee routing algorithm, RN + node in the route discovery to the surrounding nodes just off the route request packet RREQ information received node in the network to find the optimal path to the target node by forwarding the RREQ. A condition of the optimal path is the least number of hops path, and if the the RREQ packet forwarding hops hops over Cluster-Tree algorithm according to the formula (number of hops and path 5.6.7 draw), set the source node A purpose Node B, and the depth of the source node DA, the depth DB of the destination node, the common parent node depth Dx.

Then $Step = D_a - D_x + D_b - D_x$ (8)

Jump over Step is not to find the optimal path so continue forwarding this RREQ packet does not make sense

(2) reduce the underlying node forwards pressure

The tree structure of the Cluster-Tree algorithm determines the more low-level node forwards the greater the pressure, it may lead to an early death of the underlying node. In order to prevent this from happening needs, reducing the priority of the low energy node. And the RREQ the last path selection is by RREQ packet arrives at the order, so just extend forwards RREQ packets can achieve lower priority purposes.

(3) limit the RREQ forwarding direction

ZigBee broadcast mechanism RN + node receives a RREQ packet, if he is not the destination node forwards RREQ packets, but forwards there is no purpose, it is possible and the destination node in the opposite direction. Forward these RREQ packet is meaningless. So if we can determine the approximate direction of forwarding, can narrow the scope of the forwarding RREQ packet. More than their predecessors from the topology of the parent-child relationship as a breakthrough, but there may be, the goal is not the child nodes of the original node forwarding through the child nodes of the path is the optimal path. Forwarding node is excluded by this method is still relatively low, there are significant limitations. The idea is so I made by obtaining the relative position between the nodes, and a master node of a layer 0 of the center to construct a two-dimensional graph. Such a large extent in the nodes between the original node and the destination node contains a transfer information optimal path, while the

opposite is no longer a node between the two points largely not the optimal path through the node can be excluded. This can greatly reduce the RREQ packet forwarding flooding effect.

Optimization algorithm idea is the introduction of a new parameter, add a two-dimensional coordinates of each node can find the newly added nodes, based on previous studies, according to three nodes known location by its contrast with the new node RSSI value two-dimensional coordinates [7] [8].

Such selected nodes only make the decrease in the number of hops within the search range, but at the same time the decrease in the sum of the actual distance between the nodes, so that the transmission signal in the case of the number of nodes between the same to jump stronger, higher transmission success rate .

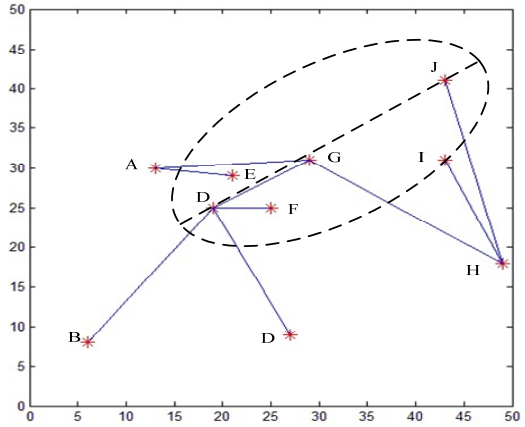

Figure 2 forwarding RREQ in zoning

ZigBee network is actually laying on the ground, each node communication radius, K transmission from point D to point the optimal path in the original node and the destination node is connected to the straight line around the node probabilityFollowing the node.

For example, the forwarding node in Figure 2 B, C, etc. is meaningless. So thereon characteristics to D, K two points for the focus draw an ellipse, the node will forward the RREQ packet within this range.

The establishment of the source node is D, and the destination node is K,

$$|DP|+|PK| \leq 2a \quad (9)$$

$$a = DK \times k \quad k>1 \quad (10)$$

When the received RREQ packet node satisfies the equation 8, the point P to meet the requirements can be forwarded RREQ. Although this algorithm may not be able to find the shortest path, but this greatly reduces the forwarding node to participate in the RREQ routing to reduce the effects of flooding.

2.2 low energy state of the network construction

All limit the effects of the flooding are generally forwarded by reducing the number of nodes in the RREQ packet, but the move will reduce the number of paths from the source node to the destination node discovery, all nodes have sufficient energy at the beginning, the algorithm is excellent , but when the running time is too long, nodes, have died, the entire network conditions become harsh. The original less hop count path can not be used to find the optimal path, then you need a larger range. By sacrificing the energy to return the transmission success rate in order to extend the length of the survival of the entire network.

Therefore, the introduction of the nodes proportion of deaths

When deadNode> x% (x% = k * node density, k experimental coefficient)

Instructions to start the low-energy, issued by the aggregation node start the original ADOVjr algorithms route available to them, come in a wider range. In order to maintain a robust network.

2.3 Node arithmetic formula

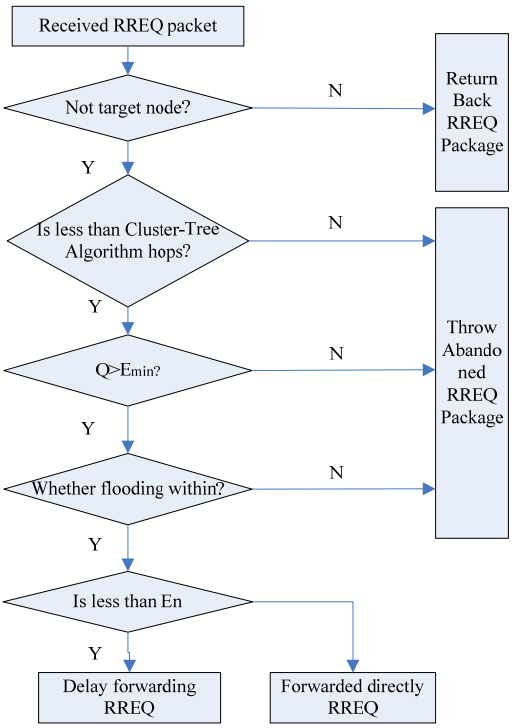

Figure 3 received the RREQ packet node computing flowchart

(1)Previous hop node receives RREQ packets sent, first to determine whether the target node, if the identified target node, reply directly return RREQ packet. If it is not a target node jump to (2).

(2)To determine multi-hop whether more than the number of multi-hop Cluster-Tree algorithm, when multi-hop over Cluster-Tree algorithm hops, discarding RREQ packet, stop forwarding, otherwise transfer (3).

(3)Determines the energy exceeds a forward node minimum limit (10%), if more than forwards (4), otherwise discard the RREQ packet, stop forwarding.

(4)Whether flooding within, If the turn (4), otherwise discard RREQ packet, stop forwarding.
(5)Is greater than En, is forwarded directly RREQ, if less than E delay forwarding the RREQ.
(6)When the node number of deaths exceeds x reversal original AODVjr algorithm.

3 actual simulation

The new algorithm for the ZigBee routing AODVjr algorithm optimized by introducing new coordinates to reduce RREQ packet flooding effect. Which to compare the deaths by the total energy consumption of the network nodes, network nodes AODVjr algorithm optimization results. The simulation results show, optimized AODVjr algorithm prompted the original algorithm achieved the desired effect.

The simulation tool using MATLAB. The network covers an area of 400 × 400, network node 40, node initial energy of 2500J. Setting Cm is = 4, RM = 3, Lm = 6, x = 10%. Equation 10, k = 1.5 nodes transmission distance of 60m. When reduced to 60J node node energy to lose sending data capacity, the node energy reduced to 10J nodes deaths.

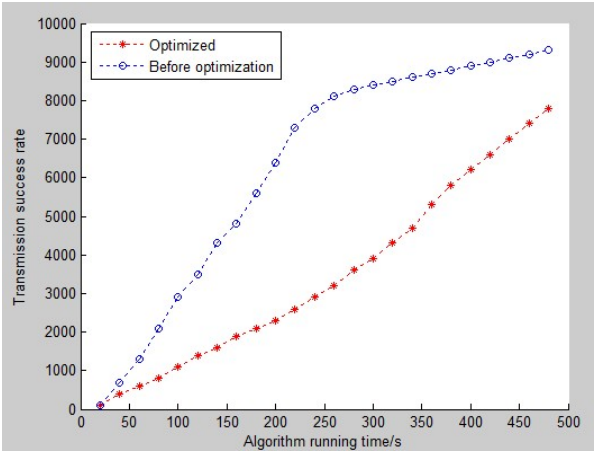

Figure 4 overall network energy consumption comparison

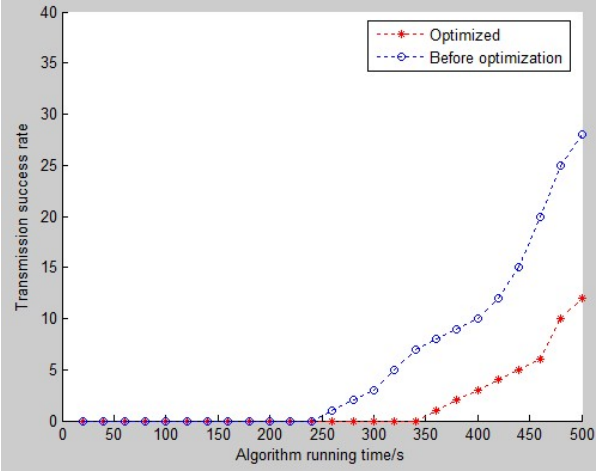

Figure 5 deaths node comparison

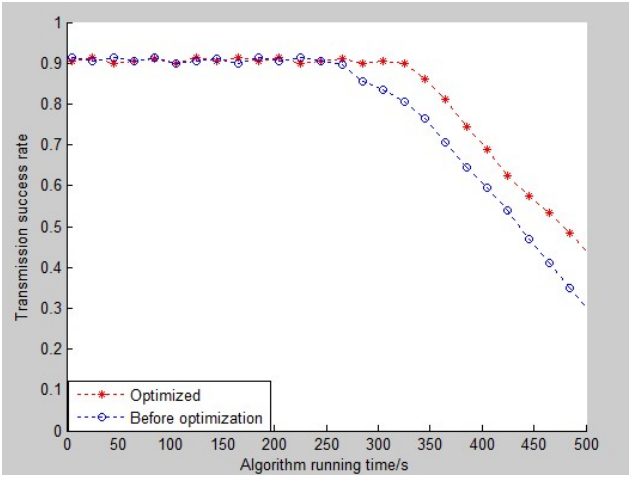

Figure 6 transmission success rate

4 Conclusion

In this paper, the introduction of the coordinate parameters to determine the range of packet forwarding RREQ, reduce the effects of flooding RREQ packets. Low energy state algorithm also to improve the robustness of the network switch. Figure simulation also obvious that the new algorithm is effective to reduce the energy consumption and prolong the life of the network. The results surface optimization algorithm is very successful.

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