빌딩 자동화를 위한 무선 센서 네트워크 라우팅 프로토콜

Routing Algorithm of Wireless Sensor Network for Building Automation System

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Abstract - Wireless Sensor Network (WSN) has been very popular in unattended surveillance systems recently. For Applying WSN into Building Automation system (BAS), a novel hierarchial network structure and static routing algorithm which eliminates the scalability limitation of Zigbee are proposed in this paper. The static routing algorithm relying on the hierarchial network address reduces the computational complexity to a great extent and has a real-time performance which satisfies urgent applications well.

Key Words :Wireless Sensor Network, Building Automation System, Zigbee, Backbone, Local Control Network

1. Introduction

As technology develops last decades, the building automation industry has grown remarkable. Building managers and facility managers are increasingly looking forward to novel technology to lower the total installation and maintenance cost of building automation systems. Wireless technology is a key solution in reaching those goals because of its several advantages such as installation cost reduction, easy deployment and extension, aesthetic benefits, and so on.

In this paper, a novel two-tier wireless network structure for Builidng Automation System(BAS) and the cluster based static routing algorithm improved from Zigbee cluster-tree routing in terms of buildings' specific spatial environment and routing requirements are proposed. The main attractive point of the algorithm are the proposed cluster-based routing can satisfy scalability requirement and the static routing algorithm based on the proposed "Hierarchical Network Address" can provide a real-time performance for urgent applications.

The chapter 2 gives out the network architecture, and network structure of backbone and its routing algorithm is discussed in chapter 3 and chapter 4 gives the conclusion. At last the future work is given.

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2. Network Architecture

A typical building network infrastructure consists of independent control networks on every floor named "Local Control Network(LCN)", which connect sensors and actuators at the room level. All the local control networks are connected through a backbone for central monitoring and control, remote maintenance and diagnostics, which may span building complexes.

2.1 Building Structure

In multi-floor building, rooms are basic space unit and relatively independent and close. They are connected by hallways and stairs between two floors. Therefore, the space in building are divided into two spaces:

1) Room space is a close space (rectangular or square) where the WSN can be regularly or irregularly deployed. E.g., Lighting Control System, the ballasts are deployed onto the lights which are evenly deployed in rooms, whereas alarm system is not the case. whereas the alarm system is not the case.

2) Hallway space connects rooms in the building spatially. In order to make the whole building covered by WSNs, WSNs can be deployed at the hallways.

2.2 Two-Tier Network structure

WSNs which are deployed into room level named Local Control networks are the first tier. Backbone acts as the second tier network which is deployed into the long and thin hallways. Therefore, it is much more irregular than local control network. Backbone makes the WSNs in the

room level connective in the whole building and different routing protocols are designed separately for backbone and local control networks in terms of different routing requirements. Fig. 1 shows the two-tier network structure.

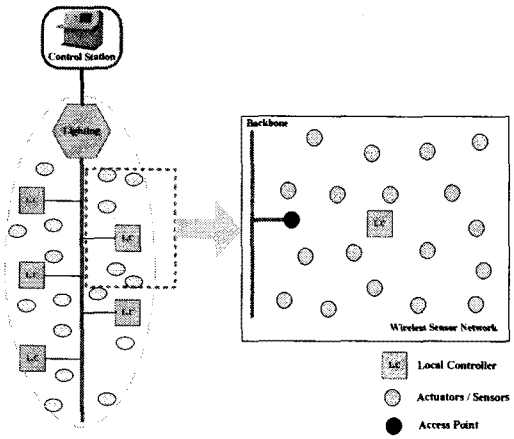

Fig.1 Two-tier network structure

3. Routing Algorithm of WSN for BAS

3.1 Routing for Local Control Network (First tier)

Normally, WSNs in most of home automation systems are static , battery-powered for easy deployment and cost reduction, a main-powered Local Controller in the middle. Refer to Fig. 1. Local controller is for gathering data in the network, management and data storage. The room space is close, so radio (2.4G Hz) can not go through the walls to access the backbone if packets should be forwarded to other floors or rooms. Therefore, Access Point(AP) is set in the backbone near the door through which nodes in LCNs can access outside the close space. All the nodes in LCNs which want to send packets outside one room should firstly access AP. AP sends packets to the corresponding AP of destination by backbone, and at last to the destination. The synchronous research work routing algorithm of LCN can be found in [1]. In this paper, only backbone routing algorithm which connects the LCNs of room level in the whole building is discussed.

3.2 Static Cluster-based Routing for Backbone network (Second tier)

The typical and widely-used wireless sensor network technology is Zigbee[2]. In case of irregular and relatively closed building environment, Zigbee can not serve BAS very well because its "Distributed Network Address assignment" will early exhaust the 16 bits network address especially in the long and thin backbone network deployed into hallways in the building. In this part, a new network address assignment scheme is proposed.

3.2.1 Requirements of Backbone routing algorithm

Definitely, backbone network should be scalable enough to make the whole BAS covered by the WSNs no matter how large the building is, high-rise building or building complex. Moreover, backbone will be responsible for some real-time packets delivery in alarm applications. Mobility and energy efficiency are relatively relaxed because most of the nodes in backbone are static and main powered.

3.2.2 Backbone Network deployment

All nodes are static, main-powered, a little redundantly deployed one by one on the ceiling of hallways in a linear cluster format. Cluster Head(CH) is firstly deployed at head of one cluster; while GateWay(GW) is deployed at the tail of cluster. CHs are connected with the GWs of upper clusters. Backbone will undertake the main data traffic among the BAS. Refer to Fig. 2.

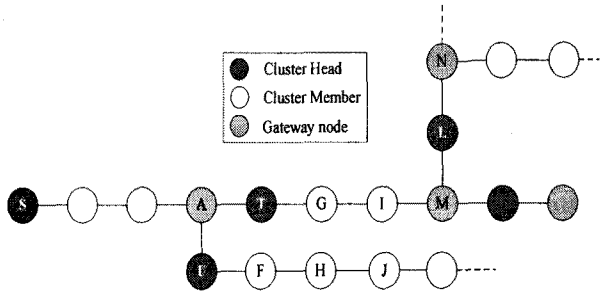

Fig. 2 Backbone in hallways

3.2.3 Hierarchical Network Address assignment

The paper [3] has given out a novel address assignment improvement of Zigbee for the irregular and long-thin network. A novel hierarchical address assignment scheme is specifically designed here.

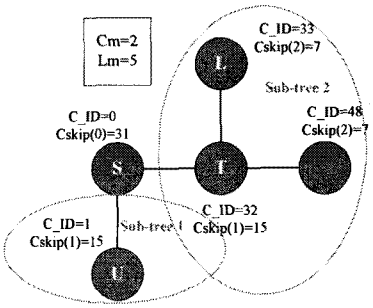

Fig. 3 Logical model of backbone

Node hierarchical address format is defined which includes "F_ID(8bits)"- floor ID, "C_ID(6bits)"-cluster ID, "N_ID(6bits)"-backbone node ID. Floor ID is easily to set (assume it is first floor) during the network deployment. and "C_ID" assignment modified from the "Distributed Network Address Assignment" of Zigbee to eliminate its scalability limitation is developed as follows. Also the node ID assignment will be shown in the following.

Seeing each cluster as a node and parent-child cluster

relationship as an edge, logical model of Fig. 2 can be shown in Fig. 3. Network is divided into two different sub-trees with cluster s as the root.

Using Cskip scheme to assign C_ID for all the nodes in Fig. 3. The node s has a C_ID of 0. For each node at depth d in Fig. 3, if its cluster ID is C_ID, its i-th child's cluster ID is assigned as: $C\_ID_i = C\_ID + (i-1) \cdot Cskip(d) + 1$. where,

$$Cskip(d) = \frac{1 - Cm^{Lm-d}}{1 - Cm} \quad (1)$$

d is the current node depth from coordinator(node s in Fig.3), Cm is the maximum children number of each node and Lm is the maximum depth. For saving the network address space, set the maximum children number of one node in Fig. 3 is 2 (Cm=2), while the 6 bits C_ID length determines the Lm:

$$Cskip(0) = \frac{1 - Cm^{Lm-0}}{1 - Cm} = \frac{2^6}{2} - 1 = 2^5 - 1 \quad (2)$$

so, Lm=5. Assign each node its cluster ID by using Cskip scheme the same as Zigbee manually and get the result as shown in Fig. 3. So all the nodes in one cluster will get the same cluster ID.

As for N_ID, It is assigned by CHs in sequence following the increasing order of the distance away from CHs. E.g., Node U's N_ID=0, while it will assign that of node F=1, node H=2, and node J=3 in sequence automatically. Refer to Table I, the three fields are separated by dots.

TABLE I Address Table

Node	Address	Node	Address
T	1.32.0	U	1.1.0
G	1.32.1	F	1.1.1
I	1.32.2	H	1.1.2
M	1.32.3	J	1.1.3

3.2.4 Backbone routing

Suppose that a destination node D with an address $(F\_ID_D \cdot C\_ID_D \cdot N\_ID_D)$, the current node A which is receiving a packet headed to node D with an address $(F\_ID_A \cdot C\_ID_A \cdot N\_ID_A)$. The actions of node A:

1) If $F\_ID_A = F\_ID_D$, they are in the same cluster. Node A sends the packet to its neighbor node U such that "$C\_ID_U = C\_ID_D \,\&\&\, \min(|N\_ID_U - N\_ID_D|)$".

2) If $C\_ID_A < C\_ID_D < C\_ID_A + Cskip(d-1)$, node D is in the descendant cluster of node A. The next cluster the packet should be forwarded is:

$$NC\_ID = C\_ID_A + 1 + \left\lceil \frac{C\_ID_D - (C\_ID_A + 1)}{Cskip(d)} \right\rceil \cdot Cskip(d) \quad (3)$$

3) Otherwise, node D is the ancestor or not in the same sub-tree as node A. So node A sends the packet to its ancestor cluster through its CH and repeat from step 1 till the packet arrives at node D.

E.g., Node J sends a packet to node I in Fig. 2. Firstly, node J detects the destination node I is not in the same cluster and also not in its descendant cluster. Therefore, it sends the packet to its upper cluster S. When node A receives the packet, it finds the next cluster is cluster T by using equation 3 and sends it to the cluster and at last arrives at node I.

The above shows the basic algorithm of Backbone routing. All the packets delivery between two different LCNs will be forwarded by the Backbone routing to its destination.

4. Conclusion

The algorithm for Backbone network just relies on the network address in the network, no extra command traffic for route discovery and maintenance is needed. Therefore, the real-time performance is very good. Moreover, the cluster based backbone structure is scalable enough for various building environments which eliminates the disadvantage of Zigbee.

5. Future work

The future work is simulation of the proposed static algorithm in Network Simulator version 2. After that, modify the network layer of TI Zigbee stack and establish the test bed in real system.

6. References

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