Energy Consumption based Rejoin Procedure for Cluster Tree in 802.15.4 Sensor Networks

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Abstract

In this paper, we propose a method to save energy consumption for the rejoin procedure for Cluster Tree in 802.15.4 Sensor Networks .An improved node rejoin procedure has Cluster Head(CH) periodically calculates link quality (LQ) and broadcasts to its child nodes. By receiving LQ value, it stores in its Neighbor Quality (NQ) table. When a node lost its connection with its parent node, it selects the suitable parent node with high link quality. When two nodes have similar LQ value, it selects the suitable parent in terms of tree depth value. This process is completed by processing network response and reply message. Our rejoin procedure conserves more energy and incurs low delay.

Keywords: IEEE802.15.4, Sensor Networks, Cluster Head (CH), Link Quality (LQ), Neighbor Quality (NQ) .

1 Introduction

1.1 IEEE 802.15.4 Sensor Networks

The wireless network with minimum data rate, reduced energy consumption and minimum cost is formed by IEEE 802.15.4 standard. The distinctive characteristics of the standard makes it more approving module for wireless sensor networks and remote monitoring applications. The physical layer and medium access control layer of data link layer are the lowermost layers of the protocol that is defined by the standard. [1] It offers a minimum power, economic and a consistent protocol for wireless connectivity among low-cost, permanent and moveable devices. These devices can figure out into a sensor network or wireless personal area network (WPAN) [2]. The network holds two categories of the devices such as full function devices (FFD) and reduced function devices (RFD). FFD functions as a router. It is capable of linking to other FFD and RFD devices. RFD has capability to link with FFD devices. [3] IEEE 802.15.4 is utilized to interlink minimum cost sensors, actuators and processing devices in the wireless manner. The several applications of 802.15.4 devices includes industrial control, environmental and health monitoring, home automation, entertainment and toys, security, location, and asset tracking, emergency and disaster response[4].

The most hopeful minimum span wireless communication technology corresponds to Bluetooth that is depended on time-division multiple access (TDMA) and frequency hopping spread spectrum (FHSS). The main features such as interference flexibility and power efficiency are possessed by this network that is required by the wireless sensor networks [5]. The ultimatum of portability of mobile connections has resulted in the recurrent raise of attention for Bluetooth wireless personal area network (WPAN) technology. It offers new personal technology. It offers new personal communication prospects and services. [6] In relation to Bluetooth, several communication services can be offered by various WPAN frameworks. It can be interlinked to facilitate allocation of information. In addition, it permits communications with the physical environment. The devices that utilize Bluetooth become Pico nets. It performs the communication in slave-master-slave prototype. A Pico net possesses one master device and seven active slave devices. [6]

The merit of setting up Bluetooth is that the individual channel are utilized by all the sensor nodes in the radio range for preventing the interference and fight for a shared channel. In addition, the minimum power feature of Bluetooth permits the radio to penetrate the power saving mode when there is lack of dynamic communication. The problem of Bluetooth based sensor network lies in maintaining effective scatter net configuration and in performing routing for a multi-hop network. The simultaneous route discovery performed by the multiple sources can result in complexity. [5]

2. Related Works

Li-Hsing Yen et al. [9] have proposed a ZigBee-compliant, distributed, risk aware, probabilistic beacon

scheduling algorithm. Their proposed algorithm permits a node to assess locally the risk of slot reuse, and based on the assessed risk it adopts the slot with the lowest latency to its parent. They have predicted such a risk as risk probability, that is, the probability that slot reuse between two nodes will cause beacon collisions as seen by a future joining node. To assess this risk probability, they classify pairs of nodes that are at most two hops apart into Inhibited Pairs (IPs), Visible Pairs (VPs), Hidden Pairs (HPs) and Uninhibited Pairs (UPs); and according to the pair type, calculate the corresponding risk probability.

Zdenˇek Hanz´alek et al. [16] have proposed a Time Division Cluster Scheduling (TDCS) mechanism. Their proposed scheme is constructed based on the cyclic extension of RCPS/TC (Resource Constrained Project Scheduling with Temporal Constraints). It is a problem for a cluster-tree WSN and it assumes bounded communication errors. It is designed to meet all end-to-end deadlines of a predefined set of time-bounded data flows while minimizing the energy consumption of the nodes by setting the TDCS period as long as possible. Since each cluster is active only once during the period, the end-to-end delay of a given flow may span over several periods when there are the flows with opposite direction. Theie scheduling mechanism assists system designers to efficiently configure all required parameters of the IEEE 802.15.4/ZigBee beacon-enabled cluster-tree WSNs in the network design time.

Anis Koubâa et al. [17] have introduced a scheduling mechanism that utilized Time Division Beacon Scheduling approach (TDBS). It is presented for building a ZigBee cluster-tree WSN based on a time division approach. More importantly, their proposed TDBS mechanism can easily be integrated in the IEEE 802.15.4/Zig-Bee protocol stack with only minor add-ons. Initially, they have identified and analyzed the beacon frame collision problem, and the different approaches proposed in Task Group. Futher, they have also proposed a beacon frame scheduling mechanism (TDBS) based on the time division approach to build a synchronized multi-hop cluster-tree WSN. Finally, they have concluded by introducing a duty-cycle management methodology for an efficient utilization of bandwidth resources in the cluster-tree network.

Ismail Salhi et.al [18] have presented a CoZi, which is a new packet scheduling mechanism for large scale ZigBee networks. CoZi aims at enhancing the reliability of the data delivery and the bandwidth utilization of the network. Their scheduling mechanism entirely based on simple network coding at intermediate nodes to offer better bandwidth utilization and reliable communications with extremely negligible network overhead. Using clever topology inferring from ZigBee signalization messages, this mechanism helps to perform more optimized coding decisions in order to allow a larger range of decoding nodes whether for routed or dissemination based ZigBee sensor networks. CoZi can be included in sleep-awake mechanisms for better energy efficiency.

Mohamed k. Watfa et al. [19] have proposed a novel scheduling algorithm for WMSNs. Their algorithm divides the frame sent from the cluster-head to the Base Station (BS) into slots and gives a percentage of these slots into each node. The base station (BS) sends a certain query to the cluster-head. Upon receiving query, the cluster head will propagate it to specified nodes and wait for these nodes to sense the medium and come back with needed data. The nodes will respond by sending packets of data to the cluster-head. The job of the cluster head is to schedule these packets coming from different nodes to send them in frames to the BS. One of the advantages of this algorithm is that it is derived for a multi-user network and it is shown to converge to the optimal schedule. Another advantage is that the setting is realistic and thus it is feasible.

3. PROPOSED SOLUTION

Each node maintains a neighbor quality table (NQ) (as per equation-3) for its neighboring node. The NTQ table is used by each node to keep tracks the quality of each node. The NQ table contains the neighboring node ID, sequence number, duration field, LQ value and possible parent. Here, the duration field refers to the time interval since a last link quality status is received. This field is maintained to check the newness (freshness) of link quality. The field possible parents can be any neighboring node that a node wants to join with it after it disconnects the connection with previous parent. The header format of NQ table is given below,

Table 1: Header of NQ Table

Neighbor Node ID	Sequence Number	Link Quality (LQ)	Duration	Possible Parents

Each cluster head (CH) periodically estimates and broadcasts the LQ of its child nodes. By receiving the LQ value, each node updates its neighbor table. When the parent node is out of power and failed, the child nodes of corresponding parent trigger the rejoin procedure to find suitable parent to connect with the coordinator. Let n_i be node i, where i = {1, 2 ... n} The rejoin procedure of a node is as follows,

(i) When node i lost connection with his parent node it triggers rejoin procedure
(ii) It looks NQ table and finds all neighboring nodes that exist within its transmission range.
(iii) The field possible parents can be constructed by choosing the nodes with latest duration field.
(iv) The chosen possible parents' nodes are stored in NQ table for selecting suitable parent node.
(v) From stored possible parent nodes, n_i selects the node with high LQ value

(vi) When more than one node has similar LQ value then the further parent node selection(vi) When more than one node has similar LQ value then the further parent node selection is based on depth of a node in the tree structure.

(vi) The node with low depth is elected as suitable parent

(vii) After the selection of suitable parent, node n_i transmits Nwk-Join (Network Join) message to the selected suitable parent.

$$\text{Node } n_i \xrightarrow{Nwk-Jin} \text{Suitable Parent}$$

(viii) While receiving the Nwk-Join message, the suitable parent node transmits back the Nwk-Res (Network Response) message to the corresponding node.

$$\text{Node } n_i \xleftarrow{Nwk-Re\,s} \text{Suitable Parent}$$

(ix) By receiving the Nw-Res message, node ni joins with the selected parent

(x) If node n_i does not receive the Nw-Res meassge even after the time interval of I_{res}, the corresponding repeat the same process again to find the suitable parent.

Consider the scenario given in figure-1; we can observe that node n7 lost its connection with its parent node n5; this disconnection may be due to the failure of node n5. After the failure of n5, node n7 invokes the rejoin process. It has four successful neighbor nodes in its NQ table. By considering duration time, n7 selects 8, 6 and 9 as possible parents. After checking LQ value of three nodes, n7 found that n6 and n8 has similar high LQ value than n9. Now, it selects node n8 as its suitable parent by considering depth value. Using Nwk-Join and Nwk-Res messages, n7 joins with n8.

Figure-3 Rejoin Procedure

4. Simulation Results

4.1. Simulation Setup

The performance of the proposed Rejoin Procedure for Multiple Cluster Tree (RPMCT) is evaluated using NS2 [21] simulation. A network which is deployed in an area of 50 X 50 m is considered. The IEEE 802.15.4 MAC layer is used for a reliable and single hop communication among the devices, providing access to the physical channel for all types of transmissions and appropriate security mechanisms. The IEEE 802.15.4 specification supports two PHY options based on direct sequence spread spectrum (DSSS), which allows the use of low-cost digital IC realizations. The PHY adopts the same basic frame structure for low-duty-cycle low-power operation, except that the two PHYs adopt different frequency bands: low-band (868/915 MHz) and high band (2.4 GHz). The PHY layer uses a common frame structure, containing a 32-bit preamble, a frame length.

The simulated traffic is CBR with UDP source and sink. Table 2 summarizes the simulation parameters used.

Table 2: Simulation Parameters

No. of Nodes	21,41,61,81 and 101
Area Size	50 X 50
Mac	IEEE 802.15.4
Simulation Time	20,40,60,80 and 100sec
Transmission Range	12m
Routing Protocol	RPMCT
Traffic Source	CBR
Packet Size	80 bytes

4.2. Performance Metrics

The performance of RPMCT is compared with the Risk-Aware Beacon Scheduling (RABS) protocol [9]. The performance is evaluated mainly, according to the following metrics.

Energy Consumption: It is the average energy consumed by the nodes for the transmission process.

The simulation results are presented in the next section.

4.3 Results

A. Based on Nodes

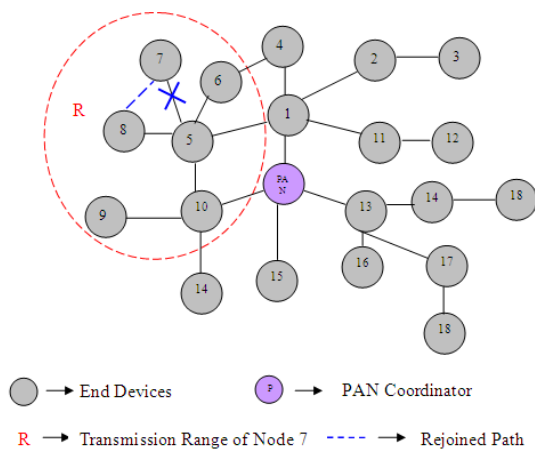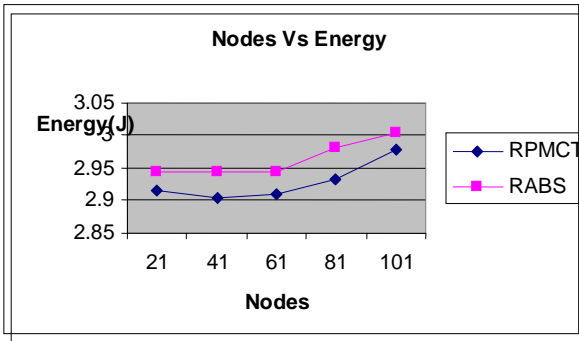In our first experiment we vary the number of nodes as 21,41,61,81 and 101.

Figure 1: Nodes Vs Energy

From figure 1, we can see that the average energy consumption of our proposed RPMCT is less than the existing RABS protocol.

B. Based on Simulation Time

In our second experiment we vary the simulation time as 20,40,60,80 and 100 sec.
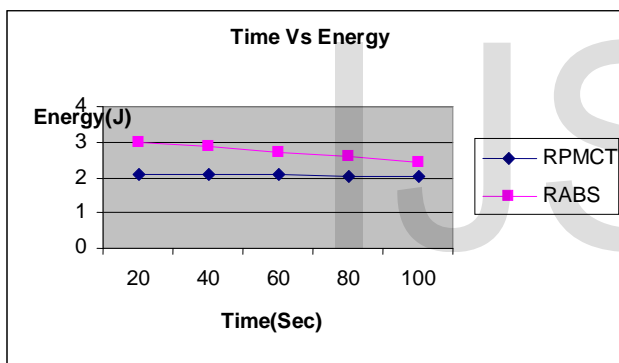

Figure 2: Time Vs Energy

From figure 2, we can see that the average energy consumption of our proposed RPMCT is less than the existing RABS protocol.
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5. Conclusion

In this paper, we have proposed a rejoin procedure for cluster tree in Zigbee sensor networks. In this technique, an improved rejoin procedure is used to select the suitable parent considering link quality indicator. The rejoin procedure reduces time delay and energy consumption by avoiding rescanning of entire network. Through simulation results, the proficiency of our technique has proved. Our technique conserves more energy and incurs low delay.

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