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Energy efficient distributed cluster head scheduling scheme for two tiered wireless sensor network

G. Kannan [a,*], T. Sree Renga Raja [b]

[a] *Department of Electronics & Communication Engg, B.S.Abdur Rahman University, Chennai, Tamil Nadu, India*
[b] *Department of Electrical & Electronics Engg, Anna University: BIT Campus, Tiruchirappalli, Tamil Nadu, India*

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Abstract Wireless Sensor Network (WSN) provides a significant contribution in the emerging fields such as ambient intelligence and ubiquitous computing. In WSN, optimization and load balancing of network resources are critical concern to provide the intelligence for long duration. Since clustering the sensor nodes can significantly enhance overall system scalability and energy efficiency this paper presents a distributed cluster head scheduling (DCHS) algorithm to achieve the network longevity in WSN. The major novelty of this work is that the network is divided into primary and secondary tiers based on received signal strength indication of sensor nodes from the base station. The proposed DCHS supports for two tier WSN architecture and gives suggestion to elect the cluster head nodes and gateway nodes for both primary and secondary tiers. The DCHS mechanism satisfies an ideal distribution of the cluster head among the sensor nodes and avoids frequent selection of cluster head, based on Received Signal Strength Indication (RSSI) and residual energy level of the sensor nodes. Since the RSSI is the key parameter for this paper, the practical experiment was conducted to measure RSSI value by using MSP430F149 processor and CC2500 transceiver. The measured RSSI values were given input to the event based simulator to test the DCHS mechanism. The real time experimental study validated the proposed scheme for various scenarios.

1. Introduction

A wireless sensor network is a highly complex distributed system comprising huge number of tiny wireless sensor nodes and base station (BS). Each wireless sensor node consists of sensor, processor, memory, RF transceiver (radio), peripherals, and power supply unit (battery) [1]. These wireless sensor nodes are deployed over a geographical area in an ad hoc fashion for event detection and observe data for various ambient conditions. The WSN could collect this real time data to design the

* Corresponding author.
E-mail addresses: kannan_ins@yahoo.co.in (G. Kannan), renga_raja@rediffmail.com (T. Sree Renga Raja).

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environment with more intelligence [2]. The WSN is also focused on disaster management such as tsunami warning, earthquake monitoring, flood forecasting and pipeline monitoring systems.

The rapid deployment, self-organization and fault tolerance characteristics of sensor networks make them a very promising sensing technique for military applications [3,4]. Since WSN needs to operate on resource constrained environment, either changing or recharging batteries is an unmanageable task. Even the failure of single node due to low energy can prostrate the entire system. Hence this problem forced the academic researchers for developing an energy efficient protocols focusing node and network level [4,5]. In the network level a variety of energy efficient routing protocols were developed in the recent years [6–8]. The routing protocols in WSN are classified under three main heads: data centric protocols, location based protocols and hierarchical protocols.

This paper mainly focused on hierarchical protocols which deal with organizing WSN into a set of clusters. In each cluster, a dedicated node called cluster head (CH) node and remaining sensor nodes are called as cluster nodes (CN). The role of each CH is to carry out the following three tasks. The first task is to gather sensed data from the cluster nodes periodically and aggregates the data in an effort to remove redundancy among correlated values [9]. The second task of the cluster head is to generate a Time Division Multiple Access (TDMA) schedule through which sensor nodes receive a time slot for data transmission. The third task is to transmit the aggregated data to nearby CH or directly to the base station. Hence the lifetime of CH would be a very short span of time if the fixed node performs all the three tasks and it becomes essential to shift the cluster head periodically in a well-structured manner. In this work a new CH selection mechanism was proposed for the two tiered WSN architecture based on residual energy and communication distance between the sensor nodes.

Most of the existing papers [10] distance was estimated by the standard mathematical coordinate system. The proposed work performs real time experimental setup to carryout the estimation of distance among the sensor nodes based on RSSI values. RSSI value can be estimated by measuring the received power of radio signal and most of the IEEE 802.11 and 802.15.4 radio modules support the measurement of RSSI. The relationship between the received power (P_{Rx}) and RSSI is shown in the following formula [11]:

$$\mathrm{RSSI} = 10\log_{10} P_{\mathrm{Rx}} \tag{1}$$

The Friis transmission equation is generally described as the propagation of radio communication. This equation gives the relation between transmission distance (D) and received power (P_{Rx}) as follows:

$$P_{\mathrm{Rx}} = \frac{P_{\mathrm{Tx}} G_{\mathrm{T}} G_{\mathrm{R}} \lambda^2}{(4\pi)^2 D^2} \tag{2}$$

where P_{Tx} is the transmission power, G_{T} is transmitting antenna gain, G_{R} is the gain of receiving antenna and λ is the wavelength of the RF signal.

This experimental report is organized as follows: Section 2 discusses about related work. Section 3 explains the network model and proposed DCHS mechanism in detail. Section 4 contains experimental setup and results. Eventually Section 5 concludes with future enhancement of this work.

2. Related works

This section takes the advantages of valuable prior work in WSN hierarchical clustering protocols which are primarily focused to improve the network lifetime.

Low Energy Adaptive Clustering Hierarchy (LEACH) proposed in [12] is one of the most popular hierarchical routing protocols designed to aggregate and *disseminate* data to the base station. LEACH obtains energy efficiency by partitioning the nodes into clusters. The LEACH operates on rounds where each round comprised of setup phase and steady state phase. During setup phase the sensor nodes will select a random number between 0 and 1. If this random number is below the threshold value $T(n)$, then the corresponding sensor node will act as a cluster head during the given period, called a round. LEACH distributes the role of cluster head among the member nodes in the cluster based on threshold value, which is calculated by the following formula:

$$T(n) = \begin{cases} \frac{P}{1-P*\left(r \bmod \frac{1}{P}\right)} & \text{if } n \in G \\ 0, & \text{otherwise} \end{cases} \tag{3}$$

where P is the desired % of cluster heads, r is current round, and G is the set of nodes that have not been CH in the last $1/P$ rounds. During steady state phase the elected CH creates a TDMA schedule and assigns a time slot for each member node for data transmission. After a particular period of time the network returns into the setup phase to select new CH. This approach selects the cluster head based on a predetermined probability and does not follow any energy efficient mechanism while choosing $T(n)$.

LEACH-Centralized (LEACH-C) uses centralized algorithm for the selection CH and the same steady state phase as LEACH [13]. In the setup phase, the base station collects the position and energy level of the sensor nodes and the node having greater energy than average energy of all sensor nodes would be elected as CH. Since this approach only considers the energy level of sensor nodes while selecting the CH, there may be a greater probability of elected CH is far away from BS which consume more energy when the communication between BS and CH.

Younis [14] presents a protocol, HEED (Hybrid Energy-Efficient Distributed clustering), that periodically selects cluster heads according to their residual energy. The authors do not make any assumptions about the presence of infrastructure or about node capabilities, other than the availability of multiple power levels in sensor nodes. However the proposed algorithms support only for building a two-level hierarchy, and lack for multilevel hierarchies.

Yu et al. [15] present a new energy-efficient dynamic clustering technique which deals with each node estimates the number of active nodes in real-time and computes its optimal probability of becoming a cluster head by monitoring the received signal power from its neighboring nodes. The authors also developed energy-efficient and power aware (EEPA) routing algorithm and lifetime is compared with AODV, MTE and MRE routing protocols.

Jung et al. [16] propose a cluster based energy-efficient forwarding scheme which ensures that while multiple nodes in a cluster receive a packet, only one node among them is elected to send the acknowledgment back. The binary exponential backoff algorithm was used to elect the node. Akhtar et al.