Load and Energy Consumption based Scheduling Algorithm for Wireless Sensor Networks (LECSA)

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Abstract

Sleep/Wake up scheduling for Wireless Sensor Networks has become an essential part for its working. In this paper, the Low Energy Adaptive Clustering Hierarchy (LEACH) which introduced the concept of clustering in sensor networks, Energy-Efficient Clustering routing algorithm based on Distance and Residual Energy for Wireless Sensor Networks (DECSA) which describes about scheduling based on distance and energy and the Energy efficient clustering algorithm for data aggregation (EECA) were discussed and their merits and demerits were compared. LECSA-Load and Energy Consumption based Scheduling Algorithm which gives a simplified method for scheduling using a single deciding parameter has been introduced and detailed. *Keywords*: Sensors, Schedule, Wireless Sensor Networks, Centralized, Distributed Radio, etc...

Keywords: **Sensor Networks; Clustering; Scheduling; Energy Consumption.**

1. Introduction

The sensor networks are infrastructures to collect data from the environment and the data can be used to study many problems like climate change, animal migrations, and behaviour changes of buildings. The sensor nodes are deployed over a geographical area to monitor physical phenomena. The wireless sensor networks (WSN) is defined as a network of devices denoted as nodes that can sense the environment and communicate the information gathered from the monitored field through wireless data networks. The wireless sensor networks consist of hundreds to thousands of tiny, inexpensive and battery-powered wireless sensing devices which organize themselves into multi-hop radio networks.

The wireless sensor networks are a self-organizing ad hoc network with potential applications in autonomous monitoring, surveillance, military, health-care, and security. The sensor nodes consist of three major subsystems. They are computation, communication and sensing. The computation subsystem has an embedded processor, program memory and data memory. The communication subsystem has a low power radio operating at ISM band frequency. The sensing subsystem is used to convert the external world phenomena into an equivalent electrical quantity which in turn is digitized by analog to digital converters.

The wireless sensor networks are characterized by sensing and communication coverage. The communication coverage refers to how well the sensor nodes are in communication range of each other. The sensing coverage refers to how well the terrain under monitoring is sensed by all the sensor nodes. The wireless sensor network is to determine the node density which is one of the primary challenges faced by the design of large WSN. The requirements of wireless sensor networks are fault tolerance, increased lifetime, scalability, power management, security and budget.

The wireless sensor networks are composed of tiny individual nodes that are programmed in embedded systems. They are capable of interacting with their environment through various sensors and processing information locally and communicating this information wirelessly with their neighbours.

2. WSN Applications

The Wireless Sensor networks consist of many different types of sensors and they are used in wide range of applications. The wireless sensor networks are used in military applications, environmental applications, health applications, home applications, industrial applications [1][2]. The examples of military applications are smart dust, snipper detection and VigilNet. The examples of environmental applications are great duck island, CORIE, ZebraNet, flood detection and volcano monitoring. The examples of health applications are artificial retina, patient monitoring and emergency response. The example of home application is water monitoring. The examples of industrial applications are preventive maintenance, structural health monitoring and surveillance. Many of these applications share the same interaction pattern like event detection and classification, periodic measurements, function approximation and edge detection and tracking of mobile sources.

2.1. *WSN Nodes*

The sensor node hardware consists of three components and can be either an individual or embedded into a single system. They are wireless modules, sensor board and programming board. The wireless modules or motes possess the communication capabilities and programmable memory where the application code resides. A mote consists of a microcontroller, transceiver, power source, memory unit and sensors [9]. A sensor board is mounted on the motes and is embedded with multiple types of sensors.

The sensors can be integrated into the wireless module such as in the Telos, Iris or the SunSPOT platform[2]. A programming board is also known as the gateway board and it provides multiple interfaces including Ethernet, WiFi, USB, or serial ports for connecting different motes to an enterprise or industrial network or locally to a PC/laptop. The programming boards are used either to program the motes or gather data from them. Fig.1 shows the wireless sensor nodes.

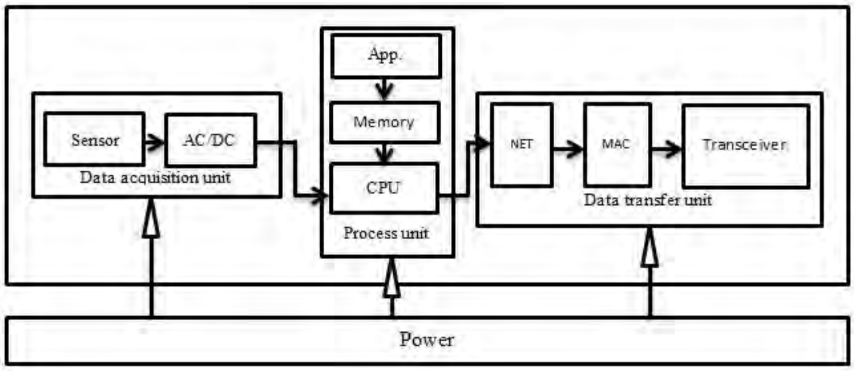

Fig 1. Wireless Sensor Nodes

2.2. *Difference between WSN and Ad-hoc Networks:*

There are many differences between WSN and Ad hoc networks. The WSN and ad-hoc networks vary in number of nodes. The sensor nodes are densely developed and sensor nodes are prone to failures. The topology of a sensor networks changes very frequently. The WSN performs broadcast communication but ad-hoc networks perform point to point communication. The sensor nodes are limited in power computation capacities and memory. The sensor nodes may not have global identification.

3. Sleep/Wake-Up Scheduling

The transceiver of sensor nodes has three states/modes. They are active state, idle state and sleep state. The mechanism of alternatively switching between sleep and wake-up (active or idle) mode to avoid energy wastage is termed as sleep/wake-up scheduling or duty cycling scheme. The main objective of sleep/wake-up scheduling is to put the transceiver in sleep state during idle periods. The sleep/ wake-up scheduling are most effective mechanism for energy conservation and significantly prolong the network lifetime in WSN [3]. To achieve minimum energy consumption, transceiver should be in sleep state mostly and be activated (wake-up state) only when required. In sleep/wake-up scheduling, a complete cycle consists of sleep state and wakeup state, and is termed as frame. Fig.2 shows the wakeup and sleep scheduling.

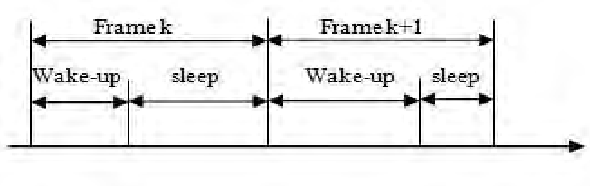

Fig 2. Sleep/wake-up scheduling

3.1. *Sleep/Wake-up protocols*

These protocols describe scheduling which instructs the sensors to wake up and sleep according to a pattern. So the sensors while in active state receive the data and aggregate them [4]. During their next active state forward the load to their cluster heads to the sink node. The sleep/wake-up protocol is characterized by different phases. They are synchronization phase, adaptation phase, wake-up phase and sleep phase. Fig.3 shows different phases of sleep/wake-up protocols.

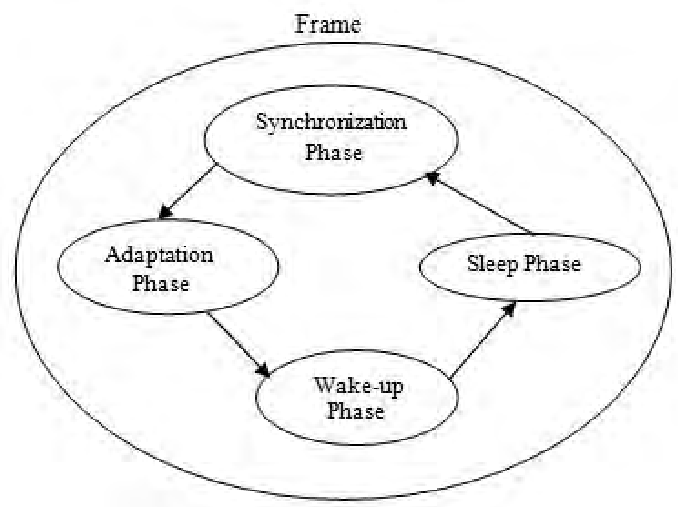

Fig 3. Phases of Sleep/Wake-up protocol

4. LEACH

LEACH (Low Energy Adaptive Clustering Hierarchy) is one of the classic clustering protocols. LEACH protocol can save more energy than the plane multi-hop routing protocols and static network clustering algorithm. In LEACH, the nodes organize themselves into local clusters and one node acting as the cluster head. All other non-cluster head nodes transmit their data to the cluster head. The cluster head node receives data from all the cluster nodes and performs signal processing functions on the data and transmits data to the BS. Fig.4 shows the Cluster architecture of LEACH.

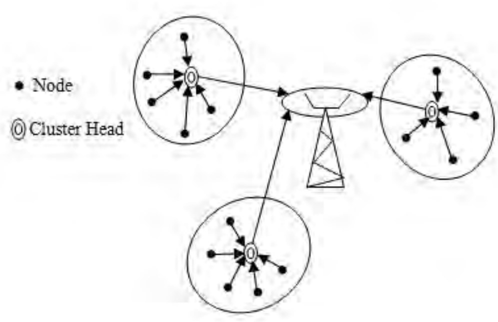

Fig.4 Cluster architecture of LEACH

The operation of LEACH is divided into rounds. Each round begins with a set-up phase when the clusters are organized, followed by a steady-state phase when data are transferred from the nodes to the cluster head on to the BS. LEACH forms clusters by using a distributed algorithm, where nodes make autonomous decisions [10] without any centralized control. Fig.5 shows the rounds of LEACH.

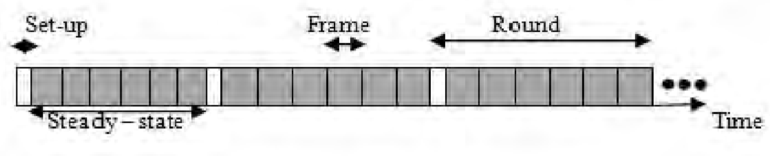

Fig. 5 Rounds of LEACH

5. EECA

EECA (Energy Efficient Clustering Algorithm) is determining the energy of each sensor and the initial nodes clustering over the measurement space and initialization [7]. It consists of two phases. First is adaptive clustering and the second is data transfer.

The clustering of EECA takes the same mechanism of rotation that each round of rotation is divided into set-up phase and steady phase. In the set-up phase, all nodes are organized to form cluster first and then cluster-head allocates time division multiple access (TDMA) time slot to cluster members and at the same time data gathering trees are formed among cluster-heads. In steady phase, cluster member nodes send data to cluster-heads according to the allocated TDMA slot and cluster-heads transmit aggregated data to sink node via data gathering tree as shown in Fig.6.

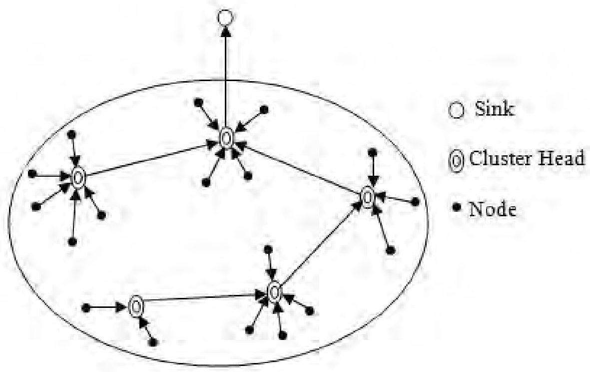

Fig.6 Topology described in EECA

EECA algorithm separates sensor network into a two layer structure. Cluster-head nodes form the upper layer of backbone network nodes and cluster member nodes form the lower layer of the other nodes.

6. DECSA

DECSA (Distance – Energy Cluster Structure Algorithm) is distributed competitive unequal clustering algorithm, it considering both the distance and residual energy of each node. It improves the process of cluster head selection and the process of cluster formation and it reduces the adverse effect on the energy consumption of the cluster head, resulting from the non-uniform distribution of nodes in network and avoid the direct communication between the Base Station and cluster head, which has low energy and far away from Base Station. Fig.7 shows the three level hierarchy structure network model of DECSA.

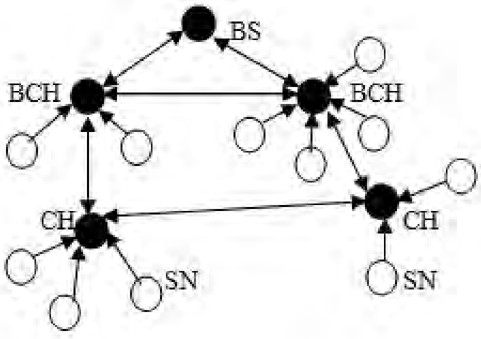

Fig.7 Three level hierarchy structure network model of DECSA

The DECSA protocol continues by round and each round can be divided into two stages. They are initialization stage and stable working stage. In the initialization stage, cluster head is selected and TDMA time slots are distributed to ordinary member nodes by the cluster head. The process of cluster head selection has two parts they are election of cluster head node (CH) and election of base station cluster head (BCH). In the cluster head selection, DECSA employs both residual energy and distance parameter. In the stable working stage, base station broadcasts the message to the entire network.

7. Comparison of Protocols

7.1. *LEACH and EECA*

The Network lifetime of EECA algorithm is obviously longer. The first node's dead time of EECA algorithm is twice as much as that of LEACH algorithm.

Average residual energy of nodes under EECA algorithm is obviously greater than that of LEACH algorithm because EECA adopts a novel cluster-head election mechanism so as to average the clustering of whole network and balance the energy load of nodes, and there is one and only cluster-head node communicating with sink node which efficiently reduce the energy cost of nodes.

The proportionality of network energy consumption of EECA algorithm is much better than that of LEACH algorithm, and the value is more stable.

7.2. *LEACH and DECSA*

The number of nodes alive in DECSA is more than LEACH algorithm at the same round. DECSA has a better performance than LEACH in terms of energy consumption. The DECSA algorithm effectively reduces the energy consumption, increases the lifetime by 31% and reduces the energy consumption by 40%. It claims to have a better performance than the original LEACH protocol.

8. Load and Energy Consumption based Scheduling (LECSA)

In our newly proposed scheduling algorithm, unlike the previous scheduling algorithms like LEACH, DECSA and EECA, the important factors like residual node power, distance and the load i.e. the number of data packets it possess are also taken into account and then the scheduling is done. In the DECSA, the k value and the threshold value calculations were done in two different methods. In LECSA that calculation is made simple and in a uniform manner only a single deciding parameter named α is used throughout.

In our simulation of the LECSA, 80 nodes are randomly arranged in an area of 200m X 200m. The nodes which are within a distance of 10m are grouped together as clusters. If a node is satisfying this condition for two clusters, then that node will be added to a cluster which has less number of nodes.

Initially for the first cycle all the nodes in the network generate a random number as their α parameter. In matlab the following equation is used to generate the random numbers for the α of all the nodes.

$$\alpha = \text{random}(0\ ..\ 1)$$

This will assign a random value in-between 0 and 1 for every node in the network. The nodes in the cluster compare their α values and the one which has higher α value will be selected as the initial Cluster Head (ICH). Then every node will be continuously working. For the second cycle, the α value will be calculated by

$$\alpha = E_{it} + 1/L_{it}$$

Where Eit denotes residual node power (remaining power) of the node i at time t and Lit denote the load of the node i (number of data packets it has at the instant t). Then by comparing this α parameter, the node which has the maximum α value will be selected as the Cluster Head (CH). All the nodes in the cluster sends their data according to the schedule created based on their α value. The one which is having very low α value will occupy the initial slot of the schedule for becoming active. Then according to the increasing order of the α value the nodes will be given slots to transfer their data to the Cluster Head. Since the CH is having the highest α value, it will have more residual node power and it will be active for the entire cycle.

At the next higher level all the CHs have to forward their data to the next CH in line to reach the sink node. So the CH of a node will forward the data to a node in the neighbour cluster whose CH has been selected as the next CH in line on its route to transfer its data to the sink node. Since the distance between the nodes are already computed at the first stage (setting up of the network) itself, it will be easier to forward the data. After forwarding the data the CH will go to sleep state. For the next cycle because of the exhausted state of the CH, during the α calculation that CH will have very low α value then obviously there will be a new CH for the cluster.

9. Conclusion

The explanation of LEACH, EECA and DECSA were given in the initial part of this paper. Then their comparisons were made. Finally the description of the newly proposed algorithm Load and Energy Consumption based Scheduling Algorithm is explained with its simulation study. It has been observed that all the crucial factors which are responsible for energy wastage like the load of the node, its remaining power and the distance from other nodes for communication have been taken into account in LECSA. The simulation also proves that by using this scheduling, the number of active nodes at any instant of time is less provided the optimum throughput is attained. Obviously the energy consumption is also reduced because of the reduced number of active nodes.

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