Study of Energy Efficient Routing Protocols of Wireless Sensor Networks and their further researches: a Survey

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Abstract: **Wireless sensor networks are deployment of micro, less expensive sensors to obtain the certain scenario of an environment by combining the data of different nodes. In the wireless sensor network the end user can remotely monitor physical events in the environment depending upon the desired application where the region can vary from a small to large region and where the deployment of sensor nodes varies from a limited number to large number by considering the energy conservation as major consideration .Micro-sensors are loaded with a sensor module equipped with a sensors(image sensors, object tracking, environmental monitoring) capable of sensing some quantity about environment ,a radio module for communication, a battery to provide energy for operation ,a digital module for processing the signals from the micro-sensors .The main two function performed in the wireless sensor networks are gathering the information from the autonomous micro-sensor nodes and passing it to the base station that has uninterrupted power supply. In this paper we have done review study of advances made in Low energy adaptive clustering hierarchy protocol a cluster hierarchy protocol and Geographic adaptive fidelity protocol which is location based protocol and how further researches are better than classical protocol.**

***Keywords* : LEACH (Low energy adaptive clustering hierarchy), GAF (Geographic adaptive fidelity), CODE, LEACH-CC, WSN (Wireless Sensor Network).**

1. INTRODUCTION

Wireless sensor networks are equipped with autonomous sensor nodes with a major motive to sense the environmental and physical conditions and route to the master sensor node that is base station that has uninterrupted power supply and is generally fixed. The major task of the master sensor node is to process the sensor nodes data for further actions or decisions. This act as an interface. Micro sensor nodes are distributed evenly in the particular area to be sensor for environmental and [1] physical conditions for particular applications. Each micro-sensor nodes is capable of limited amount of processing and then the data from all this nodes is combined. The energy consumption at sensor nodes is major issue. Gathering sensed information in an energy efficient manner is critical to operate the sensor network for a long period of time .Energy consumption not only occur while sensing but networking and data processing also. The relation between energy consumption and communication range [1] in WSNs is $E = kd^n$, where E is the energy consumption, d is the communication range, and 2<n<4, k is a constant. From the formula, we can see that the longer the range is, the more the consumption is. The major limitation is limited buffer size, limited energy supply, limited computing power, and limited bandwidth. So researchers are all involved in designing the energy efficient routing protocols or doing amendments in existing energy saving protocols for the energy conservation of sensor nodes. There are many energy efficient protocols but we will do the review study for only two energy efficient protocols that is LEECH and GAF.

2. DESIGN GOALS OF WIRELESS SENSOR NETWORK

The wireless sensor networks have its own limit that makes it differ from mobile adhoc networks and thus designing a wireless sensor network is very challenging. Firstly, generated data traffic has significant redundancy in it since multiple sensors may generate same data within the vicinity of a phenomenon. Secondly, sensor nodes might be deployed densely in the sensor networks. Unnecessary nodes should be turned off its radio while guaranteeing connectivity of the entire sensor field. Thirdly, sensor nodes are limited in power, processing capacities and memory. Those require careful resource management. Fourthly, sensor nodes may not have global identifications (IDs) [4].

Scalability

Scalability is also critical factor. For a large scale sensor network, it is likely that localizing interactions through hierarchical and aggregation will be critical for ensure scalability

Latency

The user is interested in knowing about the phenomena within a given delay. Therefore, it is important to receive the data in a timely manner

Energy Efficiency

Energy efficiency is the most important consideration due to the power constrain of sensor nodes. multi-hop routing will consume less energy than direct communication, since the transmission power of a wireless radio is proportional to distance squared or even higher order in the presence of obstacle. However, multi-hop routing introduces significant overhead for topology management and medium access control.

3. LEACH (LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY)

LEACH uses [6] Code Division Multiple Access (CDMA) or Time Division Multiple Access (TDMA) MAC to share channels (Akyildiz et al., 2002; Heinzelman et al., 2000) which is integrated with clustering and a simple routing protocol in wireless sensor networks (WSNs). The goal of LEACH is to lower the energy consumption required to create and maintain clusters in order to improve the life time of a wireless sensor network. LEACH is a hierarchical protocol in which most nodes transmit to cluster heads, and the cluster heads aggregate and compress the data and forward it to the base station (sink). Each node uses a stochastic algorithm at each round to determine whether it will become a cluster head in this round. LEACH assumes that each node has a radio powerful enough to directly reach the base station or the nearest cluster head, but that using this radio at full power all the time would waste energy. By data-fusion and energy-equilibrium, LEACH can extend the life of network but has certain disadvantages as: At first it uses random number to decide a node whether becomes a cluster-head node, so when a low-energy node becomes cluster-head node, it will die immediately. Secondly, LEACH doesn't care the neighbor nodes when makes cluster head nodes, so when some nodes are far from its cluster-head node in long time, they will die immediately too. Finally, every node uses single-jump routing to transmit data, which makes that commutation between nodes too costly. LEACH inspires many hierarchical protocols such as Power-Efficient Gathering in Sensor Information System (PEGASIS), Threshold sensitive Energy Efficient sensor Network protocol (TEEN), Adaptive TEEN (APTEEN) etc.

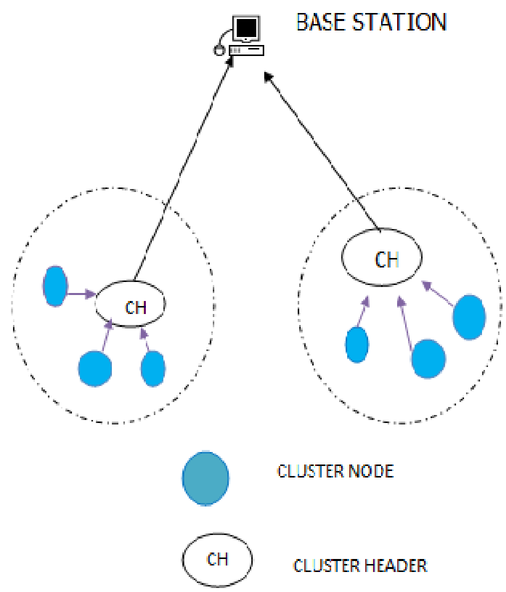


Fig. 1 Leach Protocol

3.1 Recent advances in LEACH

Improved LEACH protocol (WLEACH) [3] that is Wise Low Energy Adaptive Clustering Hierarchy by three improved sides: the first side is adding considering of energy ,the second aspect is adding multi-jump routing between nodes, and the third aspect is adding dormancy of cluster head node. Considering the first side, known that LEACH protocol limits the node times to become the cluster head, which can avoid node's death based on cluster-head node' more energy-using, they also become low-energy and easy to die. In order to solve this problem, it is necessary to limit the energy a node become cluster-head. Now there has been some theory about energy threshold, such as initial node's energy, the average energy of whole cluster and the average energy of whole network. In order to get the comprehensive state of the network, they chose the average energy of whole network as the energy threshold parameter. The specific mechanism is as follows: In every round every sensor node transmit it's energy to its cluster-head node, the cluster-head node fuse these energy information and transmit to sink node, and the sink node transmits all energy information to all nodes by broadcasting, then every node can decides whether becomes a cluster-head node using these energy state. The average energy of whole network can shows as Er , in which r means round. This paper divides the cluster-made stage to two stages, the first stage is same as LEACH, the choosing node cluster shows as $C(n)$, in which n means number. In the second stage, all choosing nodes that energy low than threshold Ec will be removed their cluster-head state, which makes the new cluster $C(m)$, Ec can shows as formula (2):

$$E_c=f(E_r)=f\left(\left(\sum_{i=1}^{n-dead} Ei\right)/(n\text{-}dead)\right) \quad (2)$$

In formula (2), *N* means initial node's number, *Ei* means energy of *i* nd node. In addition, considering the best number of LEACH *kbest*, if *m* is more than best number *Nc* , the redundant nodes will be removed their cluster-head state too. So using two or three stages' choosing, the final cluster *c*(*l*) can be made and the netwok can be optimized, *Ec* means

$(\sum_{i=1}^{n-dead} Ei)$)/2(N-dead), in which N_c set as $1.5K_{best}$

About the second aspect, LEACH uses distance to decide cluster, which can ensure communication between nodes in the same cluster costs less. But the communication between cluster-head nodes and sink node uses single-jump routing, which makes cluster-head nodes' energy-using too much. In some environment the energy-using even can be fourth power proportional to the distance, which can seriously shorten life of the cluster-head nodes and whole network. Now considering at this problem, they used geographic routing and multi-jump routing to make improvement and PRIM algorithm to establish minimum spanning tree. Different from classic PRIM algorithm, they used distance between nodes to fix weight of adjacency edge, which can reduce the possibility of low-energy nodes to become cluster-head node. The formula is:

$$Wc=W/(Ea+Eb)$$

Where *Wc* means final weight, *W* means initial weight, *Ea* and *Eb* means energy of nodes between the adjacency edge. About the third aspect, most WSN is used in monitoring; the transmitting frequency of sensor nodes and the processing frequency of sink node decide the performance of network together. If the transmitting frequency of sensor nodes is too high, the pressure of sink node will be too big, and the energy using of sensor node will be too much. In addition, in some environment, the monitoring data is transmitted only when it more than threshold. These characteristics of WSN decide that appropriate dormancy is necessary for WSN. They set the dormancy as follows: if sensor node *S*(*i*) becomes cluster-head node in one round, its' dormancy timer will be set as *T* and the unit is round. In transmission of every round, every node first check its' dormancy timer, then transmit normally if it is 0, or only transmit data to nearest node that dormancy timer is 0 and energy more than threshold. If there are not these nodes, the monitoring data this round will not be transmitted, but be saved to fused with the next round's data and transmitted together. Because the energy-using of data-fusing is less than data transmission for unit data, this dormancy can reduce energy using effective and uses the saving and fusing ability of all nodes.

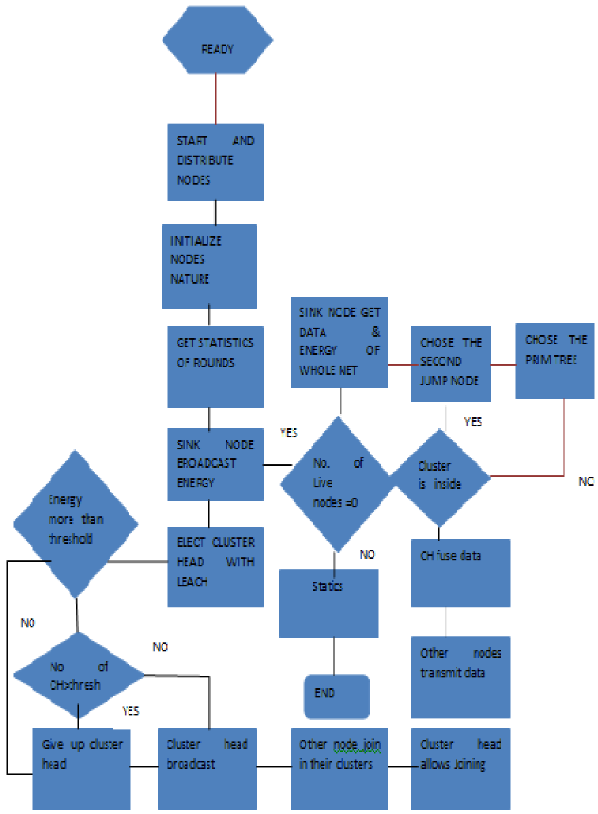


Fig.2 WLEACH processing.

3.1.1 LEACH-CC

LEACH Centralized with [2] Chain protocol is a hierarchical protocol. Where there are merits of using LEACH distributed cluster formation algorithm, where each node makes autonomous decisions that result in all the nodes being placed into clusters, this protocol offers no guarantee about the placement and/or number of cluster-head nodes. Since the clusters are adaptive, obtaining a poor clustering set-up during a given round will not greatly affect overall performance of LEACH. However, using a central control algorithm to form the clusters may produce better clusters by dispersing the cluster-head nodes throughout the network. Then a chain routing between cluster-heads is established to reduce the amount of nodes which communicate with the base station. Further improvement in energy cost for data gathering can be achieved if only one cluster-head transmits to base station and if each cluster-head transmits only to local neighbor cluster-heads in the data fusion phase. This is the basis for LEACH-CC (LEACH-Centralized with Chain). During the set-up phase of LEACH-CC, each node sends information about its current location and energy level to the base station. The base station runs an optimization algorithm to determine the clusters for that round. The clusters formed by the base station will in general be better than those formed using the distributed algorithm. However, LEACH-CC requires that each node transmit information about its location to the base station at the beginning of each round. This information may be obtained by using a global positioning system (GPS) receiver that is activated at the beginning of each round to get the node's current location. The steady-state operation is broken into frames, where nodes send their data to the cluster-head at most once per frame during their allocated transmission slot. The cluster-head must keep its receiver on to receive all the data from the nodes in the cluster. Once the cluster-head receives all the data, it can aggregate the data. Since the base station may be far away, the difference from LEACH is to use multi-hop routing by forming chains between cluster-heads and selecting only one cluster-head to transmit to the base station instead of using multiple cluster-heads to reduce the dissipation of the energy. The main idea in LEACH-CC is for each cluster-head to receive form and transmit to close neighbor cluster-head and take turns being the leader for transmission to the base station. This approach will distribute the energy load evenly among the sensor nodes in the network.

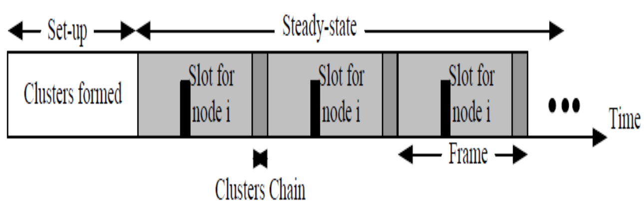


Fig.3 Timeline showing LEACH-CC operation.

4. GAF (GEOGRAPHICAL ADAPTIVE FIDELITY)

Geographical Adaptive Fidelity, [7] a location based protocol, in this the sensor nodes are addressed by the location. Location information of sensor nodes is required by sensor networks to calculate the distance between two particular nodes so that energy utilization can be estimated. GAF is an energy-aware routing protocol primarily proposed for MANETs, but can also be used for WSNs because it favors energy conservation. The design of GAF is motivated based on an energy model that considers energy consumption due to the reception and transmission of packets as well as idle (or listening) time when the radio of a sensor is on to detect the presence of incoming packets. GAF is based on mechanism of turning off unnecessary sensors while keeping a constant level of *routing fidelity* (or uninterrupted connectivity between communicating sensors). In GAF, sensor field is divided into grid squares and every sensor uses its location information, which can be provided by GPS or other location systems, to associate itself with a particular grid in which it resides. GAF is based on mechanism of turning off unnecessary sensors while keeping a constant level of routing fidelity (or uninterrupted connectivity between communicating sensors).It has three types of states in GAF a) Discovery state, b) Active state and c) Sleeping state .This kind of association is exploited by GAF to identify the sensors that are equivalent from the perspective of packet forwarding.

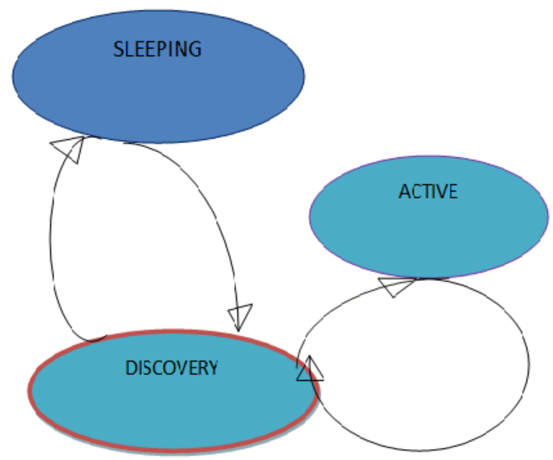
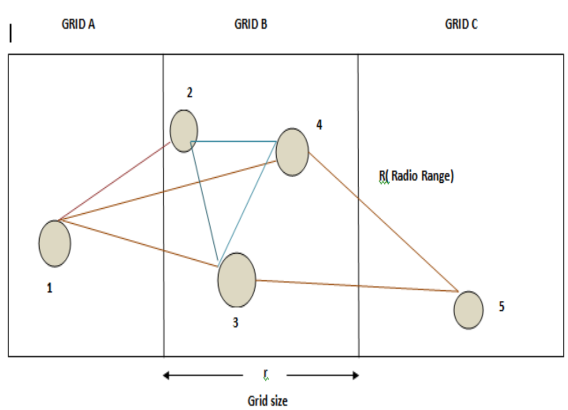


Fig. 4 State transition in GAF Protocols.

In this, each node uses location information based on GPS (Global Positioning System) to associate itself with a "*virtual grid*" so that the entire area is divided into several square grids, and the node with the highest residual energy within each grid becomes the master of the grid. Two nodes are considered to be equivalent when they maintain the same set of neighbor nodes and so they can belong to the same communication routes. Source and destination in the application are excluded from this characterization. GAF uses discovery messages to learn about other sensors in the same grid. Even in the active state, a sensor periodically broadcasts its discovery message to inform equivalent sensors about its state. [7] The time spent in each of these states can be tuned by the application depending on several factors, such as its needs and sensor mobility. GAF aims to maximize the network lifetime by reaching a state where each grid has only one active sensor based on sensor ranking rules. The ranking of sensors is based on their residual energy levels. Thus, a sensor with a higher rank will be able to handle routing within their corresponding grids. For example, a sensor in the active state has a higher rank than a sensor in the discovery state. A sensor with longer expected lifetime has a higher rank. In GAF, sensor field is divided into grid squares and every sensor uses its location information, which can be provided by GPS or other location systems to relate itself with a particular grid in which it resides. This kind of association is exploited by GAF to identify the sensors that are equivalent from the perspective of packet forwarding As shown in Fig , the state transition diagram of GAF has three states, namely, discovery, active, and sleeping. When a sensor enters the sleeping state, it turns off its radio. GAF aims to maximize the network lifetime by reaching a state where each grid has only one active sensor based on sensor ranking rules. The ranking of sensors is based on their residual energy levels. Thus, a sensor with a higher rank will be able to handle routing within their corresponding grids. For example, a sensor in the *active* state has a higher rank than a sensor in the *discovery* state. Nodes use their GPS-indicated location to associate itself with a point in the virtual grid. Inside each zone, nodes collaborate with each other to play different roles. For example, nodes will elect one sensor node to stay awake for a certain period of time and then they go to sleep. This node is responsible for monitoring and reporting data to the sink on behalf of the nodes in the zone and is known as the master-node. Other nodes in the same grid can be regarded as redundant with respect to forwarding packets, and thus they can be safely put to sleep without sacrificing the "*routing fidelity*" (or routing efficiency). The slave nodes switch between off and listening with the guarantee that one master node in each grid will stay awake to route packets. For example, nodes 2, 3 and 4in the virtual grid B in Fig are equivalent in the sense that one of them can forward packets between nodes 1 and 5 while the other two can sleep to conserve energy. Hence, GAF conserves energy by turning off unnecessary nodes in the network without affecting the level of routing fidelity. Each node uses its GPS-indicated location to associate itself with a point in the virtual grid.[7]

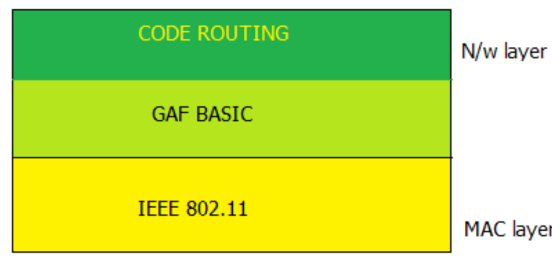


Constraints with GAF:

1. GAF is dependent on global information. It fails in applications were geographic location information is not available and hence GAF can be used in very limited applications
2. In GAF if a grid has only one node then is not possible to balance the energy usage for that virtual grid and the network may have pockets of low energy virtual grids which in turn may lead to network partitioning.

4.1 Advanced Researches using GAF

CODE [4] protocol is based on GAF protocol and grid structure to reduce energy consumed. It considers energy conservation not only in communication but also in idle-to-sleep state. CODE for short, addresses mobile sinks .In CODE, we rely on the assumptions that all sensor nodes are stationary. Each sensor is aware of its residual energy and geographical location. Once a stimulus appears, the sensors surrounding it collectively process the signal and one of them becomes the source to generate data report .The sink and the source are not supposed to know any *a-prior* knowledge of potential position of each other. To make unnecessary nodes stay in the sleeping mode, CODE is deployed above *GAF-basic* protocol depicts CODE general model where the routing algorithm is implemented above the GAF protocol.



CODE system model

The basic idea of CODE is to divide sensor field into grids. Grids are indexed based on its geographical location. According to GAF, each grid contains one coordinator which acts as an intermediate node to cache and relay data. CODE consists of three phases: data announcement, query transfer and data dissemination. As a stimulus is detected, a source generates a data-announcement message and sends to all coordinators using simply flooding mechanism. Each coordinator is supposed to maintain a piece of information of the source including the stimulus and the source's location. As a mobile sink joins in the network, it selects a coordinator in the same grid to act as its Agent. When it needs data, it sends a query to this Agent. The Agent is in charge of forwarding the query to the source based on the target's location and grid IDs. An efficient data dissemination path is established while the query traverses to the source. Receiving a query, the source sends the data to the sink along the data dissemination path. The Agent helps the sink to continuously keep receiving data from the source when the sink moves around. Periodically, the sink checks its location. If the sink moves to another grid, it first sends cache-removal message to clear out the previous data dissemination path and then re-sends a query to establish a new route. CODE differs from such protocols in three fundamental ways. First, CODE exploits GAF protocol [11] to reduce energy consumption and data collision while the nodes make decision to fall into sleeping mode. Second, based on grid structure, CODE can control the number of transmitted hops and disseminates data along a path shorter than others such as TTDD. Third, the number of re-transmitted queries is reduced by maintaining an Agent to relay data to the sink when it moves within a grid. In addition, CODE takes into account of query and data aggregation, to reduce the amount of data transmitted from multiple sensor nodes to sinks like other approaches

5. CONCLUSION

In the past years, wireless sensor network has gained a lot of attention in which researchers are all involved in finding the new way or making amendments in the existing energy efficient routing protocols in which nodes assume less energy. The energy consumption of the sensors is dominated by data transmission and reception. In this paper we have shown the amendments made in the LEACH protocol and GAF protocol on the basis of following properties .In this, we have studied the limitations of LEACH and how WLEACH and LEACH-CC is better. WLEACH is better than LEACH as it considers the energy, the multi-jump routing and adding dormancy that reduces energy of the cluster head node which were all absent in LEACH. The first stage is same as LEACH. In the second stage, all choosing nodes whose energy low than threshold *will* be removed their cluster-head state, which makes the new cluster .LEACH-CC is also better than LEACH in a manner by using central control algorithm it will make better clusters and improve energy cost only when one cluster-head transmits to base station and if each cluster-head transmits only to local neighbor cluster-heads in the data fusion phase. GAF is based on mechanism of turning off unnecessary sensors while keeping a constant level of *routing fidelity* (or uninterrupted connectivity between communicating sensors) whereas CODE is based on grid structure and GAF protocol to reduce energy cost. CODE exploits GAF protocol to reduce energy consumption and data collision while the nodes make decision to fall into sleeping mode. Secondly based on grid structure, CODE can control the number of transmitted hops and disseminates data along a path shorter than others.

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