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Enhancement techniques incorporated in LEACH- a survey

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Abstract: In this paper, we present a survey of various improvements made in LEACH that has produced different routing protocols for WSNs and highlight their features. Further this paper also addresses the other challenges of cluster-based routing protocols that need to be considered in future designs.

Keywords: Wireless sensor network, LEACH, clustering

Introduction

Sensor nodes are often left unattended, which makes it difficult or impossible to re-charge or replace their batteries. This necessitates devising novel energy-efficient solutions to prolong the network lifetime. In most of the applications, sensors are required to detect events and communicate the collected information to a distant Base Station (BS). In BS the parameters characterizing these events are estimated. The cost of transmitting information is higher than computation and hence to attain the advantage of energy reduction, it becomes necessary to organize the sensors into clusters, where the data gathered by the sensors is communicated to the BS through a hierarchy of Cluster-heads. Thus, network lifetime will be prolonged. LEACH (Low Energy Adaptive Clustering Hierarchy) protocol is the first cluster based routing protocol for wireless sensor networks, which uses a stochastic model for Cluster head selection. LEACH has motivated the design of several other protocols which try to improve upon the cluster-head selection process. The Protocols basically differ depending on the application and network architecture used in their design.

Wireless sensor network (WSN) is an emerging technology that has attracted a great deal of research attention due to the extensive ability to monitor and instrument the physical world. A wide-range of potential applications such as environmental monitoring, industrial sensing, infrastructure protection, battlefield awareness etc., can be developed by this network. WSN consist of thousands of sensors (nodes) that are densely distributed over the region of interest. These smart sensors have capabilities like sensing, computing and communicating through wireless medium. They are self-configured (Akyildiz *et al*., 2002) but are limited in computation and communication abilities because sensors are typically battery powered and recharge or replacement of the battery is usually very difficult or impossible due to remote or hostile environments where sensors work.

A large number of routing protocols for WSN has been developed recently (Akkaya & Younis, 2005). Due to the limited energy resources of sensor nodes, designing efficient energy-aware routing protocols has been one of the most challenging issues for WSN (Min *et al*., 2000; Chiasserini *et al*., 2002). In recent years, clustering routing protocols have been developed in order to reduce the network traffic toward the Sink (Banerjee & Khuller, 2001; Bandyopadhyay & Coyle, 2003). Moreover, cluster heads is being used to enhance the efficiency of the energy-aware routing protocols (Lin & Gerla, 1997; Amis & Prakash, 2000; Chatterjee *et al*., 2002; Younis *et al*., 2002). Though configuration and maintenance of clustering increases overhead, earlier works demonstrates that cluster-based protocols exhibit better energy consumption and performance when compared to flat large-scale Wireless Sensor Network (Schurgers & Srivastave , 2001).

Energy aware routing protocols

In this section, we will present selected energy-aware clustering routing protocols that are motivated by LEACH.

Low Energy Adaptive Clustering Hierarchy Protocol (LEACH)

In LEACH, nodes organize themselves into clusters and all non-cluster head nodes transmit sensed data to the cluster-head as shown in Fig. 1. The cluster head performs data aggregation and transmits the data to the remote Base Station (Klein, 1993). Therefore, cluster-head nodes are much more energy intensive than non-cluster head nodes.

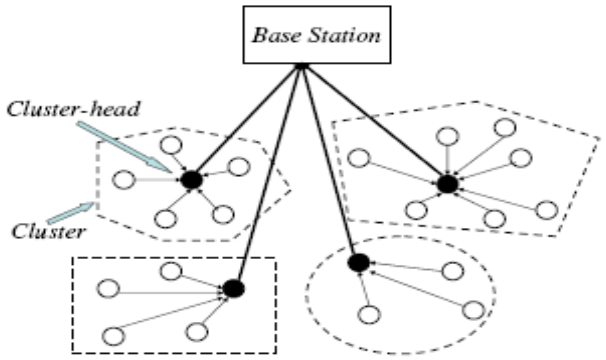

Fig.1. Cluster-based mechanism in WSN

In this protocol, Cluster Head selection is done in setup phase (Heinzelman *et al*., 2000), by considering two factors. First, the desired percentage of nodes in the network and second the history of node that has served as cluster-head. This decision is made by each node *n* based on the random number (between 0 and 1)

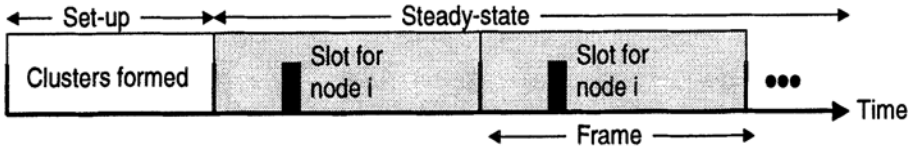

Fig. 2. Time line operation of LEACH

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generated. If the generated random number is less than a threshold value T (n), then the corresponding nodes becomes cluster-heads CHs (p) for that round. The threshold value T (n) is calculated from equation 1:

$$T(n) = \begin{cases} \dfrac{P}{1 - P\left(r \bmod \frac{1}{P}\right)} & \text{if } n \in G \\ 0 & \text{Otherwise} \end{cases} \quad \text{---------- (1)}$$

where P is the desired percentage of cluster-head, r is the number of round and G is the set of nodes that have not been cluster-heads in the last $1/P$ rounds.

Once the nodes have elected themselves to be cluster heads they broadcast an advertisement message. Each non cluster-head node decides its cluster for this round by choosing the cluster head that requires minimum communication energy, based on the received signal strength of the advertisement from each cluster head (Lin & Stojmenovic, 1998). After each node decides to which cluster it belongs, it informs the cluster head by transmitting a join request message (Join-REQ) back to the cluster head as depicted in Fig. 2.

The cluster head node sets up a TDMA schedule and transmits this schedule to all the nodes in its cluster, completing the setup phase, which is then followed by a steady-state operation. 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 slot.

Although LEACH is able to increase the network lifetime, there are still a number of issues about the assumptions used in this protocol. LEACH assumes that all nodes can transmit with enough power to reach the BS if needed and that each node has computational power to support different MAC protocols. Therefore, it is not applicable to networks deployed in large regions. It also assumes that nodes always have data to send and nodes located close to each other have correlated data. It is not obvious how the number of predetermined Cluster Heads [CH (p)] is going to be uniformly distributed throughout the network. Therefore, there is a possibility that the elected CHs will be concentrated in one part of the network. Hence, some nodes will not have any CHs in their vicinity.

Furthermore, the idea of dynamic clustering brings extra overhead (head changes, advertisements, etc.), which may diminish the gain in energy consumption. Finally, the protocol assumes that all nodes begin with the same amount of energy capacity in each election round and all Cluster Heads consume approximately same amount of energy in each round.

The protocol need to be extended to account for non-uniform energy nodes. An extension to LEACH, LEACH with negotiation was proposed (Heinzelman *et al*., 2000). The main theme of the proposed extension is to precede data transfers with high level negotiation using meta-data descriptors. This ensures that only data that provides new information is transmitted to the CHs before being transmitted to the BS.

Power-Efficient Gathering in Sensor Information Systems: (PEGASIS)

Lindsey & Ragavendra (2002) proposes an enhancement over the LEACH protocol called Power-Efficient Gathering in Sensor Information Systems (PEGASIS). It is a near optimal chain-based protocol. The basic idea of the protocol is that, in order to extend the network lifetime, all nodes communicate only with their closest neighbors, which in turn communicate to the BS as shown in Fig. 3. A round ends, when all the nodes communicate with the BS. This reduces the power required to transmit data per round. It also guarantees that the depletion in power in each node is uniformly distributed.

Hence, PEGASIS has two main objectives. First, increase the lifetime of each node by using collaborative techniques. Second, allow only local coordination between nodes that are close together so that the bandwidth consumed in communication is reduced (Lindsey *et al*., 2001). Unlike LEACH, PEGASIS avoids cluster formation and uses only one node in a chain to transmit to the BS instead of multiple nodes. To locate the closest neighbor node in PEGASIS, each node uses the signal strength to measure the distance to all neighboring nodes and then adjusts the signal strength so that only one node can be heard. The chain in PEGASIS will consist of those nodes that are closest to each other and form a path to the BS. The aggregated form of the data will be sent to the BS by any node in the chain and the nodes in the chain will take turns sending to the BS. The chain construction is performed in a greedy fashion.

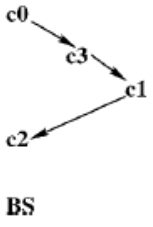

Fig.3. Chain construction using greedy algorithm

Simulation results shown in Fig.4 demonstrate that PEGASIS performs better than LEACH by about 100 to 200 % when 1 %, 25 %, 50 %, and 100 % of nodes die for different network sizes and topologies (Lindsey *et al*., 2002). Such performance gain is achieved through the elimination of the overhead caused by dynamic cluster formation and reduction

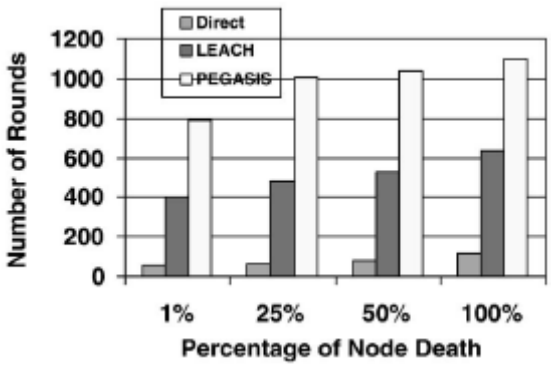

Fig. 4. Performance results of PEGASIS "LEACH"

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of number of transmissions through data aggregation. Although the clustering overhead is avoided, PEGASIS still requires dynamic topology adjustment as the energy status information of each node should be known to determine alternate routing path for data communication.

Moreover, PEGASIS assumes that each sensor node has the potential to directly communicate with the BS which conflicts the practical implementation. Also, PEGASIS assumes that all nodes maintain a complete database of the location of all other nodes in the network. The method by which the node locations are obtained is not outlined. In addition, PEGASIS assumes that all sensor nodes have the same level of energy and are likely to die at the same time. PEGASIS also introduces excessive delay for distant nodes in the chain to communicate to BS. The single leader in this protocol can become a bottleneck. Finally, although in most scenarios sensors will be fixed or immobile as assumed in PEGASIS, some sensors may be allowed to move and hence affect the protocol functionality.

An extension to PEGASIS, called Hierarchical PEGASIS, was developed in (Savvides *et al.*, 2001) whose objective is to minimize the delay incurred in transmission to the BS. This is achieved by performing simultaneous transmission of data to the BS. However this leads to collision in the medium. To alleviate this issue, CDMA access scheme was adopted. In this protocol, a hierarchical tree is constructed by the CDMA based nodes. Nodes with higher level of energy transmit data to the nodes in the upper level of hierarchy.

Threshold-Sensitive Energy Efficient Protocols (TEEN)

Two hierarchical routing protocols called Threshold-Sensitive Energy Efficient Sensor Network Protocol (TEEN) and Adaptive Periodic TEEN (APTEEN) were proposed in (Manjeshwar & Agarwal, 2001, 2002). These protocols were proposed for time-critical applications. In TEEN, sensor nodes sense the medium continuously, but data transmission is done less frequently. The Cluster Head nodes send two threshold values known as Hard Threshold (HT) and Soft Threshold (ST) to its members.

Hard Threshold is the threshold value of sensed attributes and Soft Threshold is a small change in the value of the sensed attributes that trigger the nodes to switch on. Thus, hard threshold tries to reduce the number of transmissions by allowing the nodes to transmit only when the sensed attribute is in the range of interest. The soft threshold further reduces the number of transmissions that might otherwise occur when there is little or no change in the sensed attribute. A smaller value of the soft threshold gives a more accurate picture of the network, at the expense of increased energy consumption. Thus, the user can have tradeoff between energy efficiency and data accuracy. When CHs change, new values for the above parameters are broadcasted (Kawadia & Kumar, 1997). The main drawback of this scheme is that if the thresholds are not received, the nodes will never communicate and the user will not get any data from the network at all. The nodes sense their environment continuously. The first time a parameter from the attribute set reaches its hard threshold value, the node switches its transmitter on and sends the sensed data. The sensed value is stored in an internal variable as Sensed Value (SV).

The nodes will transmit data in the current cluster period only when the following conditions are true:

• The current value of the sensed attribute is greater than the hard threshold.

• The current value of the sensed attribute differs from SV by an amount equal to or greater than the soft threshold.

Important features of TEEN include its suitability for time-critical sensing applications. Also, since message transmission consumes more energy than data sensing, the energy consumption in this scheme is less than in proactive networks. At every cluster change time, fresh parameters are broadcasted, so the user can change the value of HT and ST as required. APTEEN, on the other hand, is a hybrid protocol that changes the periodicity or threshold values used in the TEEN protocol according to user needs and the application type. In APTEEN, the CHs broadcast the following parameters:

• Attributes (A): a set of physical parameters about which the user is interested in obtaining information

• Thresholds: consists of the Hard Threshold (HT) and Soft Threshold (ST)

• Schedule: a TDMA schedule, assigning a slot to each node

• Count Time (CT): the maximum time period between two successive reports sent by a node.

The node senses the environment continuously and only those nodes that sense a data value at or beyond HT transmit. Once a node senses a value beyond HT, it transmits data only when the value of that attributes changes by an amount equal to or greater than ST. If a node does not send data for a time period equal to CT, it is forced to sense and retransmit the data. A TDMA schedule is used and each node in the cluster is assigned a

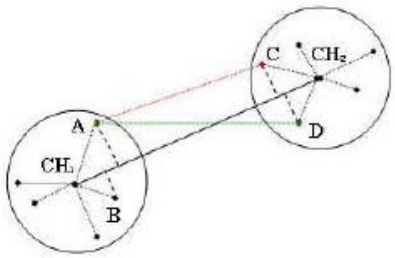

Fig.5. Intra and inter clusters Communication

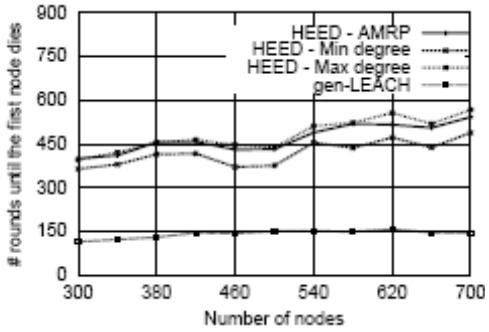

Fig. 6.Network lifetime (HEED vs LEACH)

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transmission slot. Hence, APTEEN uses a modified TDMA schedule to implement the hybrid network. It combines both proactive and reactive policies. The main features of the APTEEN scheme include the following.

It offers a lot of flexibility by allowing the user to set the CT interval and the threshold values for energy consumption can be controlled by changing the CT as well as the threshold values. The main drawback of the scheme is the additional complexity required implementing the threshold functions (HT, ST) and CT. Simulation results of TEEN and APTEEN has shown (Manjeshwar & Agarwal, 2001, 2002), demonstrate that these two protocols outperform LEACH. The experiments have demonstrated that APTEEN performance is somewhere between LEACH and TEEN in terms of energy dissipation and network lifetime. TEEN gives the best performance since it decreases the number of transmissions. The main drawbacks of the two approaches are the overhead, complexity associated with forming clusters at multiple levels, the method of implementing threshold-based functions and how to deal with attribute-based naming of queries.

Hybrid Energy-Efficient Distributed clustering (HEED)

A stand-alone distributed clustering protocol that considers a hybrid of energy and communication cost has been proposed (Younis *et al*., 2002), which has five primary goals: (i) operating in a completely distributed manner, (ii) prolonging network lifetime by distributing energy consumption, (iii) terminating the clustering process within a constant number of iterations/steps,(iv) minimizing control overhead(to be linear in the number of nodes), and (v) producing well-distributed cluster heads and compact clusters. HEED does not make any assumptions about the distribution or density of nodes or about node capabilities, e.g., location-awareness. HEED assumes that all nodes are equally significant and energy consumption is not necessarily uniform among nodes.

The HEED clustering operation is invoked at each node in order to decide if the node will elect to become a cluster head or join a cluster (Lin & Gerla, 1997). The two important tasks that are performed by a cluster head are intra-cluster coordination and inter-cluster communication as shown in Fig. 5. Power level refers to the transmission power level of each node. It is lower for intra -Cluster communication while higher for inter-cluster communication. Selection of cluster heads is based on two parameters: a primary parameter and a secondary one. Node residual energy is considered as primary parameter. Thus, a node with high residual energy has a higher chance to become a cluster head. The secondary parameter is the intra-cluster "communication cost" which is used to "break ties", that is nodes that are common to more than one cluster head. Cluster size and transmission power level of both intra-communication and inter-communication are considered as functions to determine the communication cost.

Simulation results shown in Fig. 6 demonstrate that HEED outperforms LEACH in terms of prolonging network lifetime for a large network (Younis *et al*., 2002). HEED can be applied to design sensor network that require energy efficiency, scalability, prolonged network lifetime and load balancing.

Hierarchical Cluster-based Routing (HCR)

Hierarchical cluster-based routing (HCR) technique is an extension of the LEACH protocol. In HCR, each cluster is managed by a set of associates and the energy efficient clusters are retained for a longer period of time. The energy-efficient clusters are identified using heuristics-based approach. Moreover, in a variation of HCR, the base station determines the cluster formation. A Genetic Algorithm (GA) is used to generate energy-efficient hierarchical clusters. The base station broadcasts the GA-based clusters configuration, which is received by the sensor nodes and the network is configured accordingly.

The main objective of the HCR (Sajid Hussain & Abdul W. Matin, 2006) protocol is to generate energy-efficient clusters for randomly deployed sensor nodes, where each cluster is managed by a set of associates called a head-set. Using round-robin technique, each associate member acts as a cluster head. CH receives messages from the cluster members and transmits the aggregated messages to a distant Base Station (BS). As all the transmissions are single-hop, cluster members transmit short-range broadcast messages and CHs transmit long-range broadcast messages. The head-set approach can be a good solution for clusters where the CH dies during a round.

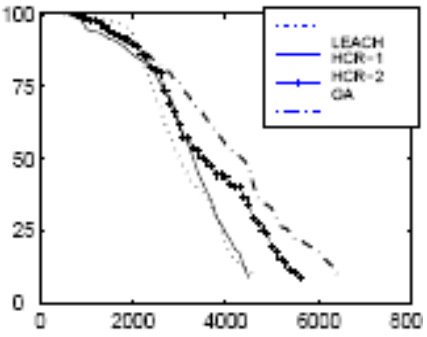

Fig. 7. Percentage of alive nodes vs number of transmission

Since the role of a CH is energy consuming, after a specified number of transmissions, a new set of clusters is formed. In other words, the clusters are maintained for a short duration called a *round*. A round consists of an *election* phase and a *data transfer* phase. In an election phase, the sensor nodes self organize into a new set of clusters, where each cluster contains a head-set (Banerjee & Khuller, 2001). In data transfer phase, the head-set members transmit a specified number of long-range transmissions to BS.

At the end of each round, all the clusters are not destroyed, however, cluster is retained for the number of rounds equal to the head-set size. In other words, the nodes of clusters with the head-set size of 1 become candidates in the next round but the nodes of the clusters with the head-set size greater than 1 do not participate in

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the next election. This approach reduces the number of Cluster Head elections. The burden of long-range transmissions is more efficiently distributed among the nodes. Moreover, for the next election, the percentage of headers is decreased according to the number of retained clusters. The retaining of clusters in HCR protocol results in a significant amount of improvement compared to the LEACH protocol as shown in Fig. 7.

Distributive Energy Efficient Adaptive Clustering Protocol (DEEAC)

Udit Sajjanhar & Pabitra Mitra (2007) proposed an enhancement over the LEACH protocol called Distributive Energy Efficient Adaptive Clustering (DEEAC). It is an optimal cluster- based protocol with the basic idea is to extend network lifetime. The design of protocol considers the data reporting rates and residual energy of each node within the network. Moreover the protocol is adaptive and cluster formation is done based on the spatio-temporal variations in data reporting rates across different regions (Loscr *et al*., 2005).

The regions in the network having high data generation rate are considered to be "hot regions". "Hotness" value of a node is a parameter indicating the data generation rate at that node relative to the whole network. DEEAC optimizes the energy consumption of the network selecting nodes belonging to hot regions as cluster heads. Thus nodes belonging to hot regions, which transmit data more frequently, transmit data over shorter distances, thereby resulting in balanced energy consumption over the network.

DEEAC selects a node to be a cluster head depending upon its hotness value and residual energy. This is an improvement over stochastic approach used in LEACH in terms of energy efficiency. The main principle behind this protocol is to choose nodes with high residual energy and greater hotness values as cluster heads. This is achieved by making some beneficial adjustments to the threshold T (n) proposed in LEACH. Modified
T (n) is denoted in equation 2

$$T(n) = \begin{cases} k \times \frac{E_{res}}{E_{est\_net}} \times Hotness\_factor \end{cases} \quad \text{----- (2)}$$

Using this equation each node decides whether or not to be a cluster-head for the current round, where K is the optimal number of cluster-head nodes per round, E_{res} is the residual energy of the node and E_{est_net} is the estimate of the residual energy of the network. Hotness_factor is the relative hotness of the node with respect to the network.

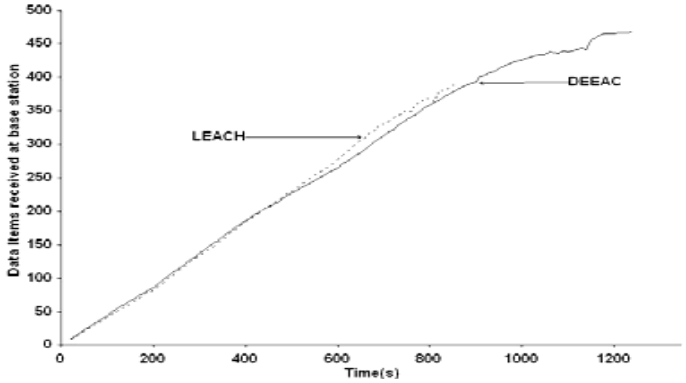

Fig. 8. Total amount of data received at BS over time

Simulation results shown in Fig.8 demonstrate that DEEAC is able to distribute energy consumption more effectively among the sensors, thereby prolonging the network lifetime by as much as 50% compared to LEACH (Udit Sajjanhar & Pabitra Mitra, 2007). DEEAC has cluster heads from *hot* regions which reduces the energy loss due to transmission for the nodes expected to transmit frequently, thereby delivering the same amount of data with less energy dissipation.

Although the first node dies earlier in DEEAC, both have almost the same death rate up to 80% nodes alive, after which LEACH has an abrupt fall. LEACH selects cluster-heads assuming that each time a node becomes a cluster-head it dissipates the same amount of energy. This leads to inefficient selection of heads towards the end of simulation thereby depleting the network quickly. DEEAC selects cluster-heads based on the residual energy of a node with respect to the residual energy of the network, thereby prolong the network lifetime.

Distributed Energy-efficient Clustering Hierarchy Protocol (DECHP)

Distributed Energy-efficient Clustering Hierarchy Protocol (DECHP), which distributes the energy dissipation evenly among all sensor nodes to improve network lifetime and average energy savings has been proposed by Omar Moussaoui & Mohamed Naimi (2005). DECHP uses a geographical and energy aware neighbor cluster heads selection heuristic to transfer fused data to the BS (Lindsey *et al*., 2001). The two key elements considered in the design of DECHP are the sensor nodes and BS. The sensor nodes are geographically grouped into clusters and capable of operating in two basic nodes: i) the cluster head nodes, ii) the sensing node. In the sensing node, the nodes perform sensing tasks and transmit the sensed data to the cluster head. In cluster head node, a node gathers data from the other nodes within its cluster performs data fusion and routes the data to the BS through other cluster head nodes. The BS in turn supervises the entire network. Initially, the nodes organize themselves into local clusters based on their localization, with one node acting as the cluster head (Lindsey et al., 2002).

DECHP uses a class-based addressing of the form <Location-ID, Node-Type-ID>. The Location-ID identifies the location of a node that conducts sensing activities in a specified region of the network. It is assumed that each node knows its own location information from GPS or some localization system and remaining energy level. Each node within the cluster is further provided with a Node-Type-ID that describes the functionality of the sensor (Shah & Rabaey, 2002).

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Simulation results show (Omar Moussaoui & Mohamed Naimi, 2005), that DECHP reduces overall energy consumption and improves network lifetime compared to LEACH. Energy balancing and reduction in routing complexity is achieved as only the CH routes the sensed data progressively towards the BS. The results also show that DECHP outperforms the system lifetime of LEACH, LEACH-C and PEGASIS. This is because all the cluster heads in both LEACH and LEACH-C transmit data directly to the distant BS, which in turn causes significant energy losses in the cluster head nodes.

Both DECHP and PEGASIS alleviate this problem by having one node forward the data to the BS. However, the geographical and energy-aware routing approach, used by CHs to transmit data to the BS, let DECHP still exceeds the system lifetime of PEGASIS. The utilization of the greedy algorithm in PEGASIS results in a gradual increase in neighbor distances. This in turn increases the communication energy cost for those PEGASIS nodes that have far neighbors. Increasing neighbor distances will have a significant effect on PEGASIS performance when the area of the sensor field is increased.

DECHP outperforms both LEACH and LEACH-C as network area increases. This is mainly because the two version of LEACH do not ensure that the cluster heads are uniformly placed across the whole sensor field. As a result, the cluster heads in LEACH and LEACH-C can become concentrated in a certain region of the network, in which case nodes from the "cluster head deprived" regions will dissipate a considerable amount of energy while transmitting their data to a faraway cluster head. DECHP alleviates this problem by evenly allocating cluster heads across the sensor field. It is also observed that the performance gain of DECHP over its counterparts increases with the area of the sensor field. Therefore, DECHP provides an energy-efficient routing scheme suitable for a vast range of sensing applications.

Clustering-based data-gathering protocol with mobility (CM)

A clustering-based and time-driven protocol which minimizes energy dissipation for data-gathering with mobile sensor nodes has been proposed Chuan-Ming Liu et al., (2004) :Chuan-Ming Liu & Chuan-Hisu Lee, (2005). In this protocol, the cluster formation is done based on node's mobility (Heinzelman *et al*., 2000). Each node is assumed to have a GPS device attached to them that calculate its speed and direction. In CM protocol, the sensor node uses the information obtained from GPS device to estimate its distances from all other CHs at a given time *t*. This estimate helps the nodes to decide the cluster to which it needs to associate. Thus, the given time t is defined as *clustering factor* Tc impacts the organizing of the clusters (Kalpakis *et al*., 2002; Liu *et al*., 2004).

Clustering-based data-gathering protocol consists of a number of rounds and each round has two major phases: (1) organizing clusters and (2) message transmission phases. The organizing clusters phase consist of two steps: one step is to elect the cluster-heads and then the following step is to form the clusters (Lindsey *et al*., 2002). This protocol also provides two distributed algorithms (CM-IR and CM-C) which avoid the case that there is no cluster-head in a round. The basic idea of the first algorithm is based on LEACH but simply skips the round which has no cluster-heads elected. The other distributed algorithm uses the unique IDs of the sensor nodes and decides the cluster-heads by counting. The experimental results shown in Fig.9 describes that these protocols make the system lifetime longer than LEACH: (1) protocol CM makes the system lifetime 5%-10% longer than LEACH and (2) Protocols CM-IR and CM-C perform much better and have 40% - 55% longer system lifetime than LEACH (Chuan-Ming Liu *et al*., 2004: Chuan-Ming Liu & Chuan-Hisu Lee, 2005).

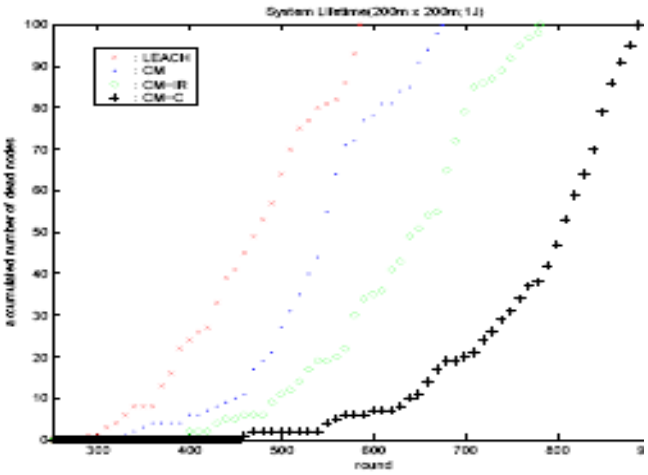

Fig. 9. Mobility of nodes vs system lifetime

Sensor Protocol for Energy Aware Routing (SPEAR)

Bhuvaneswari *et al*. (2007) proposed a hierarchical clustering protocol, SPEAR (Sensor Protocol for Energy Aware Routing) that presents an adaptive and conceptually novel paradigm, for the election of cluster heads based on energy as well as spatial distribution. Due to its heterogeneous-aware nature, SPEAR yields longer stability periods and consequently a higher average throughput and longer network lifetime compared to heterogeneous oblivious protocols such as LEACH.

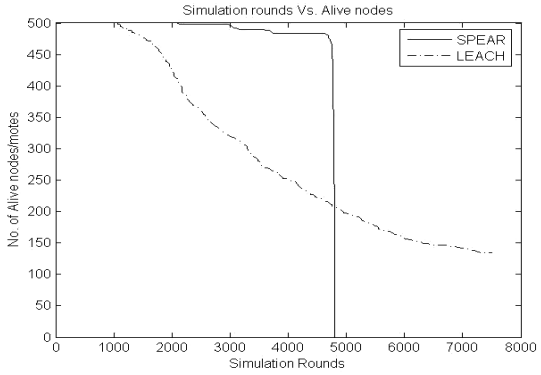

Fig. 10. Simulation rounds vs alive nodes

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In the SPEAR protocol the cluster head election process is made energy aware leading to scalability in terms of node heterogeneity. The protocol also ensures a uniform distribution of CHs in the deployment area as CH election is based on a threshold distance. The protocol maintains a minimum threshold distance between any two cluster head leading to a uniform energy load distribution among the nodes. The protocol has two phases namely setup and steady state. In Setup phase, the CH election and cluster formation is done while data transfer between CHs and BS is carried out in Steady state phase.

The CH election process is purely based on the energy level of nodes which implement a stack that guarantee a uniform distribution of cluster heads. The functionalities of steady state phase of LEACH are maintained in SPEAR.

The experimental results with simulation round vs alive nodes as depicted in Fig.10 reveals that the SPEAR protocol gives a stable operation for about 4500 rounds while the nodes in LEACH die for around 1000 rounds (Bhuvaneswari *et al.*, 2007). This is due to the non uniform energy load distribution in LEACH which is taken care by the energy aware cluster head election scheme in SPEAR. The same optimization takes care of scalability issues in cases of node heterogeneity in terms of energy. By taking the node energy into consideration during cluster head election, advanced nodes are utilized much more than normal nodes, leading to a balanced energy load distribution. As per total effective data transmitted to the BS is considered, It may be seen that while the data transmitted saturates for LEACH protocol at around 1500 rounds due to heavy node death, this is not the case in SPEAR where the data transmission goes on till 3500 rounds indicating a steady and superior operation with a higher throughput for a given number of nodes. Due to its heterogeneous-aware nature, SPEAR yields longer stability periods and consequently a higher average throughput and longer network lifetime compared to heterogeneous oblivious protocols such as LEACH.

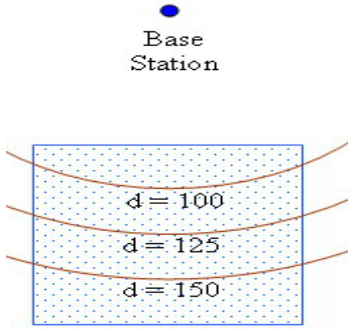

Fig. 11. Network areas is divided into 4 clusters with broadcasting 3 different messages from base station

Energy-Efficient Protocol with Static Clustering (EEPSC)

Amir Sepasi Zahmati *et al.* (2008) proposed a novel hierarchical with static clustering routing protocol called Energy-Efficient Protocol with Static Clustering (EEPSC). EEPSC, partitions the network into static clusters as shown in Fig.11. This eliminates the overhead of dynamic clustering and utilizes temporary-cluster-heads to distribute the energy load among high power sensor nodes; thus extends network lifetime.

The experiment results show that EEPSC outperforms LEACH in terms of network lifetime and power consumption minimization (Zhao & Guibas, 2004). The protocol assumes all nodes to be immobile and homogeneous and all nodes has always data (sensed at fixed rate) to send to the base station. The protocol in each round chooses the node that has maximum energy in each static cluster as cluster head; thereby remove the overhead of dynamic clustering (Rappaport, 1996). The new idea proposed in this protocol is the usage of temporary -Cluster Heads and selection of responsible node in between setup and steady state phase as that of LEACH. The cluster formation in EEPSC is done by the base station, broadcasting k-1 different messages with different transmission powers, where k is the desired number of clusters. By broadcasting different messages all the sensor nodes which hear this message (are in the radio range of this message) set their cluster ID to k and inform the base station that they are member of the cluster k via transmitting a join request message (Join-REQ) back to the base station. These messages are small messages containing node's IDs and a header that distinguishes them as announcement messages. The nodes within the clusters are allocated with time slot based on TDMA schedule.

In the responsible node selection phase, at the beginning of each round two temporary Cluster Heads are selected, one with maximum energy level and another with minimum energy level. The temporary Cluster Heads with maximum energy performs local data aggregation and communicates the combined data to the base station (Lindsey *et al.*, 2002). The temporary Cluster Heads with minimum energy sends the round-start packet which indicates the beginning of next round to all nodes. Since every sensor node has a pre-specified time slot, changing the Cluster Heads has no effect on the schedule of the cluster operation.

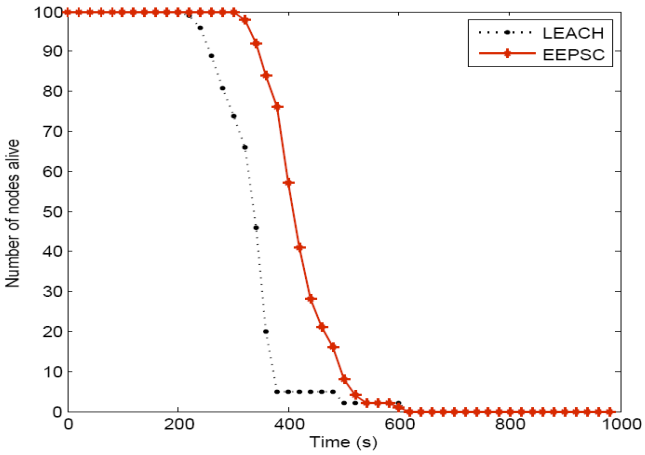

Fig. 12. Number of nodes alive over time

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During steady-state phase, the data transmission between cluster members to Cluster Heads and Cluster Heads to base station occurs. The salient feature of EEPSC is adoption of direct transmission between Cluster Heads and base station than multi-hop routing. It is proved that the total energy expended in the system is greater using multi-hop routing than direct transmission to the base station. Further energy dissipation is reduced by turning off the radios of non-cluster head nodes while keeping awake that of cluster heads to enable continuous transmission between Cluster Heads and base station.

Fig.12 is the simulation result of the EEPSC for Network lifetime. The improvement gained through EEPSC compared to LEACH indicates that the lifetime of network is extended and the overall number of messages received at Base Station is increased. With LEACH, all nodes remain alive for 220 seconds before the first node dies, while in EEPSC, all nodes remain alive for 320 seconds; which is 45% more than LEACH (Amir Sepasi Zahmati *et al*., 2008).

Conclusion

The limited energy resources of sensor nodes pose challenging issues on the development of routing protocols for WSN. Introducing clustering into the network's topology reduces number of transmissions in the network. It also provides energy efficiency as cluster heads aggregate the data's from its cluster members, thereby reduce duplication of transmission and enhance the network lifetime. In this paper, we have presented selected clustering protocols for WSNs which describes various modifications carried over with the primitive LEACH and highlighted their features. The Cluster-head selection algorithm carried out in the discussed protocols are formulated by considering various parameters like residual energy, spatio-temporal variations in the data reporting rates, geographical information and mobility of nodes. We also highlight the design trade-offs between energy and communication overhead savings in some of the routing paradigm, as well as the advantages and disadvantages of each routing technique. Some of the achievements derived by the discussed cluster-based routing protocols are scalability, heterogeneity and prolonging network lifetime. Although many of these routing techniques look promising, but there are still many challenges that need to be solved in sensor networks.

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