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An energy efficient for routing in wireless sensor networks

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Abstract

Wireless Networks are becoming popular due to the concept of "3 any"-any person, anywhere and anytime. Technological advancements in wireless communication paved way to the development of tiny low-cost, low-power and multifunctional sensor nodes in wireless sensor networks. The network layer deals with routing issues in sensor networks. Since radio transmission and reception consumes large amount of energy, power is an important factor to be investigated on. Energy conservation is thus a key issue in wireless sensor networks. Ongoing research involves designing routing protocols that requires less energy during communication thereby extending the networks lifetime. For most of the applications, a replacement of energy is too expensive. An energy harvesting wireless sensor networks make use of nodes that are able to harvest energy from environment. A comparison between Modified LEACH and Mobile Sink improved energy- efficient PEGASIS-based routing protocol is done using MATLAB. Paper also introduces the energy harvesting concept.

***Keywords:*Routing protocols, Energy efficiency, Wireless sensor networks,**

INTRODUCTION

The advances in Micro-Electro-Mechanical Systems (MEMS) technology lead to the tremendous increase in the popularity of Wireless Sensor Networks. We require immediate information in every aspect of our lives and wireless sensor networks are becoming a need for mankind. A processing device can gather information, process it and send it to another processing device which is further aggregated intelligently in such a way that it is comprehendible to the humans. In Wireless Sensor Networks, these devices are called sensors or motes. Wireless Sensor Networks (WSNs) are composed of a large number of sensor nodes which are densely deployed either inside a physical phenomenon or very close to it [1]. Sensors are tiny devices which monitor various conditions like temperature, humidity, pressure etc. and later convert it into electrical signal. These sensor devices have the ability to communicate either directly to the Base Station (BS) or among each other. Each node hence requires a power source that is smart enough to give a node maximum life in spite of its tiny size. The self-organizing capability of sensor nodes provides several challenges for the researchers in designing the network protocols.

The communication architecture of WSN, shown in Fig 1(a) consist of sensor nodes scattered in a sensor field with each of the nodes capable of collecting and routing data back to sink and the end users. The hardware architecture as shown in Fig 1(b) consists of four components: Sensing Unit, Processing Unit, Transceiver Unit anda Power Unit. They may also have location finding system, a power generator and a mobilizer depending on the applications. The major concern for scientists and researchers is the power unit. To optimize life time of node, algorithms and protocols that can make maximum out of the limited power source should be designed.

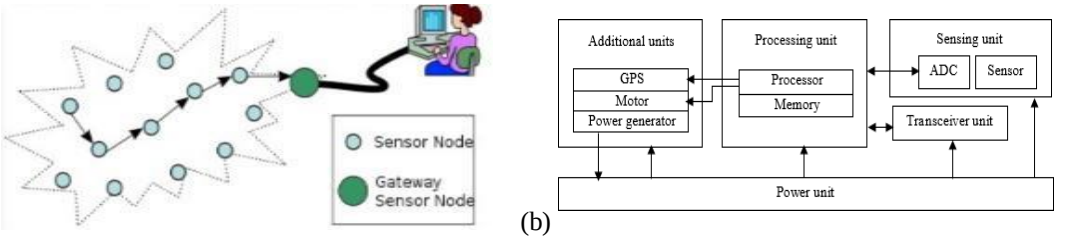

Fig.1. (a) Communication architecture. (b) Hardware architecture.

WSN applications can be categorized into two: monitoring and tracking [2]. The potential applications include military sensing, air traffic control, traffic surveillance, industrial and manufacturing automation, environment, health, home and other commercial areas. In WSN the network layer aims in maximizing the lifetime by finding ways for energy-efficient route setup and reliable relaying of data from sensor nodes to sink. Many routing protocols have been proposed in order to solve the routing problem in WSNs. The designs of routing protocols are also affected by various factors such as deployment, energy consumption, security etc. Researchers thus focus more on designing energy efficient nodes and protocols that could support various operations.

1. ENERGY EFFICIENT ROUTING IN WSN

Sensor nodes are constrained in energy supply and bandwidth which necessitate energy awareness at all layers of networking protocol stack. The network layer aims in finding techniques for energy efficient route setup and reliable relaying of data from sensor nodes to sink in order to maximize the lifetime. Selection of routing strategies is an important issue in WSNs. All routing protocols shares same goals [6] such as improvement of network survivability, availability and service; increase of sensor network lifetime; reduction of complexity; efficient energy consumption control; minimization of transfer delay of mission critical information and improvement of WSN performance.

1.1. Classification of routing protocols

In [3,4, 6] a detailed description about classification on routing protocols in WSNs are provided. Routing protocols are classified based on the network structure, communication scheme, topology schemes and reliable routing schemes as given in Fig.2. We are interested in the first category i.e. Network Structure.

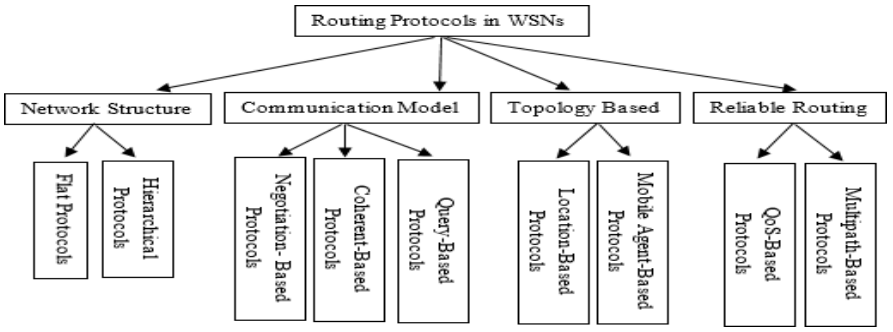

Fig. 2. Classification of routing protocols [6]

2.1.1. Network structure

The schemes in this category address two types of node deployment or structures: nodes with the same level of connection and nodes with different hierarchies.

- Flat Protocols: all the nodes in the network are given equal roles to perform the sensing tasks. A data centric routing where base station sends queries to certain regions and waits for data from sensors present in that regionis followed. This architecture provides the advantage of minimal overhead to maintain the infrastructure between communicating nodes.
- Hierarchical Protocols: routing protocols in this scheme impose a structure that achieves energy efficiency, stability and scalability. In this class, the network is divided into several clusters where one node (with higher residual energy) becomes the cluster .

The protocols in this category are related to the way the packets are routed in the network and focus on delivering more data for a given amount of energy. A low delivery ratio for the data is a drawback in this scheme. The protocols are classified as follows:

- Query-based protocols: communication is made through propagation of queries.
- Coherent and non-coherent based protocols.
- Negotiation based protocols: series of negotiation messages are sent before real data transmission to prevent redundant information.

2.1.2. Topology based scheme

The operations of topology based protocols are based on the topology of network and use the principle that every node in a network maintains topology information. The protocols under this scheme are:

- Location-based protocols: a node should know location of other nodes and take advantage of it to relay receiveddata to certain region and not the whole WSN.
- Mobile agent-based protocols: mobile agent migrates among the nodes of network to perform a task intelligently and this protocol provides flexibility to network.

2.1.3. Reliable routing based scheme

The protocols under this scheme achieve load balancing routes and satisfy certain QoS metrics such as delay, energy and bandwidth thereby becoming more resilient to route failures. Classifications under this scheme are:

- Multipath-based protocols: it achieves load balancing and enhances reliability thereby becoming resilient to failures.
- QoS-based protocols: data transmission has to meet a particular level of quality along with efficient energy consumption.

Energy efficiency is an important factor in WSNs since the devices used in a WSN are resource constrained and limits their overall operations. For the network to be operated for a longer period, it needs to minimize the energy consumption. The paper [7] discusses certain approaches to tackle the energy consumption problem such as radio optimization, data reduction, sleep/wakeup schemes, battery repletion and energy efficient routing. We are interested in the energy efficient routing mechanisms and are categorized as follows:

- Cluster architectures: network is organized into different clusters with each cluster managed by a cluster head (CH).Cluster techniques enhances energy efficiency and improves network scalability.
- Energy as a routing metric: routing algorithms select the next hop by focusing not only the shortest paths but also on its residual energy.
- Multipath routing: single path routing protocols rapidly drains energy of nodes on the selected path. Multipath routing in contrast, enables energy to be balanced among nodes and also enhances network reliability enabling the network to recover faster from a failure.
- Relay node placement: the optimal placement of the nodes through even distribution or by adding a few relay nodes ensures improved coverage, capacity and avoids sensor hot-spots.
- Sink mobility: sensors located close to the base station runs out of power due to the fact that all the traffic is forwarded by them to the sink. This load can be balanced by using a mobile base station which collects node information by moving in the network.

Development of routing protocols that will consume less energy for extending the network lifetime is an ongoing research area. Performance of energy efficient routing protocols is evaluated using several metrics such as Network Lifetime, Average Energy Dissipated, Low Energy Consumption, Total Number of Nodes Alive, etc.

2. ENERGY EFFICIENT HIERARCHICAL BASED ROUTING

In WSNs, data transmission is the most energy consumer and provides a need for an architecture in which the transmission to a Base Station (BS) is kept as low as possible and that, all decisions are made at node level. Also scalability proves to be important as number of nodes grows and the size of network gets increased. A suitable approach is the hierarchical architecture. Here, the entire network is divided into some virtual layers (clusters) and nodes in the same layer will have same role. Some of the nodes are elected as cluster head (CH) of each cluster in order to effectively manage tasks among the nodes. Clustering reduces the load on network by utilizing the correlation among the data, aggregating them, resulting in a more efficient energy consumption. CHs are responsible for gathering and aggregating the data from nodes and finally transmit it to the BS.

The main goal of hierarchical based routing protocols is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a cluster and by performing data aggregation and fusion. This reduces the number of transmitted messages to the sink and transmission distance of sensor nodes. Each clustered WSN is said to have three main characteristics: cluster properties, CH properties and clustering process properties. Cluster properties include number of clusters, cluster size, intra-cluster communication and inter-cluster communication.

There are several hierarchical protocols such as LEACH, LEACH-C, PEGASIS, TEEN, APTEEN, BCDCP, HEED, etc. [3,4,6,8] of which this paper compares the variants of LEACH and PEGASIS protocols in the next section.

3. COMPARISON OF LEACH AND PEGASIS PROTOCOLS

3.1. Low energy adaptive clustering hierarchy (LEACH)

LEACH is a self-organizing single hop hierarchical protocol which means that nodes create clusters by themselves with one node acting as CH. If a fixed architecture is incorporated in network, the chosen node will die

out at a faster rate. Randomizing the rotation of CHs provides a way to tackle this issue thereby maximizing lifetime of nodes. CHs are elected at a given time with certain probability and they broadcast their status to non CHs. NonCH nodes selects those CHs that requires less communication energy and decides to which cluster they should belong to. LEACH consists of a setup and a steady state phase. In setup phase, cluster organization and CH selection takes place whereas data transmission takes place in steady state phase. Data fusion compresses data before transmitting to BS thereby reducing energy dissipation. LEACH protocol makes WSN scalable and robust [9].

3.2. LEACH-Centralized (LEACH-C)

LEACH-C is another improved version of LEACH where BS takes the decision regarding cluster formation. Each node in the network is capable of calculating its energy level. Nodes send this information along with its location to BS. BS elects CHs based on the energy level and distance between node and BS. Initially BS calculates average energy of nodes. Once it identifies a node with energy above this average, that particular node is selected as CH for the current round. Similar to LEACH, this protocol has setup and steady state phase [5].

3.3. LEACH-MF

The insufficiency of LEACH is improved in this protocol. LEACH-MF adopts a method of multi-layer clustering in order to eliminate redundant information. Increase in distance between sink nodes and CHs tremendously increases energy consumption of network. Cluster heads create another set of clusters among them to form super cluster heads. Super CHs send data to sink node improving lifetime with increase in scale of the network [10].

3.4. Modified LEACH (MODLEACH)

In LEACH new CHs are elected in every rounds resulting in unnecessary routing overheads. An efficient cluster head replacement algorithm is required to reduce this excessive use of limited energy resources. MODLEACH incorporates such a mechanism along with a dual transmission power level mechanism. The latter allows farthest and nearest nodes from BS to transmit their data with different power level providing a balance of energy in the network[11].

A comparison among LEACH variants in terms of scalability and energy efficiency is given in Table1.

Table 1. Comparison of variants of LEACH protocols

Protocol	Scalability	Energy efficiency
LEACH	Poor	Poor
LEACH-C	Medium	Medium
LEACH-MF	High	High
MODLEACH	Very high	High

3.5. Power efficient gathering in sensor information systems (PEGASIS)

PEGASIS is a chain-based protocol where each node communicates only with its immediate neighbors. Construction of chain starts with farthest node from BS. Token passing is adopted to start data transmission and data fusion is performed at each node except at end nodes. Average energy spent by each node per round is reduced and improves network lifetime up to 300% as compared to LEACH [12].

3.6. PEGASIS-for energy reduction

Here the nodes are arranged in a way that data packets arrive to destination through the shortest path reducing total energy consumption. The chain structure is modified such that distances between nodes will always be minimized. Further, the data aggregation also reduces total energy consumption in the network [13].

3.7. Energy efficient PEGASIS based protocol (EEPB)

It is a chain based protocol which adopts distance threshold when constructing chain, to decrease the formation of long links. Since energy dissipation of nodes is proportional to transmission distance, the leader is selected by considering both residual energy of nodes and distance between node and BS. Complexity and uncertainty in threshold are drawbacks of EEPB [14].

3.8. Mobile sink improved energy-efficient PEGASIS-based routing protocol (MIEEPB)

MIEEPB is a multi-chain model incorporating sink mobility thereby achieving smaller chains and reduced loads on leader nodes. A mobile sink minimizes energy usage of sensor nodes and also helps in reducing data delivery delay for all the nodes. Multi-chain concept reduces the distance between connected nodes. It decreases network overhead since there are only fewer nodes in the chains [15].

A comparison among PEGASIS variants in terms of scalability and energy efficiency is given in Table2.

Table 2. Comparison of variants of PEGASIS protocol

Protocol	Scalability	Energy efficiency
PEGASIS	Good	Good
Energy reduction algorithm	Very high	High
EEPB	Good	High
MIEEPB	High	Very high

4. SIMULATION AND RESULTS

4.1. Simulation

The performance of MODLEACH and MIEEPB was simulated using MATLABR2013a by considering the following parameters: number of nodes alive per rounds (network lifetime), residual energy of the network, number of dead nodes per rounds and normalized average energy consumption. On comparing it was observed that MIEEPB provides 72% improvement compared to MODLEACH. The simulation parameters are given in Table 3.

Table 3. Network parameters

Network parameters	Value
Network Size	100 x 100 m^2
Initial energy of nodes	0.5 J
Packet Size	3000 bits
Number of nodes considered for simulation	100 nodes
Number of rounds taken for simulation	3500 rounds
Transceiver idle state energy consumption	50 nJ/bit

4.2. Results

The results obtained from the simulation are depicted in Fig.3. Fig. 3(a) shows network lifetime where 1st, 10 and 100 nodes for MODLEACH and MIEEPB dies out at 750, 1120, 1750 and 820, 1250, 3000 rounds respectively. TheFig. 3(b) indicates the residual energy of network over rounds. It was observed that, at round 1500 MODLEACH and MIEEPB has its residual energy reduced to 0J and 2J respectively. Fig. 3(c) shows the comparison on number ofdead nodes over rounds and Fig. 3(d) provides normalized average energy consumption comparison for MODLEACH and MIEEPB.

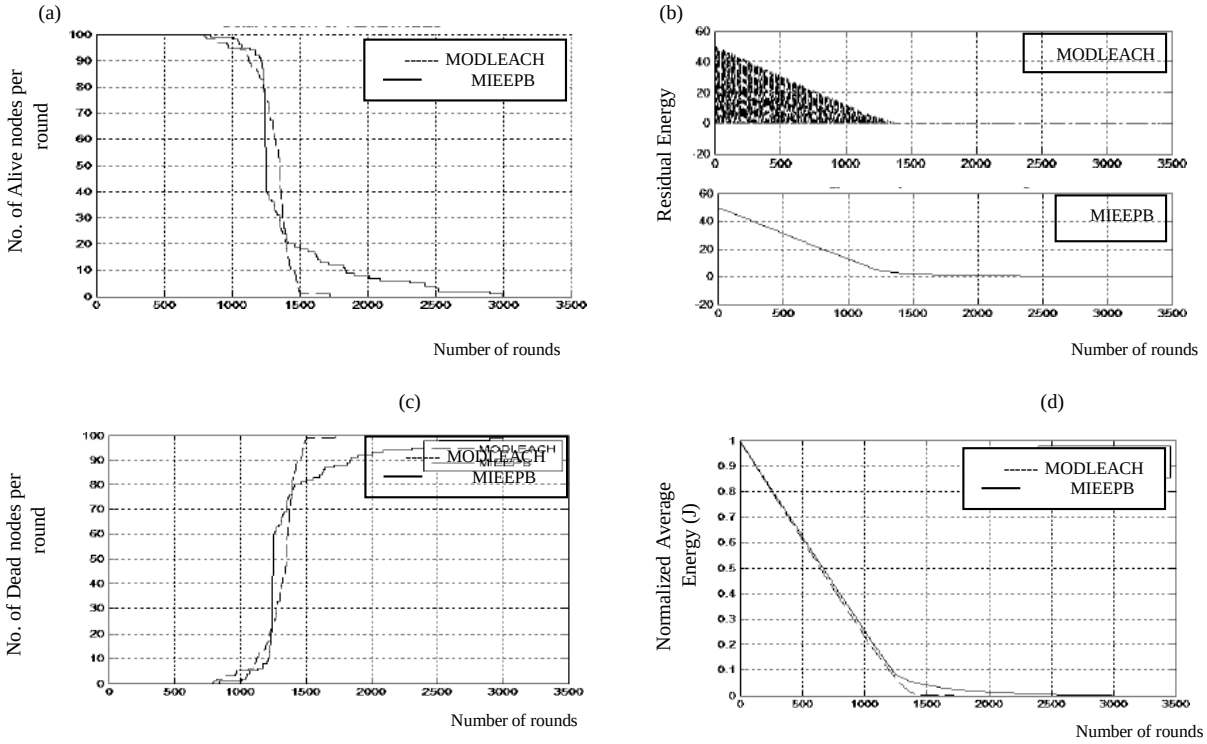

Fig.3. (a)Comparison on network lifetime; (b) Comparison on the residual energy of network (J); (c) Comparison on number of dead nodes; (d) Normalized average energy of network (J).

5. ENERGY HARVESTING WIRELESS SENSOR NETWORKS (EH-WSN)

Energy consumption is an important issue in the design of WSNs. A WSN has infinite lifetime when it is not depending on limited power. Renewable resources like solar, wind, water etc. is being harvested to generate electricity. EH-WSNs convert ambient energy from the environment into electricity to power the sensor nodes. Energy harvesting technology thus supports power hungry applications.

6. CONCLUSION

This paper surveyed about wireless sensor networks, routing techniques, the hierarchical architecture and provides a brief description about energy harvesting wireless sensor networks. Protocols designed should aim in

keeping sensors alive for long period to fulfill the application requirements and should meet the scalability issues. Hierarchical architecture approach is considered to be the best to provide scalability along with extended network lifetime. Simulated two protocols MODLEACH and MIEEPB using MATLAB and on comparison showed that MIEEPB performs better than MODLEACH. Energy is the greatest problem faced by WSNs.

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