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-:Contact:-

Prof. K.N. Shelke

Flat No. 01,
Nirman Sagar Coop. Housing Society,
Thana Naka, Panvel, Navi Mumbai. (MS), India. 410206.knshelke@yahoo.in

Cell: +91-7588058508

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Energy Efficient Performance in Wireless Sensor Networks: A Literature Survey

Mr. Chaitanya Mahamuni *PG Research Student,*
Dr. KTV Reddy *Professor & HOD, Dept-.EXTC,*
Ms. Nishan Patnaik *Assistant Professor,*

Fr-CRIT, Vashi, Navi Mumbai, (Maharashtra) India

Abstract

The energy efficiency in wireless sensor networks is one the great challenges to develop any real time application. The energy consumption in sensor networks is primly associated with the routing of data, coverage and connectivity. This paper presents a literature based study of existing routing protocols and coverage in sensor networks highlighting different challenges and solutions to address the issue of energy efficient performance in wireless sensor networks.

Key Words: energy efficiency, coverage, connectivity, routing, power consumption

1. Introduction

A wireless sensor network is an example of extreme form of ad-hoc networking in which a large number of very small sensor nodes called as motes are very densely deployed in the phenomenon which has to be sensed or very close to it. A sensor node comprises of different elements for data sensing, data processing and communication. The position of the sensor node is not fixed or predetermined. The sensor nodes are randomly deployed in highly inaccessible regions where the human intervention is very difficult like seismic activity monitoring, earthquake monitoring, disaster relief operations etc. The sensor nodes are usually fitted with an inboard processor. The sensor nodes carry out simple computations locally, partially process the data and then transmit it. The sensor nodes are broadly classified into two type's namely proactive sensor networks which periodically switch the transmitters, sense the parameter and transmit the data to the network and reactive sensor networks wherein the sensor nodes react immediately to sudden and important changes in the value of the sensed parameter.

The wireless sensor networks have very limited computing abilities, change their topologies frequently as per the need of particular application and are prone to failure .The sensor nodes are in several orders of magnitude, densely deployed and limited in memory. Thus the multi-hop communication is required which reduces the signal propagation effects in long distance wireless communication but increases the power consumption. Thus the power conservation to prolong the network life time is one the major challenges in development of this technology. Each of the application in sensor networks has its own problems like topology discovery, power efficient routing, data recovery and security. There are many crucial issues like medium access control mechanisms, node management, routing of data, fault tolerance, reliability and low power design which is needed to be resolved for optimum performance of wireless sensor network

2. Routing in Wireless Sensor Networks

The author [2] gives a very brief and clear idea about routing in sensor networks. The one of the most difficult tasks in wireless sensor networks is design of a routing protocol. The existing routing protocols can be classified in two main categories: hierarchical clustering routing and data centric routing. The hierarchical clustering routing protocols uses the sensor's proximity to the cluster head without taking into account the nature of the sensed data which may lead to inefficient data aggregation and losing energy. Also, the cluster information does not consider the position of the observed event. The intra cluster routing between the nodes inside the cluster uses flooding technique which is not energy efficient. The possibility of occurrence of mobile event is also not covered in the existing hierarchical routing protocol which is necessary in the object tracking applications.

In data-centric routing protocols, despite the in-data processing between the selected sensor nodes like data aggregation and data fusion, these operations lack organization between the nodes. Data fusion is the process of aggregating similar data gathered by adjacent nodes in certain region before sending it. Furthermore, the large numbers of messages that flood the sensor network in order to find the specific nodes and establishing them and the sink consume too much energy

There is a need for general middleware architecture in wireless sensor networks which could work fine with or without fixed infrastructure support with minimum hardware and software requirements. The middleware architecture keeps the optimal performance of the system by dynamically distributing the processing power between more capable numbers of nodes within the network. This prolongs the network lifetime and also ensures that the data provided by the sensors is available for longer time

With advances in Micro Electro-Mechanical System (MEMS) technologies, the wireless sensor networks for a wide range of application domains. They also need to provide self organization environment sensing and distributed processing, one of the major challenges is to find a way by means of which mobile sinks can co-ordinate effectively the mobile sink and the distributed data processing. The unpredictable delays are caused by network congestion, unreliable communication and data collision. This affects the execution of tasks dependent on these messages.

The different routing protocols supported by wireless sensor networks are listed below:

Location-based Protocols: MECN, SMECN, GAF, GEAR, Span, TBF, BVGF, GeRaF.

Data-centric Protocols: SPIN, Directed Diffusion, Rumor Routing, COUGAR, ACQUIRE, EAD, Information-Directed Routing, Gradient Based Routing, Energy-aware Routing, Information-Directed Routing, Quorum-Based Information Dissemination, Home Agent Based Information Dissemination.

Hierarchical Protocols: LEACH, PEGASIS, HEED, TEEN, APTEEN.

Mobility-based Protocols SEAD, TTDD, Joint Mobility and Routing, Data MULES, Dynamic Proxy Tree-Base Data Dissemination.

Multipath-based Protocols: Sensor-Disjoint Multipath, Braided Multipath, Nto1.

Multipath Discovery Heterogeneity-based Protocol: IDSQ, CADR, CHR.

QoS based protocols: SAR, SPEED, and Energy-aware routing.

3. A. Coverage & Connectivity

The paper [4] discusses about coverage and connectivity which are the two most fundamental issues in sensor networks. A significant problem is randomly deployed sensor nodes over a wide area to cover the monitoring region perfectly. Coverage and connectivity are the two most fundamental issues in the sensor network [4] which have a great impact on energy efficient performance of sensor networks. Optimal node deployment, sleep scheduling mechanism and coverage radius cannot reduce only the cost but also network lifetime.

The evaluation of the performance of coverage and its algorithm is very important for the network's usability and effectiveness. The main factors are considered as follows:

QoS of Coverage: The QoS of coverage decides the completion of network tasks reflects the network sensing ability to the physical world and is the basis of algorithm evaluation.

Number of active nodes: In case of meeting the coverage requirements, the fewer number of active nodes are, the larger effective coverage will be. In other words reducing active nodes will do well in the performance of energy consumption

Associating the node location or not: Coverage control algorithms associated with a node location depend on external infrastructure (such as GPS) or some position mechanisms, relatively cost high or need to consume a lot of energy. Meanwhile there are still accuracy issues on position. Therefore, the coverage control algorithms not involving any positive information have a greater advantage.

Energy efficiency: Coverage control algorithms require not only the lowest energy consumption in a single monitoring task but also maintain the energy balance of the network in a series of monitoring tasks.

Communication overhead: Data transmission is the main source of a sensor node of energy consumption. Coverage control algorithm with a low cost in the process of communication has a greater advantage.

Network scalability: Coverage control algorithm should be able to adapt to both scale of different sensor networks and network topology dynamically changed and hence forms important factor.

3. B. Coverage Deployment Strategy

Coverage in sensor networks has attracted a great deal of research attention due to its relation to optimization of resources in the sensing field. The maximizing of the coverage and maintaining a lower cost of deployment has unknown and possibly hazardous. An effective approach for energy conservation in sensor networks is coverage deployment strategy. Many simulation results show the optimal node deployment strategy can achieve a certain degree of results with less number of nodes.

There are two types of coverage namely static and dynamic coverage. The type of nodes whose location remains fixed in the deployed area is static nodes and they cover a fixed area called static coverage and the nodes moving in the deployed area for sensing the information in area of movement is dynamic coverage.

The energy efficient approaches in wireless sensor network are based on integration of coverage and connectivity. Depending on the objectives and applications, they can be roughly classified into three types: area coverage, point coverage and path coverage. The area coverage problem is mostly taken into consideration as it focuses on coverage with minimum number of sensor nodes and energy consumption when the area is connected by WSN. The different coverage protocols for wireless sensor network include CCP, ASCENT, OGDC, KCCS, RIS, CDCS, LADS and LEACH protocol. The comparative study of these coverage schemes is as shown below where B: Binary Disc Model, P: Probabilistic Model, D: Distributed algorithm, C: Centralized Algorithm, 2DC stands for two dimensional areas and the circular in shape.

PROTOCOL	CCP	ASCENT	ODGC	KCCS	RIS	CDCS	LDAS
Commn Range	Fixed	Any	Fixed	Fixed	Fixed	Fixed	Fixed
Sensing model	B	P	B	B	P	P	B
Deploying strategy	Any	Any	Any	Any	Deterministic	Any	Any
Sensing area	2DC	Any	2DC	2DC	2DC	2DC	2DC
Algorithm Char	D	C	D	C	D	C	D
Network Structure	Flat	Flat	Flat	Flat	Hierarchical	Flat	Flat
Known Location	Yes	No	Yes	Yes	No	No	No

Table no.1: Comparative study of various coverage schemes in WSN.

4. Sleep Scheduling Mechanism

Energy is paramount concern in sensor network applications that need to operate for longtime with limited battery power. Another effective approach for energy conservation in sensor networks is scheduling sleep intervals for extraneous nodes while the remaining nodes stay active to provide a continuous service [4]. For the sensor network to operate successfully, the active nodes must maintain both sensing coverage and network connectivity. In order to the sleep scheduling mechanisms, one first needs to differentiate various energy saving modes that are provided by a sensor. One complexity here is that different types of sensors may support different set of modes or even if they support to the same set of modes, they often use different terminology. To explain, the major modes of sensors are as defined below:

On-duty: All components in the sensor node are turned on. The sensor is able to collect sensory data, send or receive messages, process data and messages and do other type of computations. This mode is an active mode and not an energy conserving mode.

Sensing unit on duty: At least one sensing unit and processor are turned on, but the transceiver is turned off. In this mode, the sensor is capable of sensing and processing sensory data, but not transmitting or receiving messages.

Transceiver On-duty: The transceiver and the processor are turned on but all the sensing units are turned off. In this mode, the sensor is capable of transmitting, receiving and processing messages but not sensing.

Off-duty: The whole components of the sensor nodes are turned off, but a timer or some triggering mechanism may be running to wake up the sensor. This mode is also called sleep mode.

5. Optimal Node Deployment

The random deployment is a very common method used in the applications where the physical access to the nodes is a problem. In such cases there is wide possibility that the nodes get scattered over the area given non-uniformly and the effective coverage becomes an issue.

To tackle these problems some heuristics have been proposed to find sub-optimal solutions. The optimization strategies is mainly static i.e. assessment of the quality of the candidate position based on structural quality such as distance, network connectivity, and biasing the analysis of fixed topology. The optimization of hybrid and dynamic networks is an ongoing research.

6. Link Generation through Optimization of the Distance

The process of generation of communication link when the sensor nodes are randomly thrown over a huge area is as shown in the figure drawn below:

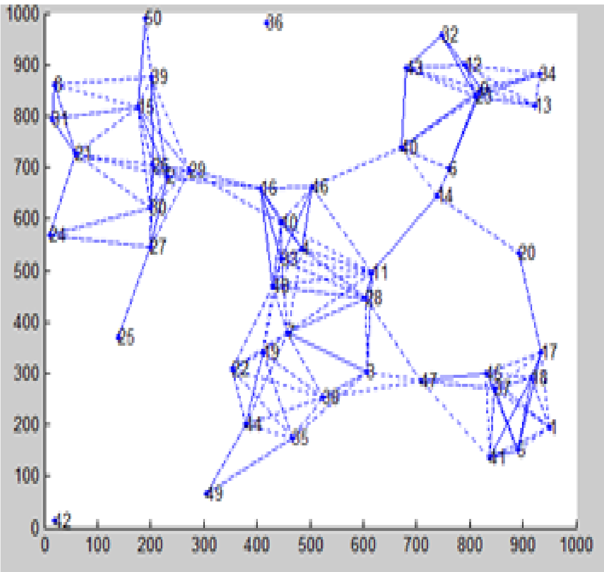

Fig no.1: Link establishment by searching neighbors, non-optimized case

The X-axis represents the horizontal distance of the node or X-location and the Y-axis represents the vertical distance or Y-location of the node. The X-location and Y-location of the node together determines the position of the node in the plane. Once the nodes are deployed over a given area the function stat rand (0, T) randomly allocates a time to each node and each of the nodes will start at this time i.e. the radio module becomes on, they will broadcast a hello packet and all the neighbors in the communication range of that node will reply to this hello packet and a link will be established to all its neighbors. The neighbors will follow the same procedure and gradually a very complex network will be formed. Hence the establishment of the link through optimal distance is necessary.

In the first optimization algorithm, one node will be set as zero node or null node. When any of the nodes becomes on at its random time, the node will find all its neighbors in the communication range and compare the distance of each neighbor with the distance of that node from null node.

A cost function will decide the optimal distance and the link will be established to that neighbor which is shown in the following figure:

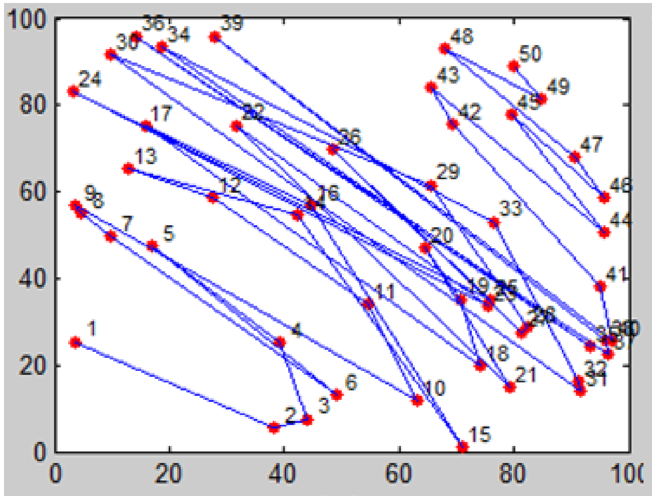

Fig no.2: Link establishment through optimal distance, first case

In the second case, the node when it gets activated at its random time then it will find all its neighbors in the communication range of it, find the distance of the node from all the neighbors and select the nearest neighbor instead of finding the optimal distance with respect to null node. A better formation of network. This type of optimization is as shown below

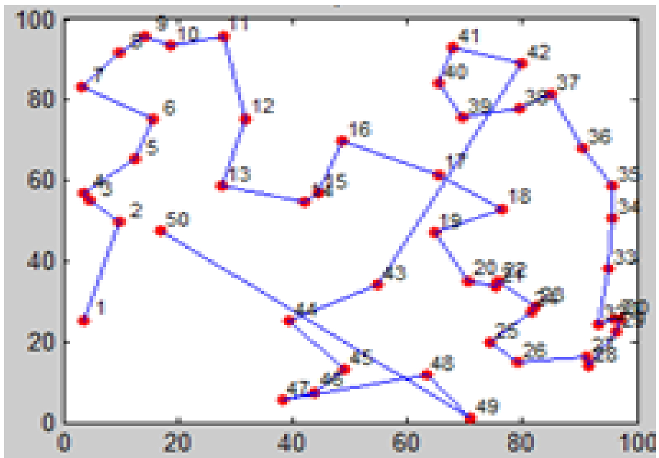

Fig no.3: Establishment of the link by optimal distance, second case

Thus the formation of the link amongst the sensor nodes when they are randomly thrown over a very large area by searching of the neighbors i.e. the nodes that have fallen with the communication range of a particular node is a very haphazard way the network is formed which is not a very effective method for which the above two optimization methods are used. The optimal distance link formation plays an important role in energy efficient performance in sensor networks.

7. Conclusion

The energy efficient performance is one of the most important points which comes into the picture while development of any real time application using sensor networks. The power consumption and energy saving is mainly concerned with the routing of data, effective coverage, back-off time and sleep scheduling performance in the sensor networks. The existing traits and the research challenges and some direction for solutions to these were discussed in the paper. The development of new algorithms, schemes and mathematical models associated with routing of data, coverage and back-off sleep time which targets of energy efficiency in sensor networks is the direction for future work.

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Editor-In-Chief

Prof. K. N. Shelke

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Flat No. 01, Nirman Sagar Coop. Housing Society, Thana Naka,
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