IMPORTANCE OF ENERGY IN WIRELESS SENSOR NETWORKS: A SURVEY

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Abstract. In the past decades, Wireless Sensor Network (WSN) has become a wide area of research. In WSN, numerous sensor nodes are randomly setup with different energy level. Energy acts as power source and is available to each sensor node in limited quantity. The limiting factor is that sensor nodes are energy constrained and recharging or replacing battery is costly and complex process. This paper explores the different energy consumption factors which effect the lifetime and performance of the WSN's. The main factors which effect the energy consumption in WSN's are scalability, load balancing, reliability, communication, collision, over-hearing, ideal listing and latency. Researchers have proved that the node near to sink node discharge very fastly. Apart from these, most of the energy is consumed during the transfer of data from sender to receiver. In this paper effort is made to analyze the effect of different factors on energy consumption in WSN's.

Keywords: Wireless Sensor Networks, Energy efficiency, Scalability, Load balancing, Reliability, Over-hearing,Latency.

I. Introduction

Wireless Sensor Networks(WSN's) is a network consisting of numerous sensor nodes. A sensor node(SN) is a multifunctional, low-power and low-cost tiny size device. SNs are randomly deployed over a zone to measure various phenomena like humidity, moisture, vibrations and many more. By enhancing the capabilities of sensor nodes, realization of WSNs based on the collaborative effort of sensor nodes is easy[1]. SN has four basic components Sensing unit, Processing unit, Transceiver unit and Power unit are shown in Figure 1.SNsare broadlyclassified as normal nodes,advanced nodes and super nodes. Apparently, the normal nodes have the least energy level, the advanced nodes have more energy than the normal nodes and the super nodes have the highest level of energy[2].The major advantages of SNs incomparision to the normal nodes are their ability to operate in harsh environment in which contemporary monitoring is risky and sometime not feasible.SN's are established randomly in field of interest by uncontrolled means like dropped by a helicopter etc. The general architecture of WSN's is shown in Figure 2. SNs collect data and transmit to the base station or sink node[3]. Therefore data collection can be single hop or multi-hop.Sink nodeis an intermediate node which receives the data from the sensor field and transmits over the internet. In WSN's, SNs are randomly setup in a geographical region. This region is divided into sub-regions called clusters. In each cluster, one of the nodeis selected as cluster head (CH) and the remaining nodes are cluster members[4]. CH is chosen on the basis of weighted probability. The node having highest weight probability has more chance to become a CH. Weight probability is the ratio of residual energy of node and average energy of wireless sensor network.

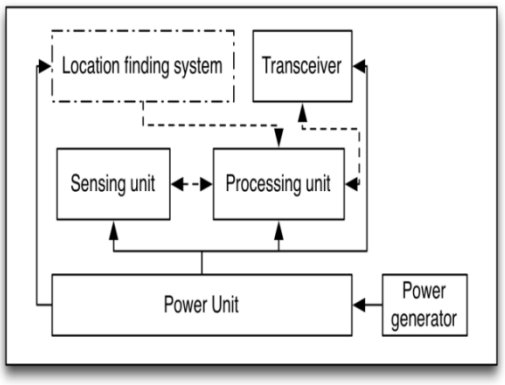

Fig1. Components of sensor node

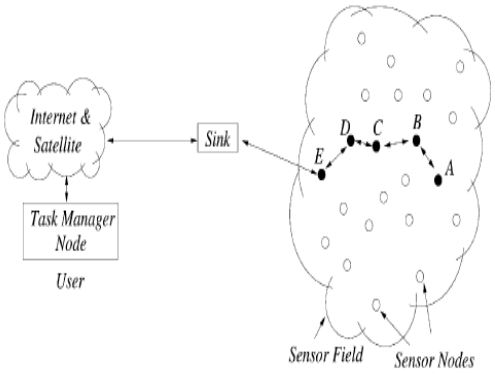

Fig2. WSN's architecture

The rest of the paper is structured as follows. Sections II presents the related work on various aspects of energy management in WSNs. Discussion of various energy consumption protocols is carried out in section III and Section IV concludes the paper.

II. Related work

Heinzelman et al. developed and analysed low-energy adaptive clustering hierarchy (LEACH) protocol for energy-efficient cluster based routing and data aggregation to achieve better output in system lifetime, latency and application-perceived quality. Authors also found that LEACH works on rotation of cluster head position to equally divide the energy load among all the sensor setup in WSNs field [4]. Lmdsey and Raghavendraproposed Power-Efficient Gathering in Sensor Information Systems (PEGASIS) for solving data gathering problem.In PEGASIS, each node communicated only with a close neighbour and takes turn totransmit data to the base station[5].

Zabin et al.proposed an energy-aware WSN routing protocol called Reliable and Energy Efficient Protocol (REEP) whichestablishes more reliable and energy-efficient path for data transmission. The performance of REEP was evaluated under different scenarios and communication paths established in REEP were inspired by the observation of strictly local communication in physical systems[6].

Xin et al. proposed hierarchical clustering algorithms for long lived sensor network that was an energy efficient hierarchical clustering algorithm (EEHCA). EEHCA achieves good performance in terms of lifetime by minimizing energy consumption for communication and balancing the load for all nodes placed in WSN. In EEHCA algorithm the concept of backupCHs is used to improve the performance of fault tolerance[7].

Kumar et al.reviewed the effect of heterogeneity in the form of energy in WSNs which was hierarchically clustered. Kumar et al. introduced an energy efficient heterogeneous clustered (EEHC) scheme for WSNs on behalf of the weighted election probabilities of CHs selection. EEHC enhances the life of the WSN by 10% as compared with LEACH by placing same powerful node in network. Authors concluded that the performance of the proposed system using EEHC was better in terms of reliability and lifetime[8].

W. Min and L. Shining proposed a multipath routing algorithm (MRA-AHP) based on the directed diffusion. MRA-AHP establishes multiple paths from the source node to the destination node. A selection weight matrix is formulated on the basis of three different parameters: residual energy of the neighbour node, the transmission delay and bandwidth of the link to that neighbour and after updating the weight matrix in each iteration.The selection weight is transferred to next relay node for selection of next hop. This makes multiple paths of better performance.After selection of multiple pathsthe data is forwarded only for one of the optimal paths. The remaining path are kept in case primary path fails. MRA-AHP uses a load balancing approach to divide the traffic over the multiple route discovered. Both the next hop selection algorithm and load balancing scheme apply

Analytical Hierarchy Process (AHP).MRA-AHP correspondingly assigns the data packets transmission ratio corresponding to the reinforcement weights. The path which has higher reinforcement weight will tackle higher number of data packets. This load balancing tacticbalances the traffic over the multiple paths discovered which contributes in increasingthe network lifetime[9].

D.Kumarproposed and examined two new clustering-based protocols for heterogeneous WSN's called single-hop Energy Efficient Clustering Protocol(S-EECP) and Multi-hop Energy Efficient Clustering Protocol (M-EECP). In S-EECP,the CHs are selected on the basis of weighted probability based on the ratio of residual energy of each node and the average energy of the network. Node having more weight probability has higher chance to be selectedasCHs In M-EECP, the data from CHs to base station is transferred via multihop communication[10].

Velmani and Kaarthickproposeda Velocity Energy-efficient and Link-aware Cluster-Tree (VELCT) scheme for data collection in WSNs. VELCT effectively mitigate the problems of coverage distance, mobility, delay, traffic, tree intensity and end-to-end connection. VELCT constructs the Data Collection Tree (DCT) based on the cluster head location. The data collection node in the DCT does not participate in sensing the information in a particular round, however, it simply collect the data packet from the cluster head and delivers it to the sink. VELCT scheme minimizes the energy exploitation, reduce the end-to-end delay and traffic in the cluster head in WSNs by effective usage of the DCT[11].

P. Chatterjee and N. Das proposed a multiple sink deployment technique in Multi-hop WSNto enhance lifetime, packet delay and load balancing. In thistechnique network is partition into the number of sub-graphs or clusters around unique (each) sink node to gather the data. Authors proposed multi-sink deployment technique to optimize both the number of clusters and cluster diameter based on graph theoretic approach and used distributed greedy cluster formation algorithm on randomly generated networks to generate a predefined number of clusters. In this algorithm, multiple sink nodes are placed in each cluster to gather sensitive data of the sensor in a limited number of hops, which result in decreasing the relay workload and latency of data[12].

A decentralized protocol namely CoverageMaximization with Sleep Scheduling protocol (CMSS) has been developed by C. Danratchadakorn and C. Pornavalaiwhich increase the sensing power of network. The area of network is partitionedinto grid cells. Each sensor established a neighbour table andconvert into cell-value table. These tables are used to makedecision mode (either sleep or active) on each node. Sensors collect data from environment and sends the sensed data to processing unit before going to sleep mode in order to save energy. Each sensor exchanges information with its neighbouring sensors and define waiting time. During sensors waiting time, a sensor can receive a sleep message from neighbour nodes and updates its own neighbour table and cell value table [13].

III. Discussion

Various protocols discussed in section II are analysed and their outcomes/methodology are presented in tabular form as shown in table I. WSN approaches discussed in section-II have been categorized into three main catagories:data-centric routing protocol, hierarchical protocols and aggregation based protocols. In the field of WSN's, LEACH protocol solves the problem of energy consumption due rotation of cluster heads in setup phase of cluster formation[4]. In LEACH, data gathering problem developed does not reachan optimal solution. PEGASIS protocol was developed for solving data gathering problem. The key point of PEGASIS is to make chain to nearest sensor node so that each node can receive and transmit data to closestSN[5]. PEGASISgives better performance in comparesion to LEACH. In both LEACH and PEGASIS network simulators are used to measure the efficiency of WSN's.LEACH doesn't have the data-centric routing capability. A new protocol calledREEP was developed for reliable and energy efficient data-centric routing[6]. In data-centric routing,the BS sends queries to certain regionsand waits for data from deployed sensors, hence data is collected through queries[14]. EEHCA was developed to overcome the problem of load balancing.EEHCA is a hierarchical and data aggregation based WSN protocol. EEHCA increased the WSN's lifetime with the help of backup cluster

heads. In EEHCA if the primary CH is depleted of all itsenengy then secondary CH manages the load. EEHC was developed for energy efficiency maximization on the basis of weighted election probability of their residual energy.To fulfil the objective of energy efficient and load balancing scheme, a approach called S-EECP and M-EECP was developed. In S-EECP the single hop communication is established inside the clusters between non-CHs and CHs whereas multi-hop communication is established between CHs and BS by M-EECP[10]. The latest protocol for achieving the mobility and decreasing the delay in transmission of data is VELCT. VELCT construct the DCT based on cluster head location which helps in reducing the end to end delay of network.

Table 1. Comparative analysis of different algorithms and protocol

Technique	**Objective**	**Simulator Used**	**Data-centric**	**Hierarchical**	**Data aggregation**
LEACH	· Increase lifetime and quality of network · Decrease latency	Network simulator(NS)		✓	✓
PEGASIS	· Removed ata gathering problem	NS-2	✓	✓	✓
REEP	· Increase reliability of routing · Lifetime of WSN's · Fault-tolerance	Matlab 7.4	✓		✓
EEHCA	· Balancing energy load · Increase lifetime of WSN's	Matlab		✓	✓
EEHC	· Energy efficient	Network simulator(NS)		✓	✓
MRA-AHP	· Load balancing · Energy efficient	NS-2		✓	
S-EECP &M-EECP	· Energy efficient · Load balancing	NS-2		✓	
VELCT	· Mobility	NS-2			

	· Delay		✓	✓	✓

Further in depth analyzation the effect of different parameter such as load balancing, reliability, ideal listening and latency in data transmission. The first factor, load balancing is the distribution of energy load throughout the WSN's for maximizing the network lifetime. The primary objective of protocol listed in Table 2 is balancing the energy load and providing a reliable communication between SNs[9]. Reliablity means protocol is working according to their functionality or specification without any failure. Ideal-listening occurs when a node is not receiving any message but still in an active state for incoming messages, hence the energy is consumed[15]. In order to reduce the energy consumption due to idle-listening in WSNa protocol called Sparse Topology and Energy Management (STEM)has been developed. STEM efficiently wakes up nodes from a sleep state to active state when there is any massege to recive. However the nodes doesn't suffer from idle-listening[16]. Latency means delay in packet transmission; hence more energy is consumed if packet takes a long route[17]. REEP, S-EECP, M-EECP and VLECT protocol suffer with problem of ideal-listening.

Table 2. Effect of various techniques over selected parameters

Factors~~Protoc~~→ ols ↓	**Load balancing**	**Reliability**	**Ideal-listening**	**Decrease Latency**
LEACH	✓	✓		✓
REEP	✓	✓	✓	✓
MRA-AHP	✓	✓		✓
S-EECP& M-EECP	✓	✓	✓	✓
VLECT	✓	✓	✓	✓

On analyzation of WSN protocols we have found some research gapes. In EEHCA the data transmission capability and inter cluster communication can be improved. The REEP protocol has been designed for static nodes only so it can also be desingn for mobile node which will helpful for tracking a moving devices. In REEP lots of energy is waste when the node in active mode so its also design for sleep or active mode operation for saving energy and lifetime of WSN is increases.

Another interesting issue in energy consumption protocols is the selection of cluster head among available sensor nodes. A cluster head perform data aggregation and transmition to BS. Many researchs have been done in WSNs to build optimized clusters with efficient and reliable data collection techniques, but still there are research gaps in cluster formation and CH selection. Most of the protocol assumes that sink node is stationary. However there are some situations where the sink node is mobile like a battlefield where the information of enemy and battleships current location are frequently transmitted to the control rooms hence the sensors energy drains rapidly. So new protocols are needed for handling the changes in topology and mobility overhead.

IV Conclusion and future works

At present, WSNs is an emerging research area. In this paper we have summarized the WSNs protocols and proposed a comparative study based on the data-centric routing, hierachichal and aggregation based protocol. Furthermore, the protocol is classified based on the energy consumption factors like latency, load balancing and energy efficiency. Although many of WSN protocol look promising but still there are many challenges that needs

to be solved in WSNs. We highlight those challenges and pointing out future research in the direction to solve energy consumption problem.

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