The study of Energy Efficient Techniques for the enhancement of Lifetime of the wireless sensor network

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Abstract: Now a day's Information has big role for any task accomplishment and hence collection of it is a big issue. To save the time, human effort, errors and resources it is required to increase the use of machines, they help to increase the efficiency of task. The investigation is done to observe that how information gathering will be increased using specially organized wireless sensors for the specific application. Various machine learning algorithms are used by researchers till date but still noticeable comparison among them is needed. To enhance the lifetime of the sensor network, various techniques developed for different technological section of wireless networking like physical domain, software communication stake, application domain and so on. In this paper, investigation is based on duty cycling of wireless sensor nodes which is controlled at the MAC layer of networking layer.

Keyword: WSN, MAC, TDMA, LEACH.

Introduction: Wireless sensor network referred from the domain of mobile computing [1], the investigation in mobile computing for the various problems with the respective solution is still unexplored. Wireless communication has many domains where improvement is required like reliability, battery power, coverage, efficiency, mobility etc [2]. This paper is prepared to investigate the various approaches of energy conservation in WSN [3]. There are many areas where energy of the wireless unit can be saved for example during connectivity, sensing activity, processing, communication etc.. The consumption of Energy is understood by the amount of energy consumed in joules per node. The energy consumption divided into two groups viz. energy used during networking, sensing processing and communication. The other category is useless consumption of energy in the sensor networks structure such as overhearing of nodes, Ideal condition, collisions, redundant information etc. [4]. Network structure consisting of sensor nodes for data collections of specified application, they are randomly deployed over the geographical area of interest. Nodes are connected in one of the topology planned earlier. One of the architecture is shown below.

According to specific application, there are hundreds of jobs classified in different categories such that for the weather forecasting we need applications like temperature sensing, humidity sensing, pressure sensing, wind speed sensing etc, similarly enemy inspection at border we require, motion sensing, cameras target detection etc.. Arrangement if sensor nodes as shown in the above figure 1 [4] is relay architecture or multi-hop network of nodes arrangement where nodes are connected with each other only when they are in the communication range of each other. They have certain range of detection during sensing activity and hence they collect data from the area of interest and forward to the next node to whom it directly connected. Next node forward the information to the next and ultimately it reaches to sink node which is connected to the rest of the world via internet. Other technique is to forward the data from sensor node to the cluster head that forward the data to the sink node as shown in figure 1 [5]. This paper is discussed the clustered model and its problems. The functioning of sensors, communication technology, networking is all well explored and specified in clustered figure 2 model. Nodes are self organized by transmitting and receiving negotiable
information to each other and this responsibility is taken by cluster head of the cluster. Nodes are assigned the task either at before initial planning and deployment or dynamic programming is done during sensing. The activity of nodes are also monitored by cluster head and assigned time slot to them for sensing and transmission of data. Time slot is given to save the energy of the nodes so that they survive for long time and hence sleep-wake up technology is used. Sleep-Wake up [6] technique require time division schedule decided by cluster head. During sensing data is collected by sensor and transmitted to the cluster at their TDMA schedule after which it again goes into sleep mode. Cluster head continue in wake-up condition and collect data from all the sensor and process them to generate a consolidated data fragment which is further transferred to network via sink node. Whole process requires energy for different activities as discussed above but they are necessary even still some of the area remains affected by unwanted energy drain such transmission of redundant data through the network, overhearing of other nodes transmission, static TDMA [7] schedule allocation, improper selection of cluster head, improper deployment of sensor nodes, unwanted noise and information sensing, improper algorithm used for cluster selection and communication etc. . The different techniques are investigated and implemented to solve the problem of energy drain which is discussed in the literature survey. Among which some of the energy draining areas and solution through AI technique will be cover in this literature.

Technological survey:-

The literatures can be categorized with the relevance of problem solution and hence there are many areas of WSN where problems are identified which are covered in this literature.

Nodes Deployment:-
The paper authored by Suganthi K and Dr. Vinayaga Sundaram B [8] explain that how k-connected graph solve the problem of energy hole in the heterogeneous network environment by designing minimum spanning tree using local search. André Siqueira Ruela et.l [9] proposed a cooperative co-evolutionary algorithm for the proper cluster head location. The position is selected on the basis of total cost sum of initial cost and data propagation cost. The technique proposed in the paper by R. Algeswaran et.l. [10] is to place the sink node at the position selected by Particle swarm optimization method. Position of the nodes are calculated using random function their optimal distance based on energy requirement for the transmission of bits are calculated with different positions of sink node and compared to get the optimal one. Also the Euclidean method is used to find the range of the nodes and then applied the PSO algorithm to find optimal location for the Sink node. Xu Xu and Weifa Liang [11] proposed the technique for the placement of optimal number of sink nodes in the network by keeping number of hop to 1 for optimal solution with low computation complexity and high scalability. The Breadth first search technique with sink node as root of the tree is applied. Looping is done over the number of sink nodes to select them for covering as many uncovered sensor as possible.

Data Collection:-

WSN is installed only for data collection and also faces the problem of energy drain due to redundant information collection and transmission, forwarding data without proper processing, useless data collection, improper programming etc. There are some of the author proposed solution in this area of defect, MARIO DI FRANCESCO, SAJAL K. DAS and GIUSEPPE ANASTASI [12] surveyed mobile element for the data gathering in three major phases, discovery, data transfer and routing. Query optimization is another way to collect data from the sensor node by keeping cost low in terms of energy consumption and provide scalable solution. Rajeev Gupta and Krithi Ramamritham [13] proposed a technique optimized query planning of continuous aggregation at specific coherencies. There I an optimal query plan by divideding query into sub queriers and assign to suitable data aggregators. The number of refresh messages is a metric through which client query coherency requirement is satisfied. A continous weighted aggregation query is calculated as:

\[ V_q^q(t) = \sum_{i=1}^{n_q} s_i(t)w_i^q \]

where \( V_q^q \) is the value of a client query \( q \) involving \( n_q \) data items. The weight \( w_i^q \) is the \( i^{th} \) data item being \( 1 \leq i \leq n_q \). The value of the \( i^{th} \) data item at the data source is \( s_i(t) \) at time \( t \). In this paper author compared his work with other techniques such as opic, random, min-cost and max-gain and found good difference with the growth of average number of message per query. To achieve it author uses maximum gain heuristic relatively compare the sum difference between the data items are aggregated as a single sub-query and the
case when each data item is obtained individually. Guoqiang Zheng, Shengyu Tang [14] proposed a technique based on spatial correlation MAC protocol for event driven sensor network. They used priority filed inside the packet structure to identify the highly required data first or transmit. The second thing is to select nodes for data transmission having good signal strength is prioritized through an algorithm of non uniform probability distribution. The probability distribution function of each node is given as in the equation. \[ p(c) = \left( \frac{1}{1+e^{-a\gamma c+1}} - \frac{1}{1+e^{-a\gamma}} \right) \alpha = f(Z), c \in [1,CW] \] where \( p \) is a function of \( \alpha \) (0 \leq \alpha 1), \( c \) denotes time slot. \( \lambda \) is constant

![Figure 2: Clustered architecture of Wireless Sensor Network](image)

According to the work proposed by JINHUAU ZHANG et.al. [15] a hybrid scheme of packet reduction and Ho-by-Hop Automatic repeat request is implemented to improve the energy efficiency performance that assured the low transport delay and high reliability. The method divides the communication area into two parts viz. load light area and load heavy area. The number of packets added by reproduction is reduced through scheme known as HBH ARQ when packets are passes through LHA via multi hop. Time to live parameter is used to reduce further packets whose ACK is not received beyond the certain limit. Maximum retransmission is limited hop by hop till the packet is reached at sink and hence proposed hybrid scheme is better than HBH ARQ in network delay by 48.94\% and PR in energy consumption by 28.19\% under the guarantee of almost the same network reliability. There is more approaches such as one of the clustering hierarchy proposed by HASSAN EL ALAMI and ABDELLAH NAJID [16] deals with reduction of redundant data from the adjacent overlapped nodes. Nodes in the range communicate with each other and share their status of sleep and wakeup schedule, selection of nodes for sleep and wakeup is decided by residual energy of the nodes and also sensing range is checked. In this paper energy is saved in different phases of WSN communication like cluster head selection as mentioned in the equation, where \( E_{CH} \) is energy of cluster head, \( k \) is number of clusters, \( n_w \) is the number of waking nodes, \( n_{up} \) number of unpaired nodes, \( E_{DA} \) is the energy dissipated by cluster head in terms of data aggregation, \( d_{BS} \) is the distance from CH to BS. \( E_{elec} \) is the energy consumption per bit of transmission and reception, the energy consumed by a normal node \( N \) for transmitting 1 bits to the CH. Hence, optimal number of cluster nodes obtained by the following equation

\[
E_{CH} = 1E_{elec} \left( \frac{n_w + n_{up}}{k} - 1 \right) + E_{DA} \left( \frac{n_w + n_{up}}{k} \right) + E_{elec} + E_{elec}d_{BS}^2 \text{ as mentioned in the equation.} \]

where \( p_{opt} \) is optimal probability of node to become cluster head in the next round and \( k_{opt} \) is optimal number of nodes. Lifetime is enhanced with 27-17 \% more than the most advanced technique such as LEACH-ACH and LEACH.

**Duty Cycle Approach:**

In this approach there are many algorithms developed in this categories and that can be further classified with range of years of development. First duty cycle approach is incorporated in year 2002 by Wei Ye, John Heidemann, Deborah Estrin [17], energy conservation by periodically use of sleep and wakeup by avoiding idle listening and also message passing to reduce the contention latency for sensor-network applications. There are numerous development and improvement done by researchers like variable duty cycle (T-MAC), asynchronous DuC with preamble, Dynamic sleep period, Short strobe preambles, Dense high traffic support etc. Recently one of the literature based on CSMA/CA-TDMA [18] MAC protocols is developed to differentiate between the task of Sink nodes and sub-group of the nodes in model defined in 3D space. Position(x, y, z) of sensor nodes is selected. The sink node can adaptively adjust its transmission power...
calculated on location coordinates (x, y, z) to save energy. Energy harvesting approach is one of the newest technique that exploit the ultra low power wake-up radios proposed by Alain Pegatoquet et. al [19] used model as shown in the figure 3

The End devices (ED) is equipped with dual radio system: main radio for data transmission (MRF) and for control information it has a wake-up radio (WUR). The power(mW) of WUR is used when all components are switched off that saves noticeable amount of energy. WUR uses two different data rates one for slow where low data rate is required to notify the incoming wake-up calls. According to the work proposed by Dongyu Yang, Ying Qiu, Shining Li, Zhigang Li [20], it uses piggyback technique to reduce the idle listening period of sender node by passing the information of remaining wakeup interval. It combine the approaches of RI-MAC and WiseMAC that reduces the vulnerable period of collision and optimize the packets send sequence to improve throughput. Node calculates sleep interval for listening beacon from receiver and it saves energy. Calculation of sleep wait time is performed by the equation as

\[ t_{prev} = t_{arrive} + T_{interval} - T_{cycle} \]

Where \( t_{prev} \) is the prior time a beacon from certain receiver should be received, \( t_{arrive} \) is the time beacon arrives, \( T_{interval} \) is the available wakeup time of receiver that is contained in the beacon, \( T_{cycle} \) is the sleep/wakeup interval of the node. Mobile wireless sensor network faces the challenges of control packet overhead and delivery ratio degradation, Marwan Al-Jemeli and Fawnizu A. Hussin [21] proposed the technique which reduces the energy consumption due to problem motioned by using cross layer approach in protocol 802.15.4 to accumulate four layers of network layers viz. application, network, medium access and physical layers. Location information at the application layer is passed to the network layer by using one of the additional field structured inside the route reply packet, that is further used for the calculation of distance. The distance information is further used in MAC layer passed as additional field inside the MAC frame where transmission power is adjusted on the basis of distance. The route reply message structure is shown in the figure 4. The 32 bit location information contains 16 bit X coordinates and 16 bit Y coordinates. For the short distance between nodes the transmission power is adjusted according to the location information of the next hop. The transmission power for the nodes is limited by the transmission range \( (TP_{Adj} \leq TP_{MaxRange}) \). The proposed work calculate the node energy through the summation of different energy consumption in different domains like Transmission, Reception, idle period, sleep period Transmit power etc. as in the equation.

\[ E_{node} = \sum E_{tx} + E_{rx} + E_{idle} + E_{sleep} + E_{trpower} \ldots \ldots \]

### Optimization Technique Based Methods

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The techniques of artificial intelligence has great scope in terms solving the real world problems of minimization and maximization of the objective values with the given constraints. Optimization is synonyms for the objective function that required to achieve at the end of process. The method requires knowledge of statistical and probability theory and concepts. The optimization technique includes the following different methods such as minimum norm theorem, fuzzy system, simulated annealing algorithm, tabu search algorithm and many bio-inspired algorithms like genetic algorithm, Particle swarm intelligence, ant colony optimization etc. The author Jian Chen at el. [22] proposed the method for extending lifetime of the WSN with the help of genetic algorithm that uses time weight factor for the network lifetime and also improve the coverage of network. They also worked over optimization of working nodes by choosing the strategy when determining node identification for sleeping requires its radio should be turned off in order to save energy while considering sensing coverage and connectivity of original network. Detection error range \( r_e (r_e < r) \) is introduced to measure the uncertainty of sensor detection. A probabilistic model is shown,

\[
C_{xy}(s_i) = \begin{cases}  
0 & \text{if } r_s + r_e \leq d(s_i, P) \\
e^{-\lambda \alpha \beta} & \text{if } r_s - r_e < d(s_i, P) < r_s + r_e \\
1 & \text{if } r_s - r_e \geq d(s_i, P) 
\end{cases}
\]

\( \alpha = d(s_i, P) - (r_s - r_e) \) where \( \alpha \) and \( \beta \) are parameters measuring the detection probability when \( r_s - r_e < d(s_i, P) < r_s + r_e \). If \( r_e = 0 \) then there is sensing range overlapped and hence minimization of overlapped required. The proposed work provided the solution for maximum cover set problem and maximum lifetime problem and hence it is known as multi objective optimization problem and can be said that Pareto optimal. Genetic algorithm consisting of chromosomes, that are building block and converge towards the solution path for the genetic operators and fitness function. Each sensor node is represented by 1 bit binary value called gene. The one bit value of sensor node decide its status whether it is selected or not. \( a_i = \begin{cases} 1 & \text{if } S_i \text{ is selected} \\ 0 & \text{otherwise} \end{cases} \) where \( S_i \) is the ith sensor node and \( a_i \) is the binary value. They used residual energy also to make the set of nodes which required to activate and cover the region. Feng Wang and Dan Wang [23] proposed a technique, which is based on relay node deployment with traffic availability. The problem is first converted into Euclidean Steiner Minimum Tree Problem that is explained that Minimizing the maximum energy consumption among the R nodes

\[
\min \max \sum_{i \in P_j} \gamma_j [I_{E_{\text{recv}}} + I_{E_{\text{send}}}(r_i)]
\]

Where \( \gamma_j \) is data rate at node \( s_i \), \( I_{E_{\text{recv}}} \) is the energy required for receiving packet and \( I_{E_{\text{send}}} \) is for transmitting packets. \( r_i \) is the communication range of ith node, \( p_j \) is traffic paths for \( s_i \) nodes . as shown in figure 5.

![Figure 5: An example of relay node deployment](image)

according to the topology shown above explained the deployment of relay nodes in the section of \((s_1, v), (s_2, v)\) and \((v, s_0)\). Nodes from less Traffic zone \((s_2, v)\) is shifted to heavily \((v, s_0)\) for uniform distribution of energy load among all sensor nodes. In this problem solution is achieved by following theorems Traffic in single source single traffic flow is start from the source and evenly deploy the R-nodes with a in-between distance of \( L/N \), where \( L \) is the distance between source and sink passing through the N R-nodes.\( I_{E_{\text{single}}} (L, N, \gamma) = \gamma [2c + \left( \frac{L}{N} \right)^{\alpha}] \) where \( \alpha \) is constant and has value typically between 2 and 6. Another theorem for single source and multi traffic is solved by merging flow in to one flow and apply first theorem. In the third theorem RNodeAssignment calculates the optimal number of R-nodes edges with the given graph
topology such that the maximum number energy among the edges are minimized. Network lifetime is improved by 13 percent. Number of sink nodes placement is also important steps towards energy conservation as proposed by authors Xu Xu and Weifa Liang [24], they developed a joint optimization technique for finding out number of sink nodes and implement the routing algorithm for packets propagation. A heuristic algorithm is developed to find the optimal number of sink nodes and their location so that each sensor node keeps distance not more than h hops. A load balancing forest is constructed for maximize the network lifetime where each sink node is the root of the tree and sensor node reach here not more than h hopes. Energy consumption per unit time in wireless communication by each sensor node $v_j$ is calculated using the equation.

$$ec_{T_s}(v_j) = r_a - [(dt_{T_s}(v_j) + 1)e_t + dt_{T_s}(v_j)e_r]$$

where $e_t$ and $e_r$ are the amounts of energy consumption on transmitting and receiving bit of data, $dt_{T_s}(v_j)$ is the number of decedents nodes of $v_j$ in $T_s$ tree rooted at $s$ and $r_a$ is the data rate of node $v_j$. Here the maximum energy consumption among the sensors in $T_s$ per unit time is $\max_{s \in S^T} \{ec_{T_s}(v_j)v \in C_T(s)\}$, and $C_T(s)$ is referred as children in $T_s$ and most bottleneck for energy conservation.

Lifetime of network is represented as $L = \min_{s \in S^T} \{IE \{ec_{T_s}(v_j)v \in C_T(s)\}\}$, it is improved by reducing the bottleneck nodes in $T_s$. This problem is NP complete and hence it requires heuristic approach to get the solution. Load balancing tree routed at $s$ is constructed that solve the problem in three important steps first partition the sensor in $h$ disjoint set than load-balanced tree is find out and finally load balanced forest is constructed. Another good optimization technique based on Ant optimization is proposed by Marcelo Portela Sousa, Waslon Terlizzare A.Lopes and Marcelo Sampaio de Alencar [25], they proposed a technique in which bio-inspired algorithm known as ant colony optimization with fuzzy heuristic is used. The AntNet protocol chooses the best minimum cost path between pairs of nodes. If an ant $k$ is at node $i$ and it hop to $j$ only when decision is taken by ant based on their memory storage. The ant behavior is explained through the simple equation $\tau_{ijd} \leftarrow \tau_{ijd} + \Delta \tau^k$ where $\tau_{ijd}$ is deposition of pheromone on the path by ant during travel for decision weather that path chosen or not. The $\Delta \tau^k$ is the amount of pheromone deposition by ant $k$ when it passes through the same path between nodes $i$ and $d$. The decision rule between by the following equation $\pi_{ijd}^k = \left\{ \begin{array}{ll}
A_i = \frac{\tau_{ijd}^{(1-w)n_{ijd}}}{w + (1-w)(|N_i-1|)w + (1-w)(|N_i-1|)w + (1-w)(|N_i-1|)} & \text{if } j \in M^k \\
0 & \text{if } j \in M^k \end{array} \right\}$ where $w \in [0,1]$ is weight factor between $\tau_{ijd}$ and $\eta_{ijd}$ (it is the heuristic information) and $M^k$ is the set of nodes through which ant $k$ visited that is ant memory. Pheromone deposition is evaporated with the time and it can estimated by the equation $\tau_{ijd} \leftarrow \tau_{ijd}^{1+\Delta \tau^k}$. authors proposed the technique in which updation of variable is performed as in equation $\Delta \tau^k \leftarrow \epsilon_s \rho_c \frac{\tau_{ijd}}{\zeta_s \Gamma_s}$ where $\epsilon_s$ is the residual energy of the node, $\zeta_s$ is energy consumed by the node in the previous round, $\Gamma_s$ is total number of transmission realized by node in previous round and $\rho_c$ is equal to 2 only if previous packet transmitted is recovered by the next destination. Fuzzy inference system is used to identify the value of heuristic term $\eta$, on taking value of $\tau_{s}$ and $\eta$ the finale decision of path goodness is taken and that node is selected as cluster head. Energy consumption is distributed among sensor nodes uniformly throughout the network and it improves the SNR (25 db) as compared to LEACH protocol (15 db).

**Machine Learning in WSN:**

Wireless Sensor network application and its problem is not isolated from the machine learning approach of solution. There are many publications available some of them are introduced in this category. Y. Harold Robinson et. al. [26] proposed energy efficient technique used in WSN is based on Neural Network and Fuzzy logic. Authors worked over clustering through the formation of cluster and cluster head selection keeping energy as strong parameters for the decision. The energy model for the implementation of algorithms is taken as in equation.

$$\text{Energy}_{\text{Tx}}(k, d) = \text{Energy}_{\text{elec}} * k_i + k_i * \epsilon_{\text{amp}} * d_i$$

$$\text{Energy}_{\text{Rx}}(k) = \text{Energy}_{\text{elec}} * k_i$$

The energy required for transmission $\text{Energy}_{\text{Tx}}$ of $k$ bits data to the distance $d$ and for reception $\text{Energy}_{\text{Rx}}$ for receiving data. The supervised learning network is used to train the network. The learning of the network is...
explained as equation $W_t(i, t) = W_t(i, t-1) + v \times (Output_T - Output_A) \times L$ where $W_t(i, t)$ is weight factor of $i$th cell, $i$ number of input cell, $v$ learning rate $Input_p$ is the input of the cell, $Output_T$ is the output of the network, $Output_A$ desired output, $L$ is the initial input cell. Weights are adjusted to converge the solution towards Goal state hence weights are also required to update with iteration as explained in equation.

$W_{new} = W_{old} + N \times v \times Input_p \times (Output_T - Output_A)$ where $N$ is active neuron, and $Input_p$ form previous layer to that active neuron.

Author took three parameters residual energy, signal strength and queue length for training the neural network. Fuzzy logic based system is used to confirm the selected cluster head as potential and finale cluster head by keeping residual energy, trust factor as decision parameters. About 32 percent of WSN lifetime is improved with this approach. The work ELDC proposed by Amjad Mehmood et. al. [27] is application oriented energy efficient wireless sensor network. Author proposed the rigourous training of neural network by the different scenarios of WSN through Adaptive Reasoning Theory, it also elects one chief node in the group based protocol. Chief nodes perform functions like to collect residual energy of all nodes in the given layer. Perform the average energy calculation for comparison with nodes to put them in sleep mode. Nodes having residual energy less than threshold value will keep at sleep mode. To select chief node various parameter has been taken under consideration like the residual energy of the node, number of neighboring nodes, the amount of data that is required to transmit, the signal to noise ratio, distance of CH to that node etc. The energy is conserved up-to 30-42 % as compared to LEACH and some other good clustering protocols.

Conclusion:
Wireless sensor network has many scope for the solution of different problems in many areas of networking. These solutions can be achieved by different Artificial Intelligence techniques as discussed. In future it is the most promising area of research for the people who are interested in the machine learning and swarm intelligence.

References:


