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ACOHC: Ant Colony Optimization based Hierarchical Clustering in Wireless Sensor Network

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***Abstract*—Data gathering in an energy efficient and timely manner is the fundamental task of Wireless Sensor Network (WSN). The battery operated sensor nodes are of limited energy and it is necessary to preserve their battery power to elongate the lifetime of WSN. In Hierarchical Routing Protocol (HRP) some nodes transmit data to BS which is more energy intensive task while others are engaged in local communications which provides load balancing. In this paper we propose energy efficient and load balanced ant colony optimization based hierarchical data gathering method (ACOHC). The deployment area is divided into optimal K_{OPT} number of clusters using K-means. The nodes in a cluster form a chain using ant colony optimization (ACO) with the election of a chain leader (CL). The CL's forms an upper level chain using ACO with the election of a super leader (SL) to transfer the final aggregated data to the BS. Simulation results indicate that ACOHC performs better in comparison to LEACH, LEACH-C, PEGASIS and KLEACH in terms of network lifetime, energy X delay product and throughput. The statistical significance of our results is established.**

***Keywords*—** *Wireless Sensor Network, K-Means Clustering, Ant Colony Optimization, Network Lifetime, Throughput, Energy X Delay Product.*

I. INTRODUCTION

With the introduction of Micro-Electro-Mechanical-System (MEMS) it becomes attainable to build sensor nodes in large scale at low cost [1]. Sensor nodes measure different natural phenomenon like humidity, temperature pressure from a remote hazardous area such as dense forest, deep sea floor etc. Wireless Sensor Networks (WSNs) consist of a large number of low cost, limited battery powered intelligent sensor nodes with one more sinks or Base Station (BS) [2]. The main constraints of sensor nodes are their very low finite non replaceable battery power which limits the lifetime and quality of the sensor network. So designing reasonable network is a big challenge to the researchers. Nowadays it has been recognized that energy consumption is the major issue when designing Wireless sensor network, since it is non rechargeable and non replaceable once the sensor nodes are deployed. In WSN a two tier architecture is used with energy constrained, where sensor nodes with limited battery power and computational capability belong to lower tier and abundant energy with unlimited computational powered base station (BS) in upper tier. Most of WSN application requires continue sensing of the deployment area. A naive approach has been proposed where each sensor node sends data directly to BS resulting in enormous energy consumption per round which reduces network lifetime. A round is defined as total time taken by all sensor nodes to send data to BS. To reduce enormous energy dissipation a multi hop data routing the Minimum Transmission Energy [MTE] [3] has been proposed in which each sensor node sends data to closest node on the way to BS. So the nodes proximity to the BS send a large number of data to the BS results nodes nearest to BS die out quickly causes an uneven load distribution in network. Data collection from sensor nodes to the BS is the primary task of the networks. The BS is usually located far away from the deployment area. In large scale networks, sensors nodes are generally divided into a number of small groups, called clusters for transmit aggregated data to the BS. In clustering protocols generally cluster head nodes accumulate data packets from cluster members and transmit accumulated data to the BS in either single hop or multiple hop manners. Many researchers have proposed that cluster based routing protocol excel network topology management and energy reduction. At present, there have been substantial amount of researches on clustering algorithm for WSN and a number of clustering algorithms have been proposed. One of the developing trends of WSN routing protocol is to find the optimum number of cluster along with best clustering method. In Hierarchical Routing Protocol (HRP) only Cluster Heads send aggregated data to the BS so cluster heads deplete more energy and tend to die much faster, this is known as hot spot problem. In the chain based routing a chain is constructed among deployed nodes using a greedy approach. In chain the nodes having two neighbors except two terminal nodes receive data from one neighbor, aggregates it with its own and sends to it's another neighbor. A chain leader is elected randomly for communicating to the Base Station. In LEACH [3] clusters are formed using a fully distributed manner results in sub optimal clusters. In chain based HRP's like PEGASIS [4] a greedy approach like NNA algorithm is used which results in suboptimal chain with long edges and exceptional delay. In this paper we propose a hybrid HRP coined as ACOHC by merging the conspicuous features of Cluster based and Chain based approaches. In ACOHC at the outset deployed nodes are divided into predefined number of clustered using K means clustering algorithm [5]. To overcome the sensitivity value of

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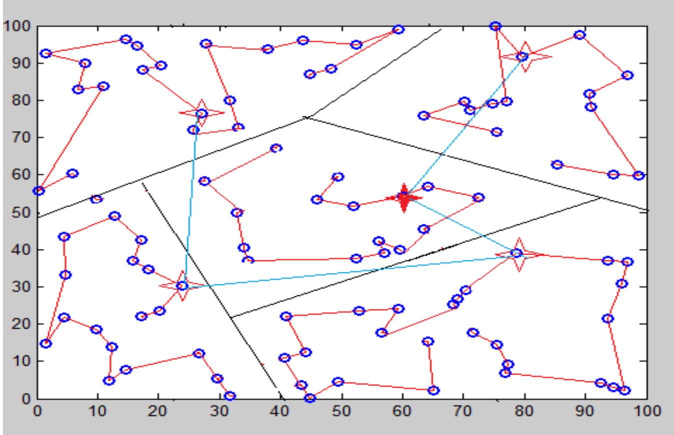

Fig. 1. A snapshot of ACOHC executed on 100 nodes randomly deployed over a 100m X 100m area. The value of K_{OPT} is 5. The cluster heads are star marked with the super leader marked with a solid star. The cluster chains and the upper chain are shown in red and blue line segments respectively.

K means a new approach is proposed where energy consumption per round is calculated with varying number of clusters. A chain within each cluster is formed using Ant Colony Optimization Algorithm [6]. Chain leader is selected based on Q factor. Among Chain Leaders an upper chain is formed using the same. A super leader is elected to transmit aggregated data to BS. A snapshot is given in Fig. 1. MATLAB simulation establishes the superiority of ACOHC compared to LEACH, LEACH-C [3], PEGASIS and KLEACH [7] in respect to extending network lifespan while maintaining load balancing. The rest of the paper is organized into seven sections. Section II discusses various hierarchical routing protocols while Section III describes our proposed method. Section IV gives the Simulation environment and results. A statistical inference is done for our results in section V while section VI drawn a conclusion remarks. The list of references appears in section VII.

II. Related Works

In hierarchical routing protocol depending on roles of sensor node, sensor nodes are categories into two. Nodes in first category communicate locally and consume small fraction of energy where as in second category nodes communicate with BS and dissipate more energy and tend to die much faster this is called hot spot problem. In LEACH[3] proposed by Wendi et al. hierarchical routing protocol for sensors networks that achieves energy efficiency by forming clusters among sensor nodes to reduce intra cluster distance as well as distance between source nodes and sink node. The operation of LEACH is organized into rounds, where each round consists of a setup phase and a steady state phase. However, LEACH does not take into account the distance and the residual energy of node's to be elected as CH node. Number of cluster in every round is not fixed and it is constructed in every round result in a greater cluster formation over head. The elected CHs may be very close to each other because LEACH depends on only the probability model, which increasing the overall energy consumption in the network. LEACH-C [3] proposed a centralized cluster formation by using simulated annealing algorithm. It provides a fixed number of evenly distributed clusters though cluster formation overhead in every round is still there. Bourzek et al. [7] proposed a K Means clustering based routing algorithm where sensor nodes are subdivided into cluster using k means clustering algorithm, within each cluster depending on residual energy cluster head is selected. Cluster formation overhead in every round is still there. For CH selection only single parameter is accounted many other important parameters like distance from BS, intra cluster distance are not taken into account. A reactive routing protocol TEEN [8] was proposed for event detection. Nodes are grouped into cluster like LEACH. CH's send two threshold values H_T (Hard Threshold) and S_T (Soft Threshold) to its cluster member. Cluster members are awake to detect phenomenon if sensed value crosses its H_T and send data to CH. It reduces unnecessary transmission between CH's and cluster member's reduces energy consumption resulting in a better network lifetime. TEEN suffers from the silent network phenomenon in which BS does not receive any data for a long time during which there is no significant change in the sensed variable. To overcome the problem a centralized routing protocol APTEEN [9] was proposed in which an extra parameter is T_C added after which a non CH node sends data to CH irrespective of any changes in sensed variable. Nodes in the cluster are grouped into sleep/idle pairs depending on their proximity in location resulting in better network lifetime. A chain based hierarchical routing protocol PEGASIS has been proposed where a chain is constructed using a greedy approach out of all sensor nodes. Sensor nodes on the chain are connected with their close neighbors .Within the chain nodes are receive data from the close neighbor and transfer fused data to another neighbor node and finally a chain leader is elected at randomly to transmit aggregated data to the BS in results it extends network lifetime with exceptional delay. LBEERA [10] have been proposed by Yongchong Yu et al. which divides the network into several equal clusters and within every cluster a chain is formed based on novel algorithm. A chain leader for each chain is elected and finally a super leader transmits aggregated data to the BS directly in results it reduces energy dissipation per round with an extension of network lifetime. Yang et al. [11] proposed a tree structure routing where a pair to attain network lifetime where every nodes form a pair with its close neighbor and transmit data to its own pair node which is on the way to Leader node and finally Leader node sends aggregated data directly to BS extends network life time with reducing significance delay. In [12] Singh et al. different classes of routing protocols are reviewed where all of the methods have tendency to enhance the lifetime of the networks. Hua et al. [13] proposed an ant colony based routing protocol where ACO is used to find optimal path results in extending network lifetime. C.D Medina et al. [14] proposed an energy efficient routing protocol based on ant colony optimization was proposed a protocol where forward ants' backward ants are defined and the basic idea is to choose a path according to the actual energy level of the nodes and the distance traveled by the forward ant. Adnan et al. [15]

Procedure ACOHC

Step.1.The sensor nodes are randomly deployed over the deployment area.
Step.2. Partition the deployed nodes into K_{OPT} number of clusters after determining K_{OPT}.
Step.3. Cluster chains are formed consisting of all the nodes in the cluster using ACO along with the election of chain leaders based on Q factor.
Step.4. An upper chain is formed consisting of all the chain leaders using ACO along with the election of a super leader based on Q factor.
Step.5. Data transmission occurs along the cluster chain to the chain leader's and then along the upper chain to the super leader which finally transmits it to the base station.
Step.6. If the number of alive nodes is not zero then go to step 3 otherwise stop.

proposed a LEACH based routing protocol in which CHs send aggregated data to BS in multi hop manner and selection of the next hop is selected using ACO. It reduces direct transmission with BS consequently energy dissipation per round and hence extending network lifetime. Chengzhi et al. [16] proposed a protocol based on ant colony optimization in which path is chosen by the ants according to the energy level of the nodes and total number of nodes visited by the ants. In [17] S. Lijuan et al. a routing protocol was proposed based on enhanced ant colony optimization to find the optimum path of the network results in extending network lifetime by reducing energy dissipation per round. In [18] D Cheng et al. a routing algorithm ASW have been proposed, distance from the node to the sink and the energy consumption of the path are the parameters to choose the path by the ants. The main aim of the protocol is to enhance the lifetime of the network by reducing the energy consumption. In [19] a predication based routing protocol based on ant colony optimization have been proposed to enhance the lifetime by checking load factor and pheromone update. Saleem et al. [20] have proposed An ACO-based transmission scheme named the unity of MPEE and MPEB (UMM) was presented in which energy efficiency and energy balancing has been simply considered for longevity maximization of WSNs. In [21] J Yang et al. proposed a routing protocol based on leach and within each cluster ACO is used to construct the chain to enhance the lifetime of the network. In [22] X-Min. H et al. a reliable lifetime enhancement routing protocol based on ant colony optimization was proposed. It reduced the energy consumption by scheduling the operation modes of the sensors. In [23] Ho et al. proposed an ant based energy efficient routing protocol called Ladder Diffusion Algorithm (LDA). This algorithm reduces energy consumption and processing time by building routing table and avoiding routing loop. LDA consists of two phases namely ladder diffusion phase and route choosing phase. In the first phase each node calculates hop distance from its neighbors and put it into routing table while in the second phase the algorithm selects route from sensor node to the sink depending on estimated energy consumption and pheromone level still it consumes excessive energy because to building routing table it requires large number of messages. S. Jung et al. [24] proposed trail using ant behavior based routing protocol by adopting not only the foraging behavior of ant colony; trail using ant behavior is also used. In this protocol a routing trail is formed in energy efficient way and it reduces energy dissipation for routing so that network lifetime is extended. By adopting trail using behavior it reduces the overhead of the network. Wei Yu et al. [25] proposed novel ACO based routing protocol where cluster formation procedure and cluster head election procedure is same as LEACH. In data transmission phase CH sends its aggregated data to the next CH using ACO provided that next CH node has enough energy to transmit data to BS otherwise it directly send to BS. CH having less energy to transmit to BS is continue to running ACO and transmits its data to the next CH and the process goes on until all nodes transmit its data to either next CH or BS. In [26] DFCR by Azharuddin et al. a fault tolerant clustering and routing algorithm is proposed where two distributed algorithm one for cluster formation and another for routing is proposed. In clustering phase sensor nodes selects its CH based on a given cost function composed of residual energy of CH, distance from the node to CH and distance from the CH to the BS. This algorithm also takes care of sensor nodes which have no CH within their communication range. A distributed runtime recovery of the faulty cluster member node due to sudden failure of CH is also proposed. In data transmission phase CH node selects next CH in such a way by given algorithm that it requires less energy and also takes care of load balancing.

III. System Model

A. Energy model

We use the system model to calculate energy loss as described in [3]. The energy dissipated for communication between two sensor nodes follows the free space model proportional to the square of the distance between them. The BS usually located far away and data transmission to it follows the multi-path model proportional to the fourth power of the distance to BS. A distance threshold d_0 is set equal to the diagonal of the deployment area. The distance d between two WSN nodes is less than d_0 and between a WSN node and BS is greater than d_0. Therefore the former follows free space model as equation (1a) while the latter follows the multi-path model as equation (1b). The reception of message in both the cases is as equation (2).

$$E_{Tx}(m,d) = E_{elec} * m + \varepsilon_{fs} * m * d^2 \quad \text{if } d < d_0 \qquad (1a)$$
$$= E_{elec} * m + \varepsilon_{mp} * m * d^4 \quad \text{if } d \geq d_0 \qquad (1b)$$
$$E_{Rx}(m) = E_{elec} * m \qquad (2)$$

The number of bits in the message to be transmitted or received is m. The electronic energy E_{elec} (nano Joules/bit) is a constant and depends on signal encoding/decoding. The other parameters like ε_{fs} (pico Joules/bit/m^2) and ε_{mp} (pico Joules/bit/m^2) are related to free space and multi-path data transmission respectively.

B. Delay model

In HRP's significant delay occurs due to cluster / chain construction, election of CH / CL and waiting for the appropriate slot. A time slot is defined as the maximum time required transmitting a data packet. We measure the delay it terms to time slots. In ACOHC data transmission is met with lower chain, upper chain and transmission to BS delay. The overhead delay consists in constructing the lower and upper chain along with the election of CL and SL. The lower chain delay in time slots is D_{LC} = max ($N_{C1}, N_{C2}, N_{C3}, N_{C4}, \ldots, N_{Ck}$,) where k is the number of clusters and N_{Ci} is the number of nodes in the i th cluster. Similarly the upper chain delay is k time slots along with a delay of one slot for transmitting to BS by SL. We assume an overhead delay of 3 slots for lower and upper chain formation along with the election of CL's and SL.
In our simulation a random spread of 100 nodes portioned into K_{OPT} =7 clusters is considered. Therefore lower and upper chain delay is 15 and 7 slots respectively assuming equal sized clusters.. The chain formation overhead is 3 with the final transmission to BS by SL taking 1 slot. So a total delay of 26 slots per round is taken. The slot delay for the other protocols is similarly determined.

IV. PROPOSED WORK

Performance of hierarchical routing protocol depends on cluster formation and cluster head selection. So cluster formation and cluster head selection are crucial tasks. In our proposed method ACOHC at the outset all randomly deployed sensor nodes are subdivided into a fixed number cluster using K means clustering algorithm [5] at BS which is located far away from the deployed area. Cluster infrastructure remains fixed throughout the entire lifetime of network to diminish cluster formation overhead in every round. A PEGASIS like chain is formed within each cluster using Ant Colony Optimization Algorithm [6] for each cluster and a Chain Leader (CL) is elected based on Q factor derived from residual energy and distance to BS. Chain Leader broadcasts a TDMA schedule to member nodes indicating their transmission slot. Except Leader nodes other member nodes enter into sleep mode only to be awakened by the arrival of their allotted transmission slot thereby saving energy. Among CL's an upper chain is formed using the same ACO algorithm and finally a super leader is elected among CL's which sends all accumulated data to BS. The procedure ACOHC gives a complete description of the entire process.

A. Cluster formation using K means clustering algorithm

Reduction of energy consumption and delay per round of data communication are of prime importance in different envisaged applications of WSN. Typically minimizing delay increases energy consumption per round and vice versa. As energy dissipation is proportional to transmission distance we need to minimize it. Delay is proportional to the possible number of parallel transmissions in different clusters which in turn depends on inter cluster interference and hence its reduction also lowers delay. We propose a k-means [6] based clustering which reduces total transmission distance and inter cluster interference in a round.

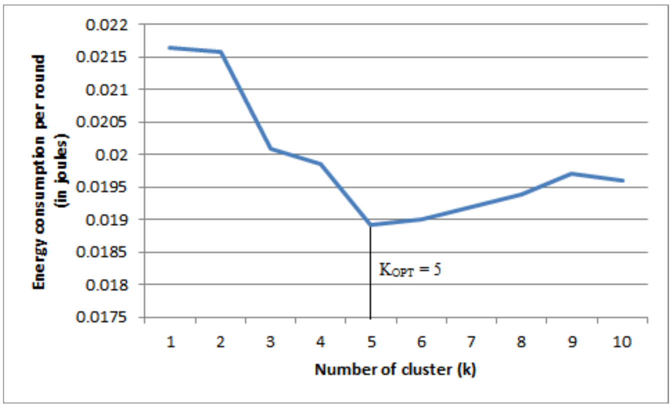

Fig. 2. Energy consumption per round against cluster number showing the value of K_{OPT}

Initially we partition the randomly scattered nodes over the deployment area into k partitions such that cumulative square error criteria E are minimized.

$$E = \sum_{i} \sum_{j} \left| p_{ij} - m_i \right|^2 \tag{3}$$

Where p_{ij} is the jth node in the ith cluster, c_i and m_i is its centroid. We then vary the value of k in unit steps and find out the energy consumption per round as shown in Fig. 2. The optimum value of k i.e. k_{opt} is found out at which the energy dissipated per round is minimum. In our case the value of k is varied from 1 to 10 and the value of k_{opt} is found to be 5. We fix our number of partitions at k_{opt} for the rest of our simulation. Hence by minimizing cumulative data transmission path length we optimize the energy spent per round which increases WSN lifetime. The clusters are initially computed by the BS and broadcasted to all others. They remain fixed until the first node dies which relieves us of the cluster formation overhead after each round as is done in LEACH.

B. Chain formation using ant colony optimization

Many bio-inspired heuristic optimization algorithm have been used in different applications, ant colony optimization (ACO) [6] is one of the most widely used algorithm. In this paper we use ACO to deplete long chain length within each cluster as a result the energy dissipated per round is reduced henceforth enhance network lifetime. Chain construction in cluster is similar to TSP problem and ACO is used to find near optimal solution. At the beginning state of this process a number of artificial ants are randomly placed at different nodes contemporaneously try to find shortest path from source to destination. At each node, an ant selects the next hop node by using the state transition probability rule as in equation

$$p_{ij}^{k} = \frac{(\tau_{ij})^{\alpha}(\eta_{ij})^{\beta}}{\sum_{l\in N_i^k}(\tau_{il})^{\alpha}(\eta_{il})^{\beta}} \quad \text{if } j \in N_i^k \tag{4}$$

where τ_{ij} is the pheromone level on the edge (i,j) and η_{ij} is the inverse of the Euclidean distance of the edge (i, j). $\alpha > 0$ and $\beta>0$ are two parameters determining the cognitive importance of pheromone and distance.

After visiting all nodes each node comes back to its starting node that is completes a tour of all nodes in that cluster. In iteration the tour of all ants are recorded and their tour length computed. After completion each iteration pheromone evaporates on all edges as per

$$\tau_{ij} = \tau_{ij} + (L^{-1}) \tag{5}$$
$$\tau_{ij} = (1-\rho)\,\tau_{ij} \tag{6}$$

only the edges belonging to the globally best tour in iteration receive reinforcement according to the following where L is the length of the path corresponding to the globally best tour after iteration. Process terminates if after a certain tour length or number of passes exceeds a predefined value. The ACO algorithm is repeatedly applied by BS in each cluster to form its corresponding cluster chain. Number of consecutive passes there is no change in global best.

C. Chain leader and super leader selection

For the first round each centered node selected as the cluster head by the K-means method becomes the chain leader (CL). Among the CL's the one with max $Q_i = \frac{E_{residual}}{d^2}$ is selected as the super leader (SL) where $E_{residual}$ the remaining energy of a node and D_i is the distance between the node and the base station. From the second and subsequent rounds the node with the max $E_{residual}$ is selected as the CL. In case of a tie the node nearest to the BS is selected as CL. Among the CL's the one with max $Q_i = \frac{E_{residual}}{d^4}$ is selected as the super leader (SL). In case of a tie the node nearest to the BS is selected as SL. The roles of super leader and chain leader are rotated every round according to the above criterion for evenly distributing the energy load among all the nodes thus enhancing network lifetime.

D. Data transmission

After the formation of lower and higher level chain and selection of CL and SL sensor starts data collection and transmission operation. The similar token passing mechanism is adopted for the initiation of the data transmission as in PEGASIS .Each end node in a chain starts by transmitting to the next node along the chain. The node in the next position receives the data and fuses this data with its own and transmits it to the next node.

V. SIMULATION ENVIRONMENT AND RESULTS

A 100m X 100m square deployment area is considered with randomly spread 100 nodes scenario with a fixed BS at location (50, 175). The nodes are immobile and homogeneous in respect to battery type, sensing and transmission range. The energy dissipation for transmission of an m bit message between two sensor nodes or between a sensor node and BS is modeled by equations (1a) and (1b) respectively as described in Section III A. The energy loss for reception of an m bit message is as equation (2). Initial node energy of 1 joule, packet size of 2000 bits, no obstacles with omni-directional antenna type are assumed. In our simulation we set E_{elec} (in nano Joules/bit) to 50, ε_{fs} (in pico Joules/bit/m^2) to 10, ε_{mp} (in pico Joules/bit/m^2) to 0.0013 and E_{DA} (in nano Joules/bit/signal) to 0.0013. LEACH, LEACH-C, PEGASIS, KLEACH and proposed method are simulated using MATLAB. The results are compared on different parameters like number of alive nodes against rounds, delay, throughput and energy * delay product. The numbers of alive nodes against number of round for 100 node scenario are shown in Fig. 3. The values for first node dies (FND), half of node dies (HND), last node dies (LND) and energy consumption per round for above mentioned scenario are shown by bar graph in Fig. 4 and Fig. 5 respectively. The energy dissipated per round (E), intezer delay per round (D), energy * delay product (E X D) and throughput are shown in Table I. It is evident from the results that ACOHC not only extends WSN lifetime but also lowers E X D product and enhances throughput. It also provides a good load balance among the nodes as indicated by narrow death span.

TABLE I. PERFORMANCE COMPARISION

Performance Metrics	E	D	E*D	Throughput
LEACH	0.058	27	1.56	66.30
LEACH-C	0.052	27	1.40	80.93
PEGASIS	0.023	100	2.30	93.40
KLEACH	0.045	27	1.21	84.05
ACOHC	0.0192	26	0.50	96.01

E: energy dissipated per round, D: delay per round, E*D: energy X delay product.

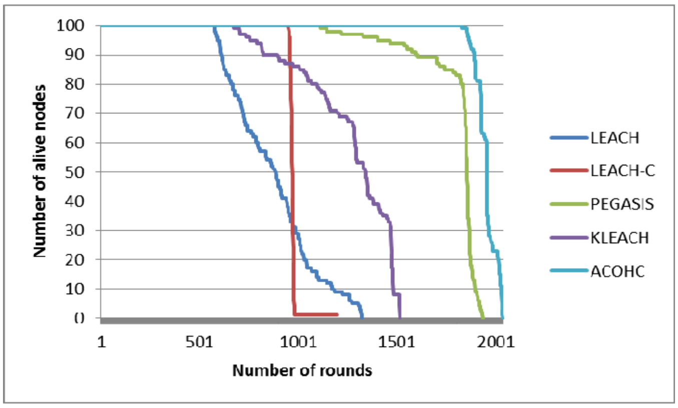

Fig.3. Number of alive nodes against rounds for a random deployment of 100 nodes.

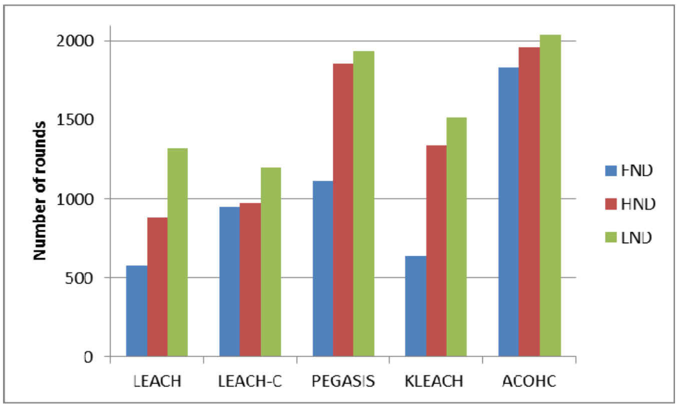

Fig.4. Bar graph showing the FND, HND and LND in rounds for a random deployment of 100 nodes

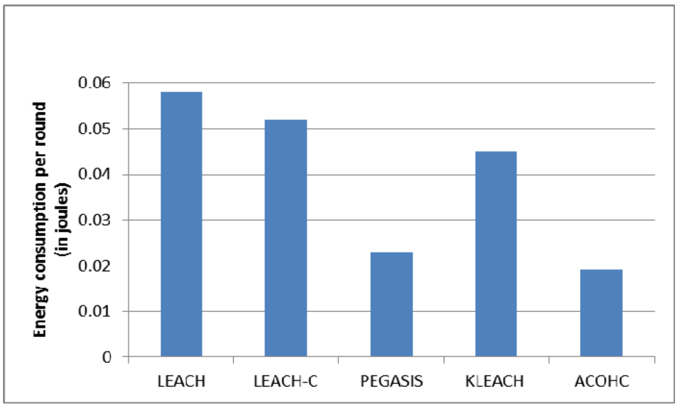

Fig.5. Average energy consumption per round in joules.

VI. Statistical Inference

The number of alive nodes (NOA) forms a bi-variate normal variable when pair wise comparison is done between ACOHC and LEACH, or LEACH-C, or PEGASIS or KLEACH after each round. The pair wise variables (x_i, y_i) are also co related which calls for the use of paired t-test [27] for drawing statistical inference. The null and alternative hypotheses for the three cases are as follows:

Null Hypothesis H_0: ($NOA_{ACOHC} = NOA_{LEACH}$). Alternative Hypothesis H_1: ($NOA_{ACOHC} > NOA_{LEACH}$).

Null Hypothesis H'_0: ($NOA_{ACOHC} = NOA_{LEACH-C}$). Alternative Hypothesis H'_1: ($NOA_{ACOHC} > NOA_{LEACH-C}$).

Null Hypothesis H''_0: ($NOA_{ACOHC} = NOA_{PEGASIS}$). Alternative Hypothesis H''_1: ($NOA_{ACOHC} > NOA_{PEGASIS}$)

Null Hypothesis H'''_0: ($NOA_{ACOHC} = NOA_{KLEACH}$). Alternative Hypothesis H'''_1: ($NOA_{ACOHC} > NOA_{KLEACH}$)

The test statistic t with n-1 degrees of freedom is defined as

$$t = D_{avg} / \left(S_d / \sqrt{(n-1)} \right) \tag{7}$$

where D_{avg} and S_d denote the mean and standard deviation of the difference of NOA in two equal sized correlated large samples of size n. The 95% confidence limits for D_{avg}

$$D_{avg} \pm t_{0.05} * \left(S_d / \sqrt{(n-1)} \right) \tag{8}$$

where $t_{0.05}$ is the 5% point of the t-distribution on $n - 1$ degrees of freedom. Let p indicate the probability of the calculated value for our test statistic t with n-1 degrees of freedom to obey the null hypothesis. A value of $p < 0.05$ indicates that H_0, H'_0, H''_0 and H''' is rejected at 5% significance level and hence H_1 or H'_1, H''_1 and H''' be accepted at 95% confidence level.

Table II shows the result of paired-t test obtained by pair wise testing of ACOHC with LEACH, LEACH-C, PEGASIS, and KLEACH respectively. In all the cases $p < 0.05$ so H_0, H'_0, H''_0 and H'''_0 is rejected at 5 % significance level and H_1, H'_1 H''_1 and H'''_1 is accepted at 95% confidence level. Also the lower and upper limits for the 95% confidence interval for D_{avg} are listed in Table 3. Hence it can be convincingly concluded that ACOHC outperforms LEACH, LEACH-C, PEGASIS and KLEACH and the results are statistically significant.

TABLE II. Results of Paired t test

Comparison of ACOHC	t value	Significance level	95 % confidence interval	
			Lower	Upper
LEACH	33.52	95%	31.81	35.77
PEGASIS	17.93	95%	5.32	6.63
LEACH-C	17.08	95%	16.87	21.25
KLEACH	27.22	95%	14.85	17.16

VII. Conclusion

Our proposal ACOHC extends WSN lifespan and reduces the data delay. The concepts of lower and upper chain along with the election procedure of CL's and SL are described. We assume homogeneous and static nodes with fixed BS. Recent applications like animal tracking, detecting ocean currents to name a few requires non-homogeneous and mobile sensors with flexible BS. ACOHC can be extended to incorporate these features.

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