Clustering Protocol for Wireless Sensor Networks based on Rhesus Macaque (*Macaca mulatta*) Animal's Social Behavior

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ABSTRACT
Clustered sensor networks have shown to increase system throughput, decrease system delay and save energy. In this paper, we propose a bio- inspired clustering protocol inheriting the social behavior of Rhesus Macaque monkeys, targeting prolonged network lifetime. The behavioral features are added to the basic LEACH, thereby reducing the energy overhead involved in the set-up phase. The simulation results prove that implanting these kinds of bio-inspired intelligence into the pre-existing protocols will tremendously increase its performance.

General Terms
Wireless Sensor Networks, Routing Protocols, Bio inspired computing

Keywords
Clustered sensor networks, Rhesus Macaque monkey, network lifetime, LEACH protocol

1. INTRODUCTION
Humans are always fascinated by the intelligence of animals. Humans are the intelligent animals of all on this Earth. Apart from him, there are other animals, which are competitively intelligent. Chimpanzees with 98% genomes identical to that of humans have unique behaviors like making tools and troops among themselves for hunting. Dolphins in oceans and seas exhibit smart behavior. Elephants have proved themselves to have good group mannerisms. They communicate, help each other in time of need and console their family members. Crow is an intelligent bird, which can communicate with varying frequencies with other crows, make tools from its beaks and exhibit outstanding group behavior. Pigs, cats, lions etc. there are many in this list having their own intelligence and manners. In this context, Swarm Intelligence was the term coined for the collective behavior of animals and many algorithms were developed in this domain. Some of them include Altruism algorithm, Ant Colony Optimization, Artificial Bee Colony algorithm, Back Tracking Search Optimization algorithm, Glow Worm Swarm Optimization, Differential Search algorithm, Intelligent Water Drops, Particle Swarm Optimization, Self- Propelled Particles, Stochastic Diffusion search, Multi- Swarm Optimization.

Few works, which uses swarm intelligence, were referred, Muhammad Salem et al. [1] makes a survey on the applications of Swarm Intelligence in WSN. Nor Azlina Ab Aziz et al. [2] use PSO algorithm for improved coverage of WSN. The work proposed by Bharathi M.A et al. [3] demonstrates the use of Elephants behavior as swarm intelligence in clustering of sensor nodes. Methodology proposed by Chao Wang et al. [4] provides an algorithm that uses Swarm Intelligence for optimal routing, thereby achieving energy efficiency. Dama et al. [5] use PSO and Artificial Bee Colony algorithm for finding the location of nodes in wireless sensor networks. Al-Obaidi et al. [6] proposes the use of swarm intelligence for increasing the network lifetime in mobile wireless sensor networks. Researchers have proposed numerous schemes and designs utilizing swarm intelligence for handling wireless sensor network related issues. The proposed work utilizes the Swarm behaviors of Rhesus Macaque monkeys targeting the improvement of network lifetime. The designed algorithm was executed in MATLAB and the results were verified with respect to the energy consumed in set-up phase.

The rest of the paper is organized as follows: section II deals with the behavioral aspects of Rhesus Macaques, section III discusses the proposed methodologies, section IV describes the simulation model, section V deals with the results and discussions and section VI with the concluding remarks on the work.

2. BEHAVIOUR OF RHESUS MACAQUES
Rhesus macaques live in large multi male and female group. Their groups may be up to hundreds depending on the availability of food, climate and environmental conditions. This monkey group is characterized by female philopatry and male dispersal. Females in a group very rarely move away from their groups but the males often wander away in search of mating opportunities after attaining their puberty. Females are arranged according to their matrilineal family relationship. Female monkeys' with younger age are always given the higher rank. If that monkey dies automatically the rank is passed to the next monkey in the hierarchy. This selection of the youngest monkey is because it is more fit and fertile. The younger female monkeys' never undergo clashes with their mothers. In male monkeys', usually the monkey which is aggressive and energetic is considered as the group head. The aggressiveness of the male monkey is judged based on slapping, pushing, pulling fur, tail yanking, and biting as well as other non-contact behaviors such as displays and threats [9]. Female monkey ranks in a group are permanent i.e., until the monkey dies. Male monkey ranks are for at least two years. Male monkeys' are the dominant monkey groups, which are at the centre, and the less dominant monkeys' are arranged towards the border in the order of their decreasing energy. The less dominant monkeys' are involved in inter

group communication for giving alert calls, but the entire group affairs are looked by the dominant males of the group. The monkey troop size is continuously checked and the group breaks if there is a poor communication between the intra group monkeys due to increased size. Good communication exists between these broken clusters and gradually decreases as the clusters move away from each other. These broken clusters maintain all the features as discussed previously [7] [8].

These intelligent behavioral aspects of animals is taken to handle clustering, locality, energy and other such wireless sensor network related parameters leading to a more efficient affectation in protocol design.

3. PROPOSED METHODOLOGY

The following were the key attributes taken for the design of protocol to increase the network lifetime:

Cluster head is elected based on the residual energy of the nodes. This Behavior is seen in both female and male monkeys' in the troop, where the highest rank for the female monkeys of the group is given based on their fitness and fertility, and for the male monkeys, it is based on the aggressiveness and energy.

Redundant cluster heads without any nodes attached to it, loses its cluster head designation and is attached to nearest other cluster. This is derived from male monkey's wandering behavior in search of mating opportunities.

As the cluster size increase, the cluster splits into smaller clusters choosing a new cluster head to facilitate good communication with its member nodes. This feature is inspired from splitting nature of the monkey group to maintain good communication with subordinate monkeys in a troop.

3.1 Energy efficient clustering protocol

This section highlights already existing LEACH protocol with its modification, which serves to be the base for the proposed protocol, the radio model used for communication with the energy consumed for packet transfer and the proposed algorithm, which shows an intelligent setup phase compared to basic LEACH.

LEACH protocol chooses cluster head by fixing threshold based on equation (1).

$$T(n) = \begin{cases} P/(1 - P\left(r mod \left(\frac{1}{P}\right)\right)), & n \epsilon G \\ 0 & otherwise \end{cases} \quad \ldots (1)$$

Where, 'P' is the percentage of cluster heads required for a round 'r', 'n' is any non-cluster head node; 'G' is the total number of non-cluster head nodes available.

The proposed algorithm is designed for a single hop network and is shown in the fig. 1. LEACH assumes that all the nodes are capable of communicating with the Base Station node (BS). All non-CH nodes (N) communicate with their cluster head nodes (CH) and CH nodes communicates with the BS node in a single hop. For a specified percentage P, equation (1) calculates the threshold value for a particular round and selects the cluster head. However, in this proposed work, equation (1) is modified. Since here the LEACH protocol is executed only once and once the cluster heads are elected, by using Nearest Neighbor approach all the non-CH nodes attach themselves with the cluster heads sensing the CH advertisement broadcast packet signal strength. In addition, the CHs learn about the other CHs nearer to them sensing these broadcast packets. These clusters are for the entire lifetime of a deployed network and if a new cluster head has to be selected, then the election is localized only within that cluster. Hence, the denominator term, which is in brackets, is neglected in equation (1) giving rise to equation (2).

$$T(n) = P \quad \ldots (2)$$

Where, P is the percentage of cluster heads for a network. This network backbone equation (2) is executed only once at the initial stage, at the time of cluster heads selection. Hence, the percentage of cluster heads has to be decided at the beginning of the network deployment and this percentage is permanent throughout the deployed network.

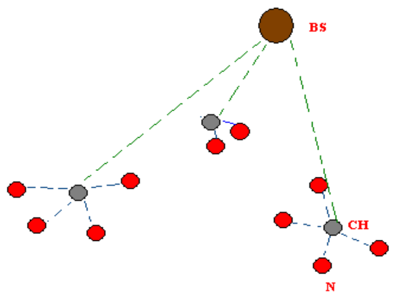

Fig. 1 Single Hop Wireless Sensor Network Deployment

If an ordinary node sends a packet to the cluster head in a cluster, then that particular cluster participates in re-election of cluster head based on the residual energy of the nodes in the cluster. Hence, all the nodes in the network get a chance to become cluster head.

In the proposed work, it is assumed that all the nodes can communicate directly with the base station as in basic LEACH. In addition, energy consumed for broadcasting packet of interest by CH was neglected.

3.2 Radio Model

This section highlights the internal features of nodes as a transceiver. The radio model consists of transmitter and receiver equivalent of the nodes separated by the distance'd'. Where E_{tx}, E_{rx} are the energy consumed in the transmitter and the receiver electronics. E_{amp} is the energy consumed in the transmitter amplifier in general, and it depends on the type of propagation model chosen, either free space or multipath with the acceptable bit error rate. We consider E_{fs} as the energy consumed for free space propagation and E_{mp} for multipath propagation.

The energy consumed in the transmitter and the receiver electronics depends on digital coding, modulation, filtering and spreading of data. Additional to this there is an aggregation energy consumption of E_{agg} per bit if the node is a cluster head. The radio model is shown in fig. 2.

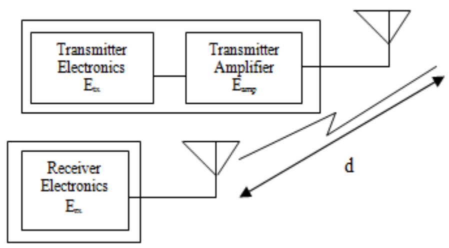

Fig. 2 Radio Model

3.3 Energy Utilization

Energy consumed by the cluster head and the nodes attached to it is calculated in this section. For all the nodes, both upstream and downstream communication is considered and for BS only upstream communication is considered.

3.3.1 *Energy consumed by cluster head*

Fig. 3 shows a single cluster head and non-CH node pair. The cluster head is then connected to a BS. The distance between BS and the CH is d' and the distance between the N and CH is given by d.

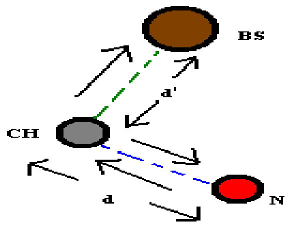

Fig. 3 BS- CH- N communication

$E_{CH1} = [(E_{rx} * L_{ctr}) + (E_{agg} * L_{ctr})]$ . . . (3)

Where, L_{ctr} is the packet sent from an ordinary node to a CH. Equation (3) depicts the energy consumed by the cluster head for receiving and aggregating a packet from an ordinary node.

$E_{CH2} = [(E_{tx} * L_p) + (E_{amp} * L_p * (d')^n)]$ . . . (4)

$E_{CH3} = [(E_{tx} * L_{ctr}) + (E_{amp} * L_{ctr} * (d)^n)]$ . . . (5)

Equation (4) is the energy consumed by the cluster head for transmitting the packet to the BS. L_p is the aggregated packet sent to BS. n is the path loss component. Equation (5) depicts the energy consumed by the CH for sending an acknowledgement packet to its member node.

In this work the ratio 'd_0' is calculated which is the comparison ratio for using free space or multipath propagation model and accordingly the energy consumed is given by E_{fs} or E_{mp} by E_{amp} block. The path loss component will be 2 or 4 respectively. Hence, the total energy consumed per communication with an occurrence of an event is given by equation (7).

$d_0 = \text{sqrt}(E_{fs} / E_{mp})$ . . . (6)

$E_{CH} = E_{CH1} + E_{CH2} + E_{CH3}$ . . . (7)

3.3.2 *Energy consumed by an non- cluster head node*

$E_{non\text{-}CH1} = [(E_{tx} * L_{ctr}) + (E_{amp} * L_{ctr} * (d)^n)]$ . . . (8)

$E_{non\text{-}CH2} = [(E_{rx} * L_{ctr})]$ . . . (9)

Hence, the total energy consumed per communication with the CH is given by

$E_{non\text{-}CH} = E_{non\text{-}CH1} + E_{non\text{-}CH2}$ . . . (10)

Equation (8) represents the energy consumed by a non-CH node for transmitting a packet to CH, and equation (9) for receiving a packet and processing an acknowledgement sent by the CH, which contains the TDMA time slot. In our work, it is assumed to be L_{ctr}. Equation (10) is the total energy consumed per communication with CH.

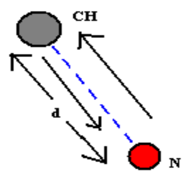

Fig. 4 CH- N communication

3.3.3 *Proposed Algorithm*

In this section, we propose overall system algorithm for dynamic clustering using monkey's behavior. Steps 1 to 4 depict the set-up-phase of the network .Soon after finishing the set-up-phase the network enters into the steady- state-phase where the nodes start actually transmitting the sensed information of interest, which is focused in step 5. Once the network enters into the steady-state-phase, partially it enters back again to the set-up-phase only for the new CH election. It is to be noted that in the proposed protocol the set-up phase is little prolonged.

Step 1. Construction of network: This step involves constructing a network with the dimensions of the plot specified. Here initialization of various energy and communication parameters, initializing nodes for deployment and various fields of a node is carried out. The parameters of the node include location of the node, its ID, type field specifying whether it is a cluster head or a non- cluster head node. It contains a field to hold the threshold count for splitting the cluster and the count field to hold the count of number of nodes attached to it when it becomes CH.

Step 2. Run the LEACH once: The percentage of CHs requirement is broadcasted from the BS. Run the LEACH with equation (2) as the backbone forming clusters. The formation of clusters is based on the Received Signal Strength of the broadcasted packets from the CHs. For evaluation of the algorithm, we considered the Euclidean Distance metric given by,

$d = [(x_2\text{-}x_1)^2 + (y_2\text{-}y_1)^2]^{1/2}$ . . . (10)

Where (x_1, y_1) and (x_2, y_2) are locations of nodes.

Step 3. Find the redundant CHs without any member nodes: identify the redundant cluster heads without any nodes attached to it.

Step 4. Attach redundant CHs to other nearest cluster and check the cluster size of the attached cluster: in this step, all the cluster heads that are without any nodes attached to it, is broken from the contact of BS and made to attach to some other nearest cluster. Its cluster head designation is removed and demoted to a non-CH node. Later the cluster size is checked with the threshold, which is set in each node by the network deployer. If the cluster head is having a count greater than the threshold, the cluster associated with that CH splits. The cluster splits in accordance with the number of nodes greater than the threshold electing a new cluster head for the split- new clusters. The nodes chosen for splitting are the nodes farthest from CH.

Step 5. Choose nodes randomly for communication and re-elect cluster head in that cluster: in this step, a non-CH node is randomly chosen for communication. Once they participate in communication, they drain their energy with their CH energy. Hence, all the nodes belonging to that cluster participate in CH re-election based on their residual energy. Later this information of new CH is updated to the BS. This depicts the example scenario of event driven WSN.

3.3.4 Algorithms

This section gives detailed description of the algorithms involved in the proposed system.

Algorithm 1. Construction of network

NetArch= CALL Procedure Network ( )

Begin

/*Fix Percentage for CH requirement, 'P'*/

/* Fix the number of nodes to be deployed */

/*fix length and width of the plot*/

/*set position of BS*/

/*set radio energy parameters for communication*/

/*fix CH and non-CH packet length*/

/*set initial energy of all nodes*/

FOR Num_of_Nodes

{

/* set the initial type of the node in 'type' field which will be 'N' (taken 'N' for non-CH and 'C' for CH in this work)*/

/* initialize the CH field (used for holding the CH ID to which a node is attached, initialized to -1 indicating, not CH yet*/

/* initialize the threshold field of the node, for splitting of a cluster*/

/* initialize the count field to zero (used to hold the count of number of nodes attached to a CH)*/

/*set the node ID's (indicating MAC address)*/

/*deploy the nodes uniformly (set the x and y co-ordinates for all nodes in the plot)*/

}

End

Algorithm 2. Run the LEACH once

ClusterModel = CALL Procedure run_leach (netArch, 'leach', P)

Begin

CALL Procedure leach (clusterModel, P)

Begin

/*Select cluster Heads based on threshold of equation (2)*/

IF (node= =CH)

{

/*set type field to 'C' and indicate that it is cluster head*/

}

/*Initialize the other necessary parameters for the operations of cluster if necessary*/

/* Form the cluster based on the nearest neighbor approach.

/*Drain the energy of all the nodes due to this initial clustering for sending request packets from node and acknowledgements from the CHs*/

IF (node==CH)

{

PKT TRANSMIT→BS; /*All the CHs transmit the packet containing information about their newly formed cluster to BS. CH loses energy for packet transmission*/

}

End

End

This algorithm selects the cluster head and initializes the various fields of a cluster head.

Algorithm 3. Find the redundant CHs without any member nodes

ClusterModel = CALL procedure redund (clusterModel)

Begin

/*All CHs, find the count of all the nodes attached and update the cluster head count field.*/

/*identify the CH which do not have any nodes attached to it*/

End

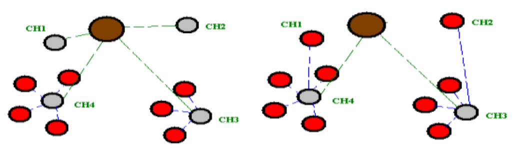

Fig. 5 Cluster heads without any nodes attached to it connects another nearest cluster head, losing its CH position

Algorithm 4. Attach redundant CHs to other nearest cluster and check the cluster size of the attached cluster

ClusterModel = CALL Procedure checkcluster (clusterModel)

Begin

/*attach the CH with non-member nodes, to nearest other CH. Remove the CH tag and make it a normal node*/

IF (cluster_size > threshold)

{

/*check the cluster size and split the cluster with CH having count>thresh (use packet size of L_{ctr} for sending and receiving 'detach' signal)*/

}

PKT TRANSMIT→ BS; /*parent cluster head sends the information about the updated member nodes to the BS*/

FOR number_of _broken_clusters

{

PKT TRANSMIT→ BS; /*elect new cluster heads in the broken clusters with clusters formed by nodes farther from the CH and drain energy of the nodes involved in new cluster formation, send this new information to the BS*/

}

End

This resembles a male monkey wandering and attaching to other groups. This process increases the network life time by eliminating the redundant nodes and is shown in fig. 5.

The process of breaking of the clusters is shown in fig. 6 and fig. 7 respectively. The split cluster is formed involving the nodes farther from the CH.

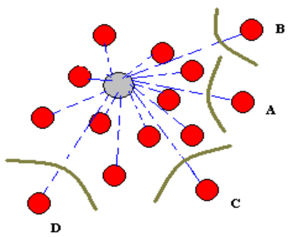

Fig. 6 Cluster with count greater than threshold=10

Assume that out of all the nodes in fig. 7, the residual energy of node A is the greatest. Hence, this node is chosen as the cluster head. The threshold has to be properly planned at the time of network deployment. In this work, one level of cluster break was introduced. Algorithm can be implemented as a cluster break recursion but may consume more time in attaining stability in the network leading to a prolonged set-up-phase and may drain more energy from the nodes.

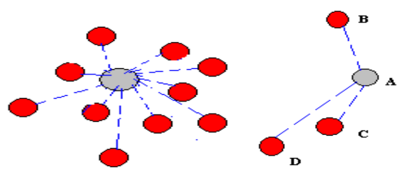

Fig. 7 Farthest nodes from the CH greater than threshold, 4 nodes form separate cluster

Energy of all the nodes in the participating clusters will be suitably drained. This energy payoff includes energy consumed for sending 'detach' signal to the nodes, reception of 'detach' signal by the nodes and energy for new CH selection.

Algorithm 5. Choose nodes randomly for communication and re-elect cluster head in that cluster This scenario is a depiction of event driven sensor activation. Each time a node is randomly selected indicating the sensing of a node.

ClusterModel = CALL Procedure selectnodes (clusterModel)

Begin

/* select node randomly for communicating with the BS via CH*/

PKT TRANSMIT→ BS; /* elect a new cluster head in that cluster based on residual energy and send this information to the BS*/

/*process repeats for successive cycles of steady-state phase*/

End

4. SIMULATIONS

Simulation was carried out with the varying percentage of cluster head selection. In each case the residual energy of the entire network, number of dead nodes, number of nodes detached from the BS and the number of clusters broken were examined. Packets reach BS when a node senses the environment, when CH attaches to some other cluster, when cluster splits, when a new CH is elected and new cluster is formed at the beginning stage of set-up phase. The various communication parameters set are given below in table 1. The energy consumed for advertisement broadcast from the CH at the beginning of the set-up phase is not considered.

Table I. Radio characteristics and other parameters chosen for simulation

Parameter	Value
Number of nodes	100
Transmitter electronics, E_{tx}	50nJ/bit
Receiver electronics, E_{rx}	50nJ/bit
E_{mp}	0.0013pJ/bit
E_{fs}	10pJ/bit
E_{agg}	5nJ / bit
Length of plot	100 m
Width of plot	100 m
L_p	6400 bits
L_{ctr}	200 bits
Initial energy of the node	0.5 J
Cluster threshold	10 nodes

Algorithm is executed and tested using MATLAB 7.6 on Intel core 2 Duo processor T5250 with windows operating system. The percentage of cluster head requirement was set to P=10% and P=30%. The results obtained are compared with the basic LEACH and proves itself as the enhancement with the basic LEACH. Number of rounds chosen is around 1000. It was observed from the results that, by adding swarm intelligence an outstanding increase in the network lifetime is found. The nodes in the fig. 8, are uniformly distributed over a plot of dimensions 100m X 100m and BS located at (50,175).

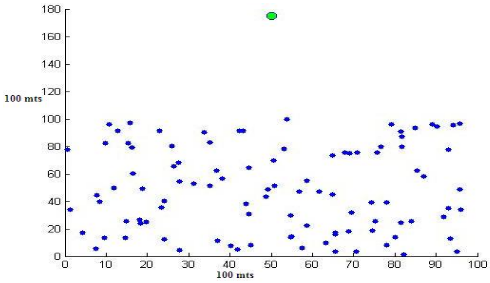

Fig.8 Distribution of nodes in 100 m X 100 m plot

5. RESULTS AND DISCUSSIONS

This part of the paper highlights the results obtained as discussed in the section 4 of this paper.

i) For P= 10%

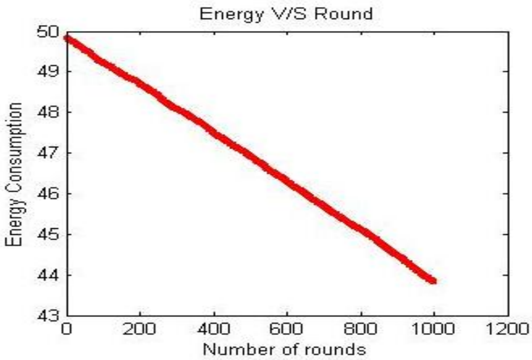

Fig. 9 Overall energy consumed by the network for 1000 round

For 1000 rounds:

Number of Dead Nodes = 0;

Number of Clusters Broken = 4;

Number of CH attached to other nearest cluster = 0;

ii) For P=30%

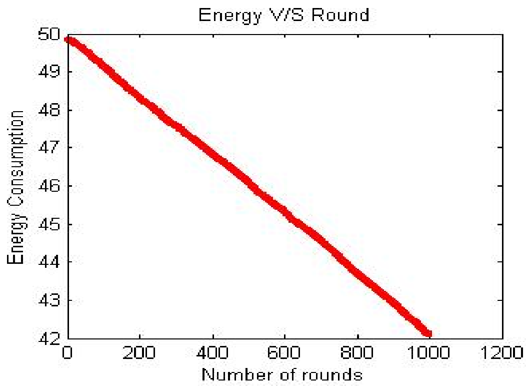

Fig. 10 Overall energy consumed by the network for 1000 rounds

For 1000 rounds:

Number of Dead Nodes = 0;

Number of Clusters Broken = 0;

Number of CH attached to other nearest cluster = 9;

iii) Basic- LEACH outputs for P=10% and P=30%

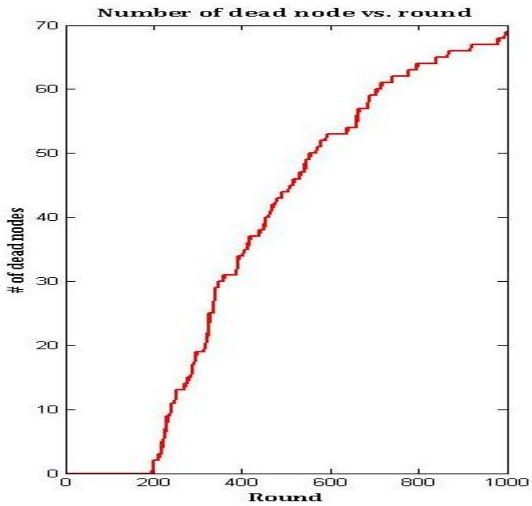

Fig. 11 Number of nodes dead after 1000 rounds with P=10%

Fig. 9 and fig. 10 depict the energy consumed by 100 nodes for 1000 set-up phase rounds. The steady-state energy is not considered as a metric in this paper, since the intelligent behaviors are part of set-up phase not the steady state phase of the protocol. The set –up phase includes non-CH node sending join request CH, CH sending the ACK to ordinary nodes and CH transmitting aggregated packet to BS, which includes the information regarding the cluster or any change in the cluster. After each round of set-up phase, it was assumed there is one cycle of steady-state phase and one node to transmit the data in that cycle.

It was observed that the energy utilized was very minimal compared to the basic LEACH energy consumption shown in fig. 12 and fig. 14. This is because in basic LEACH, all the nodes drain their energy in clustering in each round. However, in this proposed work, not all the nodes lose their energy instead only the cluster, which contains the node that wants to communicate, drains its energy. In a cluster, count may vary from one to ten nodes excluding CH. Depending on the count the energy will be drained from the clusters. Even though there is overhead involved in breaking of the cluster and attaching redundant CHs to other cluster, the energy consumed is minimal in these processes. Choosing a nominal 'P' value for CH selection is always recommended.

An increase in the percentage of CH will consume more network energy due to overhead in attaching redundant CH to some other cluster and a smaller percentage of CH increases overhead due to splitting of clusters. With the smaller 'P' value, it was observed that number of clusters broken was more.

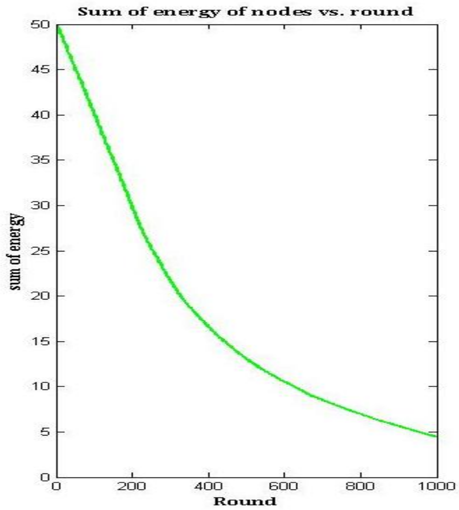

Fig. 12 Energy consumption after 1000 rounds with P=10%

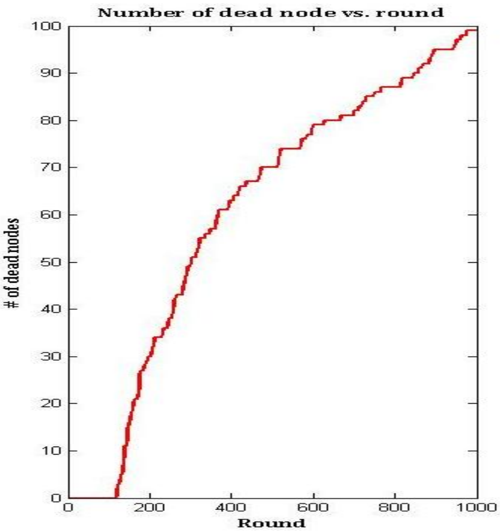

Fig. 13 Number of nodes dead after 1000 rounds with P=30%

This was because of the oversize of the cluster due to minimal number of CHs elected. Choosing a proper value for 'threshold' in each node is also essential and it mainly depends on the total number of nodes used for deploying. The threshold value should be chose such that there is minimal number of cluster breaks. In this proposed work, only one level of cluster break was proposed i.e., suppose a cluster count is 21, then it splits into 10+11, if cluster count is 11 it splits into 10+1 so on. This monkey's behavior was added to reduce the load on the CH handling large number of nodes in a cluster. Choice of threshold value depends on the deployer but not on the monkey's behavioral aspects. Because it was observed that monkey troops does not maintain a fixed size of cluster throughout their lifetime.

In the further improvements, we can even make the cluster break a recursive process such that all the clusters are uniformly distributed and sized. However, care should be taken that it does not increase the energy consumption in the deployed network. In each round, LEACH elects a CH and later using Nearest Neighbor technique, they attach nodes to it. However, by doing so, we may choose a CH without any nodes attaching to it. This is forbidden in monkeys' swarm intelligence since a CH without any nodes attached to it may not participate in the network and is equivalent to a dead node. Hence, we detach those types of nodes and attach to some other nearest CH thereby still increasing the network lifetime and fig.9 and fig.10 indicate the energy consumed by the entire network with the combined effect of all these set-up phase instincts.

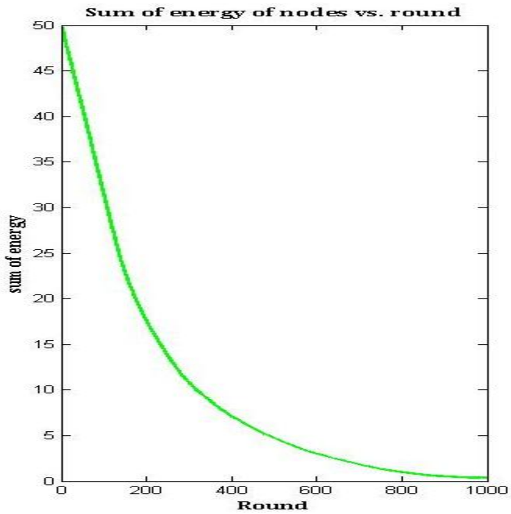

Fig. 14 Energy consumption for 1000 rounds with P=30%

The combined effect of all these behavioral aspects of monkeys', gave profound swarm intelligence in improving the network lifetime and node survival rate.

6. CONCLUSIONS

In this paper, we have proposed to embed bio-inspired intelligence into already existing WSN protocols. The concern in the proposed work is to decrease the energy consumed in the set up phase, unlike majority of the clustering protocols concentrating at the steady state phase energy. The intelligent behavioral patterns observed from the monkey troops lead to an efficient clustering protocol; thereby reducing the energy overhead involved in the setup phase up to 80% of basic-LEACH. Here it is achievable with a minimal tradeoff with the computational cost of the network. The simulation results prove that the proposed protocol is scalable, distributed and can be adapted in the future sensor networks with ease.

7. REFERENCES

[1] Muhammad Saleem, Gianni A. Di Caro, Muddassar Farooq, "Swarm intelligence based routing protocol for

wireless sensor networks: Survey and future directions", Information Sciences 181 (2011) 4597–4624, Elsevier.

[2] Nor Azlina Ab Aziz, "Swarm Intelligence In Wireless Sensor Networks: For Coverage Optimization and Energy Conservation", pp 51-60, Springer Berlin Heidelberg, 2010.

[3] Bharathi M.A, B.P. Vijayakumar, D.H. Manjaiah, "Cluster Based Data Aggregation in WSN Using Swarm Optimization Technique", IJEIT, Volume 2, Issue 12, June 2013.

[4] Chao Wang, Qiang Lin, "Swarm intelligence optimization based routing algorithm for Wireless Sensor Networks", International conference on Neural Networks and Signal Processing, 2008, IEEE.

[5] Dama lavanya, Siba.K. Udgata, "Swarm intelligence based localisation in Wireless sensor networks", PP 317-328, multi-disciplinary trends in Artificial intelligence, lecture notes in computer science, Springer Berlin Heidelberg, 2011.

[6] Al-Obaidi, Mohanad, "ENAMS: Energy optimization algorithm for mobile wireless sensor networks using evolutionary computation and swarm intelligence", Ph.D thesis, De-Montfort University, 2010.

[7]"Rhesus Macaque" http://en.wikipedia.org/wiki/Rhesus_macaque.

[8]Social Structure- http://anthro.palomar.edu/behavior/behave_2.htm

[9]Rhesus Macaque (*Macaca mulatta*) - http://www.theprimata.com/macaca_mulatta.html

[10] Waal F., "Co development of dominance relations and affiliative bonds in rhesus monkeys", Juvenile Primates: Life History, Development, and Behavior. Pereira M., and L. Fairbanks. New York: Oxford University Press, 1993.

[11]Wendi Rabiner Heinzelman, Anantha Chandrakasan, Hari Balakrishnan, "Energy-Efficient Communication Protocol for Wireless Microsensor Networks", Proceedings of the 33rd Hawaii International Conference on System Sciences – 2000, IEEE.

[12]Wang Rui, Liang Yan, Ye Gangqiang, Lu Chaoxia, "swarm intelligence for the self-organization of wireless sensor network", Pages: 838 – 842, ISBN: 0-7803-9487-9, IEEE.

[13]Bruneo D., Scarpa M., Bobbio A., Cerotti D., Gribaudo M.,. "Adaptive swarm intelligence routing algorithms for WSN in a changing environment", sensors, 2010 IEEE.

[14]B.P. Vijay Kumar, P.Venkataram, "Reliable multicast routing in mobile networks: a neural- network approach", IEEE proc- Commun. Vol. 150, No. 5, October 2003.

[15]S.C Makwana, "Field ecology and behavior of the rhesus macaque (Macaca mulatta): I. Group composition, home range, roosting sites, and foraging routes in the Asarori Forest", Journal Primates, Volume 19, Issue 3 , pp 483-492, ISSN 0032-8332, Springer.

[16]Yvette Spencer-Booth, "The behavior of group companions towards rhesus monkey infants", Volume 16, Issue 4, November 1968, Pages 541–557.

[17]M.J.A. Simpson S. Howe, "Group and matriline differences in the behavior of rhesus monkey infants", Volume 34, Issue 2, April 1986, Pages 444–459.

[18]Irwin S. Bernstein, William A. Mason, "Group formation by rhesus monkeys", ELSEVIER, Animals Behavior, Volume 11, Issue 1, January 1963, Pages 28–31.

[19]Dario Maestripieri, Christy, "Behavior and Social Dynamics of Rhesus Macaques on Cayo Santiago", pp 247-262, genetics and behavior of Rhesus macaques, Developments in Primatology: progress and prospects Springer New York, 2012.