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Energy Efficient Optimized LEACH and SEP Routing Protocol for WSN

Manjya Naik R, G A Bidkar

Abstract: ***We all know how Wireless Sensor Network (WSN) is making its way in the modern world and how its application is growing effectively. It has been useful technology which helps to transmit and receive the data. In WSN, all information of physical parameter is sensed and processed by the sensor nodes. Along with the growth of technology in WSN, growth of sensor node is also in progress, it means that size of sensor node is getting reduced. Due to this dimension of the battery of the sensor node is also decreases. Hence Power storage of the battery is also reduced which is a demerit in WSN. But in sensor network replacement of battery is not possible. So we can increase the energy efficiency of sensor node by using LEACH protocol. This protocol helps us to increase life span of network. For heterogeneous network, LEACH produces greater unstable region. To the network stable the paper proposes another protocol is Stable Election protocol (SEP). In this paper LEACH and SEP protocol are tested with MATLAB simulation and comparison of both has done.***

Keywords**:** ***LEACH, LEACH-C protocol, SEP, WSN, Sensor node, cluster member and Cluster head.***

I. INTRODUCTION

In communication field, WSN plays an important role.WSN has plenty of sensor nodes, they are of micro size. Hence its battery dimension is also tiny. The lifespan of network reduces due to the small size of the battery as it stores small amount of power.

In case if the efficiency of the sensor node is not increased means it majorly affects the rural region at replacement of battery is not possible. So, overall objective is to improve the energy effectiveness of the network, which in turn improves lifespan of the network. So LEACH protocol is proposed.

In LEACH, we assumed that the sensor node of the network have same amount of energy which can be called as homogeneous network. In homogeneous network the lifetime of sensor node is high but it produces greater instability region. To overcome the stability problem, SEP protocol is proposed which provides more stable region. In SEP, the chances of selection of sensor node depend on the initial energy of node in heterogeneous network.

II. METHODOLOGY

A. Low Energy Adaptive Clustering Hierarchy Protocol

LEACH is a routing protocol whose purpose is to gather the information and transfer information to sink. LEACH is based on MAC protocol which uses TDMA technique.

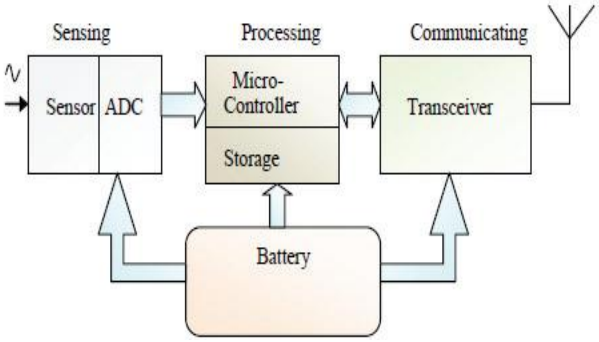

Fig. 1 Block diagram of a sensor node [5].

The important objectives of LEACH are:

- Increasing the lifetime of network.
- Each sensor node of the network decreases the energy consumption.
- It reduces the number of communication messages by using the data aggregation.

In leach protocol CLUSTER HEAD (CH) selected in a random fashion based on probabilistic formula. The task like sensing the data, transmitting the data to the CH is performed by sensor node. CH performs more tasks which are gathering, processing and sending of information to Base sink (BS) compared to cluster member and consumption energy is also more in CH when compared to cluster member. In LEACH each and every cluster member acts as a CH based on probabilistic formula. As process moves on the energy consumption of the network is increased. In this protocol sensor node energy is equally distributed and energy consumption in balancing mode because of this life span of sensor node increases [1].

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* Correspondence Author
Manjya Naik R, M.Tech IV SEM, Department of E and C Engineering at Sri Dharmastalla **Manjunatheshwara** College of Engineering and Technology, Dharwad, Karnataka, India. E-mail: manjyanaik@gmail.com
Dr. G A Bidkar, Professor, Department of E and C Engineering at SDMCET, Dharwad, Karnataka, India. E-mail: gabidkar@rediffmail.com

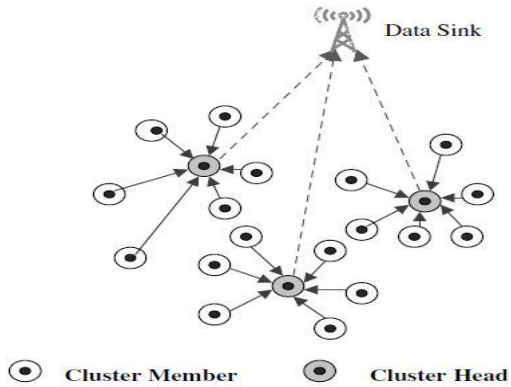

Fig. 2 LEACH network model

Basic operation of LEACH can be categorized into two distinct phases:

- Setup phase
- Steady- state phase

Setup phase: This phase performs two stapes one is for Cluster head selection and another one is for Cluster formation. In this each cluster member n selects a random number that is v which ranges from zero to one. Threshold T(n) is calculated using the below formula which is given by

$$T(n)=\begin{cases}\frac{p}{1-p(r \bmod \frac{1}{p})} & \text{if } n \in G \\ 0 & \text{else where}\end{cases} \quad (1)$$

Where, p is the optimal CH selection probability and r is the current round

G = group of cluster-members, in last (1/p) turns cluster member are not selected as CH.

The node will become CH only when the value of v is less than reference values. The value of random value v > reference T(n) than the given will not become cluster head. Once the Cluster herd selection process is completed the CH sends advertisement message (ADV) to the remaining sensor node in the network it has become Cluster head for this round based on received signal strength of advertisement message each sensor node find outs it's CH for this round. Each cluster member transmits a joint-request message back to its chosen CH. The whole process explained above defines the Cluster Formation.

Steady state phase: This phase represents the Information communication and its takes greater time for processing the data related to the Setup phase because of TDMA and CDMA techniques used in this period. In this process, CH fixed the time interval to each cluster member for sending the data. Due to this collision of signals during communications can be avoided.CH receives data from all the cluster members, then by the process of aggregation data is compressed and it finally sends to the sink. From various CH the data packet moves to the base station using CDMA techniques, to avoid interference. The process is continued like this manner, one turn is finished with the data formatting of next turn and also the method continued to be within the same way till the entire energy of the cluster member goes to die.

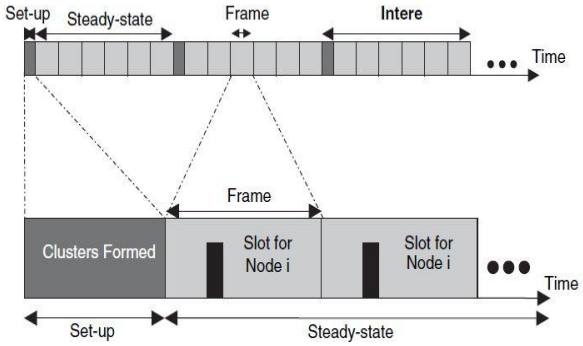

Fig. 3 Phases of-LEACH

From the two phases it is explained that, 1st phase: cluster heads are elected and clustering is formed. 2nd phase cluster member sends information packet to CH and finally CH sends data to base station using Multiplexing techniques.

B. LEACH- C

In this routing protocol sink creates the clustering process on the basis that cluster member's location and energy information is collected by the sink. Average energy is calculated by the base station of the WSN and it notices only that cluster member whose energy is greater than average-energy, as it acts as a cluster head. Simulated annealing algorithm is applied by candidate node to reduce the objective function. This algorithm is energy efficient while transmitting data from cluster member to cluster head and it minimizes the total sum of squared distance between the entire cluster member and the nearest cluster head. The occurred CH and their cluster member will be broadcasted to the WSN. If its ID of the cluster member matches with ID of CH it selects himself as a CH otherwise it finds the TDMA to send the information to respective CH.

LEACH and LEACH-C has same data transmission phase. LEACH-C has the advantage that, energy consumption is equally distributed between cluster members by placing CH into the centre of cluster. A sensor node carries the GPS receiver set but about the energy consumption balancing it does not assure in whole network.

C. Energy model for LEACH protocol

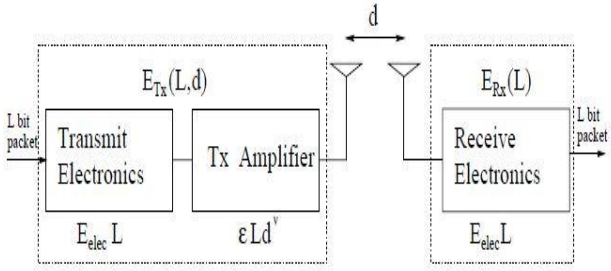

Fig. 4 Radio energy dissipation model [4].

In LEACH protocol sensor node energy dissipation can be calculated by making use of mathematical equation from the radio energy dissipation model. Table I shows the abbreviation referred in the equations and simulation. According to radio energy dissipation model the Energy loss in the transmitter node is given by below equation

$$E_{Tx}(l, d) = \begin{cases} L \cdot Eelec + L \cdot €fs \cdot d^2 & \text{if } d \le d_0 \\ L \cdot Eelec + L \cdot €mp \cdot d^4 & \text{if } d > d_0 \end{cases} \quad (2)$$

The threshold distance is calculated using the equation

$$d0 = \sqrt{\frac{\epsilon fs}{\epsilon mp}} \quad (3)$$

Assume Area 'A' = MXM square meter and 'N' represents the number of nodes that are uniformly distributed over that area. For ease, we assume that base station is located in the middle of the network and distance between node and sink should be less than or equal to d_0.

During a round the energy dissipated in the CH node is given by the following formula

$$E_{CH} = L * E_{elec} \left(\frac{n}{k} - 1\right) + L * E_{DA} \left(\frac{n}{k}\right) + L * E_{elec} + L * €fs * d^2_{toBS} \quad (4)$$

The energy used in a cluster member is given by

$$E_{nonCH} = L * E_{elec} + L * €fs * d^2_{toCH} \quad (5)$$

Assume that, the sensor nodes are uniformly distributed in the field it can be given by the below equation

$$E\left[d^2_{toCH}\right] = \iint (x^2 + y^2)\, \rho(x, y) dx dy = \frac{M^2}{2\pi k} \quad (6)$$

The dissipation of energy in a cluster per round is given by

$$E_{cluster} = E_{CH} + \left(\frac{n}{k}\right) E_{nonCH} \quad (7)$$

The total energy dissipation in the network is given by

$$E_{Tot} = L * \left(2NE_{elec} + N * E_{DA} + €fs \left(kd^2_{toBS} + N\frac{M^2}{2\pi k}\right)\right) \quad (8)$$

To achieve CH, adequate chance of the node can be calculated by

$$P_{opt} = k_{opt} / N \quad (9)$$

From the simulation results we can conclude that in this case sink is located in the centre of sensor area.

Table- I: Short forms.

Short forms	Meaning
$E_{TX}(l,d)$	Total energy loss of transmitter
l	Counts of bits in a Data packets
$E_{(elect)}$	Energy loss of transmitter/receiver
$E_{(fs)}$	Energy dissipation of amplifier for air propagation
$E_{(mp)}$	Energy dissipation of amplifier for multipath propagation
K	Path loss exponents
d	Distance between transmitter and receiver
d_0	Threshold or reference distance
$E_{RX}(l,d)$	Total energy dissipation of receiver
E_{DA}	Data aggregation energy
A	Field of WSN
N	Total counts of sensor node in network
E_0	Initial energy of a sensor node
p	Adequate CHS probability

D.SEP protocol

SEP protocol can be defined as a secondary energy heterogeneous sensor network model, this includes two type of nodes with distinct number of energies, known as common node and advanced node. Usually less initial energy is gained by common nodes than the advanced nodes. Quality energy weighted CH election algorithm is adopted by heterogeneous nodes, here more opportunities is occupied by the advanced nodes to serve as CH, hence balances the energy of heterogeneous nodes. Let us assume that 'N' be the number of nodes and 'm' represents the ratio of number of advanced nodes to the total number of nodes.

Therefore, for all the nodes energy is given by the expression,

$$N(1-m)*E_0 + N*m*E_0*(1+\alpha) = E0(1+\alpha m) \quad (10)$$

Where, E_0- implies the initial energy of normal node.

α- Represents the ratio of extra energy of the advanced node to the energy of the normal node.

When homogeneous network is compared with the heterogeneous network, we can observe that the density in the heterogeneous network has not changed, so we can say that optimal CH ratio is still in the manner with the optimal CH ratio of homogeneous network. Here, it can be assumed that the network consist of N*(1+mα) ordinary sensor nodes and their initial energy E_0 and adequate chance of cluster member to be a CH is $p_{(opt)}$.

From the LEACH protocol optimal CH number calculation method, there is a probability to become CH among the common node and advanced nodes which are represented by P_{nrm} and P_{adv} respectively.

$$p_{nrm} = (p_{out} / (1+\alpha m)) \quad (11)$$

$$padv = (p_{out} / (1+\alpha m)) * (1+\alpha) \quad (12)$$

In the SEP protocol common node election threshold is given by,

$$T(s_{nrm}) = \begin{cases} p_{nmr} / (1 - p_{nmr}(r \bmod *(1/p_{nrm}))) & \text{if } s_{nrm} € G \\ 0 & \text{or else.} \end{cases} \quad (13)$$

Where, r implies counts of currently executed turns. G-is group of nodes, that would not be considered as CH in the turn. Advanced node election threshold is given by,

$$T(s_{avd}) = \begin{cases} p_{(adv)} / (1 - p_{(adv)}(r \bmod *(1/p_{(adv)}))) & \text{if } s_{nrm} € G^1 \\ 0 & \text{or else} \end{cases} \quad (14)$$

Where, G^1-represents the process of gathering advanced nodes which are not considered as CH in the turn.

The common nodes and the advanced nodes randomly create a number between 0 and 1, which can be compared with $T(s_{nrm})$ and $T(s_{adv})$ respectively. If we generate a small digit, then that node can be elected as CH, otherwise it is just a member node. Once the CH node is discovered the entire message of network is broadcasted and the remaining nodes select the clusters which are with stronger signal based on received signal and the strong signal node is notified correspondingly.

Once the cluster is created, activities of the node are carried out by TDMA schedule and the sensor node sends data to its own time slot. The sub-nodes information's are gathered by the CH and the information will be transmitted to sink node after the data fusion.

In this process, every time the complete network enters the stage of cluster formation and then it will be a new round of CH selection process.

III. SIMULATION USING MATLAB

LEACH, LEACH-C and SEP protocol simulation and analysis is accomplished by MATLAB.

The parameter consider for results are shown in Table-II.

From the simulation some generalized conditions are noted below

- Sensor nodes are randomly distributed in the field and all the normal nodes which are of same energy are homogeneous nature.
- The cluster member devices and sink are immobile.
- Dimensions of networks are fixed
- Due to heterogeneous nature of nodes in WSN
- LEACH reaches the unstable operation faster as it is sensitive in nature for heterogeneity
- As we observed that SEP protocol extends the stable region, the throughput in SEP protocol is higher than that of present clustering protocol
- SEP protocol is more flexible than LEACH in showing that, it consumes the extra energy of advanced nodes- SEP obtains longer stability region for greater value of extra energy.

Table-II: Parameters of simulation

Parameter	Value	Units
A	200*200	m^2
N	200	
E_0	0.5	Joule
$E_{(elec)}$	50	nJ/bit
$E_{(fs)}$	10	$pJ/bit/m^4$
$E_{(mp)}$	0.0013	nJ/bit
$E_{(DA)}$	5	nJ/bit
L	4000	Bits

III. RESULTS AND ANALYSIS

In the result and analysis, we are comparing the SEP protocol with LEACH as per the same heterogeneous settings and advanced nodes extra initial energy is uniformly distributed among the entire cluster member in the area.

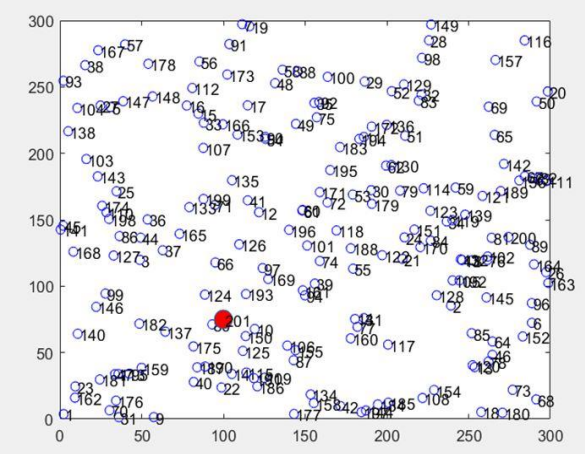

Fig. 5 Basic LEACH

Figure 5 shows the number of sensor nodes distributed in the field.

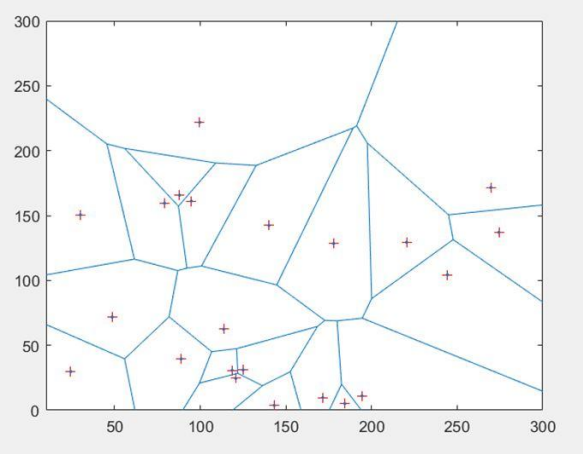

Fig. 6 LEACH Clustering

Figure 6 shows the formation of clustering in LEACH.

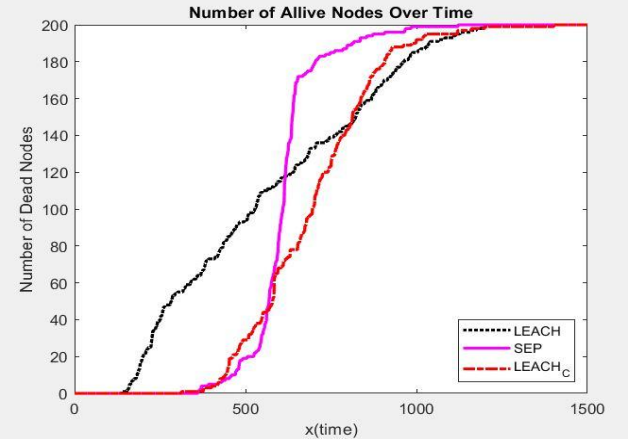

Fig. 7 shows the count of alive nodes over rounds

The count of dead nodes w.r.t the number of rounds. It is noticed that LEACH has both shortest Stability and Instability compared to other routing protocol. As the reliability of LEACH is higher than both SEP and LEACH-C, hence SEP has relatively less stable.

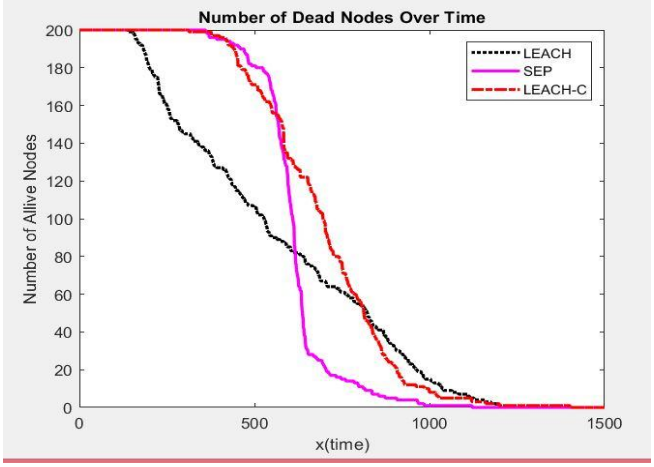

Fig. 8 the number of dead nodes over time

This graph describes, X axis implies number of turns and Y axis is the number of alive nodes. When the first cluster member of LEACH and LEACH-C protocol becomes fails around 585thturn and 600thturn respectively. LEACH and LEACH-C routing protocol suddenly drops at the 601th round of a cluster member. At the 1300th round of cluster member and 1500th round both LEACH and LEACH-C protocol become dead. The sensor node of the SEP start to fail relatively slow after 1100th turn and all cluster members fails at 1501th turn.

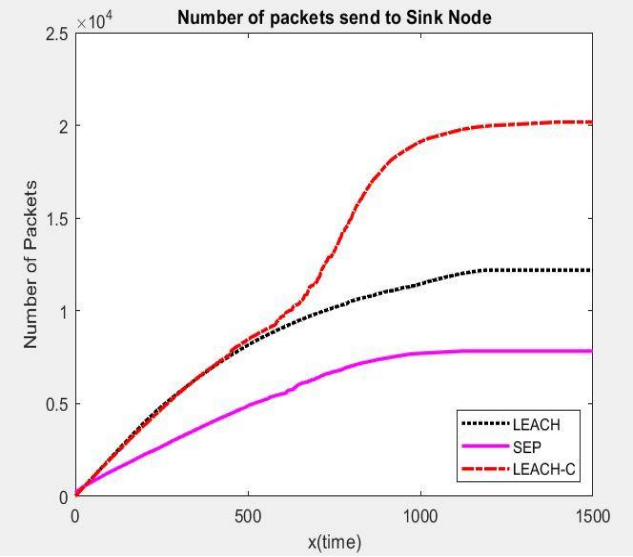

Fig. 9 Counts of data packets sends to sink

In this figure LEACH-C sends more number of data packets compare to other two routing protocol.

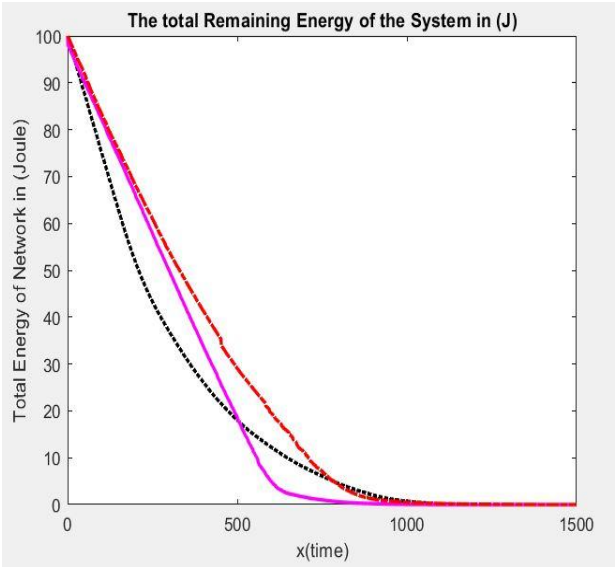

Fig. 10 the total remaining energy of the system in joule

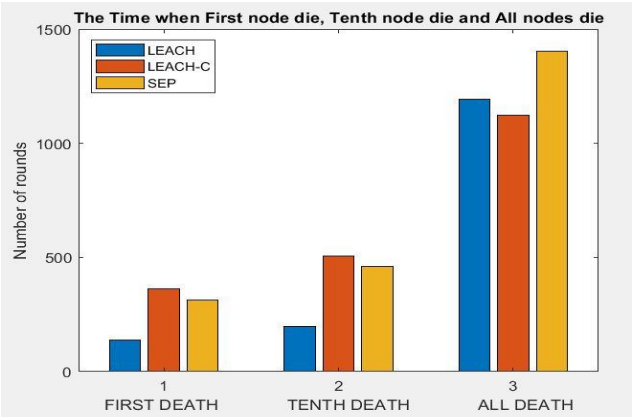

Fig. 11 the time when 1st node die, 10th node die and All nodes die

This bar chart describes, which cluster member is going to death condition in which round. SEP has comparatively less death cluster member.

IV. CONCLUSION

WSN is implemented in many of regulating application. Energy based routing protocol increases the life span of network. Here energy effective protocol called LEACH C is proposed and it aims at improving the life span of network from the higher stage of CH election on the basis of residual energy. We also proposed SEP protocol in this paper, every cluster member in a unique two level hierarchical network selects itself as a CH on the basis of its primary energy. These routing protocols are acknowledged in respect to different important characteristics of network those are lifespan of network, Throughput, information packets send to sink.

From the result and analysis, we found that for heterogeneous network LEACH produces higher unstable region. It can be overcome by SEP protocol which yields higher stability region for greater value of additional energy brought by advanced nodes.

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AUTHORS PROFILE

Mr. Manjya Naik R is final year M.Tech student, Department of E and C Engineering at Sri Dharmastalla Manjunatheshwara College of Engineering and Technology, Dharwad, Karnataka, India.
He is graduated from B. V. Bhoomaraddi College of Engineering Technology. Hubli, Karnataka in Department of E and C engineering. He is pursuing Masters in Digital Electronics from SDMCET, and he has scored 9.41 CGPA till third semester. He also 6 years of teaching experience as lecturer at Government Polytechnic Harapanahalli, Ballery (Dist) Karnataka.

Dr. Gopal A Bidkar, Professor in the Department of E and C Engineering at Sri Dharmastalla Manjunatheshwara College of Engineering and Technology, Dharwad, Karnataka, India. He is graduated from PDA College of Engineering, Gulbarga Karnataka in the Department of E and C engineering. Master degree in Power Electronics from PDA College of Engineering, Gulbarga.Ph.D from Gulbarga University, Gulbarga. He has Guided 7 under Graduates.and 15 Post Graduates. He has Conducted 2 Conferences and 8 Workshops. Published 15 number of papers at International Journal and 10 at conferences and life member of IETE and ISTE.