Maximizing Network Lifetime through Varying Transmission Radii with Energy Efficient Cluster Routing Algorithm in Wireless Sensor Networks

T. Venu Madhav and N. V. S. N. Sarma

***Abstract*—One of the major issues in wireless sensor network is developing an energy-efficient routing protocol. LEACH is very effective in enhancing lifetime of the nodes from routing aspect. This paper proposes the scheduling of energy efficient cluster nodes close to the base station called EECL algorithm. Both LEACH and EECL algorithms have been varied with different transmission radii and compared for the improvement of network lifetime. Simulation results show that there has been significant improvement in energy conservation of wireless sensor networks with EECL.**

***Index Terms*—WSN, data aggregation, network lifetime, EECL, transmission radius.**

I. Introduction

Wireless sensor networks (WSNs) usually contain thousands or millions of sensors, which are randomly and widely deployed. Sensors are powered by battery, which cannot rechargeable after deployment. But sensor networks are designed to last. Sensor nodes collaborate to be able to cope with the environment: they operate completely wirelessly, and are able to spontaneously create an ad hoc network, assemble the network themselves, dynamically adapt to device failure and degradation, manage movement of sensor nodes, and react to changes in task and network requirements as shown in Fig. 1. Thus, energy efficiency is an important issue in sensor networks. Since routing consumes a lot of energy, an efficient routing scheme in sensor networks is also important [1].

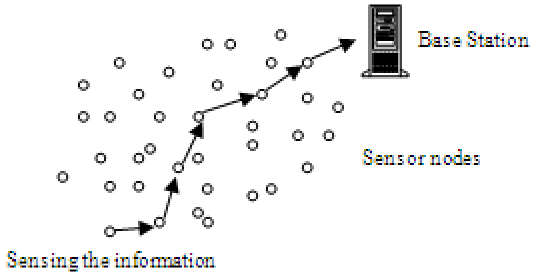

Fig. 1. Wireless sensor network

Low Energy Adaptive Clustering Hierarchy (LEACH) is a clustering-based protocol shown in Fig. 2. LEACH utilizes randomized rotation of local cluster base stations evenly distribute the energy load among the sensors in the network. It uses localized coordination to enable scalability and robustness for dynamic networks and incorporates data fusion into the routing protocol to reduce the amount of information that must be transmitted to the base station. In this paper, an improved LEACH protocol for data gathering and aggregation is proposed. Such innovation can extend the lifetime of the whole network due to much less energy dissipation for data transmission to base station [2].

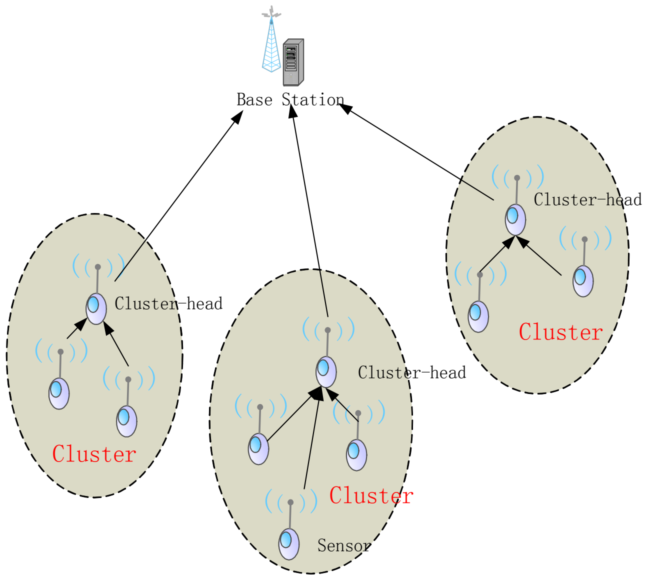

Fig. 2. Operation of LEACH algorithm

The operation of LEACH is broken up into rounds, where each round begins with a set-up phase, when the clusters are organized, followed by a steady state phase, when data transfers to the base station occur. In order to minimize overhead, the steady-state phase is long compared to the set-up phase.

LEACH outperforms several static clustering algorithms by requiring nodes to volunteer to be high-energy cluster-heads and adapting the corresponding clusters based on the nodes that choose to be cluster-heads at a given time. At different times, each node has the burden of acquiring data from the nodes in the cluster, fusing the data to obtain an aggregate signal, and transmitting this aggregate signal to the base station. LEACH is completely distributed, requiring no control information from the base station, and the nodes do not require knowledge of the global network in order for the LEACH algorithm to perform.

LEACH is based on the three factors:

1) Extension of network lifetime

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The authors are with the National Institute of Technology Warangal, Deemed University, Warangal, India (e-mail: venut@ nitw.ac.in; e-mail: sarma@nitw.ac.in).

2) Power consumption of each senor node‘s is reduced.

3) Data aggregation helps to reduce the traffic between communicating messages from all the sensor nodes’.

The use of clusters for transmitting data to the base station leverages the advantages of small transmit distances for most nodes, requiring only a few nodes to transmit far distances to the base station.

In this paper, the scheduling of energy efficient cluster nodes near to the base station collect the corresponding cluster nodes information. This gathering reduces the power consumption [3] and improves the network lifetime compared to Low Energy Adaptive Clustering Hierarchy algorithm. The cluster nodes in this algorithm collect information from sensor nodes and send to the energy efficient cluster node which is close to the base station. The cluster node close to the base station with distance less than the other cluster nodes is selected as energy efficient cluster node. This node gathers information from other cluster nodes and sends to base station reducing the power consumption dissipation compared to other algorithms mentioned above. The network lifetime has been significantly improved by varying through different transmission radii 10 degrees, 20 degrees and 30 degrees for which the results explained in Section IV.

II. Energy Efficient Cluster node Routing Algorithm for WSN

The operation of this algorithm as shown in Fig. 3 is broken into rounds, where every round begins with cluster set up phase and in next phase the data which is aggregated [4] by the energy efficient cluster node traverses to the base station. The nodes are homogeneous, means that all the nodes in the field have the same initial energy.

The new algorithm guarantees that every one of them will become a cluster head exactly once every *k/ (p+1)* rounds where *k=[r/ (1/p)]*. The number of rounds refers to *k/ (p+1)*, as epoch to the cluster nodes throughout the entire network.

When clusters are created, each node decides whether to become cluster head or not for the current round. This is decided by the suggested percentage of cluster heads for the total network. This decision is made by the node ‘n’ choosing a random number between 0 and 1.

If the number is less than Threshold value *Th (n)* , the node becomes a cluster head [5] for the current round. Using this threshold, each node will be a cluster head at some point within ***1/p*** rounds. The nodes that are cluster heads in current round cannot be cluster heads for the next ***1/p*** rounds. The probability that the remaining nodes that have not become cluster heads must be increased, since there are fewer nodes eligible to become cluster heads. Each node that has elected itself as a cluster head for the current round broadcasts an advertising message to the rest of the nodes and cluster head communicates within the cluster and forwards the information to the nearest node which is closer to the BS so that energy dissipation can be reduced .

The threshold is given by

$$Th(n) = \frac{P}{(1-P)*[(r-1)*(1/P)]} \quad (1)$$

For this “cluster head advertisement” phase, the cluster heads [6] use a CSMA MAC protocol. All the cluster heads Transmit their advertisement using the same transmit energy. The non cluster head nodes must keep receivers on during this phase of setup to hear the advertisements of all the cluster head nodes. After this phase is complete, each non cluster head node decides the cluster to which it will belong for this round. This decision is based on the received signal strength of the advertisement. In case of ties, a random cluster head is chosen.

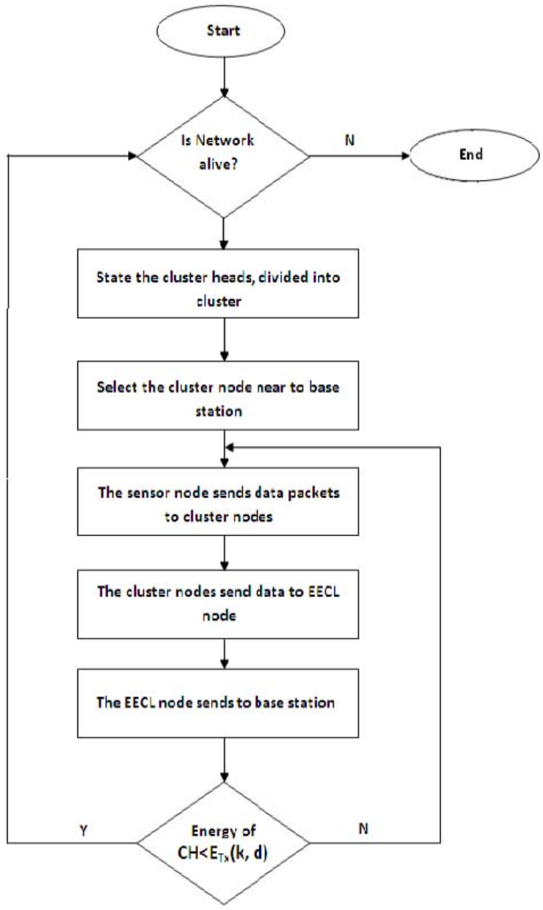

Fig. 3. Flowchart of the algorithm.

After each node has decided to which cluster it belongs, it must inform the cluster head node that it will be a member of the cluster. Each node transmits this information back to the cluster head again using a CSMA MAC protocol. During this phase all cluster head nodes must keep their receivers on. The cluster head node receives all the messages for nodes that would like to be included in the cluster. Based on the number of nodes in the cluster, the cluster head node creates a TDMA schedule informing each node when it can transmit. This schedule is broadcast back to the nodes in the cluster.

III. Energy Efficient Cluster Node (EECL) Data Transmission

Once the clusters are created and the TDMA schedule is fixed data transmission can begin. Assuming nodes always have data to send, they send it during their allocated transmission time to the cluster head. The transmission system uses a minimal amount of energy. The radio of each non cluster head node can be turned off until the nodes allocated transmission time, thus minimizing energy dissipation in these nodes. The cluster head node must keep its receivers on to receive all the data from the nodes in the cluster.

When all the data has been received, the energy efficient cluster node has to receive all the data from remaining cluster nodes. The data aggregation [7] of all the remaining cluster nodes including the corresponding sensor nodes that are associated to the energy efficient cluster node is performed. The resultant data aggregation from the energy efficient cluster node should be processed to send the information to the base station. The base station receives the information from the energy efficient cluster node every round. In this way the new algorithm as shown in Fig. 4, reduces the energy dissipation of cluster heads by sending the information to the cluster node near to the base station with maximum energy of that epoch from sensor nodes and able to prolong the network lifetime compared to other algorithms mentioned earlier.

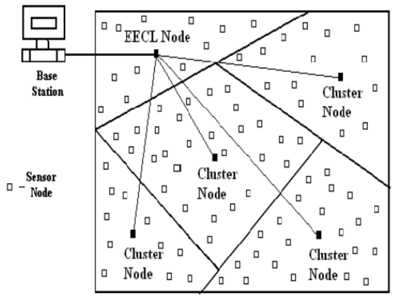

Fig. 4. The network operation of this algorithm.

A. Energy Dissipation of the Network

According to radio energy dissipation model [8] to achieve signal to noise ratio in transmitting k bit message over a distance d, the energy expended by radio is given as

$$E_{Tx(k,d)} = E_{elec} * kbit + E_{fs} * kbit * d^2 \quad (2)$$

where E_{elec} is energy dissipated per bit to run transmitter or receiver circuit, *kbit* is the control packet length for every time, E_{fs} depends on the transmitter amplifier model, *d* is the distance between sender and receiver.

To receive a k bit message the radio expends energy given

$$E_{Rx(k,d)} = E_{elec} * kbit \quad (3)$$

Assume an area over which 'n' nodes are uniformly distributed. If we assume sink is located at any place in the field, and distance of any node to the sink less than do i.e..,

$$d_o = \sqrt{(E_{fs})/(E_{ms})} \quad (4)$$

Data aggregation is the processing cost of a bit per report to sink. The energy transmission for non cluster head is obtained as

$$E = E_{elec} * kbit + E_{fs} * kbit * d^2 \quad (5)$$

d = distance between sensor nodes and its cluster head.

The data aggregation of the associated cluster head is given by

Total packet length = kbit*(all sensor nodes aggregation aggregation associated to cluster)

Then the energy transmission for cluster head is given by

$$E = EDA * totalbit + E_{fs} * kbit * d^2 \quad (6)$$

totalbit = packet length

d = distance from cluster head to node

The packet length of EECL node is given as,

Total packet length = totalbit *(sum of remaining CHs aggregation)

The data aggregation of energy efficient cluster node is given by

$$E1 = EDA * total\ packet\ length \quad (7)$$

$$E2 = E_{elec} * (sum\ of\ CHs\ aggregation) + EDA * (EECL\ nodes\ aggregation)(total\ bit) \quad (8)$$

The energy transmission of EECL node to base station is given by

$$E = E1 + E2 + E_{fs} * totalbit * d^2 \quad (9)$$

where *d*=distance from EECL node to base station.

The optimal clustering created by this algorithm focuses the energy consumption is well distributed over all the sensors and total energy consumption is minimum compared to the other algorithms discussed earlier.

IV. Simulation Experiments and Analysis of Results

This paper adopts the same wireless energy model used in [9]. The wireless transmission module can realize the transmitting power control or be shut down automatically in order to avoid receiving unnecessary data according to the distance between the nodes. For our simulation, we have assumed that the communication energy dissipation is based on the first order radio model as discussed in Section III.

Matlab tool is used to simulate the network. Specific simulation environment is: 100 nodes are randomly dispensed in the 100m×100m square region, the base station is located at (-20,70).We will measure the lifetime of the network by the number of rounds until one node ceases functioning. In this situation, it is much more important to minimize the energy dissipation of the most heavily loaded nodes than to decrease the average energy dissipation.

The parameters of algorithm are given below:

TABLE I: The Parameters Used In The Simulations

Parameter	Value
Size of the network	100 x 100m
Bandwidth	1 MB
E_{elec}(Radio electronics energy)	50nJ/bit
E_{amp}(Radio amplifier energy)	100 pJ/bit/m^2
E_{init}(Initial energy of node)	0.5J
Number of nodes	100
Data aggregation (EDA)	0.5nJ/bit
Control Packet length of EDA	2000 bytes
Transmission Radii	10m,20m,30m
Packet length	200 bytes

p=0.05, where *p* is the probability to become cluster head per every round.

A. Results

The simulations made between these two algorithms have been compared with the above parameters mentioned and the following readings with the respective graphs have been shown below.

In order to verify the performance of the algorithm, comparison is made between the LEACH and proposed algorithm with different transmission radii i.e. 10m, 20m and 30m.

B. Lifetime Improvement with Transmission Radius 10m:

The simulations made between these two algorithms have been compared with the above parameters mentioned and the following readings with the respective graphs have been presented below.

As the length of the life cycle of the network directly reflects the performance of WSN, comparison is made between proposed algorithm and LEACH in two aspects: the average energy consumption and the number of survival nodes.

As shown in Fig. 5, LEACH appeared death of node at the 810 round shown in blue line while in new algorithm the same occurred at the 1260th round in red line. The death of half of the nodes appeared at the 1250th round using LEACH while with present algorithm the same appeared at the 1750th round. All nodes die at the 1550th round in LEACH while for present algorithm it is at the 2120th round. Simulation result indicates that the new algorithm has more than 30% extension of network life compared with that of LEACH.

Fig. 6 shows the average energy consumption diagram of the proposed algorithm and the LEACH. The blue line indicates LEACH and red line indicates EECL. It reflects the change of the average power consumption of the network with time elapsing. The total energy of 100 nodes in network is 50J. LEACH appears the death of node at the 810th round, where consumption of energy in LEACH is more than the new algorithm as death of the node here appears at 1260th round. When all nodes die in both algorithms, the new algorithm has 25% less energy dissipation compared to LEACH as shown in Fig. 6 below.

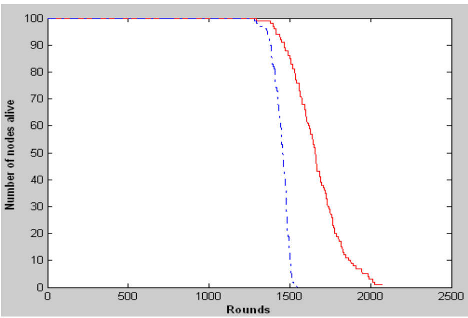

Fig. 5. Survived nodes of two algorithms.

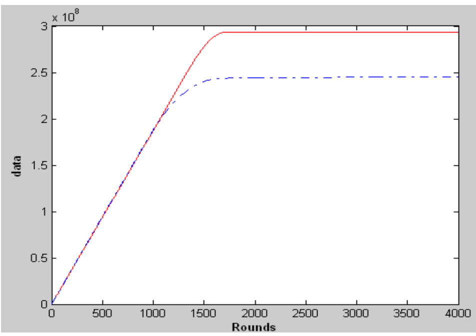

Fig. 6. Energy consumption of two algorithms.

C. Lifetime Improvement with Transmission radii 20m and 30m:

Comparison has been made between these algorithms for life time improvement by varying transmission radius in steps of 10 m. The network life time is improved in both the algorithms however, the improvement is more for EECL In the graph shown below in Fig. 7, the blue line indicates the LEACH where the death of the first node appeared at 1200th round. The lifetime of the network completes at 1790th round when all nodes dissipate complete energy. The EECL algorithm indicated with red line gives death of first node at 1350th round and network completes energy at 2250th round. The energy consumption is also reduced to some extent with the above explained statistics of improved lifetime shown in the graph below (Fig. 8).

The comparison of these two algorithms had done for the comparison of energy dissipation by varying these with the transmission radii taken in consideration as per the simulations are shown in this work. The proposed algorithm exhibited less energy dissipation compared to the existing algorithm LEACH with the above transmission radius with the effect of the EECL node. Thereby, the other cluster heads energy dissipation is automatically reduced.

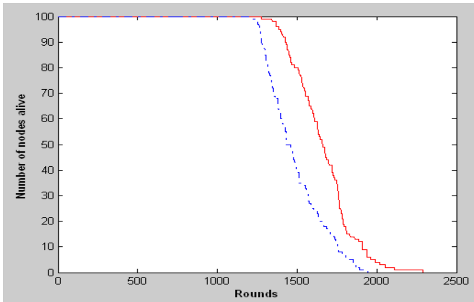

Fig. 7. Survived nodes of two algorithms.

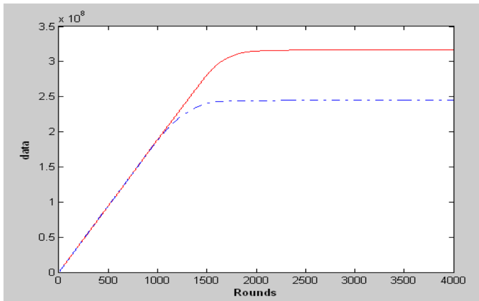

Fig. 8. Energy consumption of two algorithms.

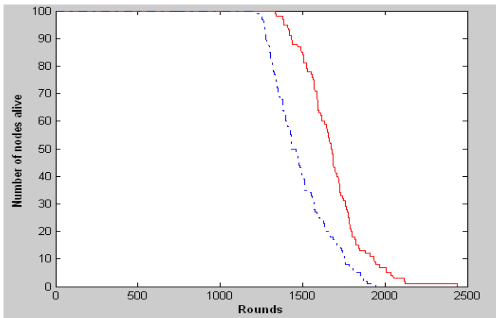

Fig. 9. Survived nodes of two algorithms.

When the transmission radius of 30 meters is taken into consideration, the LEACH algorithm, the death of first node in the network appears at 1250th round and death network completes at 1820th round. In EECL algorithm first node exits at 1400th round and network completed at 2450 rounds as shown in Fig. 9. Thereby the energy dissipation is significantly reduced with increase of transmission radius with the both algorithms as shown in Fig. 10.

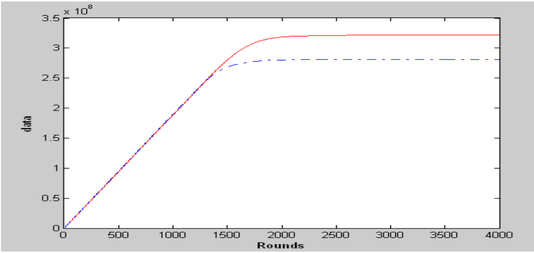

Fig. 10. Energy consumption of two algorithms.

The network lifetime and energy dissipation compared with LEACH and EECL by varying different transmission radii is displayed:

TABLE II: NETWORK LIFETIME WITH DIFFERENT RADII

Algorithms	10m	20m	30m
LEACH	1550	1790	1820
EECL	2100	2250	2450

The reduction of energy dissipation of EECL when compared with LEACH with transmission radii is given below:

TABLE III: ENERGY DISSIPATION REDUCTION FROM DIFFERENT RADII

Algorithm	10m	20m	30m
EECL	25%	30%	35%

Both the algorithms have been compared with different transmission radius which leads to significant improvement in network lifetime with the results explained above.

V. CONCLUSION

We had proposed the EECL algorithm and its comparison with LEACH algorithm shows the network lifetime and energy consumption has been significantly improved with different transmission radii taken in consideration. The EECL algorithm outperformed LEACH in these issues and provides better energy conservation to wireless sensor network energy efficient routing protocol. In WSN, routing protocols which involve in energy conservation in developing energy efficient models can be considered for future research work.

REFERENCES

[1] L. V. Hosel, T. Nieber, J. Wu. (December 2004). Prolonging the Lifetime of Wireless Sensor Networks by Cross-layer Design. *IEEE Wireless Communications.* [Online]. Volume: 11 Issue: 6. pp. 80-86. Available:http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=arnumber=1368900.

[2] W. Bo, H.-Y. Hu, W. Fu, "A pseudo LEACH algorithm for wireless sensor networks". in *Proc. IMECS*, March 2007, pp. 1366-1370.

[3] S. Wazed, A. Bari, A. Jaekel, and S. Bandopadhyay, "Genetic Algorithm Based Approach for Extending the Lifetime of Two-Tiered Sensor Networks," in *Proc. IEEE 2nd International Symposium on Wireless Pervasive Computing*, pp 83-87, 2007.

[4] M. Zhang, C. Gong, and Y. Feng, "An Energy-Efficient Algorithm for Maximum Lifetime and Minimum Routing in Wireless Sensor Networks," in *Proc. IEEE International Symposium on Computational Intelligence and Design*, pp. 507-510, 2008**.**

[5] A. Bari, A. Jaekel, and S. Bandyopadhyay.(2008). Clustering strategies for improving the lifetime of two-tiered sensor networks. *Elsevier Computer Communications* (31) [Online]. pp. 3451–3459. Available: http// www.elsevier.com/locate/comcom.

[6] W. B. Heinzelman, A. P. Chandrakasan, and Hari Balakrishnan.(2002) .An application-specific Protocol architecture for wireless micro sensor networks. *IEEE Transactions on Wireless Communications*. [Online] vol. 1, no. 4, pp. 660–670. Available: http// http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1045297&userType=inst.

[7] K. Kalpakis, K. Dasgupta, and P. Namjoshi, "Maximum Lifetime Data Gathering and Aggregation in Wireless Sensor Networks," in *Proc. IEEE International Conference on Wireless Internet*, WICON'05, pp. 138–145, 2005.

[8] A. Bari, A. Jaekel, and S. Bandopadyay, "Maximizing the Lifetime of Two-Tiered Sensor Networks," in *Proc. IEEE Electro/Information Technology Conference*, EIT 2006, MI, USA, pp. 222-226, May 2006.

[9] W. Guifeng, Y. Wang, and X. Tao, "An Ant Colony Clustering Routing Algorithm for Wireless Sensor Networks," in *Proc. IEEE Computer Society*, pp. 670 – 673, 2009.

T.Venu madhav received B.Tech degree (2006) in Electronics and Communication Engineering affiliated to Jawaharlal Nehru Technological University. Later he completed M.Tech in 2009 and also pursuing PhD from National Institute of Technology, Warangal. His areas of interest are Wireless communications and Network Communication protocols. Presently, working in developing energy conservative algorithms and networking protocols involved in above mentioned areas and published papers in 3 International conferences recently.

N. V. S. N. Sarma obtained his Bachelor's degree in Engineering with specialization Electronics and Communications Engineering from College of Engineering, Kakinada, and Jawaharlal Nehru Technological University in the year 1984. His Master's and Doctoral degrees are from Indian Institute of Technology, Kharagapur, India in the year 1985 and 1992 respectively. He worked at Tata Institute of Fundamental Research, Mumbai for a brief period during Feb'86 to July'87. He has been with the department of Electronics and Communications Engineering at National Institute of Technology, Warangal, India at various positions since 1990. He was Head of the department during Sept06 to Feb09. Two students completed their doctorate under his guidance. About 50 papers are at his credit in International and National journals and conferences. His area of interest includes Numerical Electromagnetics, Adaptive antenna arrays, Optical Networks, Wireless Communications and Wireless Sensor Networks.