Energy Efficient clustering-based Routing Protocol Adopting Enhanced Cluster Formation (EERRCUF) Protocol in Wireless Multimedia Sensor Networks

Nirmala Hiremani[1], Tiptur Gangaraju Basavaraju[2]
[1]*Visvesvaraya Technological University, Mysore, India*
[2]*Government SKSJ Technological Institute, Bangalore, India*
(E-mail: nirmalavtupg@gmail.com)

Abstract**—**As the advanced cost efficient technologies are emerging, it is possible to develop powerful nodes in the wireless sensor network (WSN) with reasonable price. The scalar services like humidity, temperature are shifting to real time multimedia applications like audio, video, imaging etc. Target tracking, video vehicle detection, and battlefield intelligence are standard example of wireless multimedia sensor network (WMSN). In this paper energy efficient cluster based routing protocol adopting enhanced cluster formation (EERRCUF) protocol is introduced for the applications like WMSNs. Initially we perform the effective clustering process using particle swarm optimization (PSO) for grouping the nodes according to the geo location properties. By using PSO all the nodes will cluster without residual nodes, subsequently the cluster head (CH) and super CH based on the trusted valued of each node computed by the differential evolution based trust inference (DETI) model. Then, an inter-cluster routing is performed by gravitational search algorithm (GSA). The simulation results show effectiveness of our EERRCUF protocol in terms of Quality of service (QoS) constraints such as energy consumption, link quality, and network lifetime; Quality of experience (QoE) constraints such as structure similarity index (SSIM), peak signal-to-noise ratio (PSNR), and video quality measurement (VQM).

Keywords—*EERRCUF protocol, WSN, WMSN, sensor nodes, clustering, CH, SCH.*

I. INTRODUCTION

There is lot of progress in the field of Wireless Sensor Networks (WSNs) which improves the communication capabilities and help us to perform many simple and advanced multimedia applications in multidisciplinary domain subjects in sensing technology [1]. Developments in Wireless Multimedia Sensor Networks (WMSNs) made collection of data very simple and cost effective. WMSNs can accumulate and transfer multimedia data such as sound streams, pictures, video, as well as scalar information such as temperature, humidity readings [2]. The advancement in micro electro mechanical systems (MEMSs) made possible to have large number of multi-functional nodes in the area of WMSNs [3]. There exist sensor nodes that are low in cost and compact nodes having Complementary Metal Oxide (CMOS) cameras, microphones and other embedded components [4], [5].

Wireless Multimedia Sensor Networks (WMSN) can collects not only the scalar data but also multiple forms of information such as pictures, text, sounds, videos etc. WSN became an active research area in the recent years, because of the rapid growth of the CMOS technology due to the combination of low-power wireless networking technologies and cost-effective hardware such as cameras and microphones. Owing the remarkable advancement in the WMSN has developed with many applications such as environmental monitoring and control, traffic avoidance, target tracking etc. [6]. Due to the fact of WMSNs, produces large amount of multimedia data which has multiple merits while processing the multimedia data makes more data traffic, which requires higher bandwidth, less packet loss and more processing capability. There are two main challenging tasks in WMSN, to handling the multimedia data such as application specialized Quality of Services (QoS) and managing the multimedia information with the limited resources.

With the intention of achieving the QoS in WMSNs, the routing is the essential mechanism which reduces multimedia traffic. Routing itself has been an active research area in the field of WMSN for the past few years. In the routing scheme there are two most crucial concerns which are Metric based path selection and management of routing metrics. In order to fulfil the routing requirements there are two major prerequisites required. The first one is proper selection of routing metrics and appropriate grouping. The second one is mathematical properties of path-weight calculation. Thus the routing metrics performs a vital role in sustaining the QoS by routing protocols [7], [8]. The proper combination of, number of routing metrics along with the cost function (path weight calculation) are considered as optimal links or optimal path. The appropriate combination of various routing metrics decides the optimal functional conventional routing protocols. The bad grouping metrics may result in the degradation of routing performances such as unpredictable data packet loss and makes severe reduction of delivery rate [9].

II. RELATED WORKS

P. Damaraju, M.S. Shayee [10] proposed QoS aware multipath routing protocol. With the intention of fulfilling various constrains of optimization conditions, they found the minimum resource utilization path. They mainly focused on designing the routing protocol that satisfies the multiple QoS constrains with multicast routing problem. Their simulation results showed that, when compared with the traditional best multicast algorithm for the NP complex problem, their proposed fair link finding strategy provide the fine solution.

M.A. Farzan and M. Bagherizadeh [12] proposed QoS Routing method for Wireless Multimedia Sensor Networks for routing using intelligent capabilities in heterogeneous environment with the different battery charging capacities. In the second step of their proposed method is data aggregation which is done by the clustering method. In order to transfer the multiple-steps information from the aggregation nodes to the base station, they used hierarchical tree based on the PSO algorithm which happens in the third stage of their proposed algorithm. By using meta-exploration algorithms, they improved the overall network performance. The major drawback of their proposed method is under certain conditions, network lifetime life time gets reduced.

E.H. Putra et. al. [13] proposed an QoS aware routing optimization algorithm for WMSNs. With the intention of discover the optimal links for transfer the sensed data to base station they have used cross-layer based routing optimization method. With the intention of improving the performances of WMSNs in terms of throughput, packets end-to-end delay and packet drop rate, the routing optimization technique plays an important role. But using this cross layer design method in certain conditions the packet drop rate in increased in multimedia wireless sensor network.

E.H. Putra et. al. [14] proposed routing protocol for multimedia transmission in WMSNs. With the usage of evolutionary programming method, they have developed their proposed energy efficient routing optimization method. With the intention of optimized routing, their dynamic programming considers the residual energy of the nodes. In any case, if the neighbouring nodes has the same minimum energy, then the second priority selection is based on smaller link cost. The main drawback of this method is, the data packets can't be transfer when it has the energy below 60%.

III. ENERGY EFFICIENT ROUTING PROTOCOL ADOPTING ENHANCED CLUSTER FORMATION (EERRCUF) TECHNIQUE

The work function of EERRCUF is consists a set of process are cluster formation, CH, SCH selection and route computation. The detailed description of these processes is described as follows. The system model of proposed EERRCUF technique in WMSN with example trust and routing is given in Fig. 1.

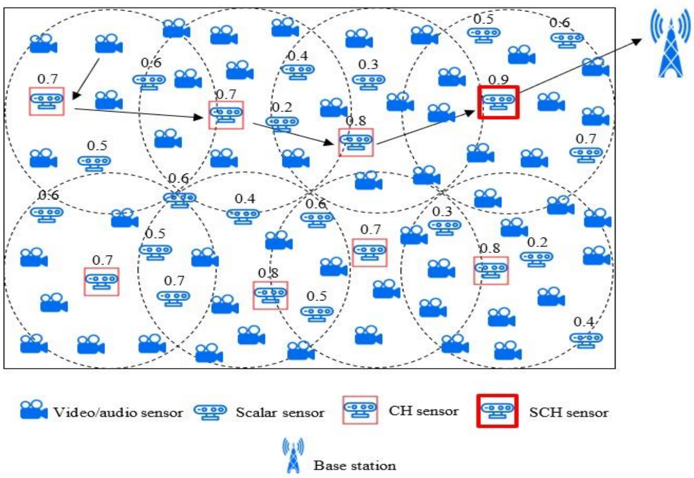

Fig. 1. System model of EERRCUF technique with WMSNs

A. Cluster formation algorithm overview

In this paper, the clustering is progressed by the Particle Swarm Optimization (PSO) [16] algorithm where each and every particle have its own position and velocity. The computation of fitness is progressed based on the particle's position and velocity. At every iteration, local best and global best particles are selected according the fitness value of the particle. Afterwards the position and velocity of the particles are getting updated based on the local best and global best value. The local best is selected based on the best fitness value in that iteration. The global best value is selected based on the overall best fitness value. This progress will continue until there is no changes happening in the fitness value of the successive iterations. With the help of PSO, the fitness of each and every particle is projected to select the cluster particles and the detailed constraints are [16],

- Energy consumption of sensor node(particle)
- Connectivity between sensor nodes
- sensor node's distance within the radio range '*a*' from node *m*
- Energy of the sensor node within the radio range '*a*' from node *m*

The fitness value calculated is used to construct the clusters in the WSN so that no node is left unclustered. The base station initiates the clustering process with the values of position energy, position and velocity. The maximum fitness value is considered to select cluster head.

B. Trust computation algorithm overview

Differential evolution algorithm (DE) appeared by Storn and Price [18] gives considerably better performance in terms of efficiency and robustness on many issues. The algorithm executes two simple operations namely mutation and crossover. For investigating search space and to achieve diversity, the mutation and crossover applied found to be promising.DE is found to be favourable in case of optimization problems. DE starts with a people of NP certain systems which may be represented to as $S_{n,G}$; $n=1,2,\ldots D$, where n denotes number of population and D dimensional vector to the population belongs. The differential evolution based trust inference (DETI) model that has been utilized to optimize the D dimensional vectors is energy consumption, mobility, received signal strength and distance between CH to neighbouring nodes. Distance denotes the transmission distance between CH to neighbouring nodes.

The working of DETI is based on the manipulation and competence of three main operators, mutation, reproduction and selection. Mutation operator is the major operator of DETI and it is the implementation of this operation that makes DETI different from other Evolutionary algorithms. DETI formulation is made by considering parameter values are randomly detached among the lower bound $s_{n,low}$ and the upper bound $s_{n,high}$ as takes after:

$$s_{n,m} = s_{n,low} + rand(0,1)\cdot\left(s_{n,high} - s_{n,low}\right); \quad n=1,2,\ldots D;\ m=1,2,\ldots,PS \tag{1}$$

Keeping in mind the end goal to create a trial vector, DETI calculation first transforms the best arrangement vector $s_{n,best}$, from the present populace by including the scaled distinction of two vectors from the present populace with the mutant vector M_n. Indices i_1 and i_2 are haphazardly chosen with the condition that they are distinctive and have no connection to the molecule list at all (i.e. $s_1 \neq s_2 \neq i$). The mutation operation of DETI applies the vector differentials among the existing population members has been applied to the individual subject of the mutation operation to determine both the degree and direction of perturbation. The mutation process from each group begins by randomly selecting three individuals in the population. The mutation scale factor SF is a positive genuine number, normally short of what one. The procedure of mutant vector era is characterized from Eq. (2).

$$M_n = s_{best} + F\cdot\left(s_{n,i_1} - s_{n,i_2}\right) i_1, i_2 \in \{1,2,\ldots,PS\} \tag{2}$$

The crossover operation is applied to mutant vector M_n, with the intention of increase the diversity of the parameter vector, and the original individuals $s_{n,m}$. The result is a trial vector $TV_{n,m}$, which is computed as follows in Eq. (3):

$$TV_{n,m} = \begin{cases} M_{n,m} & \text{if } \mathrm{rand}(0,1) \le \mathrm{CR} \\ s_{n,m} & \text{Otherwise} \end{cases} \tag{3}$$

The crossover (CR) parameter $(0 \le CR \le 1)$ controls the parameters that the mutation vector is impacting the final trial vector. The process of generation of population and fitness calculation includes 4 steps. The first step is to vector generation and computing the fitness for each vector. The second step is the generation of the trial vector. The third step is selection of crossover or mutation and selection progress and the final step is to select the better vector generation on the basis of fitness function.

The process of computation of fitness of conventional DETI algorithm by multi-dimensional metrics includes consumption of energy, mobility, achieved signal strength and distance between CHs to adjacent nodes. After the trust value computation, CH is determined by base station among multiple nodes present in the cluster that denotes as follows,

$$CH = \sum_{i=1}^{n} \max\left[TV_{n,m}\right] \tag{4}$$

In this equation, ‘i’ represents the ‘n’ number of CHs present in the network and $TV_{n,m}$ is the trust value taken from Eq. (3). Then, base station selects the highest trust value owned CH as SCH among multiple CHs present in the network.

C. Inter-cluster routing algorithm overview

Inter-cluster routing is defined as process of selecting an optimal path from source to destination (BS) and the optimization algorithm is Gravitational Search Algorithm (GSA) [16]. With the intention of the appropriate routing for sending the observed information to the base station we make use of GSA algorithm. To locate the next best node in the route the algorithm sends a request message to its neighbours. The requesting process is repeated by all nodes along the route till the base station. After collecting and aggregating the data, the CH finds the shortest path to reach the SCH and then to the base station. GSA adopts Newton’s law [16] of gravity mentioned below,

$$\mathrm{F} = \mathrm{G}\left[\frac{\mathrm{M_1 M_2}}{\mathrm{R}^2}\right] \tag{5}$$

In this equation, force between the particles is denoted as ‘F’, gravitational constant is denoted as ‘G’ ($G=6.8\times10^{-11}$ m^3 kg^{-1} s^{-2}), mass of the two particles are denoted as ‘M_1’ and ‘M_2’ respectively and distance between the particles is denoted as ‘R’. The next best node is elected by considering the energy between CHs which can be computed with the aid of Eq. (5).

IV. SIMULATION RESULTS

To implement and simulate EERRCUF with various environments are conducted using Network simulator NS2 [17]. The objective of this simulation is to show that EERRCUF algorithm can effectively performed in WMSN. The performance of EERRCUF-WMSN is compared with existing algorithm LQEAR-WMSN [15].

A. *Performance comparison of EERRCUF-WMSN*

The sensor nodes are randomly distributed over an area of size of 1000×1000 m^2. To reflect the multimedia network initial energy of all nodes are kept between 51 to 100 J. The data size is set to 1024 bits. The input video resolution is 1080×720 with 30 frames per seconds.

To imitate the unreliable network normally tend to be error prone, all the sensor nodes are assigned values between 0 to 255, representing the Link Quality Indication (LQI). The LQI are categorised into 4 types namely bad, fair, good and excellent. The simulation parameters are summarised in Table 1. The performance of EERRCUF-WMSN is compared with an existing algorithm LQEAR-WMSN [15] in terms of link quality as bad, fair, good and excellent link; QoS metrics as consumption of energy, life time of the network and available number of paths; and the QoE metrics as PSNR, SSIM index and VQM.

TABLE I. SIMULATION PARAMETERS

Parameters	Values
Number of multimedia sensors	100-1000 (Variable)
Number of scalar sensors	10-100 (Variable)
Network size	1000×1000 m2
Maximum radio range	60 meters
Bandwidth	128 kbps
Initial energy of each multimedia sensors	200 Joules
Initial energy of each scalar sensors	51-100 Joules
Packet size	1024 bits
Simulation time	100 seconds

1) *Link quality comparison*

Table 2 shows the links found for both proposed EERRCUF-WMSN and existing LQEAR-WMSN count. The table 2 represents the number of excellent, good, fair and bad links per path by varying the number of nodes EERRCUF-WMSN and existing LQEAR-WMSN. By analysing the table 2, we conclude that our proposed EERRCUF-WMSN method performed well when compared with LQEAR-WMSN in terms of number of links per path.

TABLE II. NUMBER OF EXCELLENT LINKS PER PATH

Number of excellent links per path					
Number of nodes	***200***	***400***	***600***	***800***	***1000***
EERRCUF-WMSN	40	45	55	60	65
LQEAR-WMSN	20	25	35	40	45
Number of good links per path					
EERRCUF-WMSN	26	30	32	34	38
LQEAR-WMSN	20	22	26	30	35
Number of fair links per path					
EERRCUF-WMSN	30	28	20	15	12
LQEAR-WMSN	45	42	38	30	28
Number of bad links per path					
EERRCUF-WMSN	20	18	15	14	10
LQEAR-WMSN	35	30	25	24	20

2) *QoS metrics comparison*

Fig. 2 shows the energy consumption by proposed EERRCUF-WMSN and existing LQEAR-WMSN. The plot illustrates the level of energy usage in EERRCUF-WMSN is reduced a bit at any given minute with increase in the number of nodes compared with the LQEAR-WMSN. Fig. 3 shows the network lifetime found for both proposed EERRCUF-WMSN and existing LQEAR-WMSN estimation. The plot evidently displays the level of network lifetime in EERRCUF-WMSN is increased compared to the LQEAR-WMSN. Fig. 4 exhibits the measure of paths found for both proposed EERRCUF-WMSN and existing LQEAR-WMSN. The plot obviously shows the paths in EERRCUF-WMSN is lessened at any given minute with increase in the nodes compared with the LQEAR-WMSN.

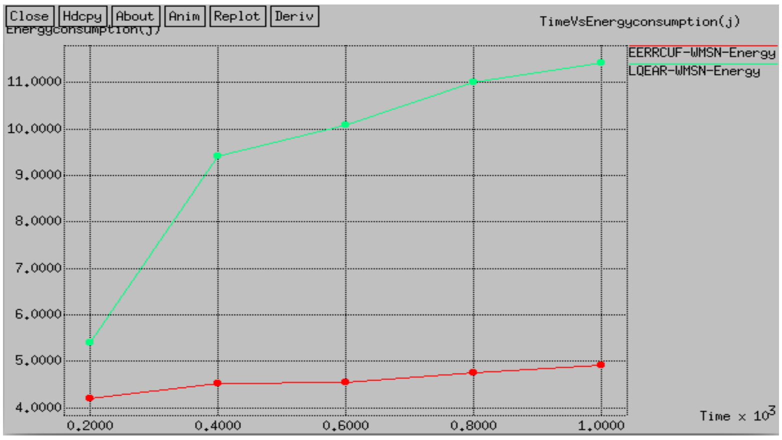

Fig. 2. Energy consumption comparison

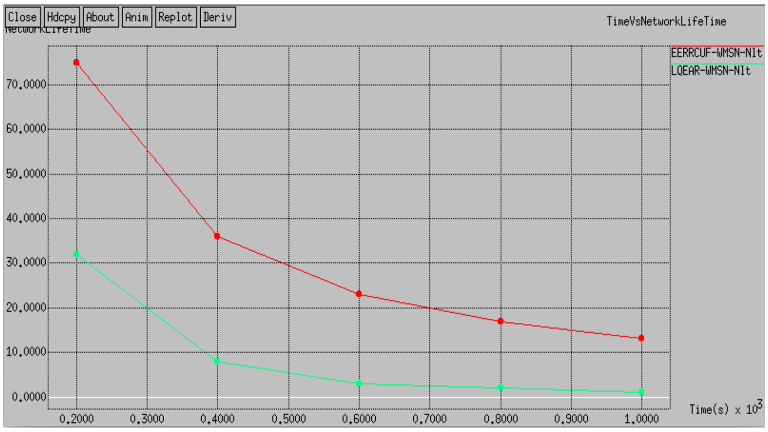

Fig. 3. Network lifetime comparison

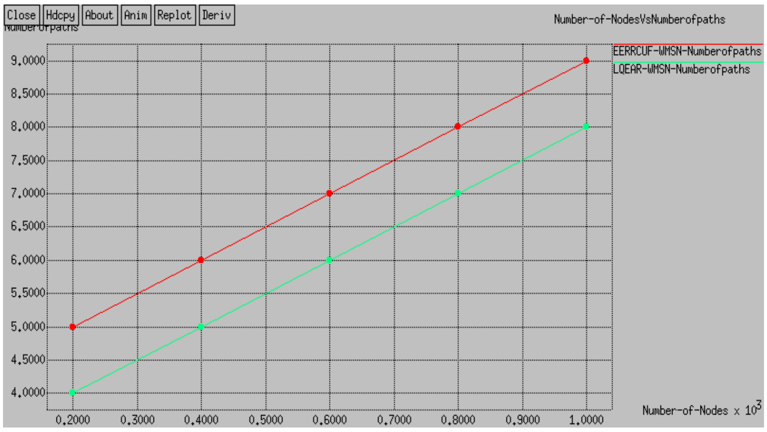

Fig. 4. Number of paths comparison

3) QoE metrics comparison

Fig. 5 shows the PSNR found for both proposed EERRCUF-WMSN and existing LQEAR-WMSN algorithm. The plot describes the percentage of PSNR in EERRCUF-WMSN is increase progressively based on the improvement on the number of nodes when evaluated with the LQEAR-WMSN. Fig. 6 shows the SSIM index found for both proposed EERRCUF-WMSN and existing LQEAR-WMSN algorithm. The plot presents the percentage of SSIM index in EERRCUF-WMSN is reducing progressively when the number of nodes getting raised and the SSIM of the LQEAR-WMSN is decreasing quickly. Fig. 7 presents the VQM found for both proposed EERRCUF-WMSN and existing LQEAR-WMSN algorithm. The graph illustrates the percentage of VQM in EERRCUF-WMSN is increase gradually with increase in the number of nodes.

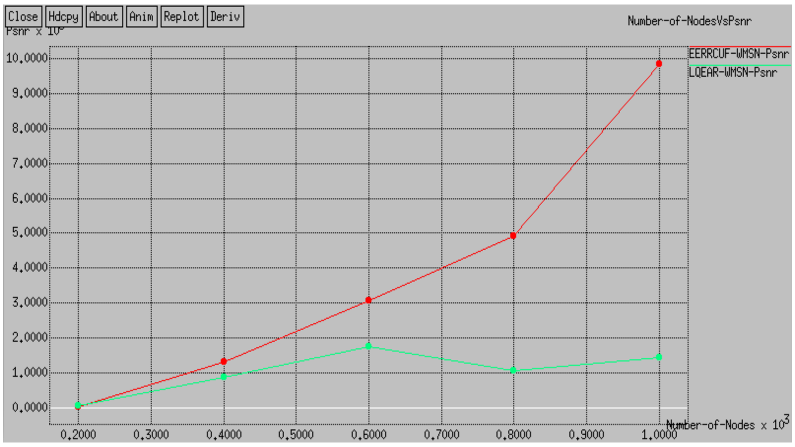

Fig. 5. PSNR comparison

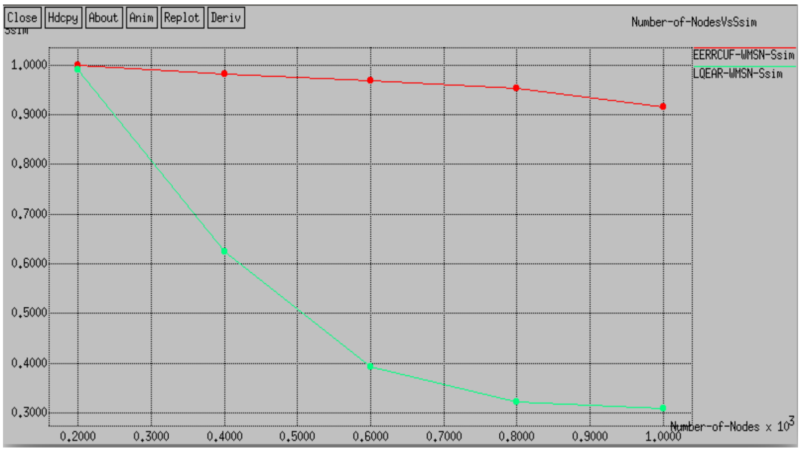

Fig. 6. SSIM index comparison

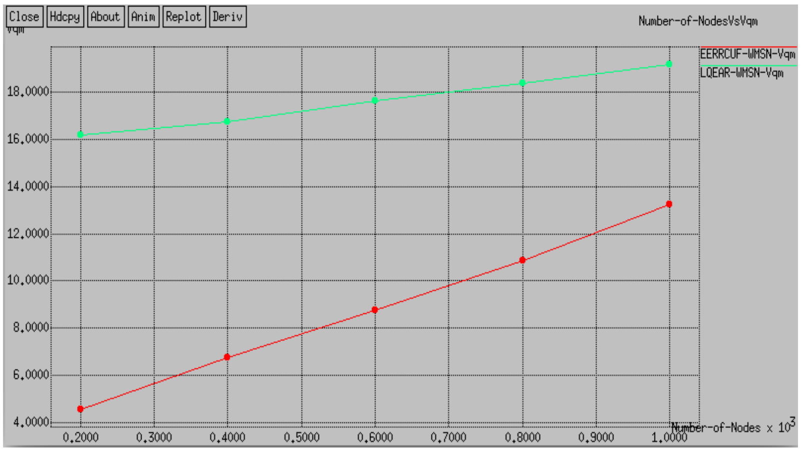

Fig. 7. VQM comparison

V. CONCLUSION AND FUTURE WORK

Our EERRCUF algorithm, achieved an effective performance rather than existing state-of-arts routing protocols. Here, the particle swarm optimization (PSO) used to create the cluster using the node constraints as position and velocity. The DETI model used to calculate trust value of the node, highest trust owned node elect as CH and SCH. Moreover, the inter-cluster routing is performed by the gravitational search algorithm (GSA) with the constraints of Force. The performance analysis proves the effectiveness of EERRCUF-WMSN protocol in terms of link quality, QoS metrics and QoE metrics. From this, EERRCUF-WMSN algorithm has suitable to adapt with different network scenarios and makes applicable in a real-life application like ambient environmental monitoring for in future.

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Nirmala Hiremani obtained her Bachelor of Engineering in Computer Science and Engineering degree at Kalpataru Institute of Technology, Tiptur. She obtained her Master of Technology degree (Computer Science and Engineering) at AMC College of Engineering, Bangalore. Her areas of interest include Wireless Sensor Networks and Mobile Ad hoc Networks. Currently she is working as Assistant Professor, Department of Computer Science and Engineering, PG Center, Visvesvaraya Technological University, Mysore.

Prof. T.G Basavaraju (Tiptur Gangaraju Basavaraju) holds a Ph.D. (Engg.) from Jadavpur University, Kolkata in the area of Mobile Ad hoc Networks. He obtained his Master's Degree in Computer Science and Engineering from University Visvesvaraya College of Engineering (UVCE), Bangalore University, Bangalore and secured first rank. He holds Bachelor's degree in Computer Science and

Engineering from University BDT College of Engineering (UBDTCE), Kuvempu University, Davangere. His major areas of research are Wireless Ad hoc Networks, Sensor Networks and Mesh Networks. He has more than 21 years of experience in Teaching and Industry. He was with Axes Technologies and Samsung Electronics as a Software Engineer. He has authored and co-authored five text books in the area of Computer Networking. One of his co-authored text book on" Mobile Wireless Ad hoc Networks: Principles, Protocols and Applications" was published from Auerbach Publishers (Taylor and Francis group), USA.

Dr. T G Basavaraju is currently working as Professor and Head of Computer Science and Engineering Department at Government SKSJ Technological Institute, Bangalore.