Energy-Balanced Transmission Policies for Wireless Sensor Networks

Y.Aswini
M.Tech in CSE Dept
S.R Engineering College
Warangal, Andhra Pradesh, India
reddy.ashwini3@gmail.com

S.P.Anandaraj
Senior Assistant Professor
S.R Engineering College
Warangal, Andhra Pradesh, India
anandsofttech@gmail.com

V. Ramana
Assistant Professor
S.R Engineering College
Warangal, Andhra Pradesh, India
naikramana@gmail.com

S.P.Poornima
Assistant Professor
S.R Engineering College
Warangal, Andhra Pradesh, India
poornima.spa@gmail.com

Abstract

Wireless Sensor Network's lifetime depends on the energy levels of individual nodes in the network. The energy usage depends on the MAC and routing protocols, topology, and transmission policy. The transmission policies in WSN as of now cause irregular usage of energy and it results in the reduction of energy levels of nodes in the network. Gradually it leads to the reduction of lifetime of the network. This paper presents a new method to overcome this problem. It divides the transmission distance into two parts based on the concentric rings which are formed around the sink as part of transmission mechanisms in WSN. The two parts are namely ring thickness and hop size. Here we consider the network lifetime as a kind of optimization problem. To achieve this we analyze the energy consumption in the transmission process and decide the optimal hop size and ring thickness. The empirical results revealed that through our energy balanced transmission policies, the network lifetime is increased substantially.

Index Terms*: *WSN, transmission policies, network lifetime, energy efficiency, MAC.

I. INTRODUCTION

In the networking domain, the recent technological innovations at circuit level have paved way for the possibility of creation of sensor nodes and thus led to the ease of establishment of WSNs. The sensors are small in size and cost is affordable with capabilities such wireless communication and also signal processing. The WSN has no fixed infrastructure. It contains a set of sensors geographically distributed and they work together in the sensing job [10], [8]. The applications of WSN are plenty and explorations of using them in new arenas are in full swing. The applications include traffic management, emergency navigation, health care systems, target tracking, surveillance systems, environment monitoring and so on [5], [4], [11], [15]. Unlike traditional networks, the WSN has difference communication mechanisms and the usage of energy levels. The communication paradigm here is many – to – one. This means that all sensors nodes in the network send the sensed data to a sink. This results in the irregular usage of energy and that leads to early demise of the nodes in terms of energy thus causing the network lifetime to get deteriorated. Apart from this sensor nodes in WSN are having less energy levels and resource constraints. They have no replaceable power sources. For this reason it is essential to let them nodes use less energy and improve the longevity of lifetime of WSN. The energy problem in WSN have been studied by many researchers [9], [17], [12], [6], [3], [13], [18]. However, they focused more on topology control, clustering, MAC protocols, and the design of energy efficient routing protocols. In the light of this fact, the recent researches [14], [16], [7], [2] revealed that the transmission policies that are used by sensor nodes in order to communicate with sink play an important role in the usage of energy by the network. However, the level of research on this area is not significant. To bring about best usage of energy levels in WSN, this paper focuses on the issue of transmission policies in order to prolong lifetime of WSN.

From our study it is understood that the following features are to be exhibited by transmission policy for improving the overall lifetime of WSN. The features include multihop, variable transmission range, energy balanced duty cycles, and regularity. Multi hop transmission policies are energy efficient when compared to single hop scheme. With respect to multi hop with fixed transmission range also not efficient. However, multi hop transmission policy with variable transmission range can brings about more uniform traffic and energy usage among the sensor nodes in WNS. Energy balanced duty cycles also have their influence on energy usage of sensor nodes. The number of duty cycles is to be allocated keeping network lifetime optimization problem in mind. Regulating the sensors in order to avoid interference nodes and also scheduling no interfering nodes also has its impact on the energy usage [1].

By finding optimal hop distance in WSN Bharadwaj et al. [14] studied the upper bound on WSN’s lifetime. Thus they tried to bring about uniform distribution of every level in WSN. However, their invention has limited use fro the reason that WSNs have higher traffic on nodes nearer to sink when compared with nodes staying at the boundaries. Research on usage of single hop and multihop transmissions are made by Mhatre and Rosenberg [16] and found the optimal transmission is possible in MH. A hybrid of SH and MH is proposed by Efthymiou et al. [7] in order to achieve balanced energy usage in WSN. In both [16] and [7] the WSN is divided into concentric circular rings. To increase overall network lifetime of WSN, this paper makes use of hop size and ring thickness considering maximization of network lifetime is an optimization problem. Traffic distribution and also energy usage distribution are considered in this paper and finally proposed three transmission schemes namely FHS (Fixed Hop Size), SVHS (Synchronous Variable Hop Size) and AVHS (Asynchronous Variable Hop Size). The performance of these policies is described in the later sections of this paper.

II. PROBLEM STATEMENT

For the WSN, we assume that sensor nodes are deployed in a region randomly and also uniform and interested in achieving energy efficient transmission policies that can maximize the lifetime of WSN in optimal, energy consumption.

A. Network Model

Proportional to size of area, we consider sensor nodes are randomly and uniform ally distributed. The whole sensing area is divided into a collection of concentric circular rings. The sensors are expected to measure physical events, air quality and temperature in their sensing zones. The expected network model is as shown in fig. 1.

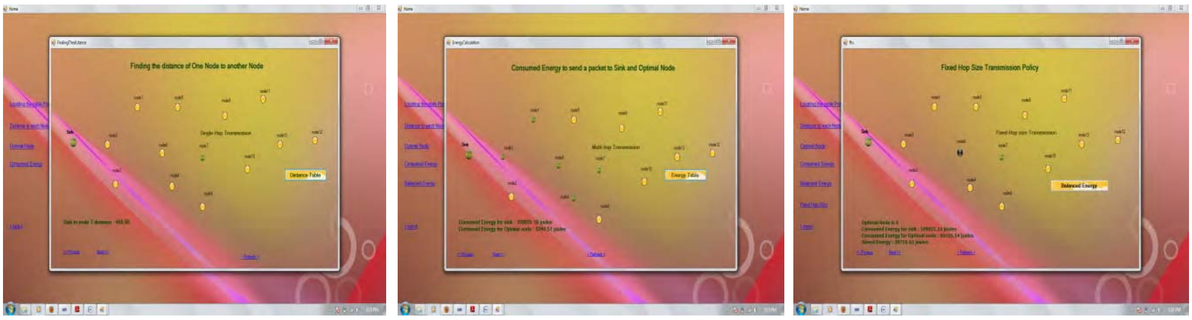

Fig. 1: WSN with SH, MH and FHS transmissions

As can be seen in fig. 1, we divide the conventional multiphop transmission distance into two things namely ring thickness and hop size. These two are the features considered in the research of this paper.

B. Energy Consumption Model

Energy consumption by sensor nodes in WSN depends on their activities like sensing data, reception, transmission and computing. We adopt the energy consumption model specified in [16] as it on the basis of the fact that transmission policies of WSN have impact on the energy usage by the sensor nodes.

C. Finding the Optimal node and Consumed Energy policies

The sensor nodes in WSN are having limited power supply or energy levels. They are constrained by this and their lifetime depends on the efficient consumption of energy. In the literature it is found that single hop networks consume more energy than multi hop networks. The research in this paper considers source-destination communication mechanism that may have many hops and does not consider many-to-one communication paradigm. The study considers the maximization of network lifetime as an optimization problem and invents new transmission policies to achieve it.

III. PROPOSED TRANMISSION POLICIES

As described in [14], [16], [7], [2], with respect to multihop scheme which makes use of fixed transmission distance and getting data forwarded with a node causes problems. Especially it results in collapse of the innermost node and leads to non-uniform energy consumption. In the following sub sections, we present transmission policies that overcome this problem. In our policy data are forwarded by a hop size (multiple nodes instead of one).Hence the method is proposed to identify the linear time algorithm to find optimal parameter solution.

A. Location of Nodes

In this module each node position will be located. The position value can be calculated with their latitude and longitude values.

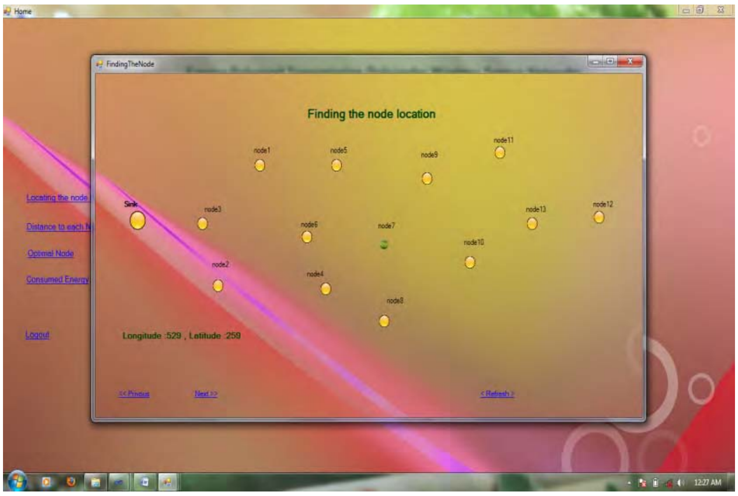

Fig.2: Locating the Nodes

B. Energy Consumption and Optimal node

The energy consumption and optimal node the nearest node towards to the sink is the optimal node.Based on the distance the optimal node can be calculate are described here. When a sensor node forwards data towards sink

C. Fixed Energy

In the proposed scheme, we divide the traditional multi hop scheme into two parts namely hop size and ring thickness. Critical energy varies based on hop size n and ring thickness w. Our goal is to minimize critical energy and thus improving the lifetime of the network.

D. Algorithm

By maintaining the above constraints, optimal values for n and w can be represented by the following linear time algorithm.

Algorithm. find Optimal Parameters

Step 1: Find a set of candidate vectors, denoted as C, of ring

Thickness and hop size pair as follows:

$C = \{[w_\eta, \eta] \mid [w_\eta, \eta]$ holds (24),

$\eta w_\eta < R$ and $w_\eta \geq r_{con}\}$.

If $C = \emptyset$ Then $C = \{[r_{con},1]\}$.

If $r_{con} \leq w_{MH}$ then $C = C \cup \{[w_{MH}.1]\}$.

$C = C \cup \{[R,1]\}$.

The last two entries as union represent multihop and

Single-hop transmissions, respectively.

Step 2: Calculate the value of $V(1,w,\eta)$ (see(16)) for each

Vector $[w_\eta, \eta] \varepsilon C$ which forms the set

$\wedge(C) = \{V(1,w_\eta, \eta) \mid [w_\eta, \eta] \varepsilon C\}$.

^ ^

Step 3: Find the optimal vector $F_{opt} = [w, \eta]$ that gives the minimum

Value in ^(C)

End.

E. Synchronous Variable Hop Size Transmission

Though the previous sub section providing lifetime optimization of network, it can be further improved by varying hop size over network lifetime. The observation is that with increase in hop size, for a given ring thickness **w** the consumption of energy per sensor in the higher indexed rings is higher and in the lower indexed ring is lower. Therefore:

$e_s(i,w,\eta+1) < e_s(i,w,\eta)$ for $i \leq \eta$ and

$e_s(I,w,\eta+1) > e_s(i,w,\eta)$ for $i > \eta$.

F. Asynchronous Variable Hop Size Transmission

The SVHS is able to achieve better energy distribution. However, using a distinct set of hop sizes for each ring, a better energy and load distribution is expected than otherwise. This idea AVHS is introduced. The AVHS transmission is represented by the following optimization problem with respect to network lifetime:

maximize $L_{av\ hs}$ ^

s.t. $H_k(\text{ɤ}) \leq 0,\ 1 \leq k \leq l,$

^

$G_k(\text{ɤ}) \leq 0,\ 1 \leq k \leq l.$

IV. IMPLEMENTATION

The experiments are made using a custom simulator developed in C# programming language. The GUI has been built using Win Forms technology.

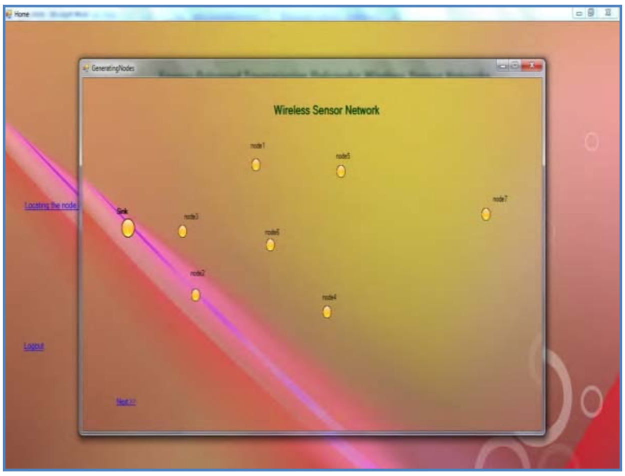

Fig. 3: Simulation of Wireless Sensor Network

As can be seen in fig. 3, there are seven wireless sensor nodes randomly located in the field and a sink. The sensors are supposed to communicate with the sink.

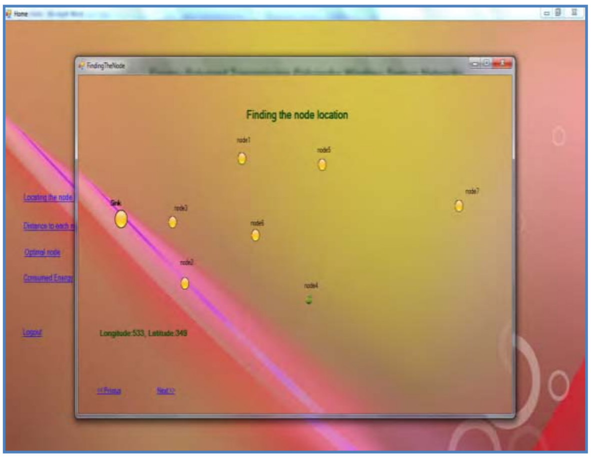

Fig. 4: Finding the location of nodes

As can be seen in fig. 4, location of any node in the filled can be known in terms of longitude and latitude. The longitude and latitude of node 4 are visible in fig. 4.

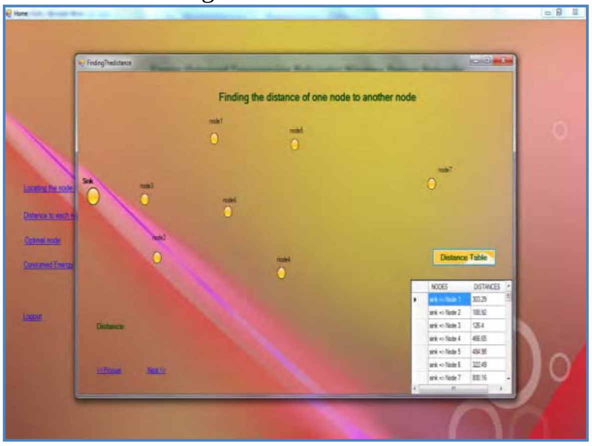

Fig. 5: Finding the distance sink and nodes

It is possible to find the distance between the sink and nodes in the WSN. As seen in fig. 5, the distance between every node and the sink in the wireless network is shown in a grid view. Knowing the distance and also the location of nodes in the field within WSN is essential to have best energy saving schemes in place and thus improving the lifetime of network.

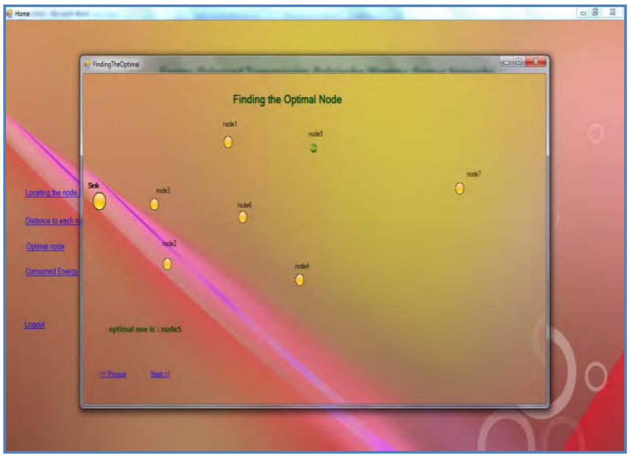

Fig. 6: Finding the optimal node

Finding optimal node in terms of communication cost and energy consumption is possible. As seen in fig. 5, node 6 is shown as optimal node.

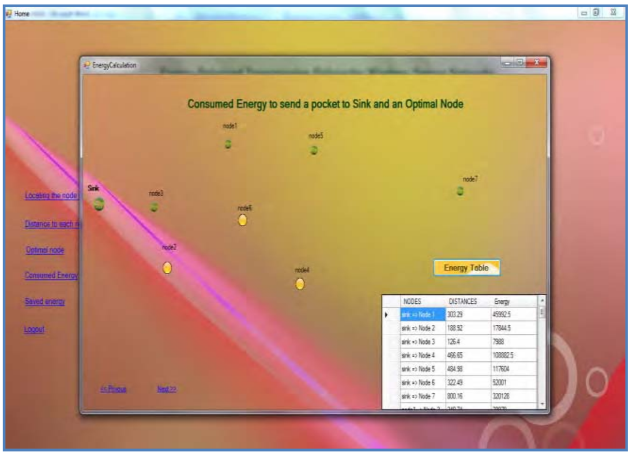

Fig. 7: Consumed Energy to send a packet to sink and an optimal node

It is possible to know the energy required by nodes to communicate with base station based on the distance. The nodes in terms of communication with sink, distances and energy consumption are shown in grid view in fig. 7.

V. PERFORMANCE EVALUATION

The system parameters are described in table 1 which is same as used in [16]. The numerical results are divided into two parts that reflect distributing of energy usage and comparison of proposed transmission policies with SH and MH which are existing schemes.

(1)Network parameters	
Network radius,R	1000m
Number of persons,n	10^5
Node con. Prob., P_{con}	0.99
Average data rate, λ_s	525 bytes/data cycle
(2)Energy parameters	$2 \le \gamma \le 4$
	a=50nJ/data cycle
	β=10pJ/bit/m^2 for γ=2
	=0.0013pJ/bit/m^4
for γ=4.	

TABLE 1: System parameters

The system parameters such as network radius, the number of sensors, number of connections and other energy related parameters are shown in table 1.

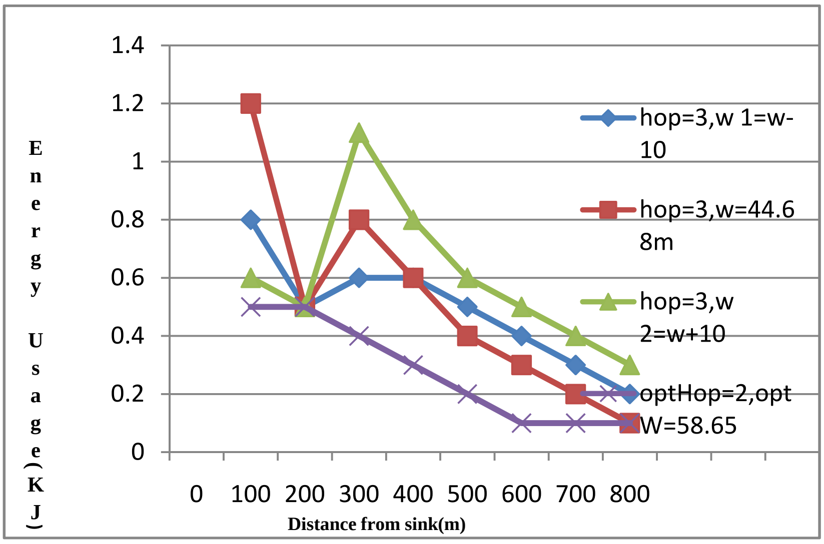

Fig. 8 shows changing rink thickness and energy usage

As can be seen in fig. 8, energy usage and ring thickness are presented graphically. It shows that critical energy is minimum when optimal hop size is used. Another observation is that for fixed hop size, energy usage in the critical has become a bottleneck that reduces the network lifetime.

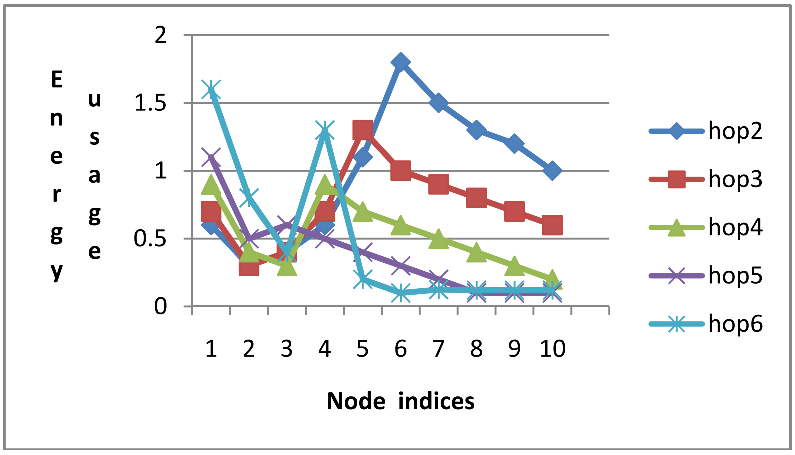

Fig. 9: Effect of changing hop size on energy usage by sensors

The fig. 9 shows the effect of hop size on the usage of energy in WSN. It shows results for hop sizes 2, 3, 4, 5, and 6. Critical energy consumption is minimum for hop size 4. This is because the ring thickness used accordingly. Energy consumption is changed in different rings of thickness. Energy consumption per data cycle is decreased for hop size 4 and 5 for all sensors that are in rings 1 and 4.

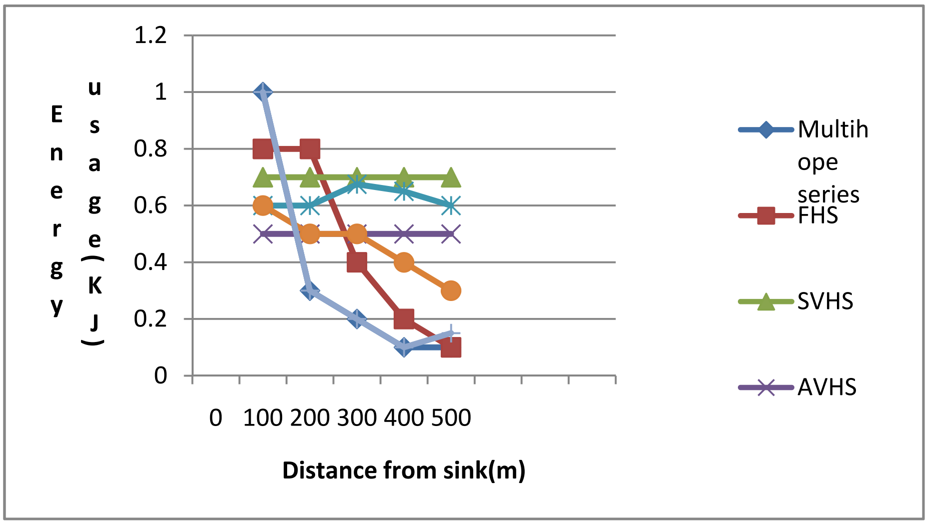

Fig. 10: Distribution of energy usage among sensors based on distance from sink

The fig. 10 compares energy usage for FHS, SVHS, and AVHS. Critical energy usage for FHS is lower than SH, MH and also hybrid transmissions. For SVHS the critical energy is even lower and distributed among the sensors. AVHS energy usage is completely balanced among sensors.

VI. CONCLUSIONS

In this paper we achieved to increase lifetime of WSN by proposing three transmission policies that optimize the usage of energy among the sensors in the network. The schemes are known as FHS(Fixed Hop Size), SVHS(Synchronous Variable Hop Size) and AVHS(Asynchronous Variable Hop Size). The ring thickness and hop size are used by FHS for optimizing network energy usage and thus ensuring the significant rise in network life time. All sensors use same hop size in SVHS while AVHS uses hop size differently node wise. The experimental results revealed that the improvement in WSN lifetime is 130, 150 and 200 percent when FHS, SVHS, and AVHS schemes are applied respectively. This achievement is because of the new transmission policies that let energy to be distributed uniform ally and the policies work when nodes in motion as well. The proposed policies can recalculate the optimum energy distribution while nodes are in transit. Thus the schemes are usable when nodes are fixed and also when they are moving around.

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ABOUT AUTHORS

	Y.Ashwini received the B.Tech Degree in Information technology from Christhu Jyothi Institute of Technology and Science, Jangaon, Warangal, A.P, India. Currently pursuing M.tech in Computer Science and Engineering at SR Engineering College, Warangal, A.P, India. Her research interests include networks, Mobile computing.
	S.P.Anandaraj received B.E (CSE) degree from Madras University, Chennai in the year 2004, M.Tech (CSE) with Gold Medal from Dr. MGR Educational and Research Institute, University in the year 2007 (Distinction with Honor).He is presently working as Senior Assistant Professor in SR Engineering College, Warangal. He has 8+ Years of Teaching Experience. His areas of interest include Information security and Sensor Networks. He has published papers in various national and International Journals, national and International Conferences. He also attended many National Workshops/FDP/Seminars etc. He is a member of ISTE, CSI, Member of IACSIT and Member of IAENG.
	V. Ramana received B.Tech (CSE) degree from JNTU, Hyderabad in the year 2006.M.Tech (AI) from university of Hyderabad in the year 2010, He has 2+ Years of Teaching Experience. His area of interest is Artificial Intelligence and Machine Learning. He has published papers in various national and International Journals, national and International Conferences. He also attended many National Workshops/FDP/Seminars etc., He is a member of CSI.
	S.Poornima received B.Tech (IT) degree from Anna University in the year 2005. She has 6+ years of experience in teaching field. Her areas of interest include Neural Networks and Wireless Sensor Networks. She has published research papers in various National and International Journals, National and International Conferences. She also attended many National Seminars/FDP/Workshops Etc., She is a life member of ISTE.