A Futuristic Analysis on the Application Problems of Wireless Sensor Networks (WSN) with Effective Strategies and Optimal Solutions

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ABSTRACT
Distributed and collaborative wireless sensor networks (WSN) plays key role in developing Smart Environment. A Smart Environment needs information about its surroundings as well as about its internal working; this information's are monitored and collected by the network of wireless sensors. The futuristic application of distributed WSN includes : Animal monitoring, Vehicle monitoring, Enemy monitoring, Machine monitoring and Medical monitoring systems. In this paper we proposed effective strategies and optimal solutions in handling the power consumption problem and the hot Spot Problem with better connectivity and lifetime for a wireless sensor networks in a distributed and collaborative Smart Environment. Our smart Environment includes Sensor Area, Sensor Nodes, Base Station and Enemy Nodes.

Index Terms – WSN - Wireless Sensor Network, Nrl Sen Sim - Naval Research Laboratory Sensor Simulator, MW - Mille Watts, B-Base Station, S-Sensor Area, G-Gateway Node, P-Probability density function.

I. INTRODUCTION
Wireless Sensor Networks (WSN) comprises numerous tiny sensor nodes that are deployed in spatially distributed terrain. Each sensor node is endowed with a limited amount of processing, but when coordinated with the information from other nodes, they have the ability to measure the given physical environment in great details or to execute a task with complex functions. Hence, a sensor network can be described as a collection of sensor nodes that coordinate with each other to perform some specific actions. Since each sensor node is fitted with an on-board processor, sensor nodes use their processing abilities to find out simple computations and transmit only the required data [6]. Optimising a wireless sensor network also bring many open issues in the network design, such as energy limitation, Hot Spot Problems, decentralized collaboration, and fault tolerance. These constraints cause many unresolved design and implementation problems, so measurements are virtually impossible. It appears that simulation is currently the primary feasible approach for analysing the behaviours of sensor network before it is developed and implemented. In this paper we proposed a novel model for WSN and there by which we have reduced the hot spot problem and improved the network connectivity and lifetime.

II. LITERATURE SURVEY OF WSN
A. What is WSN?
A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations. The *Sensor Node* is *chip set* consists of "*Micro Controller", "Memory", "Sensors", "Communication Device"* and *"Battery";* size of a single sensor node can vary from shoe box-sized nodes down to devices the size of grain of dust. A *Micro Controller* process all relevant data, the processing capacity is usually limited, *Memory* stores programs and intermediate data, S*ensors* observers the physical parameters of the environment, *and Communication Device* for receiving and sending the information over a wireless channel, *Power* is supplied by *Battery [4]*.

B. Characteristics
The networks of this type are usually collection of small-scale sensor nodes with the Constraints of *"Limited Power", "Node Failure*", *"Mobility", "Dynamic Topology", "Heterogeneity"*, and deployment in large numbers in variety of Environmental conditions [8].

C. Applications of WSN
The features of robustness, self-organizing, low-cost and fault tolerance make sensor networks appropriate for military use. Distributed sensing has the advantages of being able to provide redundant and hence highly reliable information on threats as well as the ability to localize threats by both coherent and incoherent processing among the distributed sensor nodes. It includes variety of applications [5].

1) *Military applications:* Military applications of sensor networks are monitoring army equipment, ammunition and enemy Surveillance. The data collected by sensor networks are reported to commanders in battlefield.

2) *Forest fire detection and animal monitoring:* In sensor network, sensor nodes are densely deployed in distributed wide forest area. When the nodes detect the fire or movement of animals, data is reported to Base station, which is located in a corner of the forest,

every node in the network co-operates among themselves in transferring the data to Base Station.

3) Flood Detection: An example of the flood detection is the ALERT sensors system, which was developed by the National Weather Service in the 1970s. . ALERT sensors nodes are equipped with rainfall, water level and weather detecting sensors. The detected data are reported via light-of-sight radio communication from sensor site to Base Station.

D. Issues

In WSN, sensor nodes are deployed in large numbers in various environments, including remote and hostile regions, with ad-hoc communications as key. Thus in designing and implementing the network we address the issues of Hot spot problem, Life time maximisation, Self-Configuration, Robustness, Fault-Tolerance and Mobility among nodes [4].

E. Simulators

There are several simulators that have been used in sensor network research. Here, we discuss some Standard simulators that can be used to evaluate the wireless sensor networks and after analysing we found that "*Nrl Sensor Sim*" is suitable for our experiments because it has better "*Visualization Capabilities*". The colouring capability of nodes in Nrl sensor sim helps us to easily identify the strong and weak nodes in other cases we have to analyse the trace file for this purpose.

1) Sensor Sim: Sensor Sim, which has been built on NS-2, is a simulation framework for sensor networks. It provides sensor channel models, energy consumers; lightweight protocol stacks for wireless micro sensors, scenario generation and hybrid simulation. In sensor channel models there was a dynamic interaction between the sensor nodes and the physical environment. At each node, energy consumers are said to control the power in multiple modes to efficiently use the power and prolong the nodes' lifetime. But this simulator is no longer developed, therefore, no more available.

2) *J- Sim:* J-Sim (formerly known as Java Sim), is an object-oriented, component-based, compositional simulation environment written in Java. The key benefits of J-Sim is modules can be easily added and deleted in a plug-and-play manner, and it is also useful both for network simulation and emulation by incorporating one or more real sensor devices. J-Sim provides supporting target, sensor and sink nodes, sensor channels and wireless communication channels, physical media, power models and energy models.

3) *Glomo-Sim:* GloMo-Sim (Global Mobile Information system Simulater) which is a scalable simulation environment written both in C and Parsec, is capable of parallel discrete-event simulation. GloMo-Sim is a collection of library modules each of which simulates a specific wireless communication protocol in the protocol stack. GloMo Sim is widely used to simulate Ad-hoc and Mobile wireless networks.

4) *SENS:* SENS (Sensor, Environment, and Network Simulator) is a high-level sensor network simulator for wireless sensor network applications. It consists of application, network and physical components, which are interchangeable and extensible. Application components are used to simulate the execution on a sensor node, network components are used to simulate the packet to send and receive functions of a sensor node, and physical components are use to model sensors, actuators and power and interact with the environment.

5) *Nrl Sensor Sim:* The network simulator (NS-2) supports the simulation of wireless networks, but for the simulation of wireless sensor networks, it needs to be extended. As the network simulator (NS) does not support the wireless sensor network, the Naval Research Laboratory group has extended some components from the wireless network in NS-2 to be used with the wireless sensor network and this is called as Naval Research Laboratory Sensor Simulators. This simulator supports Energy consumption model in Sensor Network, which is basically needed for our Experiments.

III. Analytical model of WSN

Let us consider an Environmental Region *S* as our *Sensor area*, where *X* Numbers of *Sensor Nodes* are deployed. The area *S* is further divided into *cells (C).* We assume that every *cell* receives at least one sensor, such that every node in the network can communicate and co-operate with its *neighbour nodes.* The data collected by the sensor nodes are forwarded to *Base Station (B)* for further processing.

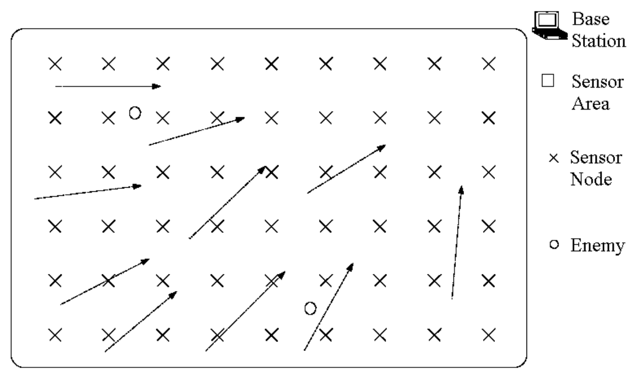

Fig. 1 Model 1: Distributed and Collaborative WSN

Here we consider *two models* of wireless sensor network. *Model1: Distributed and collaborative model, Model2: Clustered and collaborative model.* In *model1* all the *Sensor nodes* deployed in the *Sensor area* are *homogeneous* in their *Character, i.e.* All *Sensor node*s have uniform *Sensing power, Transmitting power, Receiving power and Battery power*. The data related to the movement of enemy is collected by the *Sensor Nodes* and with the co-operation of the *neighbour nodes*; the data is passed to the *Base Station* for further processing [5].

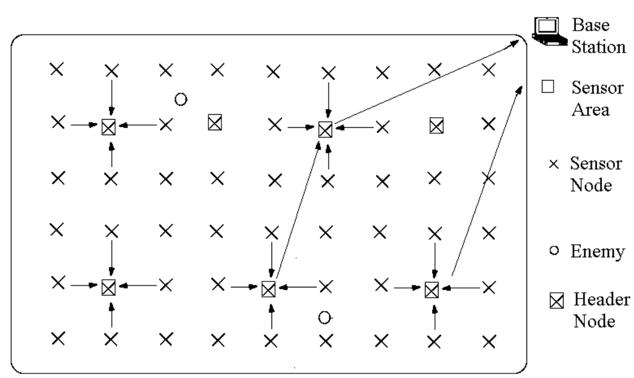

Fig. 2 Model 2: Clustered and Collaborative WSN

In *model2* the *Sensor nodes* deployed in the *Sensor area* are *heterogeneous* in their *Character, i.e. Header nodes* have more

Sensing power, Transmitting power, Receiving power and Battery power, When compared to other *Sensor nodes*. The *Sensor nodes* form Clusters by sending all its data to the near by h*eader node.* The *Header node* collects the data from the near by *Sensor nodes* and send it to the *Base Station (B)* either directly or by the co-operation of the other *Header nodes [9]*.

By comparing the models, we found that model 2 is expensive, since the header nodes need more processing capacity, transmission power, sensing power and battery power. Moreover deploying header node in sensor area is additional constraint.

IV. SENSOR DEPLOYMENT STRATEGY

A. Sensor dropping problem

When the Sensor Area is limited, we go for "*Human Deployment"* of sensor nodes. But usually we need to deploy sensor nodes in large Terrain environments. In such case "*Air Dropping"* of sensor nodes is done in the sensor Area *S.* Based on the Transmitting range of sensor node, *S* is divided into *N* number of *cells*, each cell should have at least one *Sensor Node* to ensure the connectivity in the network [2].

E. Equations

The *Sensor Nodes* are "*Air Dropped"* at point (x, y) in *S,* is accurately approximated by a *probability density function (p).* The amount of sensors needed for dropping at each point (x, y) is modeled by *Normal distribution function.* Let us consider two *Cases a)* Four sensors are dropped, one at the center of each cell; b*)* Four sensors are dropped at the center of *R,* where *R* is a square Region of area $4u$ and it is divided in four square cells of side $2u$, where u is the side of each cell, for $u \geq 0$. The amount of sensors needed to be dropped at each point is modeled by dispersion Factor σ of *Normal distribution function.*

1) Theorem 1: Let p_a and p_b denote the Probability that each cell receives at least one sensor under *Case a* and *Case b.*

$$p_a = 1 - 4 f_1(\prod/4).$$

$$p_b = 1 - (f_1(\prod/4) + (3/4))^4$$

The Proof is reported in [1].

2) *Theorem 2:* Let and X_b be the random variables that denote the number of sensors to be dropped such that every cell has at least one sensor node under *Case a* and *b.*

$$E[X_a] = 4.E[C].$$

$$E[X_b] = 25/(12P).$$

$$E[C] \approx \frac{-25 + 69p_a - 85P_a^2 + 58p_a^3 - 22p_a^4 + 4p_a^5}{p_a(-2+p_a)(3-3p_a+p_a^2)(2-2p_a+p_a^2)}.$$

The Proof is reported in [1].

V. ROUTING IN WSN

Routing in sensor networks is very challenging due to following characteristics. *First* almost all applications of sensor networks require the flow of sensed data from multiple regions to a particular *Base Station (B). Second,* sensor nodes are tightly constrained in terms of transmission power, on-board energy, processing capacity and storage and thus require careful resource management. Here we discuss some of the routing protocols, which solve the problem of routing the data in sensor networks [11].

A. Data Centric Routing

In data-centric routing, the Base Station sends queries to certain regions and waits for data from the sensors located in the selected regions. Since data is being requested through queries, attribute based naming is necessary to specify the properties of data. But in many applications of sensor networks, it is not feasible to assign global identifiers to each node due to the sheer number of nodes deployed. Such lack of global identification along with random deployment of sensor nodes make it hard to select a specific set of sensor nodes to be queried. Therefore, data is usually transmitted from every sensor node within the deployment region with significant redundancy. Hence this is very inefficient in terms of energy consumption. *E.g. Sensor Protocols for Information via Negotiation* (SPIN) uses data-centric routing mechanism. The idea behind SPIN is data negotiation between nodes in order to eliminate redundant data and save energy.

B. Energy aware routing

The approach argues that using the minimum energy path all the time will deplete the energy of nodes on that path. Instead, one of the multiple paths is used with a certain probability so that the whole network lifetime increases [10]. These paths are chosen by means of a probability function, which depends on the energy consumption of each path. The main approach of this routing is network survivability. The protocol includes *three phases.*

1) Setup Phase: In this phase route to the destination is found by flooding method. Routing table will be maintained and the total energy cost of each node is calculated in every path. For instance, if the request is send from node X_i to node X_j, X_j calculates the cost of the path as follows:

$$C_{x_j,x_i} = Cost(X_i) + Metric(X_j, X_i)$$

The energy metric includes the transmission and reception cost along with the residual energy of the node. Paths with high cost will be discarded. The node selection will be done based on the closeness to the Base station. The node assigns probability to each of its neighbours in the forwarding table (FT) corresponding to the formed paths. The probability is inversely proportional to the cost.

$$P_{x_j,x_i} = \frac{1/C_{x_j,x_i}}{\sum_{k \in FT_j} 1/C_{x_j,x_k}}$$

The X_j calculates the average cost for reaching the destination using the neighbours in the forwarding table (FT) using the following formula.

$$Cost(X_i) = \sum_{i \in FT_j} P_{x_j, x_i} C_{x_j, x_i}$$

2) Data Communication Phase: In this phase each node forwards the packet randomly by choosing a node from its forwarding table using the probabilities.
3) Route Maintenance Phase: In this phase localized flooding is performed frequently to keep all the paths alive.

C. Hierarchical protocols

The main aim of hierarchical routing is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a particular cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the Base Station. Low-Energy Adaptive Clustering Hierarchy (LEACH) is one of the most popular hierarchical routing algorithms for sensor networks. The idea is to form clusters of the sensor nodes based on the received signal strength and use local cluster heads as routers to the *Base Station (B)*. This will save energy since such cluster heads will only do the transmissions rather than all sensor nodes.

D. Location Based protocols

The main aim for this protocol is to use the location information for routing data in an energy efficient way. The location information is needed in order to calculate the distance between two particular nodes so that energy consumption can be estimated. Since, there is no addressing scheme for sensor networks like IP-addresses and they are spatially deployed on a region, these protocols are mostly not suitable for sensor networks e.g. Minimum Energy Communication Network (MECN) and the small minimum energy communication network (SMECN).

From the analysis, we found that energy-aware routing may be effective for the distributed and collaborative wireless sensor network model.

VI. Problem Definition

Let us assume that there are *X* number of *Sensor Nodes* deployed in the *Sensor area* (S), Such that each *cell (C)* in *R* has at least one *Sensor Node*. Every *Sensor Nodes* has fixed *Transmission Range* and *Battey Power* and co-ordinate with its *neighbour node* in transferring the Sensed data to *Base Station (B)*. The *Sensor Nodes* near to *Base Station (B)* acts as the *Gateway* between *B* and *S*. Data from every part of the *S* reaches *B* through *Gateway nodes (G)*. The *G* losses power more frequently than the other nodes in S is called as *Hotspot Problem (H)*. The *Connectivity and Lifetime* of the *network* depends on the *Lifetime* of *Gateway nodes (G)*.

VII. Solution Model

Let S be the fully connected and fully covered *Sensor area* deployed with *Sensor Nodes* of fixed *Transmission Range* and *Battey Power.* Since all the nodes in *Sensor area (*S) forwards the data to *Base Station (B)* through the *Gateway nodes (G).* The *Sensor nodes*, near *Base Station (B)* will die soon, when compared to other nodes in *S*. In our model we *minimized* the *Hotspot Problem (H)* by deploying few additional nodes in the *Gateway area,* there by improving the *Connectivity and Lifetime* of the entire network.

VIII. SIMULATION SETUP

Our solution model is configured using Nrl Sensor Simulator with the following Setup; *Sensor area* represented by a *grid size* 600×600, *Sensor Nodes* used 16 to 89, initial *energy level* of every *Sensor Nodes* is 0.5 *joules* , *Transmission power* 175 *mw* , *Sensing/Receiving power* 175 *mw* , *Sensing Range* 1 Scale, *Transmission Range* 1.5 Scale, and used one or two *enemy / intruder nodes*. The *enemy / intruder nodes* are blue in color, whose movement is monitored and reported to *Base Station (B).* In our experiment we focus only on the energy level of the network and not on the data that is transferred. *Sensor Nodes* will become *yellow* in color when the energy level of the node reaches the *threshold* level and will become *red* in color, when the energy level reaches *Critical* level. The node will be in *Black* color when the energy level is safe.

IX.EXPERIMENTS

We performed two Experiments with variety of cases and by analysing and observing we have come up with results.

A. Experiment 1

We have done experiment1 under 4 different cases, here we used node varying from 16 to 49 in a *grid size* 600×600, and the movement of *enemy node* in *S* is keep monitored by the *Sensor Nodes* and reported to *Base Station (B)* and we consider the Sensor area near to *B as Gateway area.* .

1) Case 1: We used 16 nodes in 4×4 matrix form on the grid of size 600×600. We cannot see any communication between the nodes. This is because the sensor nodes are not within the communication range of each other.

2) *Case 2:* we used 25 nodes in 5×5 matrix form on the grid of size 600×600. Nodes are within the communication region of each other and they are able to communicate the data to the *B*. We have seen that only one node in *Gateway area* become yellow in colour.

3) *Case 3:* we used 36 nodes in 6×6 matrix form on the grid of size 600×600. Nodes are within the communication region of each other and they are able to communicate the data to the *B*. We have seen that more nodes in *Gateway area* become yellow in colour.

4) *Case 4:* we used 49 nodes in 7×7 matrix form on the grid of size 600×600. Nodes are within the communication region of each other and they are able to communicate the data to the *B*. We have seen that more node in *Gateway area* become Red in colour.

The *results* of experiment1 show that in *Case 2* the number of *yellow* nodes is less when compared to *Case 3* and *Case 4*. Hence Case *2* is good in performance. In *Case 3* and *Case 4*, we deployed more nodes but performance is less. Thus we can say that employing more node alone will not improve the performance, we have to deploy optimal number of sensor nodes in the network.

B. Experiment 2

Here we have added few additional nodes in the Gateway area, which is nearer to the Base station and we have find improvements in the energy level of nodes in the Gateway *area*, for simplicity purpose we consider the 3×3 nodes near to Base station as *Gateway area.* The connectivity of the network depends only on the lifetime of the nodes in *Gateway area*. Hence by extending the lifetime of *Gateway nodes*, we can say that we have extended the lifetime of the network.

1) Case 1: we used 25 nodes in 5×5 matrix form on the grid of size 600×600 along with two *Enemy nodes,* which are blue in color, whose movement is monitored and reported to *Base Station (B)*. Experiment is done without adding additional nodes in Gateway *are*. Now in *Gateway area* out of 9 nodes f*ive* are in *yellow* colours, *four* in *red* colours and there are no Black coloured nodes.

2) Case 2: we used 25 nodes in 5×5 matrix form on the grid of size 600×600 along with two *Enemy nodes,* which are blue in color, whose movement is monitored and reported to *Base Station (B)*. Now by adding few more nodes in the *Gateway area,* we found the lifetime of *Gateway nodes*, improved. In the *Gateway area* out of *9 nodes* the number of *yellow* color nodes reduced to 3 from 5, *red* color nodes reduced to 3 from 4 and the *Black* color *nodes* increased to 2 from 0.

After adding few additional nodes in the *Gateway area,* we found improvement in the lifetime of the network.

C. Experiment 3

Here we have used few additional Sensor nodes in the Gateway area, which is nearer to the Base station. In *Case 1* the additional sensor node used in the gateway area has both *Sensing* Characteristic and *Transmitting Characteristic* and with *Case 2* the additional sensor nodes has only the Transmitting *Characteristic.*

1) Case 1: Initially we used 25 nodes in 5×5 matrix form on the grid of size 600×600 along with two *Enemy nodes, then* we have added six additional nodes in the gateway area, the additional sensor nodes have both *Sensing* Characteristic and *Transmitting Characteristic* as like the other nodes of the network. After running the simulation for a constant period of time, we found that in the *Gateway area* out of *15 nodes,* nine are in *yellow* colours, *four* in *red* colours and two are Black coloured nodes.

2) Case 2: Initially we used 25 nodes in 5×5 matrix form on the grid of size 600×600 along with two *Enemy nodes, then* we have added six additional nodes in the gateway area, the additional sensor nodes has only the *Transmitting Characteristic*. After running the simulation for a constant period of time, we found that in the *Gateway area* out of *15 nodes,* eight are in *yellow* colours, *five* in *red* colours and two are Black coloured nodes.

The objective of the additional nodes in the gateway area is to improving the network connectivity, Network lifetime and to minimize the hot spot problem. The additional nodes are not meant for monitoring the gateway area, thus *Sensing* Characteristic is not necessary for the additional nodes. But the results of experiment 3 shows that *Case 1* perform better than *Case 2*. This is the potential problem of the r*outing protocol*; they find the lowest energy route and use that for every communication. Using a low energy path frequently lead to energy depletion of the nodes along that path and in the worst case may lead to network partition.

X.CONCLUSION

In this paper we discussed about Wireless Sensor Networks (WSN) characteristics, Applications, the challenges and problem while designed and implementing. A detailed study on the simulators for WSN is performed. Analytical models of WSN along with sensor dropping problem and routing protocols are discussed. Our experiments propose effective strategies and optimal solutions in handling power consumption problem and Hot Spot Problem in WSN. The result of the experiments shows that we have to deploy optimal number of *Sensor nodes* in S for better network lifetime, deploying additional nodes in the gateway area performs better than the Normal deployment Strategy, it provides optimal solution for power consumption problem and hot spot problems and additional nodes in *Gateway area* with only transmitting characteristic will be effective only with energy aware routing protocols. Results of the experiments support the objective of our solution model.

Appendices

The Pie Chart represents the Energy level of the Gateway nodes improves after adding few more nodes in the *Gateway area*. In the pie chart we represent the Energy level of nodes in *Gateway area* in *3 Categories*; *Category 1: Energy of the node in Threshold level, Category 2: Energy of the node in Critical level, Category 3: Energy of the node in Safe level.*

Note: In our experiments the node in yellow colour represents the energy of that node in *Threshold level*, the node in red colour represents the energy of that node in *Critical level*, the node in black colour represents the energy of that node in Safe *level.* In the figures the *label l*, *label 2* and *label 3* represents the *Percentage* of nodes whose energy level are in *Threshold level, Critical level* and *Safe level.*

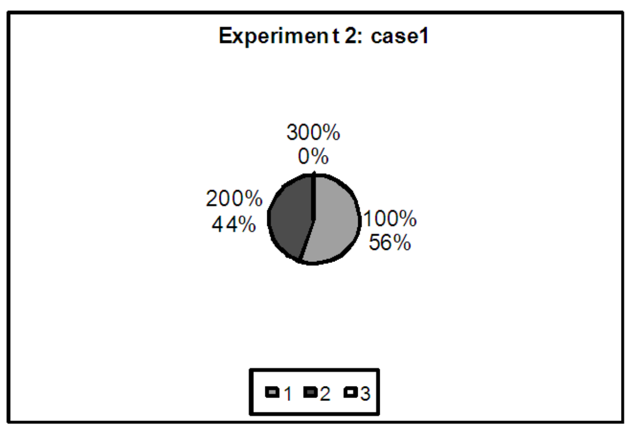

Fig. 3 Energy Categories of nodes in Gateway Area without additional nodes

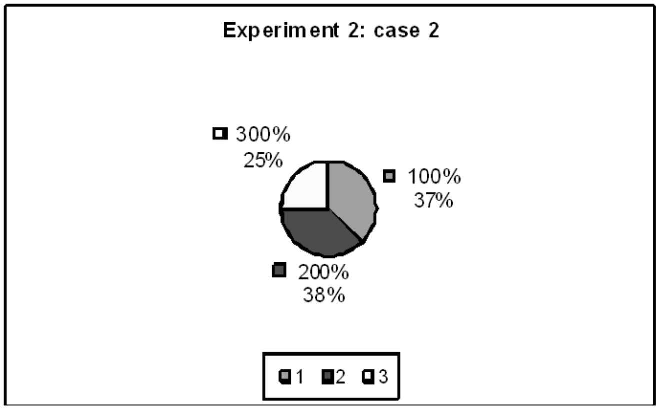

Fig. 4 Energy Categories of nodes in Gateway Area with additional nodes

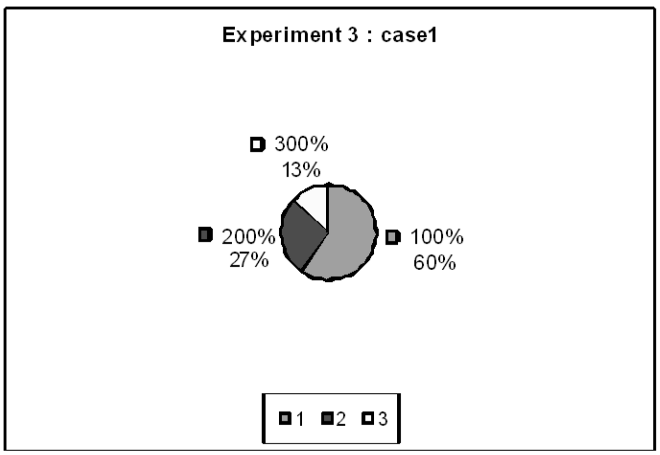

Fig. 5 Energy Categories of nodes in Gateway Area with additional nodes having sensing capability

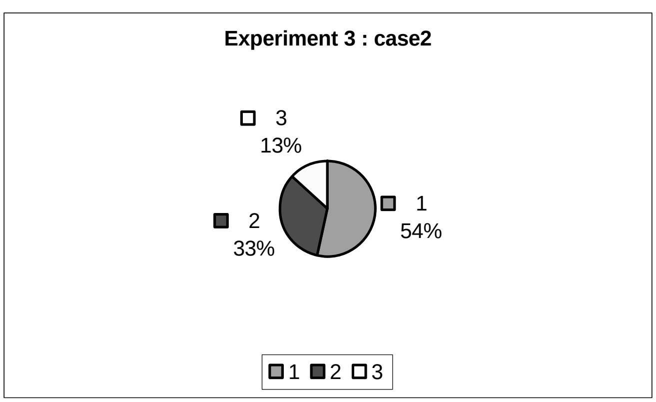

Fig. 6 Energy Categories of nodes in Gateway Area with additional nodes without sensing capability

References

[1] M. Leoncini, G. Rasta, and Paolo. Santhi, "Analysis of sensor dropping problem in wide area environmental monitoring," pp. 239-245, April 2005 IEEE.

[2] A. Hower, M.J. Mataric, G.S. Sukhatme, "Mobile sensor network deployment using potential fields: A distributed scalable solution to the area coverage problem" Conference on distributed autonomous robotic systems, pp.6-9, 2002.

[3] T. Clouqueur, V.Phipatanasuphorn, P.Ramanathan, K.K. Saluja, "Sensor Deployment Strategy for target detection," Proc. ACM Workshop on sensor networks and applications, pp. 42-48, 2002.

[4] I.Akilildiz, Sankarasubramanian, E. Cayirci, "Survey on Sensor networks," pp. 102-1145, IEEE 2002.

[5] A. Mainwarning, D. culler, J. Polastre, J. Anderson "Wireless sensor networks for habitat monitoring," Proc. First ACM international workshop on sensor networks applications, 2002.

[6] Yu. Yongchang, G. Wei, "Energy aware routing algorithm for target region monitoring in wireless sensor networks," 2007 IEEE.

[7] Gang Zhao, Xiangvian ilu, "Energy aware geographical routing for sensor networks with randomly shifted Anchors," 2007 WCNC.

[8] S. Tilak, N.B. Abu-Gazhalekh,, W.Heinzelman, "A taxonomy of wireless micro-sensor network models," Mobile computing and Communication review, vol. 6, no 2, pp. 28-36, 2002.

[9] Wuhan, Hubei, "Clustering approach for wireless sensor networks using spatial data correlation and Anti-colony optimization," vol. 1, pp 538-541, 2009 NSWCTC.

[10] M.Youssef, M. Younis, K.Arisha, " A constrained shortest path energy aware routing algorithm for wireless sensor networks," Proc. Of the IEEE wireless communication and networks conference, 2002 WCNC.

[11] K. Sohrabi, et al, " Protocols for self organization of a wireless sensor networks," IEEE Personal Communications, vol. 7, No. 5, pp. 16-27, October 2000.