THESIS REPORT

Context Aware Energy Allocation by Auction Based Method in Wireless Sensor Networks

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DECLARATION

We hereby declare that this work was carried out by us under the guidance and supervision of **Dr. Md. Muhidul Islam Khan,** Assistant Professor, Department of Computer Science and Engineering, BRAC University. The period of thesis work is from May 2015 to April 2016. This project work is submitted to the Department of Computer Science and Engineering, School of Engineering and Computer Science, BRAC University in partial fulfillment for the requirement of Degree in Bachelor of Science in Computer Science. We declare that this work has not been submitted anywhere else for the award of any other degree.

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ABSTRACT

Wireless sensor networks refer to hundreds and even thousands of small tiny devices called sensor nodes distributed autonomously to observe physical or environmental parameters like temperature, pressure, vibration and motion at different locations such as landslides. Every node in a sensor network usually equipped with one sensor, a wireless communications device like radio transceiver, a small microcontroller, and an energy supply, a battery. Since the nodes are battery operated energy plays a vital role. The application of the WSN involves several fields, like military battleground, fire detection, and other extreme environments. In these situations, it is troublesome to replace the dead nodes caused by energy depletion with new ones to provide energy for the system. Therefore, making sensor nodes operating as long as possible is the main method to maximize the lifespan of the sensor network. Context aware task allocation/energy allocation is an important issue for maximizing the lifetime of the network. In this research our goal is to minimize the wastage of energy and to maximize the usage by context aware energy allocation. We develop a context aware energy allocation algorithm based on First Price Auction method. Our simulation results show that our proposed method provides better results in terms of energy consumption comparing with the other existing methods.

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Chapter I

Introduction

A wireless sensor network is a group of specialized transducers with a communications infrastructure for monitoring and recording conditions at diverse locations. Commonly monitored parameters are temperature, humidity, pressure, wind direction and speed, illumination intensity, vibration intensity, sound intensity, power-line voltage, chemical concentrations, pollutant levels and vital body functions [12]. WSN usually is battery powered which is very energy consuming. At present efficiently allocation of energy is one of the main challenges of WSNs [5]. To use the energy efficiently researchers have been working on WSN power/energy allocation. They are emphasizing on sensing, communication, computation and energy harvesting. In general, the communication consumes huge number of energy.

In our research we are working to find out an efficient algorithm/method of energy allocation which will be context aware and power efficient for WSN.

Context Aware means to behave dynamically with the environment and to act in a way that the situation demands. Suppose for a sensor node, it needs to be in sleep mode if there is nothing to detect or if a node needs to track something it will be activated immediately.

Generally, a wireless sensor network consists of three main components: Nodes, Gateways and Software [13]. The Nodes consist of several sensors are used to monitor assets or environment we are working on. The acquired data are transmitted to the gateway, which is connected to a host system where data collection, processing, analyzing and measurement data are performed using a software. Routers are a type of node that is used to expand WSN distance and its area of implementation.

There are many different kind of tiny sensors which is used in various purposes like in military issues, shopping malls, building utilities, border areas, forests security etc. which creates a smart environment from where we can collect several data. These sensors work in different phases according to the need of the environment. A single sensor might do multiple works such as sensing, broadcasting, transmitting, bidding etc.

The main challenge in this process is to keep those sensors alive for the maximum period of time and get maximum output [1].

We propose an auction based method for context aware energy allocation in a WSN. We consider a clustered based WSN for various task allocations to the sensor nodes in a way that the energy is optimized and the performance is maximized. We consider a set of tasks/jobs. Based on a utility function and using First-Price auction cluster head of each cluster helps to allocate the jobs to the sensor nodes so that the network lifetime maximizes.

Rest of the thesis report is organized as follows. Chapter II describes the related works. Problem formulation is mentioned in chapter III. chapter IV has the description of proposed method. chapter V has simulation-results and chapter VI concludes the paper with the future direction of our work.

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Chapter II

RELATED WORK

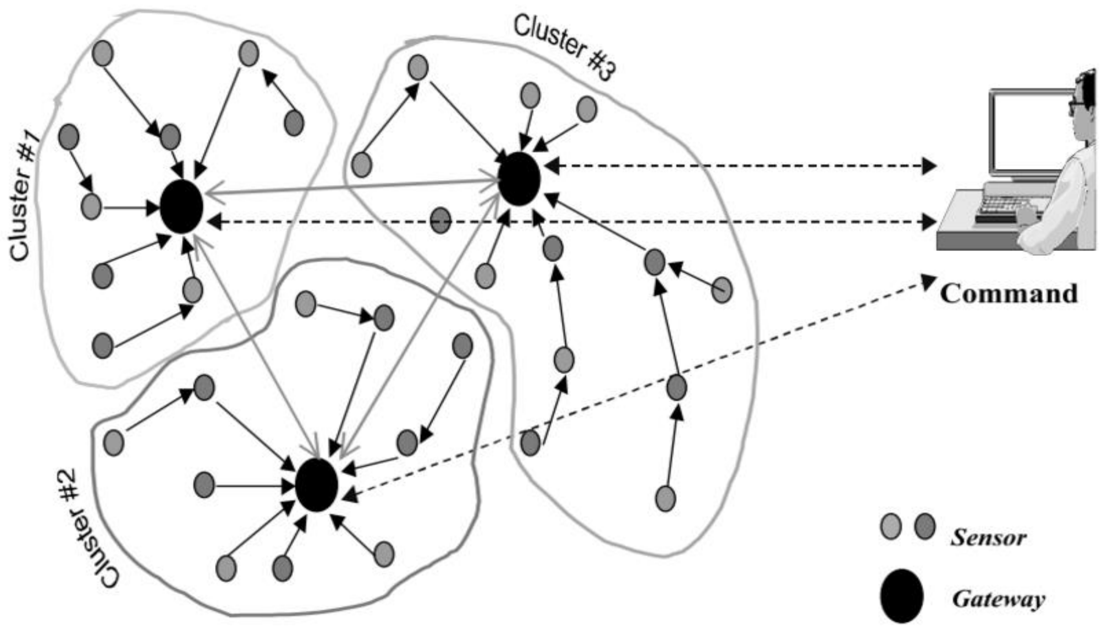

Fig. 1. Multi-gateway clustered sensor network [8]

B. Lokesh et al. N proposed[1] a system where each sensor node is pre-configured to fixed weight and Context (Either Seasonal or Time context base). After initial setup, each sensor nodes will sample data in a regular interval. Depending on the context and available information, each node will derive an emergency value which signifies the attention to be given to that particular tray. Derived value is forwarded to the Cluster Head (CH), which summarize further with other sensor nodes. Sensor nodes will also modify the event sensing rate or sleep time depending on available information, to reduce the power consumption. Catering the service to every floor by Store manager (SM) solely depends on emergency value forwarded by DSN. The cluster head (CH) acts as intermediate node to forward the data to SINK node. It collects the data from all the node belongs to its cluster. Then it summarizes the data, mainly the emergency value of particular product. Then it forward the data to next cluster which connect to SINK or another cluster. [1]

In another research, A. Sinha et al. [4] proposed a prediction based method for task allocation. They have used power aware sensor node model which works on increasing latency and decreasing power consumption. The sleep states are differentiated by power consumption, the overhead required is going to sleep and the wake-up time. In general, a deeper sleep state consumes less power and has a longer wakeup time. An event occurs when a sensor node picks up a signal with power above a predetermined threshold. Here the calculated threshold level depends on the basis of average event rate. So the sleep states/wake up of the nodes depends on the probability of the occurrence of event. As the sleep time and wakeup time is based on the prediction of previous event, in worst case 2 things can be happened.

1) Events may occur during sleep time therefore they might have missed events
2) No event may occur during wake time therefore the whole energy is being wasted during the period of time.

Compare to this prediction based model, our algorithm runs in such a way where there is a less possibility of wastage of energy and also less missed events as a node is being awaken only if the event occurs. This makes our work unique comparing with the existing approaches.

Chapter III

PROBLEM FORMULATION

Some applications of sensor networks include tracking the movements of birds, small animals, environmental monitoring in marine, soil, and atmospheric contexts, forest fire detection, meteorological or geophysical research, pollution study etc. There are some places in the world like forests and border area where it is dangerous to people to go and collect information's but which is needed. In these cases, a WSN plays a vital role. In those rural areas the sensor nodes sense the unwanted substance and transmit the information to the network.

A single sensor node does many things such as capturing temperature, humidity, vehicular movement, lightning condition, pressure, soil makeup, noise levels etc. In our paper we consider our sensors can perform four tasks.

1) **Receive**
2) **Transmit**
3) **Sense**
4) **Bidding**

Our goal is to allocate these tasks to the sensor nodes in a way that the network lifetime increases.

Chapter IV

PROPOSED METHOD

To distribute the tasks/jobs of the sensors we divide the whole process in to three sub processes:

1) **Cluster Head (CH) selection algorithm**
2) **Job allocation algorithm**
3) **Algorithm for selected node**

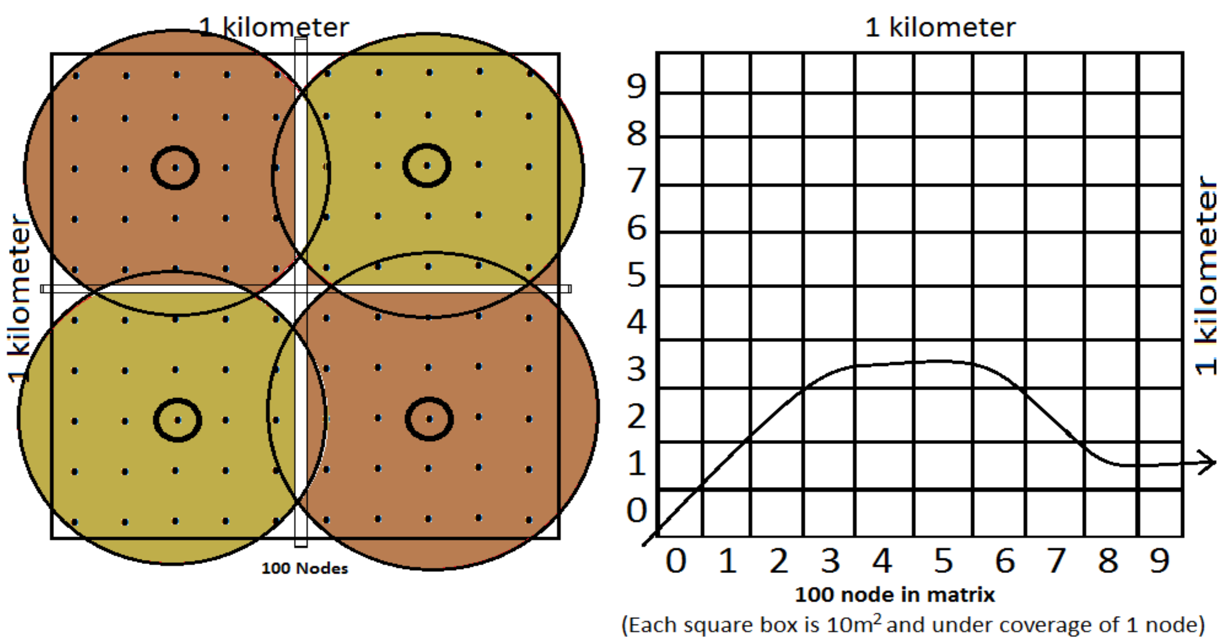

Fig. 2. Sensor node representation in 10x10 matrix

If we take an area of 1000 miter consist of 100 sensor nodes in 10/10 matrix. we take 4 main sensor nodes called main sensor nodes. These four sensor nodes will always be in ON mode. Other nodes will be in sleep mode. The Main Sensor Nodes will have all the information of other nodes. These nodes always sense if there any substance is present in their range or not. The battery power of main sensor node is higher than the other nodes.

Cluster Head (CH) selection

When one of the four main sensor nodes detect an unwanted substance in its range it calculates the area and make the nearest node of the substance Cluster Head and follows to the second algorithm (Job allocation algorithm).

Algorithm 1 ClusterHeadSelection algorithm.

Input: ***matrixOfAllNode***, ***fourMainSensorNodes***
Output: ***Cluster_head***, ***AdjacentNodes***

Step 1: Start
Step 2: ***FourMainSensorNodes*** in 4 edges start sensing
Step 3: ***if FourMainSensorNodes[x]*** detects anything

i. Detect nearest node from that location
ii. Make it ***cluster_head***
iii. Initiate ***jobAllocationAlgorithm***
iv. go to **Step 3**

Step 4: exit

Job allocation:

In this part the cluster head selects its adjacent nodes and sends them a signal to initiate bidding. The selected nodes then bid to the cluster head according to their battery life and distance based on this bidding function.

Cluster heads gets all the bidding of all the adjacent nodes. It then finds out the two highest bidders. The highest bidder gets the job to sense and transmit and the second highest bidder remains in the queue as backup and send all the other bidders a message to terminate or sleep. If the highest bidder fails to complete its job, then the backup node continues the rest of the job. If the currently active node sends a message to terminate signal, it goes back to the cluster head selection algorithm if not it goes to the third algorithm (Algorithm for selected node).

Algorithm 2 Job allocation algorithm among bidders.

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i. **Phase I: INITIATE BIDDING**
   a. Select bidders (Neighbors)
   b. Send "initiate bidding" signal to bidders

ii. **Phase II: SETTING PRIORITY USING BIDDING FUNCTION**
   i. $B_{i\ [\ i=\ 1,2,3,4,5,6,7,8]}$
   ii. Using bidding function

$$\frac{\mathbf{1}}{\boldsymbol{distance}(\boldsymbol{head}, \boldsymbol{adj}[\boldsymbol{x}][\boldsymbol{y}])} + \boldsymbol{b\_Level}[\boldsymbol{x}][\boldsymbol{y}]$$

   iii. Saves returned array:
   priorityArray[][], stored high to low priority

iii. **Phase III: WORK ALLOCATION**

a. Head knows the winner/highest bidder

b. Assign the highest bidder to the job and 2nd highest as backup

priorityArray[0] → got the job

priorityArray[1] → in power saver as backup

c. Send all other bidders sleep/terminate signal

iv. **Phase IV: RECOVERY MODE**

a. ***if*** current node, ***priorityArray[0],*** fails initiate backup, ***priorityArray[1]***

b. ***priorityArray[1] → got the job***

c. recover **priorityArray[0]** then → in power saver mode as backup

v. **Phase V: TERMINATION**

a. ***if*** currently active node sends "**terminate signal"**

i. Send terminate signal to active and backup node

ii. Terminate (go back to ***ClusterHeadSelection***)

Selected node's job:

The highest bidder will then check if the substance is in range and if DTT<0 or not. (DTT: Data to Transmit). If it is true, Then the bidder will start sensing and storing data.

If DTT >=1 the bidder will then transmit all the stored data to gateway and initiate the DTT in to 0.

If it doesn't match with any of the conditions, it means the substance is no more in the range it will transmit all the data to gateway and initiate the DTT into 0 again. Lastly it will send a signal to the cluster head to terminate its job. Thus the sensors will work according to the algorithm if it senses any substance into its range.

Algorithm 3 Algorithm for selected node. And backup node

//DTT→ Data to Transmit

Step 1: Start
Step 2: check ***if*** the object ***isInRange ()*** and ***DTT***<1
Step 3: if true continue sensing and storing data of the object
Step 4: else

if **DTT** >=1

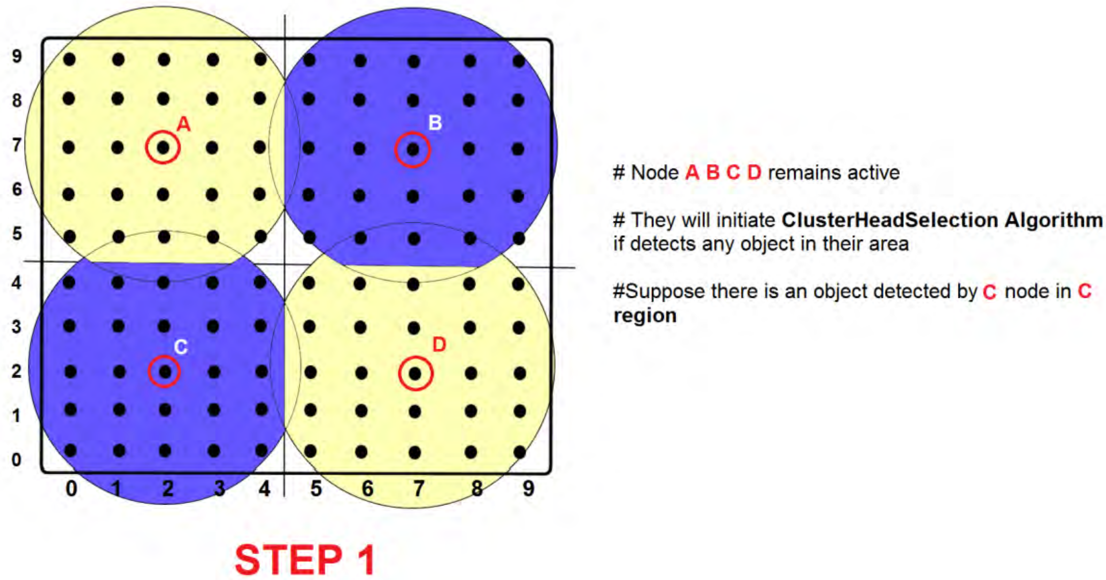
i. transmits stored data to ***gateway***
ii. ***DTT*** → 0;
iii. Go to Step 2

else // object is not in range now

i. transmits stored data to ***gateway***
ii. ***DTT*** → 0;
iii. Send terminate signal to ***cluster_head***
iv. Sleep.

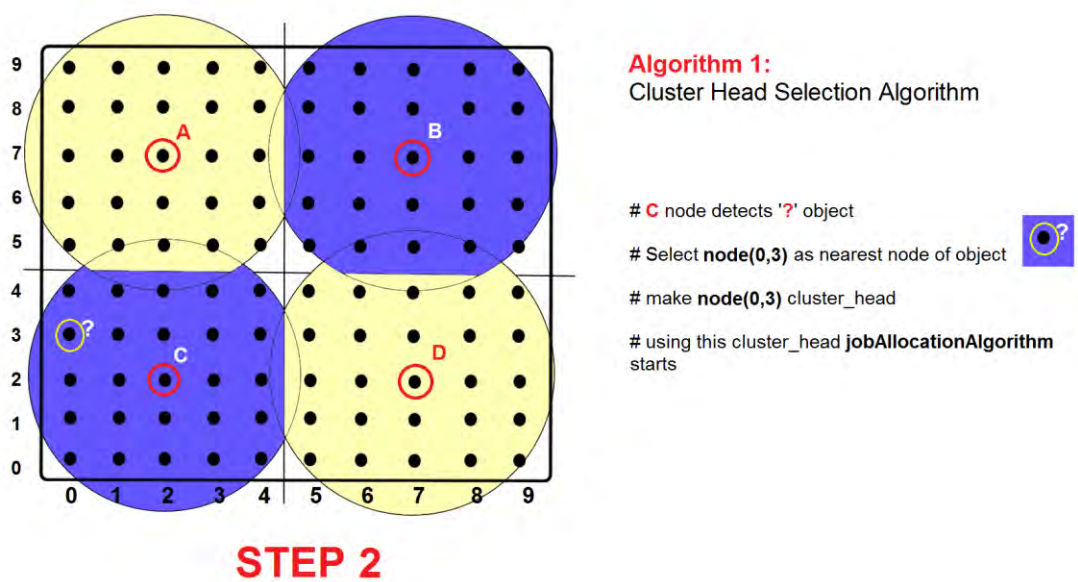
Step 5: exit

Step by step context representation:



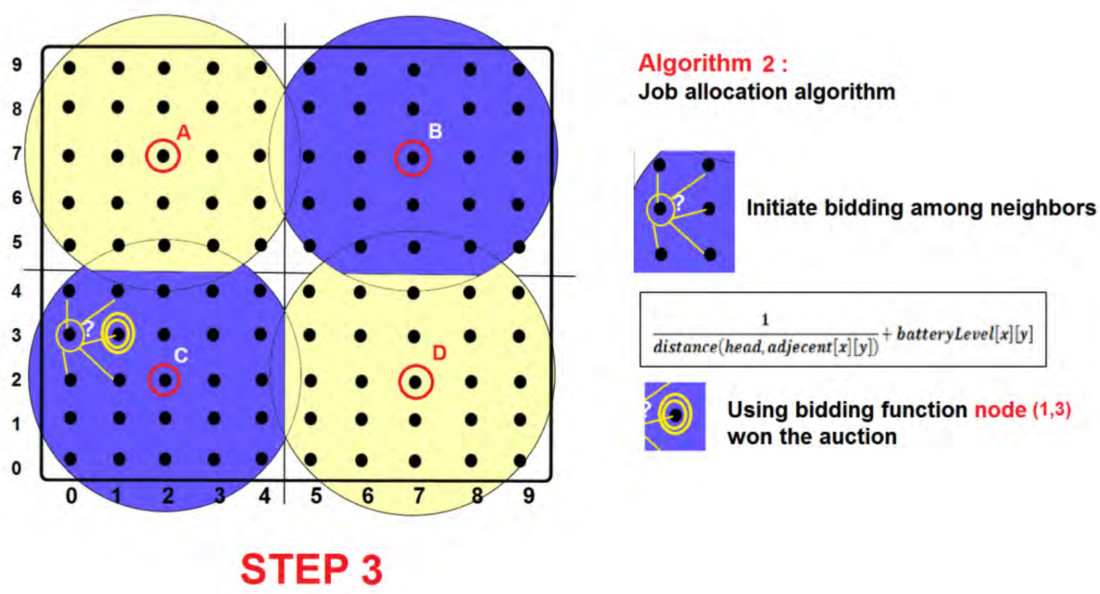
Step 1:

If the system detects any object in its area it will initiate ‘Cluster Head Selection Algorithm’.



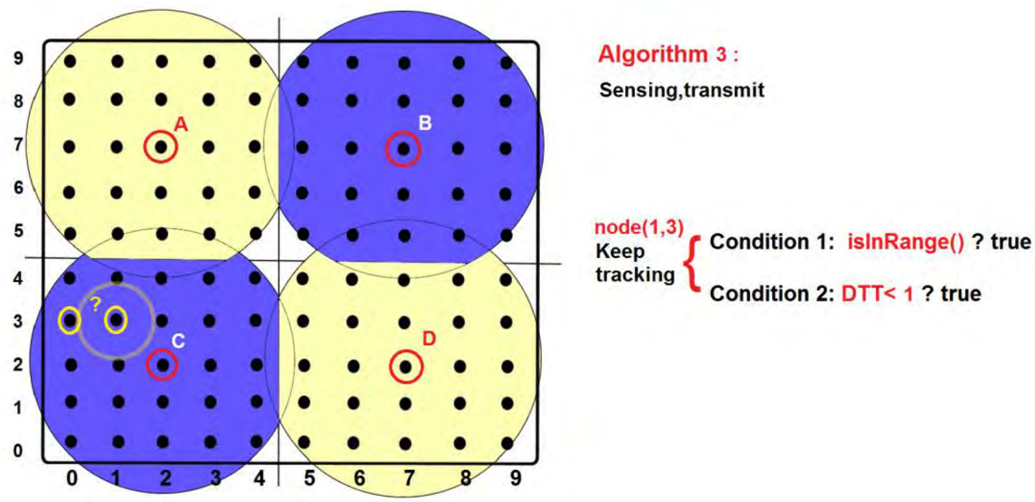
Step 2:

When an object is being detected by a main sensor node it will run the cluster head selection algorithm to make the closest node of the object as the cluster head. Here 'C' is a main sensor node which detects an object '?' and makes node (0,3) cluster head. Cluster head then initiates 'Job Allocation Algorithm' to start bidding among its neighbor nodes.



Step 3:

Cluster head bids among its neighbor nodes using the 'Bidding Function'. We can see from the function that the bidding depends on the distance from the object and battery level. So the smallest the distance is, there is the better chance to won the auction if it has a good battery level. Here in this system, node (1,3) won the auction because it is nearer and has a good amount of battery life left.



STEP 4

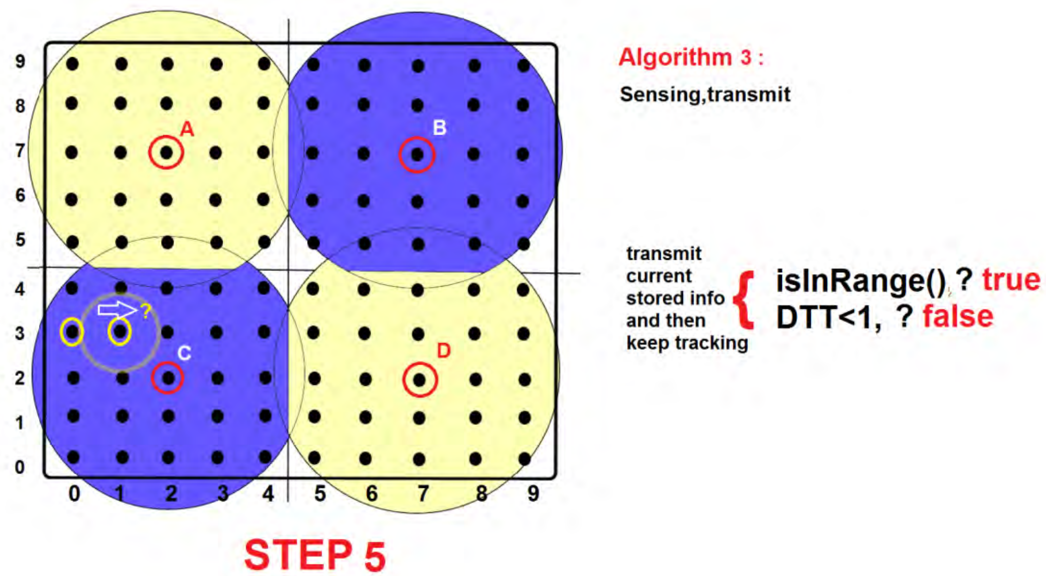
Step 4:

The winner node, Node (1,3), will check two things.

1. If object is in (active nodes) range
2. If DTT is full

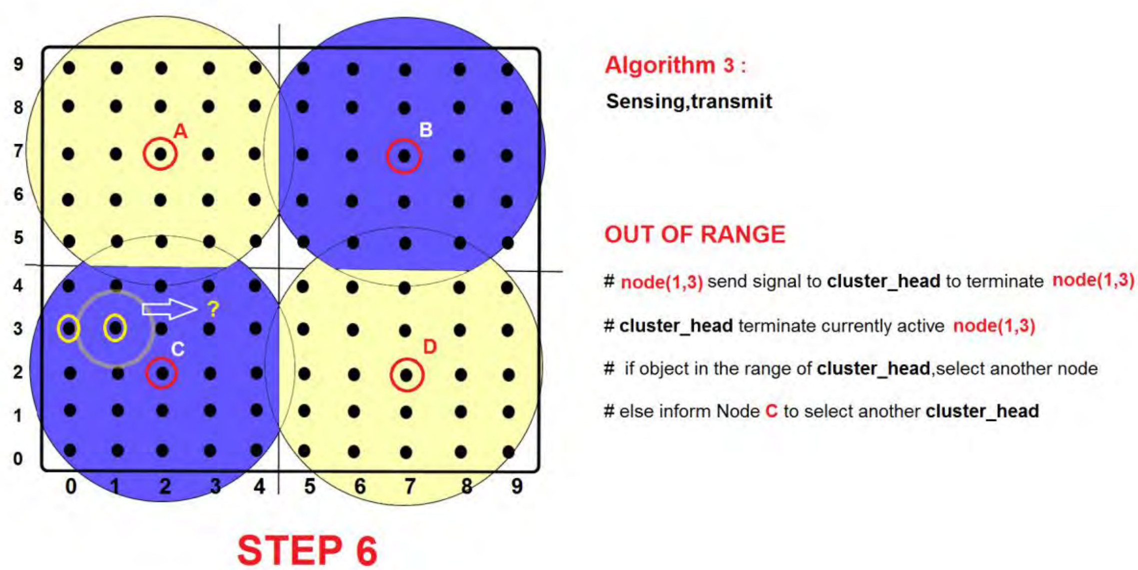
Whether the objective is in range or not and DTT (Data to Transmit) is less than 1 or not. DTT<1 it means there are some space to store data. DTT=1 means the memory is full and stored data needs to be transmitted and cleared. If both the cases are true it will keep tracking the objective and will continue in sensing the environment and collecting data.

If the object is in range but DTT is not less than 1 it will move to step 5.



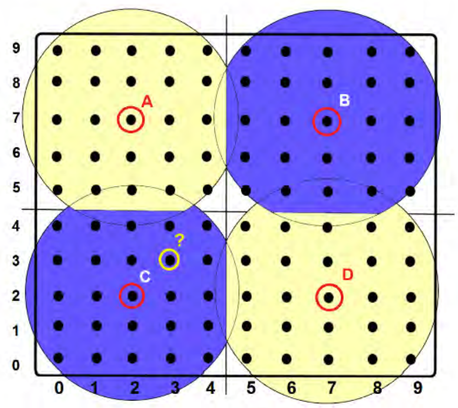
Step 5

DTT is either equals to 1 or greater than that but the object is in range. In that case, it will stop sensing and start transmitting the stored data and then again keep tracking



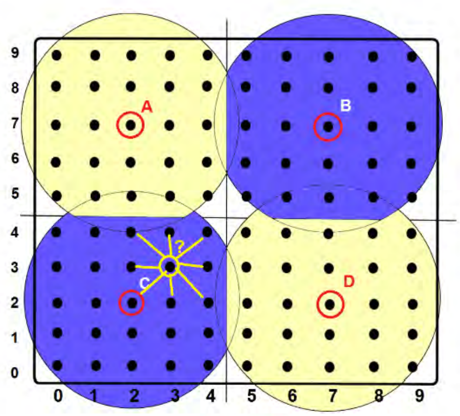
Step 6

When the object is out of range. Then the cluster head (here Node(1,3)) send signal to the Cluster Head to terminate his job. Cluster Head then terminates its job and checks is the object is under its range or not. If it is in range then it allocates another Node by job allocation algorithm. If the object is not in range then the Cluster Head informs the active main node (Here C) to select another cluster head. And repeat from step 3 again

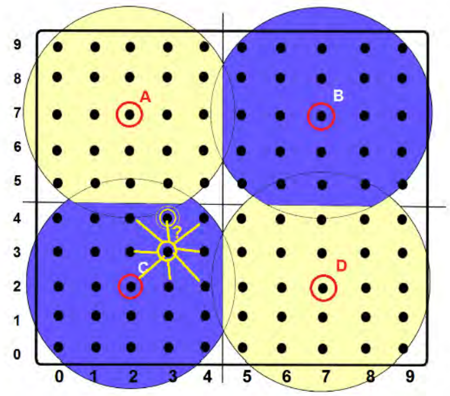


Repeat **STEP 3**

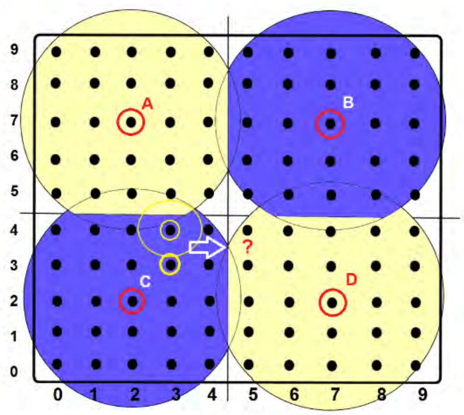
STEP 7



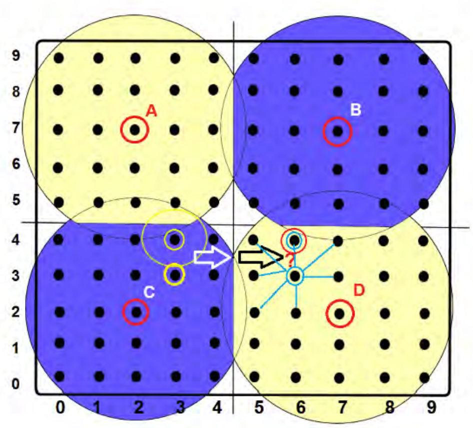
STEP 8



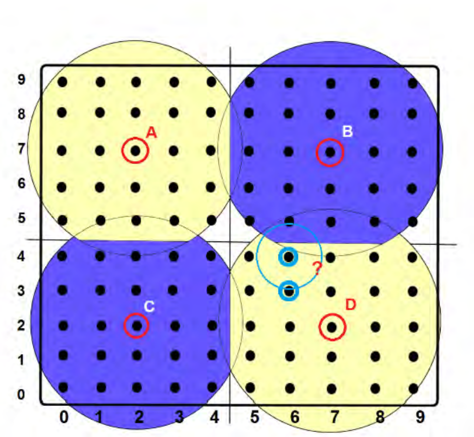
STEP 9



STEP 10



STEP 11



STEP 12

Step 3

Demonstration link

We have uploaded the animated demonstration here:

http://bit.ly/WSNBRAC

Chapter V

EXPERIMENTAL RESULTS AND EVALUATION

In this simulation we have taken 100 sensor nodes in the area of 10-meter X 10-meter area. The visibility area of each sensor node is assumed to be 1 meter. One of the main part of this system is the four main sensor nodes which is always be in active mode. Which are powerful than the other 96 nodes. In this system we have divided the whole area into 4 units. Each unit has 24 sensor nodes and 1 main sensor node. 1 main sensor node covers the rest 24 in its area. So each of the main sensor node covers 25% of the total system. When an unwanted substance comes under its (main sensor node) sensing range it calculates and makes the nearest node of the substance as cluster head. So in this system cluster head is not fixed. It is being selected dynamically by the main sensor node.

We consider the following equations for remaining total energy and used energy calculation.

Remaining total energy (Stored energy) = $\sum_{\substack{i=node(0,0) \\ i \neq A,B,C,D}}^{i=node(9,9)} \text{RemainingEnergy(i)};$

Used energy = initial energy- remaining energy

For simulation we are assuming some events.

In worst case at least one (any one) node will continuously track object and we are also assuming on an average after every 5 minute the transition (changing of currently active node because of changed location of the tracked object) will occur. During transition, at a time maximum of 8 nodes will remain active and between two transitions 2 nodes remain active. One is currently active node and another one is the cluster head.

In this case we are assuming total life time of a node is 10 days (14,400 min). It means one node can be active/live for 10 days' max if standby.

So, for every minute of activation, each node will lose **0.006944%** of its initial (100%) charge. And during the transition period 8 nodes(max) remain active simultaneously. If the transition period takes 5 secs to complete, this will cost **(0. 00007233 × 5 × 8) ÷60 %** of initial charge of total system.

Total Transition = time/5

One node for one min = 0.006944 % //discharge from own

One node for one min = (0. 006944 ÷ (100-4))
= 0.00007233% // From total system

Total used energy =
(Total Transition ×Transition cost**) + (**Total Transition ×1 min of system cost ×2 ×4**)**

Considering static allocation of energy

Static use of energy = 0.006944% loss/min

Based on the equations, calculations and the result is shown in the given datasheet:

time (minute)	Total used energy	Transitions 5 min	Remaining total energy	Remaining E (All node on)	Used energy (%)
0	0	0	100	100	0
500	0.294142	100	99.705858	96.528	3.472
1000	0.588284	200	99.411716	93.056	6.944
1500	0.882426	300	99.117574	89.584	10.416
2000	1.176568	400	98.823432	86.112	13.888
2500	1.47071	500	98.52929	82.64	17.36
3000	1.764852	600	98.235148	79.168	20.832
3500	2.058994	700	97.941006	75.696	24.304
4000	2.353136	800	97.646864	72.224	27.776
4500	2.647278	900	97.352722	68.752	31.248
5000	2.94142	1000	97.05858	65.28	34.72
5500	3.235562	1100	96.764438	61.808	38.192
6000	3.529704	1200	96.470296	58.336	41.664
6500	3.823846	1300	96.176154	54.864	45.136
7000	4.117988	1400	95.882012	51.392	48.608
7500	4.41213	1500	95.58787	47.92	52.08
8000	4.706272	1600	95.293728	44.448	55.552
8500	5.000414	1700	94.999586	40.976	59.024
9000	5.294556	1800	94.705444	37.504	62.496
9500	5.588698	1900	94.411302	34.032	65.968
10000	5.88284	2000	94.11716	30.56	69.44
10500	6.176982	2100	93.823018	27.088	72.912
11000	6.471124	2200	93.528876	23.616	76.384
11500	6.765266	2300	93.234734	20.144	79.856
12000	7.059408	2400	92.940592	16.672	83.328
12500	7.35355	2500	92.64645	13.2	86.8
13000	7.647692	2600	92.352308	9.728	90.272

13500	7.941834	2700	92.058166	6.256	93.744
14000	8.235976	2800	91.764024	2.784	97.216
14500	8.530118	2900	91.469882	discharged	all used
15000	8.82426	3000	91.17574	discharged	all used
15500	9.118402	3100	90.881598	discharged	all used
16000	9.412544	3200	90.587456	discharged	all used
16500	9.706686	3300	90.293314	discharged	all used
17000	10.000828	3400	89.999172	discharged	all used
17500	10.29497	3500	89.70503	discharged	all used
18000	10.589112	3600	89.410888	discharged	all used
18500	10.883254	3700	89.116746	discharged	all used
19000	11.177396	3800	88.822604	discharged	all used
19500	11.471538	3900	88.528462	discharged	all used
20000	11.76568	4000	88.23432	discharged	all used
20500	12.059822	4100	87.940178	discharged	all used
21000	12.353964	4200	87.646036	discharged	all used
21500	12.648106	4300	87.351894	discharged	all used
22000	12.942248	4400	87.057752	discharged	all used
22500	13.23639	4500	86.76361	discharged	all used
23000	13.530532	4600	86.469468	discharged	all used
23500	13.824674	4700	86.175326	discharged	all used
24000	14.118816	4800	85.881184	discharged	all used
24500	14.412958	4900	85.587042	discharged	all used
25000	14.7071	5000	85.2929	discharged	all used
25500	15.001242	5100	84.998758	discharged	all used
26000	15.295384	5200	84.704616	discharged	all used
26500	15.589526	5300	84.410474	discharged	all used
27000	15.883668	5400	84.116332	discharged	all used
27500	16.17781	5500	83.82219	discharged	all used
28000	16.471952	5600	83.528048	discharged	all used

28500	16.766094	5700	83.233906	discharged	all used
29000	17.060236	5800	82.939764	discharged	all used
29500	17.354378	5900	82.645622	discharged	all used
30000	17.64852	6000	82.35148	discharged	all used
30500	17.942662	6100	82.057338	discharged	all used
31000	18.236804	6200	81.763196	discharged	all used
31500	18.530946	6300	81.469054	discharged	all used
32000	18.825088	6400	81.174912	discharged	all used
32500	19.11923	6500	80.88077	discharged	all used
33000	19.413372	6600	80.586628	discharged	all used
33500	19.707514	6700	80.292486	discharged	all used
34000	20.001656	6800	79.998344	discharged	all used
34500	20.295798	6900	79.704202	discharged	all used
35000	20.58994	7000	79.41006	discharged	all used
35500	20.884082	7100	79.115918	discharged	all used
36000	21.178224	7200	78.821776	discharged	all used
36500	21.472366	7300	78.527634	discharged	all used
37000	21.766508	7400	78.233492	discharged	all used
37500	22.06065	7500	77.93935	discharged	all used
38000	22.354792	7600	77.645208	discharged	all used
38500	22.648934	7700	77.351066	discharged	all used
39000	22.943076	7800	77.056924	discharged	all used
39500	23.237218	7900	76.762782	discharged	all used
40000	23.53136	8000	76.46864	discharged	all used
40500	23.825502	8100	76.174498	discharged	all used
41000	24.119644	8200	75.880356	discharged	all used
41500	24.413786	8300	75.586214	discharged	all used
42000	24.707928	8400	75.292072	discharged	all used
42500	25.00207	8500	74.99793	discharged	all used
43000	25.296212	8600	74.703788	discharged	all used

43500	25.590354	8700	74.409646	discharged	all used
44000	25.884496	8800	74.115504	discharged	all used
44500	26.178638	8900	73.821362	discharged	all used
45000	26.47278	9000	73.52722	discharged	all used
45500	26.766922	9100	73.233078	discharged	all used
46000	27.061064	9200	72.938936	discharged	all used
46500	27.355206	9300	72.644794	discharged	all used
47000	27.649348	9400	72.350652	discharged	all used
47500	27.94349	9500	72.05651	discharged	all used
48000	28.237632	9600	71.762368	discharged	all used
48500	28.531774	9700	71.468226	discharged	all used
49000	28.825916	9800	71.174084	discharged	all used
49500	29.120058	9900	70.879942	discharged	all used
50000	29.4142	10000	70.5858	discharged	all used
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51000	30.002484	10200	69.997516	discharged	all used
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58500	34.414614	11700	65.585386	discharged	all used
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63500	37.356034	12700	62.643966	discharged	all used
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66000	38.826744	13200	61.173256	discharged	all used
66500	39.120886	13300	60.879114	discharged	all used
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68500	40.297454	13700	59.702546	discharged	all used
69000	40.591596	13800	59.408404	discharged	all used
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70500	41.474022	14100	58.525978	discharged	all used
71000	41.768164	14200	58.231836	discharged	all used
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74500	43.827158	14900	56.172842	discharged	all used
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77000	45.297868	15400	54.702132	discharged	all used
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166000	97.655144	33200	2.344856	discharged	all used
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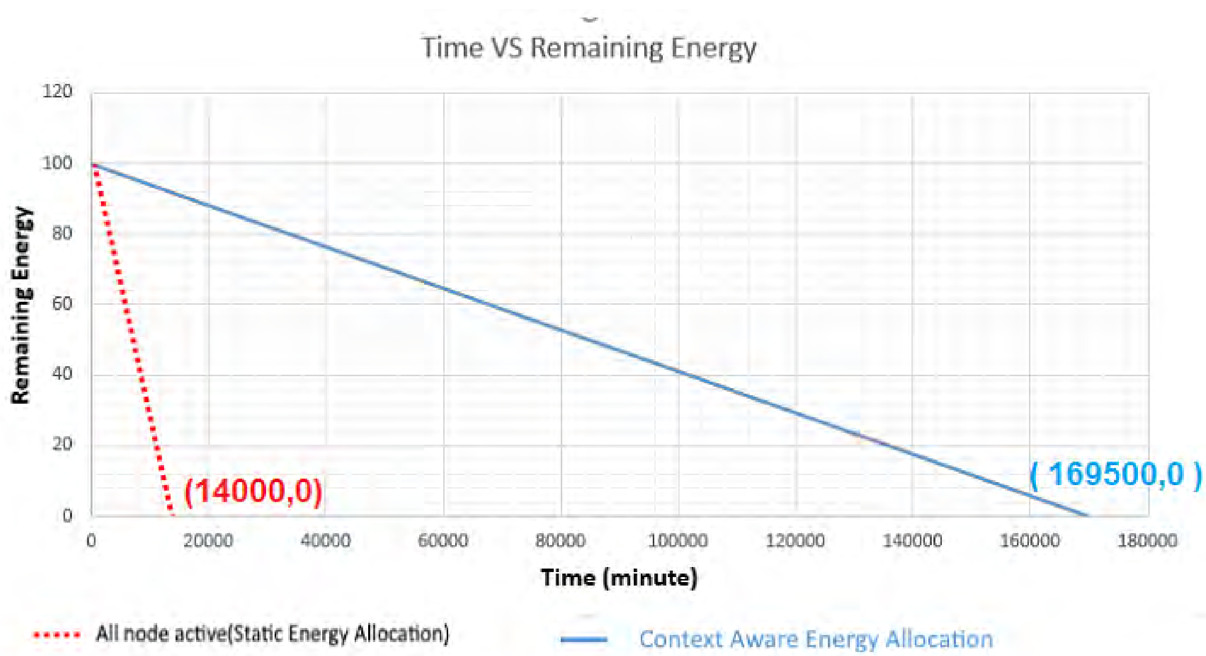

Fig. 3: Time vs Remaining energy

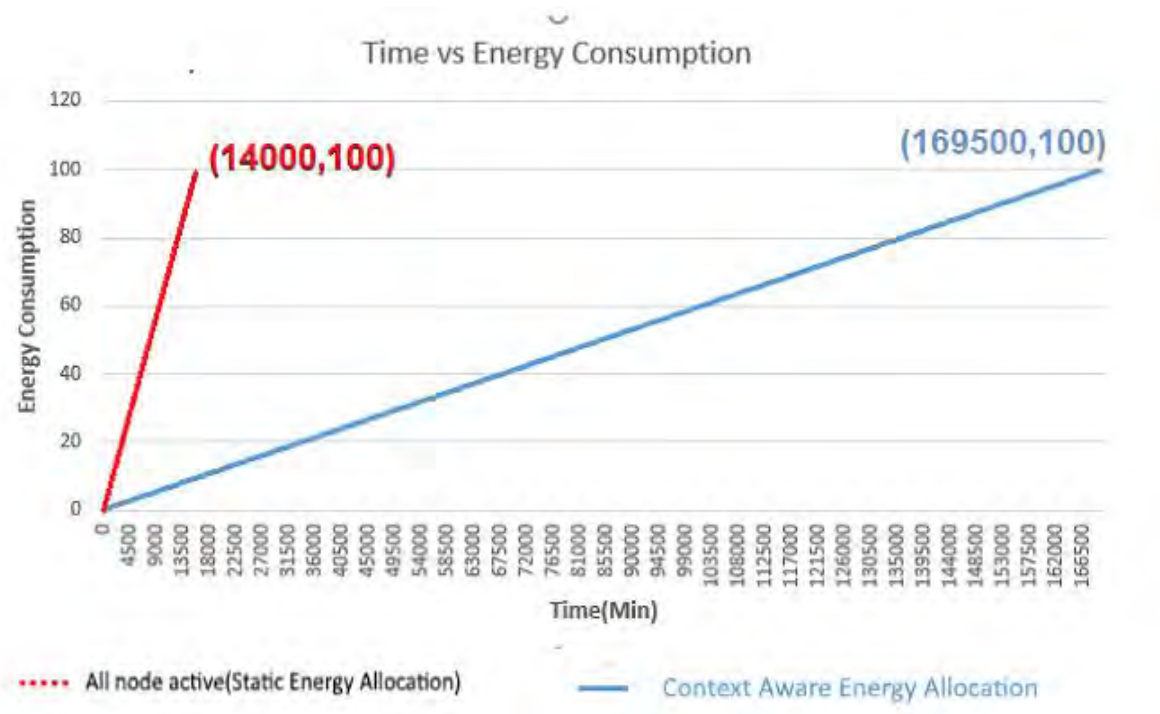

Fig. 4: Time vs Consumed energy in total system

Fig.3 and Fig.4 shows remaining energy and total consumed energy according to the change of time in worst case scenario. We started time from 0 minute where remaining energy was full (100% initially) as well as consumed energy was 0 and ended at 1,69,500 minute where remaining energy was approximately 0% and total energy was consumed by the nodes. We took 341 reading by changing time with 500-minute interval, until the remaining energy got down to 0% approximately or in other words till total energy was consumed. Fig. 3 shows that our approach provides better performance in terms of remaining energy comparing with the existing method. Fig. 4 shows that our method shows better performance in terms of total energy consumption.

According to this simulation result this 100 node can sense the area for 1,69,500 minute in worst case scenario, where 2 nodes were continuously active and at every 5 minute there were a transition period.

Chapter VI

CONCLUSION

We have used Context aware task allocation/energy allocation to maximize the lifetime of the network. In the proposed system we have used three different algorithms to collect data and transmit it when necessary. Our target was to use the Wireless Sensor Network in such a way that we can avoid wastage of energy as much as possible as well as get information. In this paper we have used a composite algorithm to select cluster head and allocation of jobs. Our proposed system focuses on job allocation so that all the nodes do not need to stay awake or active all the time. If we maintain some conditions this system can give very good solution like the main sensor nodes need to be constantly active (by using Solar System or with multiple backup power) and if simultaneously multiple event doesn’t happen.

The simulation results show that the system saves significant amount of energy comparatively.

Chapter VII

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