A Solution for Network Life Time Problem Using Content Based Energy Efficient Routing Algorithm

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***Abstract*-In This Project we consider an overarching problem that encompasses both performance metrics. In particular, we study the network capacity problem under a given network lifetime requirement. Specifically, for a wireless sensor network where each node is provisioned with an initial energy, if all nodes are required to live up to a certain lifetime criterion, what is the maximum amount of bit volume that can be generated by the entire network? In particular, those nodes that consume the least amount of power on their data path toward the base station are allocated with much more bit rates than other nodes in the network. Consequently, the data collection behaviour for the entire network only favours certain nodes that have this property, while other nodes will be unfavourably penalized with much smaller bit rates. We apply the content based energy routing algorithm for each of the nodes. This is thoroughly a distributed algorithm (the algorithm which has no centralized controller, each node can be seen as autonomous units, functioning independently). Thus the flexibility of the network is wide open. Any number of nodes can be added dynamically as per requirements.**

Key Words: Rate Allocation, Content Based Energy Routing Algorithm, Network Life Time Problem, Afn Nodes, Base Station

I. INTRODUCTION

The important performance consideration for wireless sensor networks in the amount of information collected by all the nodes in the network over the course of network lifetime. Since the objective of maximizing the sum of rates of all the nodes in the network can lead to a severe bias in rate allocation among the nodes, the base paper specifies the use of lexicographical max-min (lmm) rate allocation. to calculate the lmm rate allocation vector, they've develop a polynomial-time algorithm by exploiting the parametric analysis (pa) technique from linear program (lp), which they call as serial lp with parametric analysis (slp-pa). They've showed that the slp-pa can be also employed to address the lmm node lifetime problem much more efficiently than a state-of-the-art algorithm proposed in the literature. More importantly, they've showed that there exists an elegant duality relationship between the lmm rate allocation problem and the lmm node lifetime problem. Therefore, it is sufficient to solve only one of the two problems. Important insights can be obtained by inferring duality results for the other problem.

Wireless sensor networks consist of battery-powered nodes that are endowed with a multitude of sensing modalities including multi-media (e.g., video, audio) and scalar data (e.g., temperature, pressure, light, magnetometer, infrared). Although there have been significant improvements in processor design and computing, advances in battery technology still lag behind, making energy resource considerations the fundamental challenge in wireless sensor networks. Consequently, there have been active research efforts on performance limits of wireless sensor networks. These performance limits include, among others, network capacity and network lifetime. Network capacity typically refers to the maximum amount of bit volume that can be successfully delivered to the base station ("sink node") by all the nodes in the network, while network lifetime refers to the maximum time limit that nodes in the network remain alive until one or more nodes drain up their energy. In this project, we consider an overarching problem that encompasses both performance metrics. In particular, we study the network capacity problem under a given network lifetime requirement. Specifically, for a wireless sensor network where each node is provisioned with an initial energy, if all nodes are required to live up to a certain lifetime criterion, what is the maximum amount of bit volume that can be generated by the entire network? At first glance, it appears desirable to maximize the sum of rates from all the nodes in the network, subject to the condition that each node can meet the network lifetime requirement. This is a problem within which the objective function is defined as the sum of rates over all the nodes in the network and the constraints are: 1) flow balance is preserved at each node, and 2) the energy constraint at each node is met for the given network lifetime requirement. However, the solution to this problem shows that although the network capacity (i.e., the sum of bit rates over all nodes) is maximized, there exists a severe bias in rate allocation among the nodes. In particular, those nodes that consume the least amount of power on their data path toward the base station are allocated with much more bit rates than other nodes in the network. Consequently, the data collection behaviour for the entire network only favours certain nodes that have this property, while other nodes will be unfavourably penalized with much smaller bit rates.

We apply the content based energy routing algorithm for each of the nodes. This is thoroughly a distributed algorithm (the algorithm which has no centralized controller, each node can be seen as autonomous units, functioning independently). Thus the flexibility of the network is wide open. Any number of nodes can be added dynamically as per requirements. Thus by applying the above said algorithm we'll get to know that this is much more efficient than the lp with parametric analysis (slp-pa).

II. SYSTEM DESIGN

The main implementation of our system is based on the two tier architecture with 18 nodes being taken into being. These nodes are arranged in the form of the honey comb in five columns with the rear ones on both ends having three nodes, the penultimate columns and the centre column, all the three, having four nodes. We prefer going to honey comb structure instead of grid structure as we increase the compactness of the structure. The node centre of one and the node centre of the other are brought together. This, in turn, increases the communication efficiency, without much loss in the energy when the transfer takes place.

Each node then is assigned with some arbitrary value of energy based on which the transfer is done. Also it is noted that the values of energies are not the same from one to another in the particular column. One node is selected from each column and transfer is carried out. Also before transfer from one node to the one in next column, all the energies of nodes in the column are to be made known to it. The algorithm is implemented to each node in the system. Thus the node in next column to which the transfer should take place is determined and sent along. This is the way in which transfer takes place from one end to the other, to which it is finally reached.

III. SYSTEM ARCHITECTURE

We consider two-tier architecture for wireless sensor networks. The figures 2.2.1 (a) and (b) show the physical and hierarchical network topology for such a network, respectively. There are three types of nodes in the network, namely, *micro-sensor nodes* (MSNs), *aggregation and forwarding nodes* (AFNs), and a *base station* (BS). The MSNs can be application-specific sensor nodes (*e.g.*, temperature sensor nodes (TSNs), pressure sensor nodes (PSNs), and video sensor nodes (VSNs)) and they constitute the lower tier of the network. They are deployed in groups (or clusters) at strategic locations for surveillance and monitoring applications. The MSNs are small and low-cost. The objective of an MSN is very simple: Once triggered by an event, it starts to capture sensing date and sends it directly to the local AFN. For each cluster of MSNs, there is one AFN, which is different from an MSN in terms of physical properties and functions.

The primary functions of an AFN are:

(1) *Data aggregation* (or "fusion") for data flows from the local cluster of MSNs

(2) *Forwarding* (or relaying) the aggregated information to the next hop AFN (toward the base station).

For data fusion, an AFN analyses the content of each data stream it receives and exploits the correlation among the data streams. An AFN also serves as a relay node for other AFNs to carry traffic toward the base station. Although an AFN is expected to be provisioned with much more energy than an MSN, it also consumes energy at a substantially higher rate (due to wireless communication over large distances). Consequently, an AFN has a limited lifetime. Upon depletion of energy at an AFN, we expect that the *coverage* for the particular area under surveillance is lost, despite the fact that some of the MSNs within the cluster may still have remaining energy.

The third component in the two-tier architecture is the base station. The base station is, essentially, the *sink* node for data streams from all the AFNs in the network. In this investigation, we assume that there is sufficient energy resource available at the base station and thus there is no energy constraint at the base station. In summary, the main functions of the lower tier MSNs are data acquisition and compression while the upper tier AFNs are used for data fusion and relaying information to the base station.

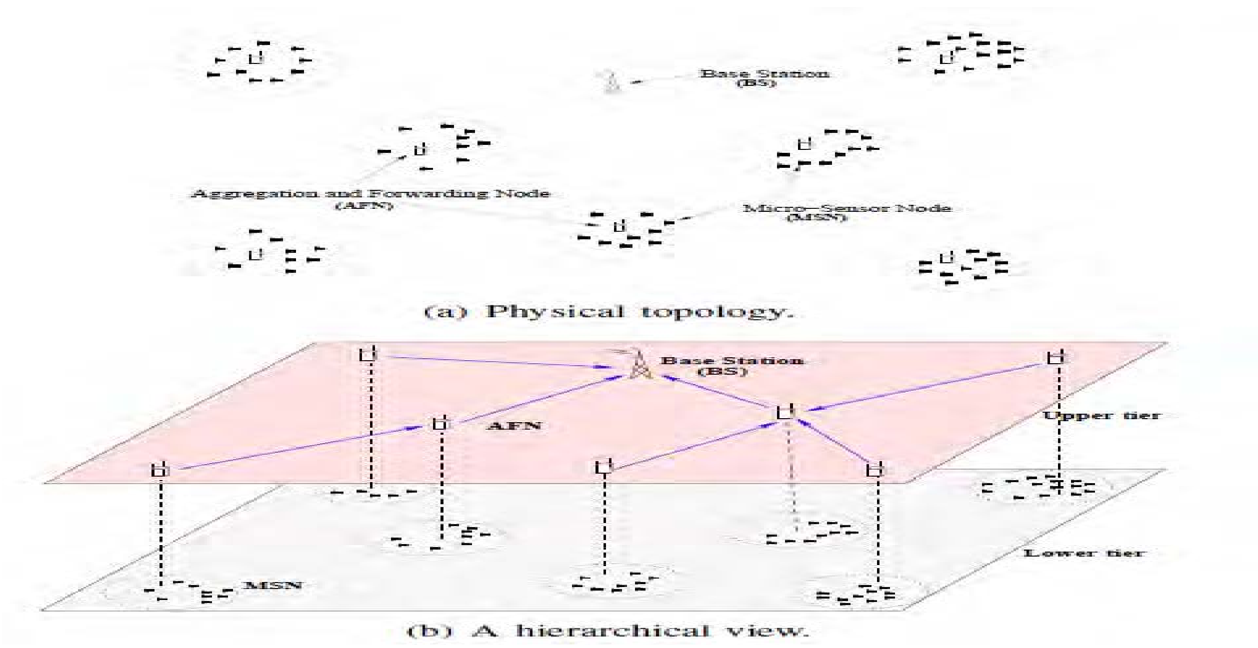


Fig 1. Architecture of Two-Tier Wireless Sensor Networks

A. AFN (Aggregation and Forwarding Node)

Basically, the aggregation and forwarding node is a module that performs the desirable task of sending the file to the Sink node. The aggregation and forwarding node contains the file. Then the node that is selected is in contact with the three nodes in the previous column (as it's a bee hive structure with each hexagon in contact with 6 hexagons touching that node with the hexagon being in any of the middle columns). The link is selected such that if the file is larger than the threshold the algorithm throws to select the maximum energy node. If the size is less than the threshold the algorithm throws to choose the minimum path. We construct a routing table for the selected node which contains the entries of the nodes that are in proximity with the node.

B. WSN (Wireless Sensor Networks)

A sensor network is Special type of network. It consists of sensors performing particular measures (SENSOR reading and processing element). Usually the sensor networks are considered to be strongly resource restricted in terms of processing, storage capability and energy.

In the construction of the complete network we basically select eighteen nodes for our implementation. Getting these nodes together, we apply the content based energy routing algorithm for each of the same. This is thoroughly a distributed algorithm (the algorithm which has no centralized controller, each node can be seen as autonomous units, functioning independently. Thus the flexibility of the network is wide open. Any number of nodes can be added dynamically as per requirements. The scalability is improved in the wireless sensor network).

The function of this WSN is that it stimulates the network that is wireless and sensor in nature, between the AFN and the SN. In the sense, it is the network or the path from the AFN to the SN which via which the file is transferred. The data aggregation happens in each and every node in the wireless sensor network.

C. SN (Sink Node)

This is nothing but the destination where the files are reached after the transfer. They are the base station or the sink of the data, representing the receiving of data from the WSNs. When we consider the broader aspect of the sink node, this has vast application. It also acts as the connecting link, in other words- the interface, between two wireless sensor networks. Thus the collaboration between the networks is achieved here.

IV. IMPLEMENTATION

A. Introduction

The implementation phase involves testing the above designed system by implementing the network with file transfer based on the content-based energy efficient routing algorithm taking into account all the considered assumptions. This is an algorithm which is distributive in nature. The algorithm is implemented at each node so as to form the network file transfer from the aggregation and forwarding node to the destination.

We apply the content based energy routing algorithm for each of the nodes. This is thoroughly a distributed algorithm (the algorithm which has no centralized controller, each node can be seen as autonomous units, functioning independently. Thus the flexibility of the network is wide open. Any number of nodes can be added dynamically as per requirements. The scalability is improved in the wireless sensor network).

Our implementation involves three phases

1) Aggregation and forwarding node
2) Wireless Sensor Network, and
3) Sink Node.

B. Algorithm

We propose a suitable distributed algorithm for the implementation, namely the content-based energy efficient routing algorithm for wireless sensor networks. This is efficient to the greater extent as this is content based and is easily implemented. Adding to its distributive property is the scalability of the algorithm and efficient implementation of the two tier architecture.

C. Variables

1) Information State: This is the percentage of the energy per bytes that a particular node contains among all the nodes that are connected to the particular node.
2) Probability State: It is the probability of the selection of the particular node in the wireless sensor network (WSN).
3) Rank Value: It is the numerical value assigned to each of the nodes based on the average of the probability state and information state.
4) Rank: The node with the lowest rank value is assigned the highest rank.
5) Threshold: The value above which the file is transmitted to the node with maximum ranks in each column and below which the transmitted to the nodes with minimum rank.
6) Information array: The array that holds the information of the nodes that have link to the particular node.
7) Probability array: The array that holds the probability value of the particular node.
8) Rank array: The array that holds the numerical values assigned to each nodes based on the average of the probability state and information state.

D. Algorithm Steps

Step 1: Start

Step 2: Sensor in searching mode

The sensor is kept in the searching mode

Step 3: Node detected or alert achieved

The link is established after finding the node. The suitable initializations to the Information array and Probability array are made.

$$information\ array = \left(\frac{1}{number\ of\ nodes}\right) * 100$$

$$probability\ array = \left(\frac{1}{number\ of\ nodes}\right) * 100$$

Step 4: Sensor in active mode

The sensor performs the following functions when the link is established.

a. Calculate the information state.
b. Calculate the probability state and probability array.
c. Update the probability array and information array.
d. Calculate the rank.
e. Predict the neighboring nodes.
f. Send file to selected node.

Step 5: End active mode

After updating, the active mode is turned off.

Step 6: Stop

Termination of the algorithm implemented here.

E. Calculations

1) Calculation Of The Information State And Information Array: In this stage we calculate the energy to data ratio by taking into account the remaining energy of the nodes and the amount of data to be transmitted. The percentage of this gives the information state values. The below equations show their mathematical representations.

Consider a node **A** which wishes to transmit its data to the sink node. After establishing the direct link between **n** nodes, each node calculates its energy to data ratio as follows:

$$energy\ to\ data\ ratio = \left(\frac{remaining\ energy\ of\ the\ nodes\ i}{amount\ of\ data\ to\ be\ transmitted\ i}\right)$$

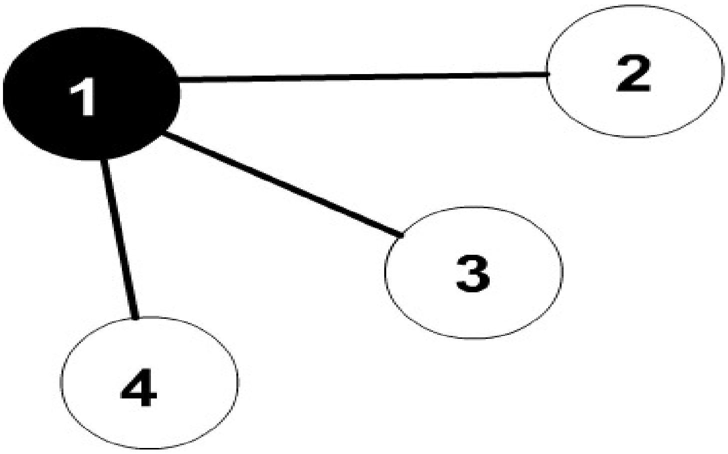
$\forall$ **1≤i≤n**, each of the nodes transmits its energy to data ratio to node **A**.

After obtaining from above, the node calculates the information states of each of the nodes. The calculation is as shown,

$$information\ state_i = \frac{energy\ to\ data\ i}{\sum_{i=1}^{n} energy\ to\ data}$$

$\forall$ **1≤i≤n**. After calculating the information state of each of the node, the node **A** updates its calculated values.

2) Calculation Of The Probability State And Probability Array: To begin with, each possible path has an even likelihood of being chosen. We consider a network of 4 nodes, with the source node 1 and destination node 2. A chance mechanism is invoked and a path is chosen.



Next Node	% chance
2	33.33333%
3	33.33333%
4	33.33333%

Probability state array

Fig 2. Probability state of network graph

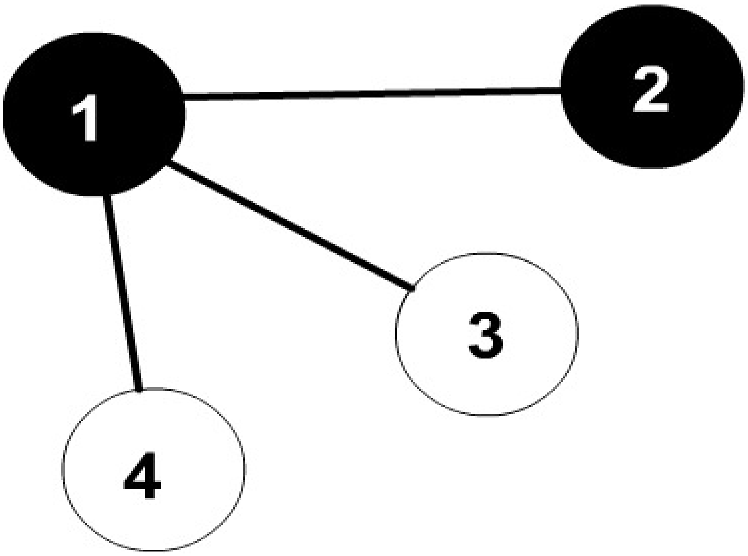
Case 1 :The network graph

In this case, node 2 has been selected and the Probabilities of the links are suitably adjusted as follows:

- Node 2 was the final destination
- It took 1 hop to get to its destination
- Divide 1 (hop) by 100: 100%
- Add 100 to the probability value of node 2 (currently 33.3333): 133.3333
- Add the values of the other nodes to 133.3333 (133.3333 + 33.3333 + 33.3333): 200 (approximately)
- Calculate the ratio: ratio = 100/200 0.5
- Set the probability of the node to its current value multiplied by the ratio
  - Node 2: 133.3333 * ratio (0.5) = 66.6666%
  - Node 3: 33.3333 * ratio (0.5) = 16.6666%
  - Node 4: 33.3333 * ratio (0.5) = 16.6666%
- Node 2 (66.6666%) + Node 3 (16.6666%) + Node 4 (16.6666%) = 99.9999%

The system isn't 100% accurate as the total will never add up to exactly 100%, but it will be close enough to allow accuracy within the level required.

The following diagram depicts how the path and pheromone table after the update has taken place.



Next Node	% chance
2	66.6666%
3	16.6666%
4	16.6666%

Fig 3. Probability array

3) Calculation of The Rank: The rank is calculated by taking the average of the probability state and the information state. It is obtained as follows,

Consider a node **A** which wishes to transmit its data to the sink node. After establishing the direct link between **n** nodes, each node calculates its rank as follows:

$$rank\ value = \frac{information\ state_i + probability\ state_i}{2} \qquad \forall\ 1 \leq i \leq n$$

This rank values is used in the sensor selection, via which the file is transferred to the sink node. The node with lowest rank value is assigned the highest rank.

F. *Aggregation and Forwarding Node Selection*

To select the aggregation and forwarding node the following criteria are taking into account:

1) *File size:* The size of the file that is to be transferred along the network.
2) *Rank:* The node with the lowest rank value is assigned the highest rank. Where,
3) *Rank Value*: It is the numerical value assigned to each of the nodes based on the average of the probability state and information state.
4) *Threshold:* It is that value above which the nodes with higher ranks are assigned for transfer. Correspondingly. Below which the nodes with lower ranks are assigned.

Now imagine the case where the file size is greater than the threshold, then the nodes with highest ranks is assigned.

In this section perform numerous tests by taking the files of various sizes and varying the value of the threshold. We calculate the amount of energy consumed by each of nodes selected for transfer of the file from AFN to sink node through wireless sensor network.

TABLE 1
Threshold -4

File Size(in mb)	(Node Selected, Energy Content of the node)				
0.5	1, 60	5,90	8,55	12,78	18,52
1	3, 43	7,86	11,75	13,69	17,83
2	1, 83	4,33	9,72	15,41	16,42
3	2, 56	5,35	10,86	14,59	17,55
4	3, 126	4,156	9,186	12,193	18,143
5	1, 110	5,151	8,98	15,164	16,181
6	2, 126	6,159	10,189	13,155	17,190
7	1, 201	5,149	11,182	14,99	18,141
8	3, 183	7,193	8,168	12,165	16,96
9	2, 149	4,97	9,89	15,113	18,139
10	1, 189	6,147	10,212	14,167	16,189

In the first we have considered the file size which varies from 0.5,1 to 10 MB and we have set the threshold value to 4 MB.

TABLE 11
Threshold -8

File Size(in mb)	(Node Selected, Energy Content of the node)				
4	1,71	7,90	10,92	15,44	16,45
5	2,25	5,74	9,59	13,68	18,43
6	1,76	4,56	11,74	15,65	18,72
7	3,87	6,93	10,86	12,38	16,33
8	2,147	5,167	9,186	14,178	17,167
9	1,183	7,134	11,123	15,164	18,156
10	3,169	5,147	8,156	13,134	17,145
11	3,183	6,123	11,182	15,156	18,117
12	2,172	6,189	9,178	14,136	16,198

In second case we consider the file which varies from 4 to 12 MB incremented by 1 and set the threshold value to 8 MB and calculate the energy consumed in each of the selected node for the transfer of data from AFN to sink node. From the above numerical results we can conclude that the content based energy efficient routing algorithm consumes less energy compared to SLP-PA algorithm proposed in the base paper. Numerical result proves content based algorithm is energy efficient for the transfer of the data.

V. SNAPSHOT OF SINK NODE

Fig 4. Sink node is provided with the functionality of setting the receiving path

A. Snap Shot Of Wireless Sensor Network

Fig 5. Routing in wireless sensor networks

B. Snap Shot Of Energy Chart

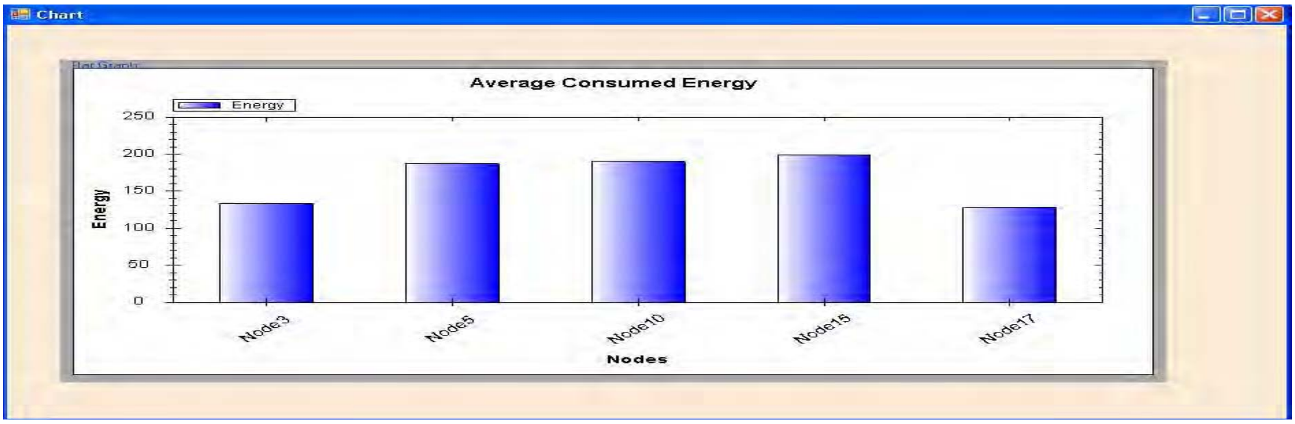


Fig 6. Graph of the nodes selected versus energy consumed

C. Snapshot of Aggregation and Forwarding Node

Fig 7. AFNs are having functionality of selecting file to be sent and providing ip address of destination.

D. Exception Handling In Sink Node

Fig 8. Receiving path exception in the sink node

E. Snapshot of Exception Handling IN Aggregation and Forwarding Node

Fig 9. Socket connection exception in AFN

VI. FUTURE IMPLEMENTATION

The future implementation or enhancements that we suggest to our algorithm are as follows: By taking the multiple values of the threshold,T_1, T_2..., T_K, the various mapping functions can be defined to map the files of various sizes to the nodes of various ranks. The implementation of the algorithm in the NS-2 simulator and validation of the algorithm. Real world implementation in wireless sensor network.

Since our algorithm chooses the nodes only on the basis of remaining energy and the content need to be transferred, it doesn't take time that is needed to transfer the data. Hence, experiments regarding the time efficiency of the algorithm is need to be carried out. In our algorithm we that all sensor nodes send reliable data to the network. In the future work the detection of faulty sensor nodes in the network, and possible precautions that can be taken against, them will be investigated.

VII. CONCLUSION

The algorithm namely the content based energy efficient routing algorithm is used so that the bias in the rate allocation among the node is reduced. Here the routing is done based on the content of the information to be transferred to the sink node and the energy of the nodes in the network. This is far more efficient compared to the lexicographical max-min (LMM) rate allocation algorithm and is distributive in nature. Sensor nodes adjust their transmission powers in proportion to their content those that have more content to transform should use more power to share their content. Thus the routing is done efficiently and the network life time problem is solved.

REFERENCES

[1] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, *"Wireless sensor networks: A survey," Computer Networks (Elsevier)*, vol. 38, no. 4, pp. 393–422, 2002.
[2] M.S. Bazaraa, J.J. Jarvis, and H.D. Sherali, *Linear Programming and Network Flows*, second edition, Chapters 4, 6, and 8, John Wiley & Sons, 1990.
[3] G. Zussman and A. Segall, "*Energy efficient routing in ad hoc disaster recovery networks*," in *Proc. IEEE Infocom*, pp. 405–421, Mar. 30– Apr. 3, 2003, San Francisco, CA.
[4] K. Kar, M. Kodialam, T.V. Lakshman, and L. Tassiulas, *"Routing for network capacity maximization in energy-constrained ad-hoc networks,"* in *Proc. IEEE Infocom*, pp. 673–681, Mar. 30–Apr. 3, 2003, San Francisco, CA. J.-H. Chang and L. Tassiulas, "Energy conserving routing in wireless ad-hoc networks," in *Proc. IEEE Infocom*, pp. 22–31, March 26–30, 2000, Tel Aviv, Israel
[5] J.-H. Chang and L. Tassiulas, *"Routing for maximum system lifetime in wireless ad-hoc networks*," in *Proc. 37th Annual Allerton Conference on Communications, Control, and Computing*, vol. 1, pp. 22–31, Sept. 1999, Monticello, IL.
[6] Sandeep Ranade and and Mark S. Miller *"Pheromone based adaptive routing and replication for fast lookups in a distributed hash table"*.
[7] W. Heinzelman, *Application-specific Protocol Architectures for Wireless Networks*, Ph.D. thesis, Massachusetts Institute of Technology, June 2000.
[8] Y.T. Hou, Yi Shi, and H.D. Sherali, "*On node lifetime problem for energy-constrained wireless sensor networks*," *ACM/Springer Mobile Networks and Applications*, vol. 10, no. 6, pp. 865–878, Dec. 2005.