ENERGY EFFICIENT BY PIEZOELECTRIC EFFECT SYNCHRONOUS MULTICAST PROTOCOL (PESM) IN WIRELESS SENSOR NETWORKS

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Abstract—The major objective of the protocol proposed in this paper is to optimize the amount of energy used for transmission in Wireless Sensor Networks (WSNs). This paper introduces an approach called Piezoelectric Effect Synchronous Multicast approach (PESM) that conserves the energy of sensor nodes and thereby improving the lifetime of the network. By applying this technique; we can regenerate an electrical effect to the nodes of WSN from natural resources. The energy required for sensor nodes is obtained by scavenging the energy from green resources. From our experiments we observe that PESM is able to improve the lifetime of the wireless sensor networks considerably.

Keywords— Sensor Networks, Multicasting, Piezoelectric effect, piezoelectric sensors, Energy Consumption, Energy Efficient, Power saving protocols, Energy Optimization.

1. INTRODUCTION

Generally, Wireless Sensor Networks (WSNs) consist of thousands of nodes for measuring the various parameters in the environment such as temperature, pressure, humidity etc., The main characteristics of sensor devices are their ability to monitor a wide variety of ambient conditions such as temperature, pressure etc,. Sensor nodes are expected to be well equipped with significant processing, memory and wireless communication capabilities. The wireless sensor networks consist of large number of heterogeneous sensor devices. These sensor devices are equipped with devices like CPU, battery, sensor and radio transceiver. The goal of a sensor node is to collect data at regular intervals and transforming the data into an electrical signal and finally send the signal to the sink or the base node. The sensor node collects data recorded by sensors but do not have sufficient power to process the collected data. The sensor nodes exchange the gathered information for collaborative processing. The sensor nodes are commercially known as motes and these motes are usually battery powered and replaceable. To prolong the lifetime of the wireless sensor network it is necessary to increase the lifetime of individual motes. Most of the sensor nodes use non-rechargeable battery. The battery power of sensor nodes is usually wasted due to bad topology (network design), idle listening of nodes for a long time and bursty nature of traffic. For proper functioning, the network employs mechanisms like congestion control, idle listening, retransmitting, overhearing, overemiting etc.

All these mechanisms spend the battery power lavishly. Hence the major challenges in sensor networks are the limited and non-replenishable energy resources. The Piezoelectric effect is used to generate electric power from green resources. It is possible to provide the energy to the sensor nodes through the variation in the

pressure or vibration that occurs in the cloud. PESM tries to make

use of this phenomenon to harvest the energy required for sensor nodes. Even though the term green resources have a broader connotation this paper refers the possible energy that can be obtained from the cloud in the sky as the green resource. Sensors are deployed to detect an event, for example a fire in a forest, a quake, etc. These are widely applied to monitor the interactions of objects and space such as asset tracking, healthcare, wildlife habitats, disaster management, emergency response, ubiquitous computing environments and monitor objects such as urban terrain mapping. It is very much useful to monitor the environmental and habitat monitoring, precision agriculture, indoor climate control, surveillance etc.

2. RELATED WORK

The mote is usually battery-powered and the battery is a non-replenishable one in many cases. Many applications need more than hundred motes for understanding the event. If any mote dies then we cannot retrieve the actions accurately. Once the node dies it is to be replaced with a new mote. It is possible to save energy and regenerate the energy from natural resources and this has the potential to increase the lifetime of a mote.Zbigniew Watral [7] has proposed various schemes for harvesting the energy from non conventional sources. In many wireless sensor networks, photovoltaic cells are the primary sources of electric energy. Generally, the photovoltaic effect generates electric energy with potential barriers. The solar radiation flux produces power with 10 to 100 mW/cm2 in the day time for a few hours per day. The existing market provides motes of high energy density. The energy density of Li-ion is 1100 J/cm3 and NiMH batteries is 850 J/cm3.However in Internet of things (IoT) since million to billion sensors, have to work in tandem even this potential energy is not sufficient. Piezo electric effect that generates energy in milli and micro watts is a reliable energy source. Piezo-source is producing energy by causing mechanical deformation i.e., the movement of ions in the crystal lattice which produces an internal electric field in the crystal. The lifetime of network [2] is defined as the time from the start of the network operation to the death of the last node in the network. The lifetime of a node depends mainly on the capacity of the battery and the energy draining rate.

3.PROPOSED APPROACH

In this section, we describe the proposed PESM approach that balances and regenerates the energy of the sensor nodes in wireless sensor networks. Piezoelectric Effect Synchronous Multicast (PESM) protocol deals with energy optimization at two levels namely energy balancing and energy generation. The block diagram of the PESM approach is shown in fig.1.
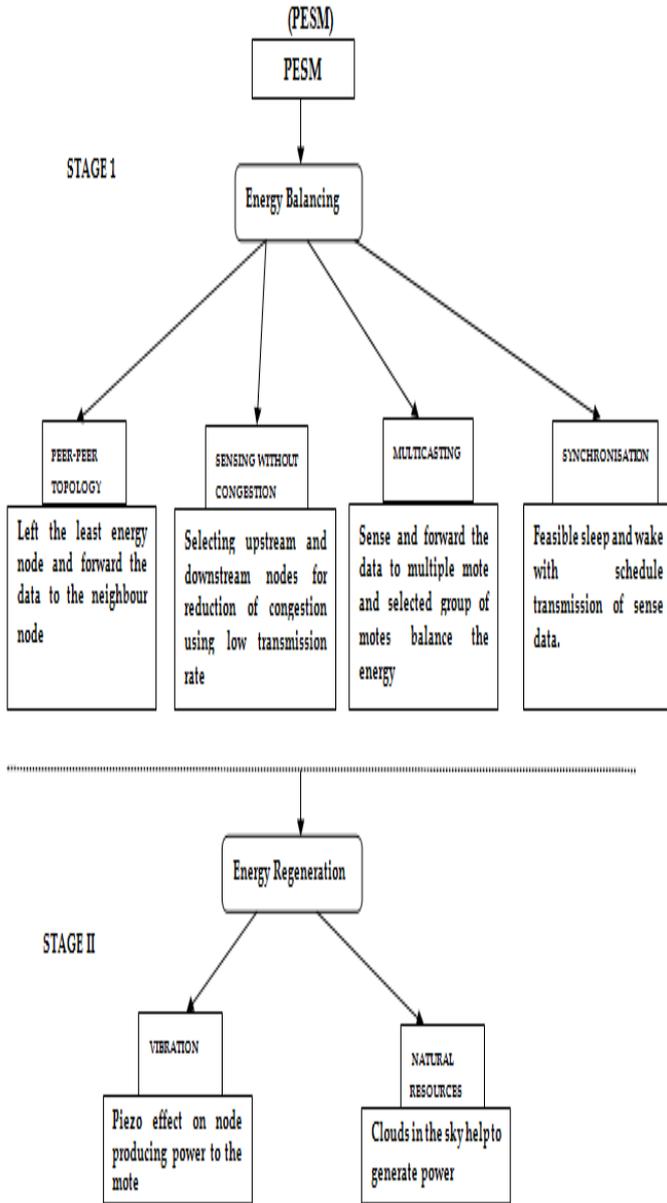
Figure 1:Process in PESM

Energy balancing is a technique that delegates the various tasks to the sensor nodes in such a way that certain nodes are not overloaded and their energy is not drained. Rather it ensures the various tasks are delegated to the nodes in a fair manner. Even though the tasks are equally distributed to the nodes the nodes can't avoid the required operations and hence the power sources of the nodes lose their energy. Hence irrespective of energy balancing it is also to go for energy regeneration from the non conventional energy sources. Proper network design, effective sensing methods that reduce congestion, employing multicasting for data forwarding and achieving synchronization among the nodes are certain ways to achieve energy balancing in wireless sensor networks. In this paper

we try to achieve energy regeneration by utilizing the variation in the pressure of vibration that occurs in the cloud.

3.1.ENERGY BALANCING

3.1 Network Design

The selection of appropriate topology helps to reduce the energy consumption by the nodes of WSNs. Maintaining topology without losing coverage irrespective of the charges will increase the lifetime of wireless sensor networks. Peer to peer topology is the good topology for large, self-controlled, self- healing and multihop networks. So the selection of peer to peer topology helps to balance the energy among the nodes of WSN.In the peer to peer topology, we have to transmit the data from one node to another in the point to point mode. During transmission of data if any sensor node has less energy than a threshold then ignore that node and select the next point of node and forward the required data through the selected node. It helps to decrease the hop count. Let us assume that the WSN is represented as the graph

$$G = (\{s_1, s_2, s_3, \ldots s_i\} \cup ss, E)$$

where s_i represents the sensor nodes and ss represents the set of target nodes (base stations) and E represents the set of edges. E includes both the edges among the sensor nodes and the edges between target nodes and the base stations. Target nodes are the ones through which the base stations can be reached and the set of target nodes are represented as .The set of sensor node whose energy level is below a threshold is given as . Each of these sensor nodes are powered with renewable energy sources. Ren et.al [4], assume an energy consumption model in which a sensor node may be either in active mode or inactive mode at a particular time. Let m be the number of active nodes, n be the number of target nodes, p be the number of nodes whose energy is less than the threshold and q be the number of nodes in inactive mode. Let ECA, ECT, ECLT and ECI be the energy consumed by an active node, a target node, a node whose energy is less than the threshold and an inactive node respectively. Then the energy consumption of the network ECNT is computed in time interval T as in equation (1).

$$EC_{NT} = \sum_{i=1}^{m} ECA_i + \sum_{i=1}^{n} EC\,T_j - \sum_{k=1}^{p} EC\,LT_k - \sum_{l=1}^{q} EC\,I_l$$

(1)

Data sensing efficiently without congestion

The motes are widely deployed for sensing the event. After sensing, the motes forward the data to the base station. More traffic occur while forwarding the sensed data to the base station if more number of motes transmit the data almost at the same time .Due to congestion ,the data may not reach other motes properly. This leads to packet loss and retransmission of sensed data. So the battery power of each mote is wasted and it leads to more energy consumption. Hence avoiding congestion by identifying the optimal routing path to the base station is necessary to improve the lifetime of the network. Raheleh Hashemzehi et.al [8] have proposed protocols for congestion avoidance and detection, congestion control and fairness, adaptive rate control, fairness aware congestion control, data fusion and priority based congestion control protocol. Trickle, Siphon, SenTCP and learning automata based congestion avoidance protocols have been applied to avoid congestion in wireless sensor networks. But these protocols do not consider the energy consumption issue. In wireless sensor networks, congestion has been detected by observing buffer size and load at the motes. It means that the intermediate nodes help to warn the downstream nodes about the

congestion. The hop-hop routing clears the traffic easily and thus reduces the packet dropping. The EmberNet mote is able to overhear the ongoing transmission and hence it is able to identify the congested motes in the network. This mote sends the information about the congested area to other nodes so that the congested area may be avoided in forwarding the data to the sink. To overcome the congestion we need to balance the load of each sensor node.

The goal of congestion control is to recover the mote from congestion quickly. Charging the batteries of a sensor node is difficult in unfriendly terrains whereas reducing energy consumption by selection of optimal routing path is easy. During congestion, retransmission of data in long distance leads to more energy consumption. Congestion detection and retransmission of data is recovered by calculating congestion ratio. Congestion ratio is defined as the congestion which occurs by transmitting/sending. It is directly proportional to the congestion that occurs by receiving as shown in equation (2).

$$Congestion\ Ratio = \frac{Congestion\ in\ Transmit}{} \quad (2)$$

If congestion occurs the mote has to detect the congestion and it has to retransmit the collided data. Retransmission always consumes more energy and bandwidth. The consumption of energy during congestion and after the removal of congestion is shown in equations (3) and (4) respectively. We have used CC 2240 (Micaz) mote in our experiments. The specifications of CC2420 (Micaz) is shown in table 1.

Table 1 CC2420 (Micaz) specifications

Parameters	CC2420(Micaz)
Transmit Power (P_{tx})	52.2 mW
Receive Power (P_{rx})	56.4 mW
Overhear Power (	56.4mW
Dormant Power	3μW
Time to transmit a	32μs
Transmission Rate	250kbps

$$E_{congested} = t_{event} - (t_1 - 1)P_{active} + (\tau_{downstream\,node}(P_{active} + P_{sleep} - P_{inactive}) + (t_{event} - (t_1 - 1) - \tau_{downstream\,node})P_{target})$$

(3)

Equation 3 and 4 mentioned above.where E_{saved} indicates that energy saved when congestion is detected. t_{event} specifies time period of the event in between two motes. P_{active}, P_{sleep} and $P_{inactive}$, P_{target} represents power of active mode, sleep mode, inactive mode and target mode respectively. $\tau_{downstream\,node}$ specifies that transmission rate of downstream node. We have measured P_{active}, P_{sleep}, P_{target}, $P_{inactive}$ and energy congestion in the network. Energy consumption in

both the cases are measured in subsequent intervals of 10 ms.

$$[(\frac{E_{saved} + P_{sleep}\,t_{event}}{}) - (t_1 - 1)P_{active}] + [(\tau_{downstream\,node} + t_{event} - (t_1 - 1)]P_{target} - [(\frac{}{}) + t_{event} - (t_1 - 1)]P_{sleep} - [t_{event} - (t_1 - 1)]P_{inactive}$$

(4) Energy consumed and other parameters in congested scenario and uncongested scenario are shown in tables (2) and (3)

Table 2 Energy consumption in congested Scenario

P_{active}	P_{ta}	P_{sl}	P_{in}	Energy Co
40.3 mW	22.2	3	1 μ	14
62.5 mW	50.5	5.5 μ	2.3 μW	22
80.7 mW	70.3	7.6 μ	4.2 μW	33
135.2 mW	87.7	10.8	6	53
190.7 mW	103.4	13.3	5.4 μW	74

Table 3 Energy consumption after the removal of congestion Scenario

P	P	P	P	Ener
40.3 mW	22.2 mW	3	1 μ	44
62.5 mW	50.5 mW	5.5 μW	2.3 μW	36
80.7 mW	70.3 mW	7.6 μW	4.2 μW	30
135.2 mW	87.7 mW	10.8 μW	6	24
190.7 mW	103.4 mW	13.3 μW	5.4 μW	18

Data forwarding through multicasting

Data communication in wireless networking comprises three types of casting viz; unicasting, broadcasting and multicasting. Communication of data done in a one to one basis in unicasting leads to more power consumption than in multicasting and broadcasting. Broadcasting in communication of data includes all nodes unnecessarily and hence consumes more power. But multicasting is done in a systematic way and hence results in less power consumption. The selection of route from source to multiple destinations is called multicasting[12] the motes needed for sensing the events form a network among them and forward the data related to the sensed events to the chosen destinations in multicast node. Hence the communication overhead is reduced considerably. Energy consumption efficiency is achieved due to the reduction of packet overhead and selection of optimal multicasting path. The figure 2 shows how motes participate in building up data

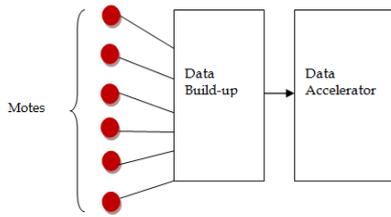and accerlate data thereby gaining energy.

Figure 2.Building up of data

The wireless sensor network under consideration is considered as an undirected graph with the set of sensor nodes as vertices and the set of links edges. In multicasting we have taken a terminal set M⊒{1 and assign source node as s $s \in$. Hence receiving nodes are considered as . Erratic schedules for data forwarding consumes more energy i.e.) the battery power of sensor nodes is wasted where as the proper schedules can save the battery power. Therefore the planning for event detection in data build up and data forwarding in wireless sensor network plays an indispensable role for optimizing the energy. Hence energy consumption of individual node is calculated as in equation (5)

$Energy\ of\ a\ sensor\ node = Transmitting\ energy + Receiving\ ener$ (5)

Two management techniques viz leave group and join group are used in energy efficient multicast routing. Those sensor nodes desiring to transmit the data or events sensed themselves indulge in grouping and such sensor nodes are called join group. There are some nodes which remain dormant and such nodes are termed as leave group. Energy consumption is less consequent on the leave group remaining dormant and the join groups alone dynamically indulges in transmitting the sensed data .The resulting effect in join group and leave group is called multicasting routing.

Low power synchronous protocol

The mote should act in the stipulated time and when it does not receive events it will go to the sleep state. The active and dormant stage of mote is diagnosed using low power synchronous protocol. The data stored has to be retraced from the initial stage because during the dormant state of the mote the sensing of data is stopped abruptly. Hence large amount of energy is required. During sensing the data the sensor node lacks synchronization and the estimate is inaccurate. The data loss has occurred due to relative drift and time period. The energy has been consumed by resynchronization and synchronization operations. The additional energy required for these operations is computed as:

$$Clock_1 = RelativeDrift * Clock_2 + offset$$
(6)

Algorithm

For each mote in the network

mote_data=last sensed data

If (mote_energy ==NULL)

Sleep signal;

else

Wake signal;

for (mote_energy =0; mote_energy ++)
mote_data
=+data;
wake data;
end

3.2 ENERGY REGENERATION

Vibration

In this paper, we assume that the motes are employed with Piezo electric crystals. During thunder and lightning vibration of enormous quantity is released and by utilizing this energy we can increase the availability of power in the motes. Since event detection is employed in remote areas like forest and uninhabitant localities it is not possible to recharge the battery in the motes. The presence of meagre amount of energy in the invisible clouds shall be utilized by the mote to generate considerable additional power in these motes. The scenario is depicted in figure 2.
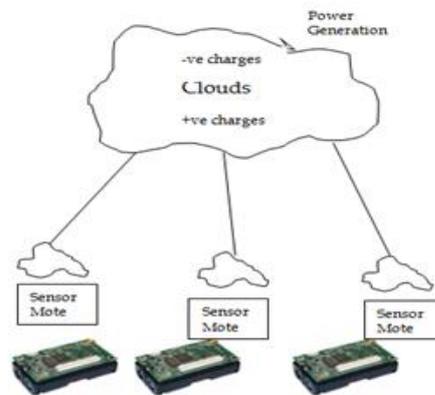

Figure 2 Power Generation

Electric current is regenerated in the sensors nodes by applying force on them. If no force is applied on the node then no additional power is generated. The various sources of vibration are thunder and lightning from the clouds,sound waves,piezo electric crystal etc.These vibrations shall be captured through appropriate equipments.If these vibrations are applied on the sensor nodes as the external force the power is regenerated.

Energy calculations
Applying the force generated by the vibration on a sensor node is able to extend the lifetime of the mote by 30%. Node death leads to communication problems in wireless sensor networks. Break of links in wireless sensor network means death of a node caused

either by the exhaustion of the battery power or by the mobility of the node to an out of coverage area.

Piezoelectric effect

The mote consumes more energy during transmission when compared to the energy spent while receiving the data. The energy consumed by the mote when it is neither transmitting nor receiving is considerably less, however it is not zero. The motes are deployed with battery and recharging of battery is difficult especially when the motes are deployed in unfriendly terrains. Hence it is necessary to minimize the energy consumption of the network to maximize the lifetime of the network. Modern motes are based on Micro Electro-Mechanical Systems (MEMS) technology and highly integrated digital electronics. Piezoelectricity is a potential solution to improve the lifetime of the motes.

Piezoelectric effect refers to the ability of certain materials to generate an alternating current (AC) voltage when subjected to mechanical stress or vibration.
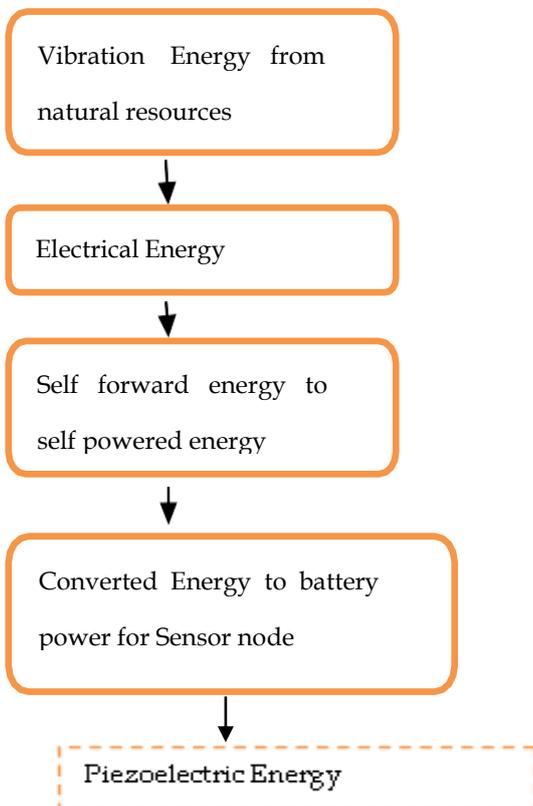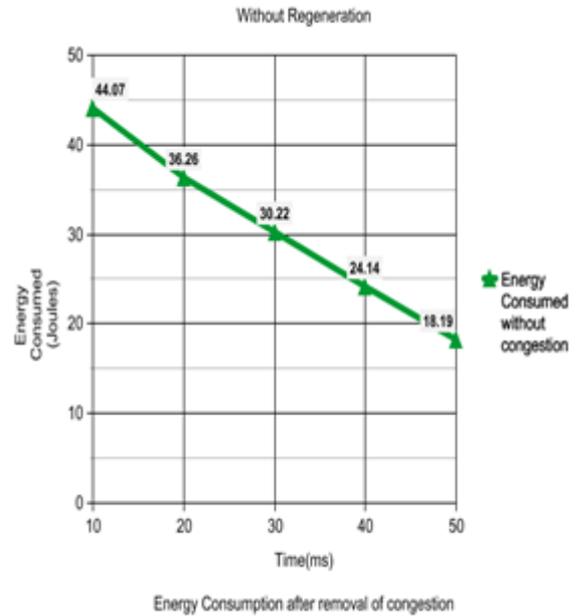
Energy Flow Chart

Figure 3 Energy flow diagram

4.SIMULATION RESULTS

Energy Consumption after removal of congestion

We now simulate a graph for energy regeneration and energy without regeneration using cooja simulator in contiki operating system. In this simulation, we used Micaz mote (CC2420) as a mote type ,Unit Disk Graph Medium (UDGM) as a Distance loss and mote startup delay is 1000 ms.Cooja interacts with simulated mote via mote interfaces. The graph generated for mote battery indication is given below.
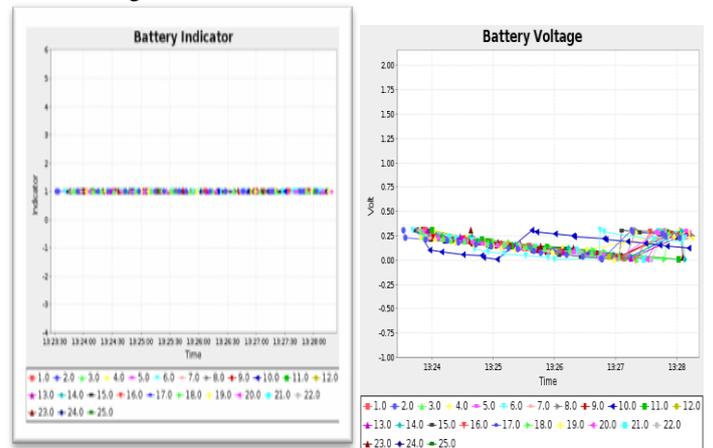

Figure.4 Battery Indication for mote Micaz

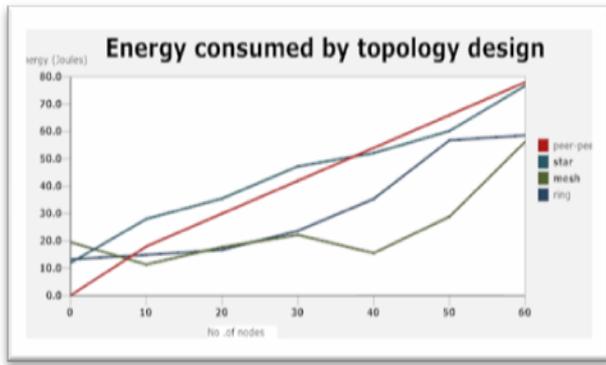The energy consumed for various topology is calculated and generated as a below mentioned graph.

Figure 5. Topology used for energy consumed

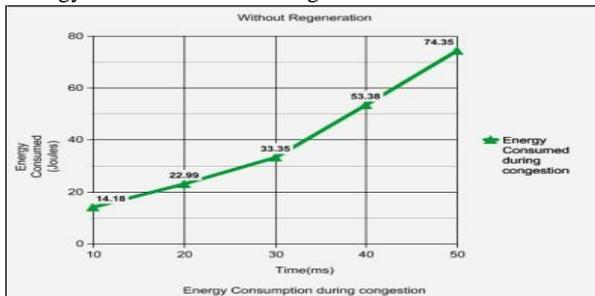The simulated graph for energy consumed during congestion and energy consumed without congestion is as follows
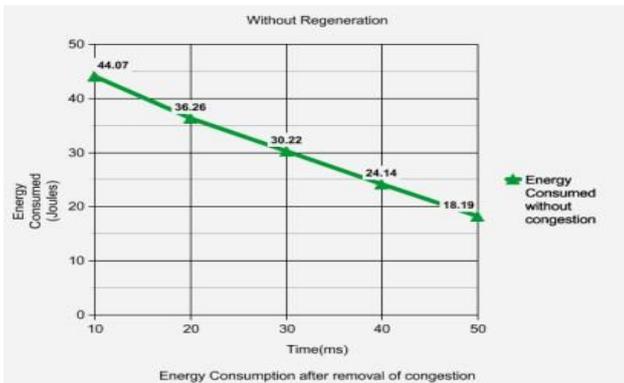

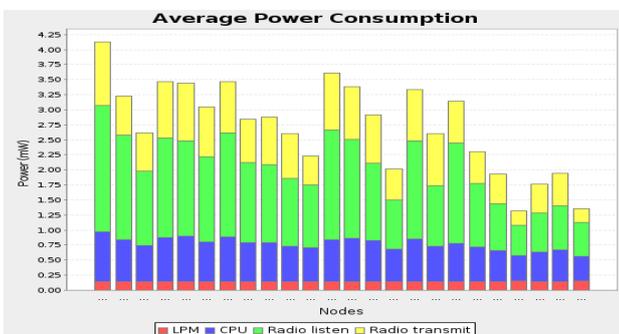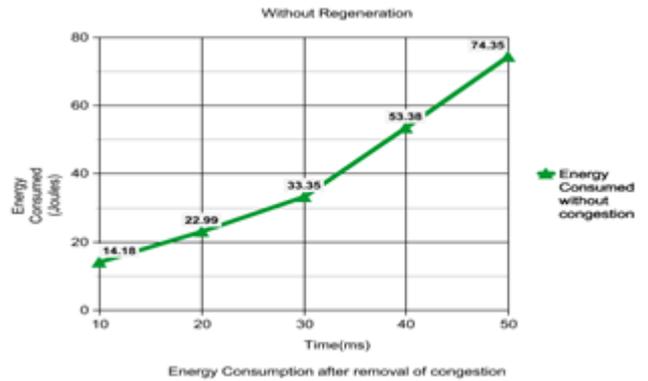**Figure 6 Energy consumed during congestion**

Figure 7 Energy consumed without congestion

5.CONCLUSION AND FUTURE DIRECTIONS

In this paper we have proposed an energy efficient usage of multiple, mobile base stations to increase the lifetime of wireless sensor networks.Therefore by exploiting piezoelectric materials we must

harvest ambient strain energy for energy storage in capacitors and rechargeable batteries. By combining smart energy saving electronics with advanced thin film battery chemistries that permit infinite recharge cycles, these systems could provide a long term, maintenance free, wireless monitoring solution.

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