Increasing the Lifetime of Wireless Sensor Networks by using AR (Aggregation Routing) Algorithm

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ABSTRACT

In this paper, We identified several advantages of a heterogeneous architecture for wireless sensor networks (WSNs) .It consists of some resource rich mobile relay nodes and a many number of simple undynamic nodes. The mobile relays have high energy than the undynamic nodes. The mobile relays can dynamically move around the entire network and help relieve sensors that are highly burdened by heavy network traffic, thus improving the lifetime. We first analyze the performance of a large dense network with one mobile relay and show that network lifetime improves over that of a purely undynamic network by up to a factor of five. Also, the mobile relay needs to stay only within a two-hop radius of the sink. We then construct a AR (Aggregation Routing) Algorithm which gives a network lifetime close to the maximum limit. The benefit of this algorithm is that it only requires a minimum number of nodes in the network to be known of the location of the relay. Our simulation results show that one mobile relay can at least improve the network lifetime in a randomly deployed WSN. By comparing the mobile relay approach with various undynamic energy-provisioning methods, we explain the importance of node mobility for resource provisioning in a WSN.

Key Words—Wireless sensor networks, Power efficiency, search, relays, aggregation.

1 INTRODUCTION

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 development of wireless sensor networks was originally motivated by military applications such as battlefield surveillance. However, wireless sensor networks are now used in many industrial and civilian application areas, including industrial process monitoring and control, machine health monitoring, environment and habitat monitoring, healthcare applications, home automation, and traffic control.

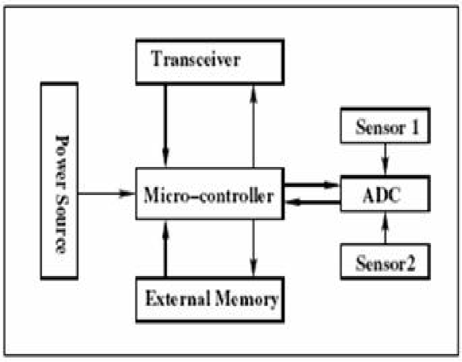

Figure8: Architecture of sensor node

The applications for WSNs are many and varied, but typically involve some kind of monitoring, tracking, and controlling. Specific applications for WSNs include habitat monitoring, object tracking, nuclear reactor control, fire detection, and traffic monitoring. In a typical application, a WSN is scattered in a region where it is meant to collect data through its sensor nodes. A number of WSN deployments have been done in the past in the context of environmental monitoring. A sensor node, also known as a 'mote', is a node in a wireless sensor network that is capable of performing some processing, gathering sensory information and communicating with other connected nodes in the network.

The main components of a sensor node as seen from the figure are microcontroller, transceiver, external memory, power source and one or more sensors. Microcontroller performs tasks, processes data and controls the functionality of other components in the sensor node. Other alternatives that can be used as a controller are: General purpose desktop, Microprocessor, Digital signal processors, Field Programmable Gate Array and Application-specific integrated circuit. Microcontrollers are most suitable choice for sensor node. Each of the four choices has their own advantages and disadvantages. Microcontrollers are the best choices for embedded systems.

In general purpose microprocessor the power consumption is more than the microcontroller, therefore it is not a suitable choice for sensor node From an energy perspective, the most relevant kinds of memory are on-chip memory of a microcontroller and FLASH memory off-chip RAM is rarely if ever used. Flash memories are used due to its cost and storage capacity. Memory requirements are very much application dependent. Two categories of memory based on the purpose of storage a) User memory used for storing application related or personal data. b) Program memory used for programming the device. This memory also contains identification data of the device if any. Power consumption in the sensor node is for the Sensing, Communication and Data Processing. More energy is required for data communication in sensors.

Energy expenditure is less for sensing and data processing. The energy cost of transmitting 1 Kb a distance of 100 m is approximately the same as that for the executing 3 million instructions by 100 million instructions per second/W processor. Power is stored either in Batteries or Capacitors. Batteries are the main source of power supply for sensor nodes. Namely two types of batteries used are chargeable and non-rechargeable. They are also classified according to electrochemical is thematerial used for electrode such as NiCd (nickel-cadmium), NiZn (nickel-zinc), Nimh (nickel metal hydride), and Lithium-Ion. Current sensors are developed which are able to renew their energy from solar, thermo generator, or vibration energy.

Two major power saving policies used are Dynamic Power Management (DPM) and Dynamic Voltage Scaling. DPM takes care of shutting down parts of sensor node which are not currently used or active. DVS scheme varies the power levels depending on the non-deterministic workload by varying the voltage along with the frequency; it is possible to obtain quadratic reduction in power consumption. Sensors are hardware devices that produce measurable response to a change in a physical condition like temperature and pressure.

One of the great challenges for WSN designers is to use such resource-constrained sensors to guarantee certain network requirements, such as network lifetime, sensing coverage, and end-to-end delay. One possible solution is to deploy a dense homogenous network, i.e., cheap sensors are scattered densely to increase the amount of resources deployed per unit area. For example, we can deploy sensors several times denser than required, then design a scheduling scheme to make them work in batches, so that the total network lifetime can be extended [1]. However, dense deployment brings many problems, such as difficulties in network management and severe medium access control (MAC) contentions. Another possible solution, which we consider in this paper, is to deploy a heterogeneous network, having a few resource rich (in terms of processing, memory, and energy) mobile nodes in addition to a large number of simple low-cost static nodes. Unlike the "Data Mule" solution [2], where mobile nodes are used for carrying data packets, we use mobile nodes to dynamically distribute network resources, such as, energy, computational power, sensing, and communication abilities. Mobility gives us a more efficient way to meet the network resource requirements, e.g., mobile nodes can move to the areas where resources are most needed, such as areas where node density is low due to the randomness in deployment or areas where more resources are required for increased sensing activities. Therefore, the resources carried by the mobile nodes can appear at the right place and time to be used efficiently. In the latter discussions, we will demonstrate that adding a few resource rich mobile nodes can provide the same performance as increasing the network density by several times. Thus, the heterogeneous network approach is more effective in terms of hardware cost than the dense deployment approach.

In this paper, we are motivated to investigate what performance improvement can accrue from mobile devices and the tradeoffs associated with a heterogeneous network architecture. We focus on using mobile nodes which have more energy than static sensors to extend the network lifetime. Static sensors only have limited energy from non rechargeable batteries. Once the battery runs out, the sensor will die. Therefore it is critical that this energy be used judiciously in order to maximize the benefit from the network before it dies. Although there is a concerted effort from the device research community at designing low-power hardware and efficient energy sources, the network research community has also realized that inefficient algorithms at the various networking layers can result in nodes dying prematurely. There are several proposals at the MAC [3], [4] and network layers [5], [6]; however, most of these proposals are based on the assumption that the entire network is composed of static nodes.

We first consider a large densely deployed WSN and show that an upper bound on lifetime with one mobile relay is four times that of the static network. More interestingly, this upper bound computation shows that the mobile relay will never have to venture farther than a two-hop distance from the sink. We then construct a joint mobility and routing algorithm which improves the lifetime of the network by almost a factor of 4. The advantage of this routing algorithm is that only nodes within a certain distance of the sink need to be aware of the location of the mobile relay. This algorithm can also be extended to the case when there are *m* mobile nodes and provide improvements close to *Am* times.

The performance of a mobile relay is further studied in the case of finite and random networks. We pose the problem of maximizing lifetime as a linear programming problem and derive the optimal schedule for the mobile node. The system model used here for mobile relay is similar to the one for mobile sink in [7] and [8]. The performance of the mobile relay is compared with minimal hop routing, energy-conserving routing and the mobile sink approach proposed in [9]. We show that using a mobile relay is better than most of the static energy-provisioning methods. However, the mobile sink approach always out performs the mobile relay approach. Actually, for a large dense network deployed in a circular region of radius , we need *O(R)* mobile relays to achieve the same lifetime as that of a mobile sink. The intuitive reason for this is the following. When the sink is static, the nodes around the sink become bottleneck nodes since they relay traffic for all the other nodes in the network. However, by making the sink mobile, we distribute the bottleneck nodes all around the network. We contend that it is not always feasible to have a mobile sink, since it is expected to act as a gateway to a backbone network. In hostile and inaccessible environments, it might not be possible to maintain continuous connectivity with the backbone network when the sink is mobile. The main contributions of this paper are as follows.

1) We proposed a new way for resource redistribution in wireless sensor networks, which uses resource rich mobile nodes to help simple static sensors. We demonstrate the usefulness of this approach by showing that in the ideal case, one energy rich mobile node can improve the lifetime of a large and dense network by four times.
2) We derived the network lifetime improvement upper bound for single mobile relay and multiple mobile relays. We then construct a joint mobility and routing algorithm to show that this bound is asymptotically achievable in large and dense networks.
3) We study the performance of mobile relay in random and finite network by formulating it as a linear programming problem. We compare the performance of mobile relay to various other static and mobile approaches and show the advantages of mobile relay approach.

The rest of the paper is organized as follows. Section 2 summarizes related work. Section 3 investigates the performance of a large dense network with a few mobile relays and gives a joint mobility and routing algorithm. Section 4 gives the simulation results on finite random networks. Finally, Section 5 concludes the paper.

2. RELATED WORK

The related works are as follows. Investigate the benefits of a heterogeneous architecture [1] for wireless sensor networks (WSNs). WSNs composed of a few resource rich mobile relay nodes and a large number of simple static nodes. The mobile relays have more energy than the static sensors. They can dynamically move around the network and help relieve sensors that are heavily burdened by high network traffic [2], thus extending the latter’s lifetime. Evaluate the performance of a large dense network with one mobile relay and show that network lifetime improves over that of a purely static network by up to a factor of four [4] and [6]. Mobile relay needs to stay only within a two-hop radius of the sink. Construct a joint mobility and routing algorithm which can yield a network lifetime [3] close to the upper bound. It requires a limited number of nodes in the network to be aware of the location of the mobile relay [5]. One mobile relay at least double the network lifetime in a randomly deployed WSN.

Drawbacks of Existing Systems are i) Constraints in the upper bound of the network life time ii) Power control scheme were not used Mobile relay node iii) power aware levels were complex iv) Sink energy consumptions were not identified.

Improve the construction of joint mobility and routing algorithm to improve network lifetime raises the upper bound. Power control mechanisms are deployed to raise the upper bound of the network life time. Compare the mobile relay approach with various static energy-provisioning methods. Evaluate the worthiness of node mobility for resource provisioning in a WSN. Measurement of power levels of the sink in the WSN to receive the data. Data fusion on the fusion nodes is calculated. Power requirements for data fusion in the relay nodes are identified.

Mobility and Routing Algorithm

Construct a joint mobility and routing algorithm whose lifetime is close to the upper bound derived. A broad outline of the algorithm is as follows. Know that the mobile relay needs to only stay within a two-hop radius in order to maximize the lifetime. Therefore the mobility pattern of the mobile relay can be as follows. Starting From the sink, the mobile relay traverses a path which forms a set of concentric circles, centered on the sink with increasing radii, until it reaches the periphery.

It stays at each point on this path for certain duration and relays traffic to the sink. More specifically, when the mobile is at position, all traffic in is first aggregated to points on the line, where is the position of the sink. This traffic is then directed hop by hop along the line until it reaches the sink. call this routing algorithm ARA (Aggregation Routing Algorithm) for the rest of this proposed project.

Power Control Scheme

For a random network with moderate size, such as 100 sensors randomly deployed in a 5*5 hops area, the randomness of sensor distribution may generate topology defects, i.e., voids or low sensor density areas. Such topology defects prevent the construction of perfect symmetric routing. However, our experiments show that a mobile relay can still improve the network lifetime by more than two times for networks with such topology defects.

First construct an optimization problem for the routing and mobility algorithm in a random finite network with only one mobile relay. The network topology is abstracted as a Random Geometric Graph with edge between any pair of vertex and of distance smaller than 1 from each other. Maximize the overall network lifetime under the energy constraints of static sensors. Similar to the assumptions used for mobile sinks, we assume that the mobile relay will stay at positions where there is a static sensor. When the mobile relay is at the position of sensor, it will take over the task of sensor and sensor will sleep for that time period.

The mobile relay will shift between sensors and try to help as many sensors as possible during the network lifetime. The mobile will always stay at the position of some static sensor during the network lifetime, since this will always give a longer lifetime than removing the mobile node. Thus, maximizing the sum of periods for which the mobile stays at each location will give the optimal network lifetime.

The minimum power configuration (MPC) approach is presented to energy conservation in wireless sensor networks. In sharp contrast to earlier research that treats topology control, power-aware routing, and sleep management in isolation, MPC integrates them as a joint optimization problem in which the power configuration of a network consists of a set of active nodes and the transmission powers of the nodes. Show through analysis that the minimum power configuration of a network is inherently dependent on the data rates of sources. Propose approximation algorithm with provable performance bounds compared to the optimal solution, and a practical Minimum Power Configuration Protocol (MPCP) that can dynamically (re)configure a network to minimize the energy consumption based on current data rates. Simulations based on realistic radio models show that MPCP can conserve significantly more energy than existing minimum power routing and topology control protocols.

In these approaches, the static sensors only send out their data when the sink is close enough to them. The disadvantage of such proposals is that there will be considerable delay in packet delivery, since a node needs to wait for the sink to approach it. In order to minimize the delay, several methods of transmitting the sensed data through multihop communication to the mobile sink are proposed in [7]-[9], and [13]. The mobile sink can either "jump" between several predefined positions or patrol on an continuous route. In the first case, the problem can be posed as a linear programming problem where a mobile sink can find the optimal time schedule to stay at these predefined points [7], [8]. Another method is introduced in [9] and [14], where the optimal route is obtained through a geographic traffic load model. In this approach, as the mobile sink goes around the network, sensors will continuously track the position of the sink and send their packets to the sink via multihop communication. In most networks, the sink is a gateway to a backbone network, over which human operators can monitor the status of the sensor field. In such scenarios, it will be difficult to engineer a system whereby a mobile sink is connected at all times to the backbone network. As we will show later, the mobile relay approach is simpler and more robust, since the network can keep operating even when the mobile relay leaves the network for recharging. Also, the mobile relay only needs to move within a small area, while the mobile sink solution requires the mobile to roam around the periphery of the network to maximize the network lifetime [9].

Another large category of energy conserving methods is to use flow control algorithms to find the optimal energy conserving routes [5], [15]. The energy conserving routing and the mobile sink approach share the same idea of distributing the traffic load evenly around the network so that the lifetime of the network is maximized. Energy provisioning in static sensor networks is studied in [16], where a total amount of energy is added in relay nodes deployed at selected positions. Such static relay nodes can heal the topology defects in randomly deployed networks, so the network lifetime can be improved greatly when the network is sparse. However, as the network density grows beyond a certain threshold, the improvement gets saturated since most of the topology defects have been mitigated. Compared to the static relay approach, the mobile relay approach can provide considerable improvements on dense networks as well as healing the topology defects.

Other solutions for energy saving have also been intensely studied, including data aggregation and topology control methods. Data aggregation and clustering methods such as [17]—[19] aggregate the sensed data to decrease traffic volume and thereby prolong network lifetime. Topology control methods such as [20] and [21] use controllable transmission range to achieve the most energy efficient network topology. In our work we do not address the issues of data aggregation or topology control. However, these ideas can be useful complements to our proposal of using mobile relays. As we will describe later, depending on the position of the mobile relay, traffic is intentionally routed via a few specific network nodes. This could facilitate the data aggregation process.

3. MOBILE RELAYS IN DENSE NETWORKS

We assume that there are *N* sensors uniformly distributed in a circular area of radius , which is much larger than the communication range of sensors. There is only one sink n_0 at the center of the circular area. We assume the network density A = N/TTR^2 is large, so that in each hop the packet can travel as far as the transmission range in any direction and the number of sensors in area *A* is *XA* almost surely.

We consider a data-logging application, where the sensors are required to send their sensed data at a fixed rate. Furthermore, for simplicity, the data generation rates for all the sensors are the same, normalized to one packet per unit time. The transmission range of all sensors is equal to 1 and the sensors do not change their transmission powers. Let *p* be the average number

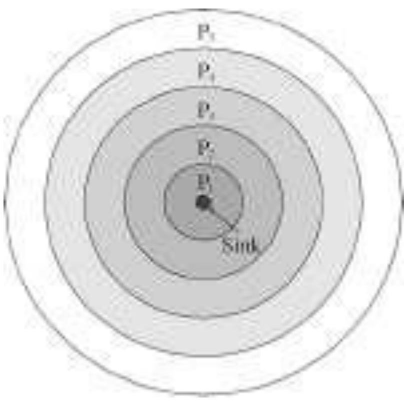

Fig. 2 Dividing the nodes to different subsets in the circular network.

of neighbors for the sink. In this paper, the lifetime of the whole network is defined as the time that the first node dies as in [5]. Since energy conserving routing is used, the network gets partitioned when the first node dies [22].

We assume that the sensor network contains a small number of mobile relays, which can move around to improve the network performance. Mobile relays have the same sensing ability and transmission range as the static sensors but they have rechargeable batteries and thus have no energy limits. To facilitate our discussion, we divide the static sensors into different sets according to their distance to the sink.

AR Algorithm with limited nodes
Parameters:
P: the current aggregation node
q: the current static relay node
r: the distance between p and the sink is r+2
ST: the straight line connecting the sink and the mobile node

Algorithm:
Switch (k: the index of M_k where p€ M_k)
Case1, 2, 3:
Call method AR:
Case 4,...z-1:
If $d(p,p_0)=k-1+r$
If the packet is generated in Q_{s-1} and it has travelled $\$_k$ in M_k

Find a neighbour in M_{k-1} whose distance to the sink is k-2+r and send the packet to it.
elseif the packet has reached line SK
Find a neighbour in M_{k-1} whose distance to the sink is k-2+r and send the packet to it.
else
Find a neighbour who is closest to line SK and whose distance to the sink is k-1+r and send the packet to it.
elseif p is on the line SK
Find a neighbour in SK whose distance to the sink is k-1+r and send the packet to it.
else
Find a neighbour who is closest to line SK and has the same distance to the sink, send the packet to it.
Case z:
If $d(p,p_0)=k-1+r$
Find a neighbour in SK whose distance to the sink is k-2+r and send the packet to it.
else
Find a neighbour in SK whose distance to the sink is k-1+r and send the packet to it.
Case z+1,...,R:
Find a neighbour who is closest to the sink, send the packet to it.

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4. SIMULATION RESULTS

The experiment is based on the simplified energy model stated in Section III without considering the MAC or physical layer. The sensors are randomly deployed on fields with different size and shapes. For each network instance, we calculate the lifetime of the static network by the linear optimization algorithm described in [5], which gives the optimal lifetime for the static network. The lifetime of the mobile relay solution on the same network instance is calculated through the optimization problem as in (11)—(14). The lifetime improvement is averaged over 100 network instances.

We have simulated this experiment using NS-2 simulator. The figure 3 shows the creation of wireless sensor network environment. The figure 4 shows the maximum life time of wireless sensor networks. Mobility and routing algorithm was simulated and method shown in figure 5. The power control scheme is simulated in figure 6. The figure 7 shows the simulation between mobility and power consumption. Here we take 50,000 mobility actions. In this, the power consumption of the existing is 1450. But the power consumption of proposed method is only 1250. It shows that 20 % of power is saved. We have done a simulation between the numbers of nodes versus power consumption.

The result is presented in the figure 8. Here also improvement in power saving. In this, we consider 26,000 nodes; the power taken by the existing system was 18,500. But in the present system are only 13,000. It represents 45% improvement in power saving. In figure 9, the analysis between the numbers of mobile relays and the power consumption by the nodes. We take assume that 50,000 MR. Existing system consumes 1.1 amount of energy. But in the present systems consumes only 0.95. Here also 10 % improvement in power saving.

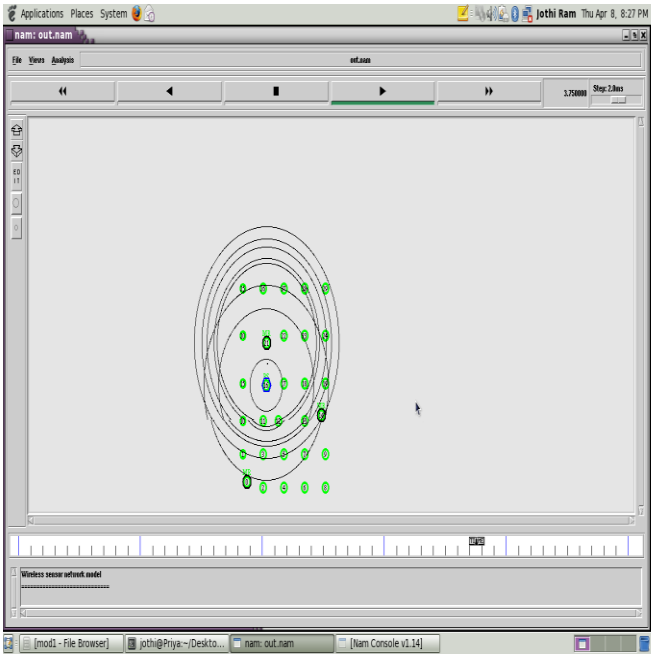

Fig 3: Wireless sensor network model

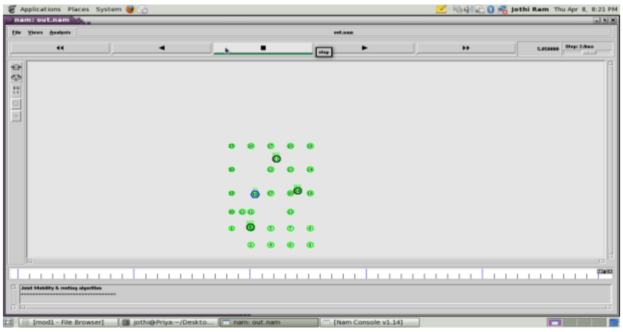

Fig 4: Upper bound on life time

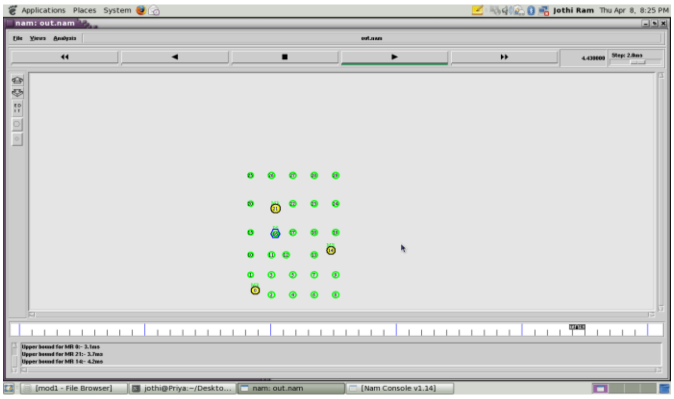

Fig 5:Joint Mobility and Routing Algorithm

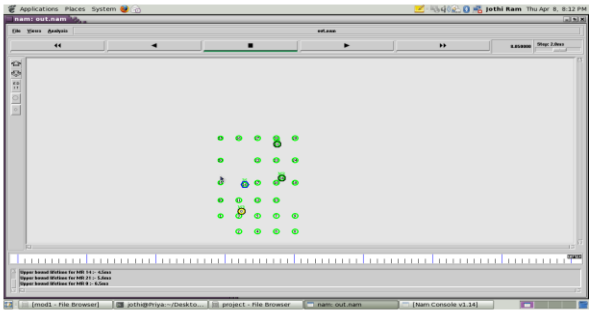

Fig6: Power Control Scheme

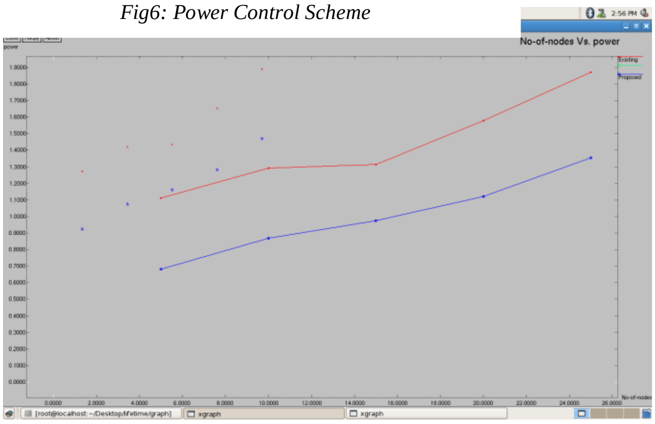

Fig 7:Mobility Vs Power Consumption

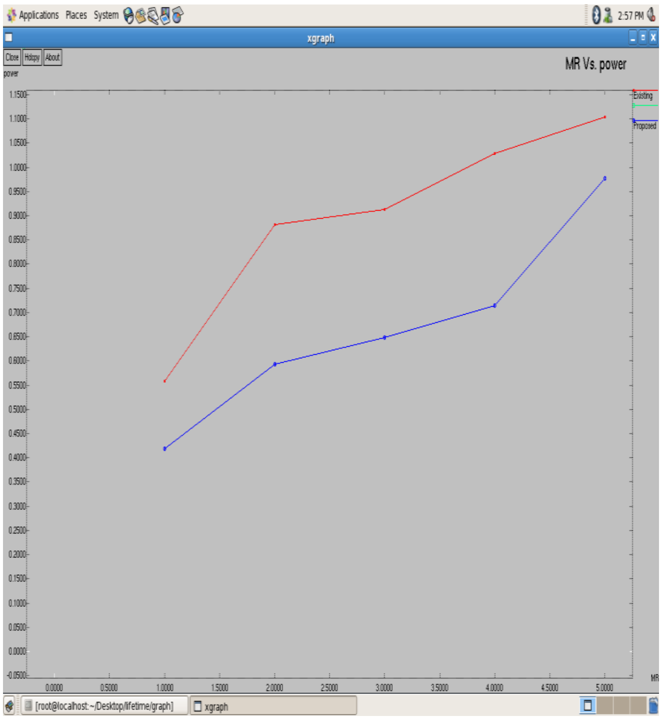

Fig 9: MR Vs Power Consumption

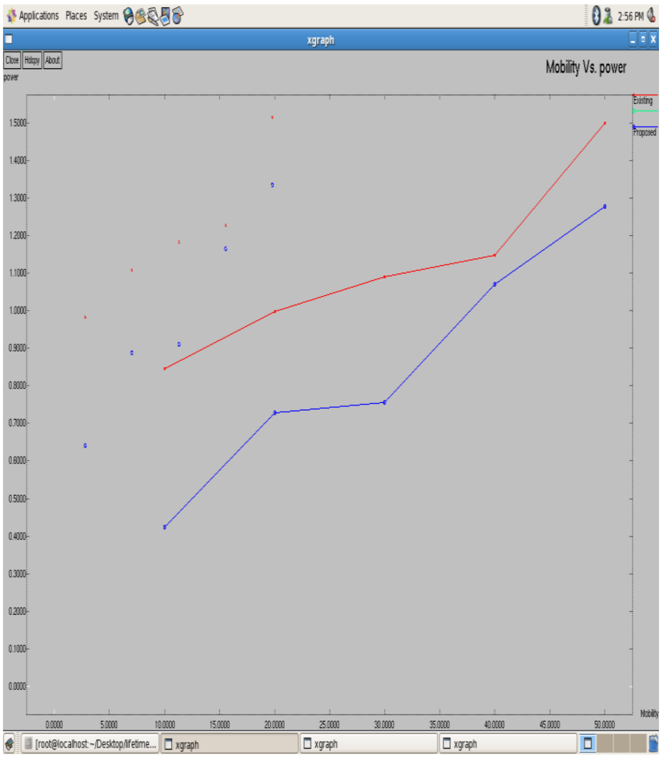

Fig8: No of nodes Vs Power Consumption

5. CONCLUSION

We have investigated the possibility of using a heterogeneous network composed of many simple undynamic nodes and a few mobile nodes. We show that node as a mobile relay, we can get a lifetime improvement of up to 40% over the undynamic network in the ideal case. Another interesting property of this mobile relay approach is that we only need to change the routing algorithm for a relatively small area to use the mobile relay. Furthermore, the mobile relay need not travel all around the network. It never needs to venture farther than two hops from the sink. We see that mobility is actually a great advantage since the mobile relay is more efficient than most static energy-provisioning methods. We also investigate other ways to use mobile nodes, such as mobile sink approach. Although it is clear from our analysis that using a mobile sink is always beneficial in terms of the lifetime of the network, there are certain tradeoffs to make the sink mobile.

In this paper, we make some simplifying assumptions, e.g., the network is running a data-logging application and sensors are incapable of power control. However, in a network which is event based, using mobile relay may be even more beneficial. Since the traffic is not uniformly distributed in such a network, we can move the mobile relay in the directions where traffic is high. In this case we may not need to redirect the traffic as in the data-logging application, so that the overhead caused by mobile relay will be reduced. Our scheme can also work together with power control or data aggregation/compression methods. Although the traffic can be reduced by data compression, the bottleneck described in this paper still exists in such network since the information generated per unit area is still fixed, and our model of uniform packet generation rate can be applied.

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