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Mobile Collector Aggregation In Large Areas Of Energy Harvesting By Wireless Sensor Networks

Ms. C. Cynthiya (M.E Communication Systems)
Department of Electronics and Communication Engineering
Sri Krishna College of Engineering and Technology
Coimbatore, India
cynthiya.1174@gmail.com

Mr.V.Karthik
Department of Electronics and Communication Engineering
Sri Krishna College of Engineering and Technology
Coimbatore, India
karthik@skcet.ac.in

Abstract-- Robust sensor network, that use mobility to circumvent communication bottlenecks caused by spatial energy variations. The mobile collector that collects data from sensors and balance energy consumptions in the network. Initially a subset of sensor locations are selected, where the mobile collector stops to collect data. The data rates are adjusted to achieve network utility. In this paper, we propose a new data-gathering mechanism for large-scale wireless sensor networks by introducing mobile data collector into the network. A mobile data collector, for convenience called an Mobile collector in this paper, could be a mobile robot or a vehicle equipped with a powerful transceiver and battery, working like a mobile base station and gathering data while moving through the field. An Mobile collector starts the data-gathering tour periodically from the static data sink, polls each sensor while traversing its transmission range, then directly collects data from the sensor in single-hop communications, and finally transports the data to the static sink. We first formalize the SHDGP into a mixed-integer program and then present a heuristic tour-planning algorithm for the case where a single Mobile collector is employed. For the applications with strict distance/time constraints, we consider utilizing multiple Mobile collector and propose a data-gathering algorithm where multiple Mobile collector traverse through several shorter subtours concurrently to satisfy the distance/time constraints. In addition, the proposed data-gathering scheme can significantly prolong the network lifetime compared with a network with static data sink or a network in which the mobile collector can only move along straight lines.

Index Terms— mesh routers, power scheduling, energy efficiency, energy management, battery aware routing, lifetime optimization ,spanning tree algorithm.

I.INTRODUCTION

Recent technological advances have made it possible to support high data throughput and long lifetime streaming data transmissions in sensor networks. The Ultra Wideband (UWB) technology allows for wireless communication with high bandwidth and low Signal Noise Ratio (SNR). Such high bandwidth, usually in the order of GHz, has a great potential in applications such as battlefield, disaster discovery and indoor security.

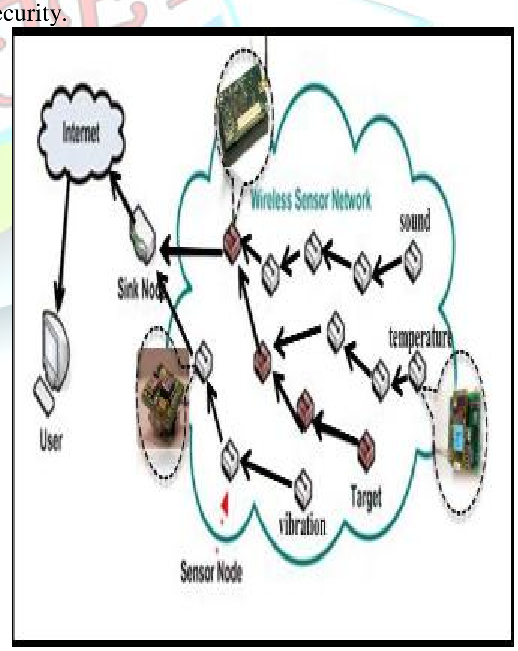

Fig 1.General representation of mobile Sensor nodes

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Wireless sensor networks (WSNs) have emerged as a new information-gathering paradigm in a wide range of applications, such as medical treatment, outer-space exploration, battlefield surveillance, emergency response, etc. Sensor nodes are usually thrown into a

large-scale sensing field without a preconfigured infrastructure. Most of the energy of a sensor is consumed on two major tasks: *sensing the field and uploading data to the data sink.* Energy consumption on sensing is relatively stable because it only depends on the sampling rate and does not depend on the network topology or the location of sensors. On the other hand, the data-gathering scheme is the most important factor that determines network lifetime.

A mobile data collector serves as a mobile "*data transporter*" that moves through every community and links all separated subnetworks together. In this paper, we consider applications, where sensing data are generally collected at a low rate and to provide a scalable data-gathering scheme for large-scale static sensor networks, we utilize mobile data collectors to gather data from sensors. Specifically, a mobile data collector could be a mobile robot or a vehicle equipped with a powerful transceiver, battery, and large memory. The mobile data collector starts a tour from the data sink, traverses the network, collects sensing data from nearby nodes while moving, and then returns and uploads data to the data sink due to the failure of relaying nodes.

II. ENERGY MANAGEMENT NETWORK

Energy management in WSNs is defined as the set of rules to manage various energy supply mechanisms and then efficient consumption of the provided energy in a sensor node. The overall aim should be to manage energy in such a way that no node becomes energy deficient and the network is operational perpetually. It is important for a sensor node to have an efficient energy management scheme for the limited source as well as the application requirement should be managed in accordance to the available energy source which includes Data gathering network utility is maximized and packet latency is bounded by a predetermined threshold. To solve this problem, proposing a two-step approach is used,

- In the first step, determining where the SenCar stops to collect data packets while guaranteeing that the total migration tour length is bounded by a threshold. These node positions are called *anchors***.**
- In the second step, after the anchors have been selected, we formulate the optimization problem into a network utility maximization problem under the constraints of flow, energy balance, battery and link capacity.

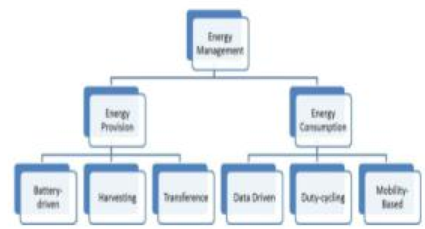

Fig 2.Energy Management Network

In particular energy conservation captures the time-varying and spatial variations of energy harvesting rates. To determine anchors and then optimize communications and SenCar's sojourn time at different anchors, by formulating the communication problem into a non-convex maximization problem and convert the non-concave objective function into a strictly concave objective function by introducing auxiliary variables. Further, by taking proximal approximation algorithm and hierarchical decomposition to transform the non-convex maximization problem into an equivalent two-level convex maximization problem. The values coincide with each other. By, decomposing the convex problem into separate sub problems of data rate, flow routing and sojourn time allocation, and provide a distributed algorithm to tackle each sub-problem. First, proposal of a new framework is done by introducing mobile data collection for energy harvesting sensor networks. Second, developing an adaptive anchor selection algorithm for the SenCar to achieve a balance between data collection amount and latency. Third, for given the selected anchors, the proposed spanning tree algorithms used to find optimal data rates, link flows for sensors and sojourn time allocation for the SenCar.

III MOBILE DATA COLLECTION

Using mobile collectors can alleviate traffic flow bottleneck around the static data sink. Based on this observation, most of existing works have focused on developing methods for finding optimal traveling paths of mobile collectors and minimizing energy consumptions. In, path planning algorithms were proposed for mobile collectors to collect data from sensors through single or multi-hop relays within a time constraint. In, network lifetime maximization was considered by utilizing node route information to mobile data sinks. Mobile relay was used for WSNs composed of energy-rich nodes to relay packets from normal nodes and a joint mobility and routing algorithm was proposed to extend network lifetime. A rendezvous approach was proposed where mobile

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collectors visit fixed locations, i.e., rendezvous points, for gathering data through multi-hop relays and an optimization problem to select the optimal path within a required delay bound was studied. A different approach was taken by partitioning the sensor field into

zones and developing an approximate algorithm to maximize network throughput while conserving energy consumption.

IV MOBILITY IN ENERGY HARVESTING WSN

A small portion of nodes can move freely in the network to search for energy from the environment. Since sensor nodes are usually energy constrained, the energy consumptions during the movement are not justified energy efficient paths are planned for a mobile powered vehicle. The paths are calculated using regression methods so that the movement of the vehicle can adapt to changes in weather conditions.
Based on the BLOS algorithm, we further consider the problem of using battery powered routers to monitor or cover hot spots. When all mesh routers follow the BLOS policy, our goal is to keep the mesh network covering all hot spots for as long as possible. We refer to this problem as the *Spot Covering under BLOS Policy problem (SCBP)*.Thus the algorithm is referred to as the *Spanning Tree Scheduling* (STS) algorithm.

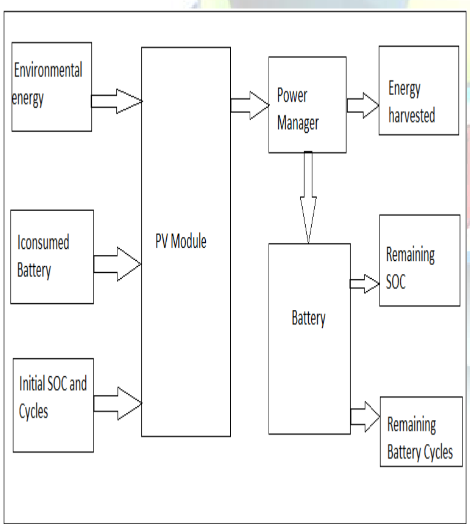

Fig 3. General Schematic of battery harvesting diagram

(a) Battery-Aware Routing

In this existing system, adapting a Mobile Collector has known benefits to distribute energy consumption more evenly compared to a static data sink, because nodes close to the data sink tend to consume more energy for forwarding packets. As energy harvesting rates depends on sensors spatial temporally, congestion could occur with a static data sink. Unless a complete environmental energy profile for various geographical locations is known, it is difficult to guarantee successful and timely data delivery in such a network.By, directing the Sencar to collect the packets from designated regions to avoid draining sensor's battery where the environmental energy supply is not sufficient at that time. Most of the works are based on finding optimal travelling path of mobile collectors and minimizing energy consumption. [8] discussed about a system, In this proposal, a neural network approach is proposed for energy conservation routing in a wireless sensor network. Our designed neural network system has been successfully applied to our scheme of energy conservation.

The routing protocol is sensitive to the battery status of routing nodes and avoids energy loss. Mobile relay was used for WSN's composed of packets from normal mode and joint mobility in routing algorithms.

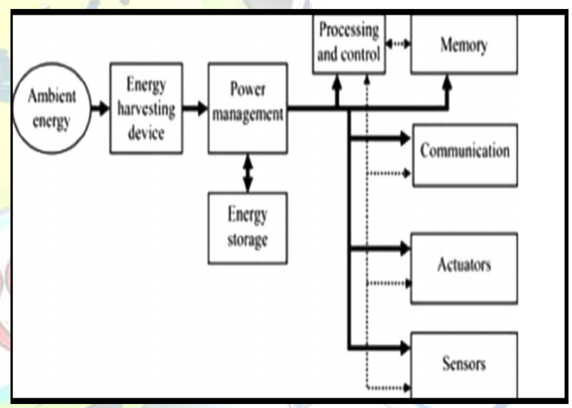

Fig4.Architecture or Harvesting Sensor networks

V ALGORITHM APPROACH

In this paper,first we approached a *distributive algorithm* for to find the optimal data rates, link flows for sensors and sojourn time allocation for the SenCar Further In this paper, we will focus on how to plan the subtours of multiple mobile collectors to minimize the number of mobile collectors. The data-gathering algorithm with multiple mobile collectors can be described as follows. First, find the polling point set by running the spanning tree covering algorithm is considered how to plan the data-gathering tour of a single M-collector. However, for some large-scale applications, each data-gathering tour may take such a long time that a single M-collector may not be sufficient to visit the transmission ranges of all sensors before their buffers overflow. A possible solution to this problem is to allow some sensors to relay packets

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from other nodes to the mobile data collector. Thus, the M-collector does not need to visit the transmission range of every single sensor, and the length of each tour can be reduced. However, the drawback of using relay is that some relaying nodes may fail faster than others. To avoid unbalanced network lifetime. The mobile collectors can gather data remotely via wireless links without visiting the *"home"* of every sensor.

Once in a while, the M-collector forwards the sensing data to one of the other nearby mobile collectors, when two mobile collectors move close enough. Finally, data can be forwarded to the M-collector that will visit the data sink via relays of other mobile collectors. There are some interesting issues here, such as how to relay the packets to the data sink energy efficiently, how to schedule the movement of mobile collectors to reduce the packet delay, and so on. In this paper, we will focus on how to plan the subtours of multiple mobile collectors to minimize the number of mobile collectors. The data-gathering algorithm with multiple mobile collectors can be described as follows. *First, find the polling point set by running the spanning tree covering algorithm.*

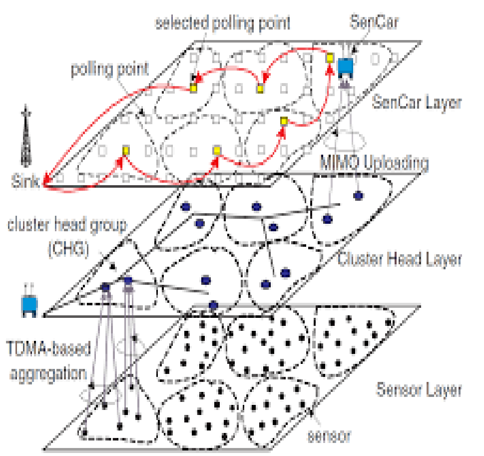

Fig 5.Multiple collector in sensor aggregation

VI MATHEMATICAL EVALUATION

A. DEFINITION AND NOTATIONS

First consider a battery being discharged in $[t, t+\delta_i]$, after that period it takes τ_i time to fully recover the discharging loss. From **(1)** we know the length of recovery time τ_i is only dependent on δ_i if given α, I **and** β. Therefore, there is a function to calculate τ_i, and we call it ***GetTau***. That is,

$$\tau_i = GetTau(\alpha, I, \beta, \delta_i) \quad \textbf{(1)}$$

Under the greedy mode, where the battery is continuously discharged under current I until it dies, we define the total lifetime function as,

$$Lifetime\ (\alpha, \beta, I) \quad \textbf{(2)}$$

In mathematical terms, let

$$\overline{T}_i = \sum_{j=i}^{n} \delta_j. \quad \textbf{(3)}$$

A policy P is defined as a schedule for a router. P describes the lengths of time $\delta_1, \tau_1, \delta_2, \tau_2.$ until the battery is used up.

An Given α_i, let T_i under the optimal policy be

$$T_i = P_i(\alpha_i) \quad \textbf{(4)}$$

Suppose that $P_i(\alpha_i)$ has been found, that is, for any given α_i, we know the optimal lengths of $\delta_i, \delta_{i+1}, \ldots, \delta_n$ such that T_i is maximized. Now we want to find $P_i{-}1(\alpha_i{-}1)$. Define the overhead to switch between active and idle. Note that

$$\overline{T}_i - 1 = \delta_i - 1 + T_i \quad \textbf{(5)}$$

Also note that if $\alpha_i - 1$, $\delta_i - 1$ **and** $\tau_i - 1$ are given, α_i is determined and can be written as

$$\alpha_i = f(\alpha_{i-1}, I, \delta_{i-1}, \tau_{i-1}) - \epsilon \quad \textbf{(6)}$$

where function $f(\alpha_x, I, \delta_x, \tau_x)$ describes the residual battery power after being discharged for δ_x time under current I and being recovered for τ_x time.

In this case $\overline{T}_i - 1$ can be maximized by adopting the optimal policy for the T_i we have already found.

From **(6)**,**(5) and (3)**, we obtain the maximum value of $\overline{T}_i - 1$

$$\overline{T}_{i-1} = \delta_{i-1} + P_i(f(\alpha_{i-1}, I, \delta_{i-1}, \tau_{i-1}) - \epsilon) \quad \textbf{(7)}$$

an optimum T_1 with a peak value.

The BLOS algorithm employs an iterative approach to finding $P_1(\alpha_1)$ for a given n. We call it ***GetBlos***.

A. Table 1. Finding Optimal Policy *P* for Given *n*

Procedure *GetBlos* (α, *i*)

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Procedure:
STS **begin**
Initially each mesh router is assigned a weight;
$\tau = 0, h = 1$;
Each mesh router computes its policy by BLOS;
repeat
Each hot spot is colored as a *black* node;
Each mesh router is colored as a *white* node;
while
the spanning tree is not connected
do
begin
Each *black* node *k* selects a *white* node *i*,

Where Distance(*I*,*k*) < Radius(*i*), and

weight(*i*)= min{weight(*j*)|distance(*j*,*k*) <Radius(*j*)};

i is colored *black*;
end
Obtain a spanning tree with *s* routers: $m_1, m_2, \ldots, m_s$;
Mesh routers not in the spanning tree are turned
idle for recovery;

$$\max\{\tau, \min\{\delta_h^{m_1}, \delta_h^{m_2}, \ldots, \delta_h^{m_s}\}\}$$

This spanning tree works for time;
$\tau = \max\{\tau hm1, \tau hm2, \ldots, \tau hms\}$;

Each node $m_l (l = 1 \ldots s)$ does:

Weight(m_l)=Weight(m_l)+δ_{weight};
$h = h + 1$;

until no spanning tree can be constructed;

end

begin
if ($i = n$)
begin
$\delta_n = lifetime(\alpha, \beta, I)$;
return δ_n;
end
else
begin
T=0;
for

$j = 1$ **to** $\lfloor \frac{\alpha}{I \times \bar{\delta}} \rfloor$ **begin**

T_n by calling *GetBlos* $(\alpha - j \times \bar{\delta} \times I - \epsilon, i + 1 \times \bar{\delta}$;

Lemma 1 *The decision version of the SCBP problem is equivalent to the* Subset Partition *problem (SP).*

Proof. First we give some properties of a valid schedule. Since all spots must be covered at time 0, some routers must have been turned on at time 0 and these routers must collectively cover all spots. Thus the decision version of the SCBP problem is equivalent to the following problem, which we call the *Subset Partition* problem (SP): Given a whole set (the spots) and some subsets (the routers), can the subsets be partitioned into *k* groups where each group of subsets covers all the elements in the whole set.

Table 2. Battery Lifetime Optimization

Alive Routers:
We first consider the number of alive routers during the network lifetime. Since the BLOS algorithm enables routers to use up battery power gradually, there should be more alive routers. The decreasing of the number of alive nodes is shown in Fig. 9 for various numbers of routers and hot spots, and α and β values. We can see that since the battery-aware scheduling is sensitive to path vertices.

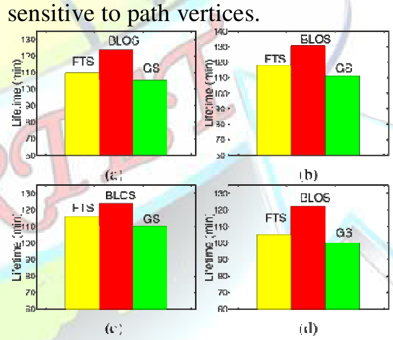

Fig 6.Schematic of general BLOS
Table 3.STS Algorithm approach

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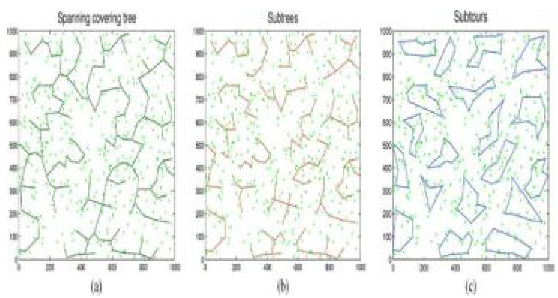


Fig 7.Spanning path Vertices

$10^4 mA\textbf{min}, \beta = 0.4, I = 1300 m\textbf{A}, \epsilon = 100 mA\textbf{min}.$

Power Dissipation.

The evaluated the network with various number of heterogeneous routers. The *X* and *Y* axes show the geographic positions of routers in the network. The *Z* axis stands for the residual battery power of routers. It can be seen that by adopting the STS, routers can preserve higher battery energy.

Data Throughput.

The evaluated normalized gross data throughput of the network under three scheduling algorithms.

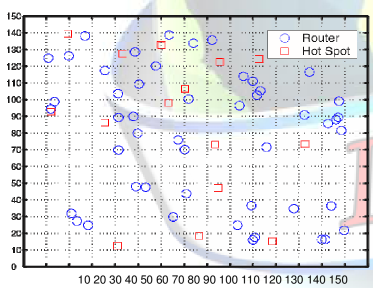


Figure 8. An example of a wireless mesh network with 50 mesh routers and 15 hot spots distributed.

Procedure *BLOS*

Begin

$n = 0$;

$T = 0$, $\bar{T}_1 = 0$; **repeat**

$T = \bar{T}_1$; $n = n + 1$;

calculate $\bar{T}_1$ by calling *GetBlos*(α,n);

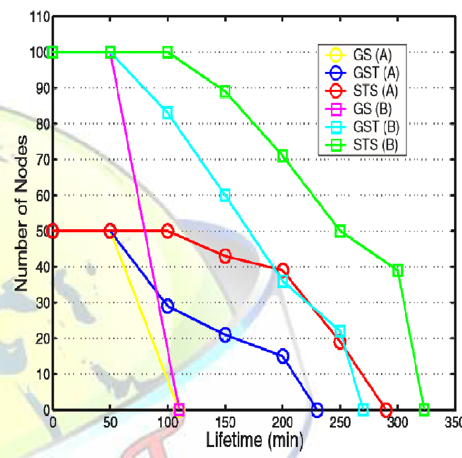
until $\bar{T}_1 < T$;

calculate τ_i by calling *GetTau*(α_i,I,β,δ_i),

for $i = 1,2,\ldots,n$;

end

VII RESULT EVALUATIONS



(a)

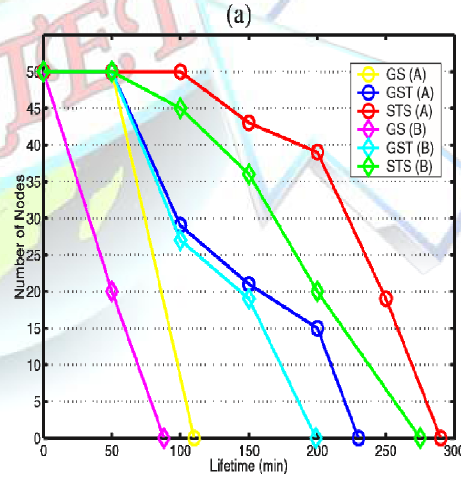


Fig 9. For approx 50 nodes in a large sensor network

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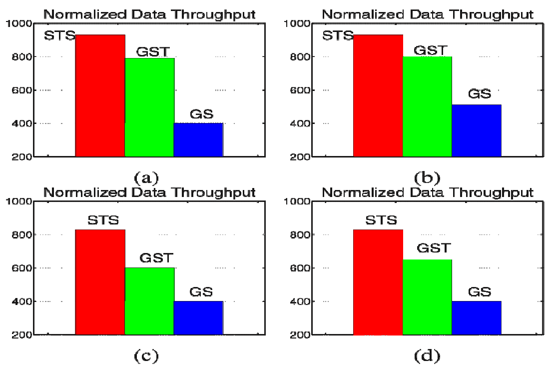
Graph Simulations



Number of alive nodes in the mesh network. (a) Simulation results for various numbers of routers and hot spots. Network A has 50 **routers and** 15 **hot spots; Network B has** 100 **routers and** 40 **hot spots. (b) Simulation results for various** α **and** β **values. Network A has identical routers with** $\alpha = 4.5 \times 10^4 mA$**min and** β = of Galvanostatic Charge and Discharge

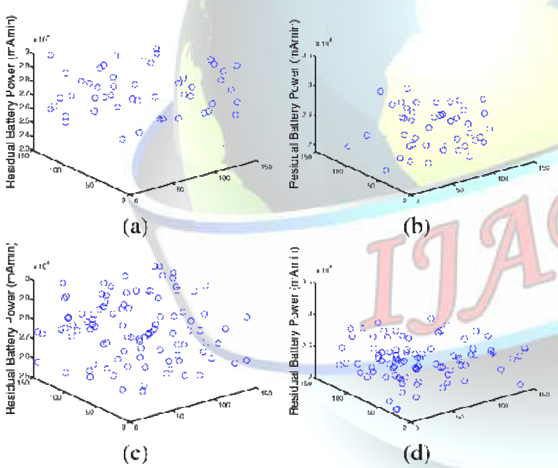


Fig.10 Simulation of Mobile Collectors in energy harvesting systems.

VIII CONCLUSION

In this paper, we have addressed the energy efficient router scheduling problem in wireless mesh networks from a battery-aware point of view. We showed that in practice batteries tend to discharge more power than needed, and reimburse the over-discharged power later if they have sufficiently long recovery time. Given this fact, we studied the relationships between discharging duration and battery lifetime, and introduced a battery lifetime optimization scheduling algorithm (BLOS) to maximize the lifetime of battery-powered mesh router. Based on the BLOS algorithm, we further considered the SCBP problem for monitoring or covering hot spots under BLOS algorithm. We proved that the SCBP is NP-hard, and give an approximation algorithm (STS) with time complexity of $O(r)$ for a network with r mesh routers. Our simulation results show that the STS can greatly improve the lifetime, data throughput and power consumption efficiency of a wireless mesh network.

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