Enhancing Network Lifetime in Wireless Sensor Network using Energy Aware - Lazy Scheduling Algorithm

M.Priyadharsini, M.Karthiga,

Abstract— Wireless Sensor Networks are an emerging technology with potential application in areas as wide ranging as habitat monitoring and industrial applications. In these applications, sensor nodes use batteries as sole energy source resulting in degradation of energy. Hence, a key issue in wireless sensor network is maximizing network lifetime. A framework to maximize the lifetime of wireless sensor network by using a novel sleep scheduling technique called Virtual Backbone Scheduling (VBS) that enables fine-grained sleep scheduling is proposed. VBS schedules multiple overlapped backbones which work alternatively to prolong network lifetime so that energy consumption is evenly distributed among all the sensor nodes. An approximation algorithms based on Scheduling Transition Graph (STG) is introduced to overcome the scheduling problem of VBS called Maximum Lifetime Backbone Scheduling (MLBS) problem. With the aim of further improving the efficiency and conservative management of energy resources, with automatic ability of foreseeing the task energy starving during run-time an Energy Aware - Lazy Scheduling Algorithm (EA-LSA) is to be proposed.

Index Terms— - Backbone scheduling, Sleep scheduling, Duty cycling, Connected dominating set, Energy harvesting

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 pollutant, at different locations. Wireless sensor network are used in places where information about environmental condition are difficult to access. The development of wireless sensor networks was originally motivated by military applications like 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.

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. 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. Sensor node transmits the data from one mote to another mote in an adhoc way and finally to a base station where the data is stored, processed and displayed. The main components of a sensor node are microcontroller, transceiver, external memory, power source and one or more sensors.

This project demonstrates the overall system architecture of sensor network and maximizing the lifetime of sensor network. A sensor node uses battery as the sole energy resource. Sensor nodes are expected to work on batteries for several months to a few years without replenishing. Hence, energy efficiency becomes critical. Among several functional components the radio consumes the major portion of the energy.

Various techniques are proposed to minimize its energy consumption. In this paper, Backbone Scheduling is focused which lets a fraction of the sensor node to turn on sensor node to forward message and lets the rest of the sensor node to turn off their radio to save energy. This technique does not affect the communication quality as WSN use redundant sensor nodes to achieve fault tolerance and quality of service. Here, we use Connected Dominating Set (CDS) algorithms to construct communication backbones [2].

However, a single backbone does not prolong the network lifetime. Hence, multiple disjoint CDSs are constructed and let them work alternatively to prolong network lifetime. The rotation of multiple backbones makes sure that the energy consumption of all sensor nodes is balanced.A novel sleep scheduling technique called Virtual Backbone Scheduling enables a fine grained sleep scheduling so that energy consumption is evenly distributed among all the sensor nodes. Duty cycling is an integral part of wireless sensor networks. A duty cycle is the time that an entity spends in an active state to the total time considered. VBS combines backbone scheduling and duty cycling to overcome node failure.

The contribution of this paper is as follows:

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- First, VBS combines backbone scheduling and duty cycling to overcome node failure. VBS employs fine grained sleep scheduling to prolong network lifetime.
- Second, it formulate MLBS problem and design a centralized approximation algorithm called
- Third, with the aim of further improving efficiency and conservative management of energy resource a new improved Lazy scheduling algorithm is to be proposed.

The restof this paper is organized as follows: Related work is described in Chapter 2. Chapter 3 describes the problem definition and existing system. Chapter 4 describes the proposed work. Chapter 5 describes the conclusion.

2 Preliminary Works

The various research groups are exploring the ways to improve network lifetime and energy balance in wireless sensor network.

Ye et al [1] proposed S-MAC. It uses three novel techniques to reduce energy consumption and support self-configuration. To reduce energy consumption during idle listening it uses a novel sleep scheduling technique and, also it sets the radio to turnoff when other nodes are transmitting. Neighboring nodes form a virtual cluster to auto-synchronize on sleep modes.

Shnayder et al [3] proposed PowerTOSSIM technique. It is a scalable simulation environment that provides accurate estimation of power consumption per each node. It employs a novel code transformation technique to estimate the number of CPU cycles executed by each node, eliminating the need for expensive instruction-level simulation of sensor nodes. Finally, the trace of each node's activity is fed into a detailed model of hardware energy consumption, yielding per-node energy consumption data. This energy model can be readily modified for different hardware platforms.

Dei and Wu [2] proposed the construction of connected dominating set. A set can be dominating if the entire hosts in the system are in the set or neighbors of host in the set. The efficiency of connected dominating set depends on overhead introduced in constructing the connected dominating set and its size. Marking process is used to quickly determine the CDS by interacting with others in the neighborhood. A set of marked host forms a small CDS. Two pruning rules are used to reduce the resultant dominating set.

Heidemann et al [4] proposed two new algorithms to control and exploit the presence of multiple schedules to reduce energy consumption and latency. The first one is Global Schedule Algorithm (GSA). GSA is a distributed algorithm that allows a large network to converge under a single globalschedule to conserve energy. Second a Fast Path Algorithm (FPA) is developed. FPA provides a fast data forwarding paths by adding additional wakeup periods for nodes along the path from source to sink.

Keshavarzian et al [5] proposed a two novel sleep scheduling technique. The methods include Scheduled wakeup: Time synchronisation among all the sensor nodes in a particular sensor field. Wakeup on demand: The nodes can be signalled and awakened at any point of time and then message is sent to node.This is usually employed using two wireless interfaces. The first radio is for data communication and second ultra-low power radio signal for paging and signaling.

Cohen and Kapchits [6] proposed an optimal wakeup scheduling algorithm to reduce energy consumption and limiting the maximum delay in network. It uses local synchronisation (i.e.) each node selects its active duty cycle and informs to all the neighbour nodes about its selection. It provide solution to trade-off on selective aspects such as, data delivery model, amount of data to be delivered, routing scheme and, whether intermediate node process packets they receive in order to merge similar observations. It reduces the energy consumption by 60%-70%.

Misra and Mandal [7] proposed rotation of CDS via Connected Domatic Partition. Nodes in a CDS have extra computation and communication load for their role as dominator, subjecting them to early exhaustion of their battery. A simple mechanism is used, switching from one CDS to another fresh CDS, rotating an active CDS through a disjoint set of CDSs. A CDP consist of several disjoint CDS. A CDP is constructed using Maximal Independent Set heuristics (MIS). By rotating CDS, it breaks the operation of high battery discharge by introducing rest times to allow recharge recovery effect in electrochemical batteries in extending battery lifetime.

3 Existing Work

Each sensor node is powered by a finite-energy battery with an available energy at the initial network deployment and is often deployed to not-easily-accessible or hostile environment. It can be difficult or impossible to replace the batteries of the sensor nodes. A sensor node ceases to operate if its battery is drained below a certain energy threshold (i.e., available energy goes below some usable threshold). Often, network lifetime is defined as the time for the first node to die or as the time for a certain percentage of network nodes to die.

Zhao et al [8] proposed a novel sleep scheduling technique called Virtual Backbone Scheduling which forms multi-

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- *Priyadharsini.M is currently pursuing masters degree program in computer science and engineering in Kongu Engineering College, Erode,E-mail:priyamoorthy@gmail.com*
- *Karthiga.M is currently pursuing masters degree program in computer science and engineering in Kongu Engineering College, Erode,E-mail:mkarthiga22@gmail.com*

ple overlapped backbones which works alternatively from one backbone to another to prolong network lifetime. So, that energy consumption is evenly distributed among all the sensor nodes.

Connected Dominating set is used for constructing communication backbones. VBS employs a fine-grained sleep scheduling technique method, which significantly prolong the network lifetime. In order to find the optimal schedule that maximizes the network lifetime Maximum Lifetime Backbone Scheduling (MLBS) problem is formulated. As it is NP-hard a centralized approximation algorithm is considered.

A. *Scheduling Transition Graph - Based Approximation Algorithm*

First centralized approximation algorithm is based on new concept called Scheduling Transition Graph (STG). In the figure 3, horizontal axis represents the time scale, counted in rounds. In each round, possible states are listed vertically, which are represented by ellipse. The number of possible states is equal to number of backbones. Each state contains a backbone and corresponding energy levels. The state and the backbone have one-to-one mapping. An initial state is placed at round 0 and is connected with all the states in first round. United directed transition edges connect state in one round to the others in next round. Each backbone consumes a fixed amount of energy at the end of each round.

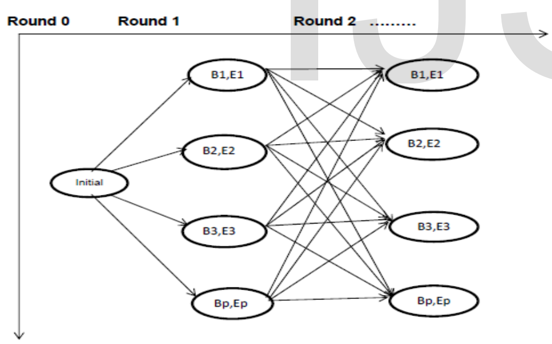

Fig. 1 The illustration of a STG. The initial state is attached as a common starting point for the scheduling.

STG calculates the longest path using

Time Span: The length of the STG is the maximum number of rounds that the network can run without depleting its energy of any sensor node denoted by C and each backbone consumes a fixed amount of energy ε. Therefore, minimum energy consumed at the end of each round is n×ε. IE denotes the initial energy and |V| denotes the number of sensor nodes in the network. The maximum round number is given as

$$C = \frac{|V|\mathbb{IE}}{n \times \varepsilon}.$$

Energy level: Energy Level indicates the residual energy of each sensor node. Zero energy levels are less than any non-zero energy level indicates the end of network lifetime.

Algorithm 1.STG- Based Algorithm

```
int CUR_ROUND = 0;
repeat
    for each state S do
        Get the associated energy levels of S;
        Prune the resultant energy levels using the min()
        function;
        Select the energy level with the maximal
        minimum energy value.
        Set S's energy level to the energy level with the
        maximum summation among the resultant
        energy levels;
    end for
    CUR_ROUND = CUR_ROUND + 1;
until All the energy levels of the states in
    CUR_ROUND are zero;
Return the schedule represented by the path ending in
    CUR_ROUND
```

In order to find the longest path, we need to record the energy levels of each state. We use min() function to prune invalid energy levels from a set of n associated energy levels, S= { $\sigma_1, \sigma_2, \ldots\ldots \sigma_n$ }

Min (S) = {σ | σ ϵ S, there is another state σ′ϵ S such that σ ≤σ′}

The energy levels produced by this function are invalid because strictly lower energy levels cannot produce longest lifetime.

4 Proposed Work

Wireless sensor networks (WSNs) have encountered a big interest among the scientific community. One of the major challenges in certain WSN applications is represented by the capability of self-powering the network sensor nodes by means of suitable energy-harvesting (EH) techniques. Energy Harvesting is used to overcome node failure. Energy Harvesting retrieves energy from external sources such as solar power, thermal energy, wind energy etc. Energy Harvesting based autonomous wireless sensor nodes are a cost-effective and convenient solution. The use of Energy Harvesting removes one of the key factors limiting the proliferation of wireless nodes the scarcity of power sources having the characteristics necessary to deliver the energy and power to the sensor node for years without battery replacement.

However, the nature of the energy captured from the environment is often inconstant and unpredictable, and therefore, some smart solution is required to efficiently use it for information processing at the sensor level. Two possible ways of intervention can be foreseen on purpose: the optimal distribution of acquired energy to the task to be executed, with the aim of avoiding the overflow of the accumulator in idle phases and task starving under high-activity conditions, and the efficient usage of available energy, in order to maximize the amount of energy dedicated to the tasks.

The output of the sensor is typically connected to a microcontroller that processes the signal created from measuring the parameter of interest (e.g., temperature, pressure, acceleration, etc.) and converts it to a form that is useful for data transmission, collection, and analysis. Additionally, the microcontroller usually feeds this information to the radio and controls its activation at some prescribed time interval or based on the occurrence of a particular event. It is important that the microcontroller and radio are operating in low power modes whenever possible in order to maximize the power source lifetime.

EH uses Lazy scheduling algorithm which represents the performing mix of scheduling effectiveness and ease of implementation. With the aim of further improving the efficiency and conservative management of energy resources with automatic ability of foreseeing task energy starving during runtime Energy Aware - Lazy Scheduling Algorithm (EA-LSA).

Energy source retrieves energy from solar, thermal or wind which is accumulated in capacitor or battery then boosted to a second storage capacitor or battery for using microprocessor or for transmitting information.

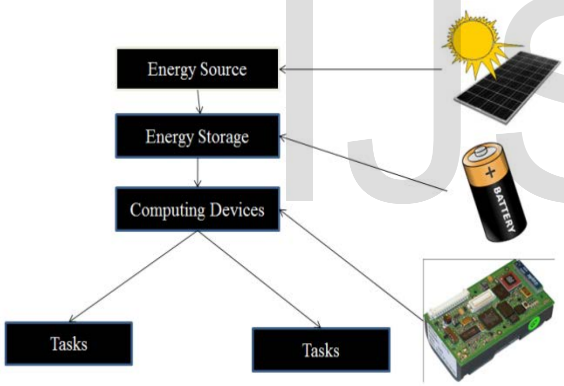

Fig. 2 Basic architecture of Energy Harvesting

A. Energy Aware – Lazy Scheduling Algorithm

The EA-LSA approach, assumes the knowledge of future availability of environmental power, described by function PH(t), and therefore the energy EH(t1, t2) acquired in the time interval [t1, t2].

Algorithm 2 EA-lazy scheduling with p_d = constant

Require: maintain a set of indices $i \in Q$ of all ready but not finished tasks J_i

$P_s(t) \Leftarrow 0$;

while (true)

  $d_j \Leftarrow \min\{d_i: i \in Q\}$;

  if $e_j > (E_C(t) + E_H(t, d_j))$ **then** remove index j from Q;

  else

    calculate s_j;

    process task J_j with power $P_S(t)$

  $t \Leftarrow$ current time;

  if $t = a_k$ **then** add index k to Q; **end if**

  if $t = f_j$ **then** remove index j from Q; **end if**

  if $E_C(t) = C$ **then** $P_S(t) \Leftarrow P_H(t)$; **end if**

  if $t \geq S_j$ **then** $P_S(t) \Leftarrow P_d$; **end if**

endif

endwhile

The optimal starting time s_n is defined as the maximum value between the two quantities s_i^* and $s_i^{'}$ and E_H are

$$s_i^* = d_i - \frac{E_C(a_i) + E_H(a_i, d_i)}{p_d}$$

$$s_i^{'} = d_i - \frac{C + E_H(s_i^{'}, d_i)}{p_d}$$

$$E_H(t_1, t_2) = \int_{t_2}^{t_1} P_H(t)dt$$

J_n identifies the generic nth task, and all parameters related to it are characterized by n as follows:

- a_n : the arrival time, namely ''phase''
- d_n : the deadline
- f_n : the task completion time instant
- s_n : the optimal starting time
- e_n : the required energy for task completion

Other relevant parameters are:

- Q : the task index set
- $P_s(t)$: the power absorbed by the device
- $P_H(t)$: the acquired power
- P_d : the power drain maximum value
- $E_C(t)$: the energy stored in the accumulator
- C : the accumulator energy capacity

B. PARAMETERS FOR EVALUATION

There are 2 parameters considered for evaluation of presented work. They are

1. Network lifetime: Providing identical initial energy for all sensor nodes and providing imbalanced initial energy for all the sensor nodes

2. Energy Balance: Calculating residual energy of each sensor nodes by applying STG and EA-LSA algorithms and comparing the network lifetime improvement.

6 CONCLUSION AND FUTURE WORK

Wireless sensor network requires sensor node to work for a long period of time without human intervention. Previously, a combination of backbone scheduling and duty cycling method called Virtual Backbone Scheduling is used. VBS improves the energy efficiency and network lifetime of the sensor node.In order to further improve battery lifetime of sensor node, a new algorithm named Energy Aware LSA is to be proposed due to its capability of foreseeing task energy starving and it allows conservative and efficient management of energy.

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