ISSN No. 0976-5697

Volume 5, No. 6, July-August 2014

International Journal of Advanced Research in Computer Science

RESEARCH PAPER

Available Online at www.ijarcs.info

Implementation of Earliest Deadline First Algorithm for Wireless Sensor Network

Ms.P. B. Lohiya
M.E (2nd yr CSE)
PRMCEAM Amravati, India

Dr. D.G.Harkut
Associate professor
PRMCEAM Amravati, India

Dr. M.S.Ali
Principal
PRMCEAM Amravati, India

Abstract: This paper presents the implementation of an earliest deadline first (EDF) scheduling mechanism for Wireless Sensor Network (WSN). In this paper we are monitoring and scheduling the sensor values in real time by embedding wireless sensor nodes. We use the LPC2148 ARM7TMDI based microcontroller which is used as core control module and design the overall structure of the system according to the basic need of wireless sensor network. We design the hardware system structure and software system structure where we implement EDF algorithm for scheduling aperiodic task of the WSN in a real time way.

Keywords: Wireless Sensor Network, EDF algorithm, Rate monotonic, Deadline Monotonic.

I. INTRODAUCTION

A WSN is a network of wireless interconnected sensors. These are usually small autonomous devices that monitor some physical conditions or other values with their sensors and use short range wireless link for communication between them and between higher level systems. The measured values typically are temperature, humidity, light intensity, etc [1] [2] [3]. Compare to other networks, a WSN has its own design and resource constraints. Resource constraints include a limited amount of energy, short communication range, low bandwidth, limited processing and storage in each node and also battery power, program memory available. Design constraints are application dependent and are based on the monitored environment. The environment plays an important role in determining the size of the network, the deployment scheme, and the network topology [4] [5]. The size of the network varies with the monitored environment. Consider we are building a network for indoor then fewer nodes are required to form a wireless network in a limited amount of space whereas outdoor environments may require more nodes to cover a larger area. When network is composed of hundreds or thousands of nodes then humans cannot access this deployment so better to prefer an ad hoc network. [6] [7].

Wireless sensor network is found in a great variety of applications, such as environmental monitoring, military surveillance and personal medical systems. These applications interface with the real world environments and the delivery of data is subject to certain timing constraints. It is a special type of embedded systems where deadline is one of the critical concerns. Applications in embedded systems are usually domain-specific. WSN applications consist of several tasks that are assumed to be independent, periodic and pre-emptible. The nature of a task is depending on the domain. In some applications the task may be periodic or aperiodic. They may be hard or soft [8].

To attain each and every task, there is need to use better scheduling algorithm. The most popular online scheduling algorithm was introduced by Liu and Layland in 1973. According to EDF which is pre-emptive and dynamic priority driven, a ready job with the earliest deadline is executed first. Dertouzos proved that EDF is optimal among all scheduling algorithms on a uniprocessor machine [9] [10]. Consequently, if a set of jobs cannot be scheduled by EDF, then this set cannot be scheduled by any other algorithm. EDF scheduling policy is better to use so that we can attain the entire task as per their deadline value [11] [12] [13]. As part of this paper, we intend to implement an EDF scheduler for WSN.

The remainder of this paper is organized as follows: Section 2 introduces related works of different real time scheduling algorithms. Section 3 discusses the implementation of hardware. Section 4 elaborates the software implementation. Section 5 is all about the results with advantages of used technique. Finally, section 6 concludes this paper with some suggestions for further improvement.

II. RELATED WORK

A. *Real Time System:*

The use of computers to control safety-critical real-time functions has increased rapidly over the past few years. As a consequence, a real-time system is a computer system where the correctness of a computation is dependent on both the logical results of the computation and the time at which these results are produced [14] [15] [16]. For example, in a brake-by-wire system, the computer that controls the braking systems of the car is a real-time system because when the brakes are applied, it is expected that the car stops within a specified amount of time. There are consequences when the results are not obtained at before a pre-specified deadline. The severity of the consequence of not meeting the deadlines further classifies real-time systems into hard and soft real-time systems.

In hard one, application may be considered to have failed, if it does not complete function within the allocated time [17]. Airplane control systems, Nuclear reactor control systems and components of pacemakers are some of the examples of hard real-time systems. In soft real-time system must process request in reasonable time. As example to turn ON AC or audio, in a car control system [18] [19]. As real time systems execute critical tasks, therefore it must be designed very carefully. For that, many scheduling policy has been already designed [20] [21] [22]. Scheduling is technique for allocating tasks on processors to ensure that deadlines are to meet. In traditional real-time embedded systems, deadline is one of the critical concerns. There are basic two types of scheduling policy: offline and online. Offline scheduling involves scheduling in advance of the operation. In online scheduling, the tasks are scheduled as they come into the system and tasks are assigned to processor based on their relative priority. The algorithm keeps task priority constant called static–priority algorithms. In dynamic-priority, algorithm, priority of tasks will change with time [23] [24] [25] [26] [27]. Figure 2.1 shows the basic scheduling algorithm function.

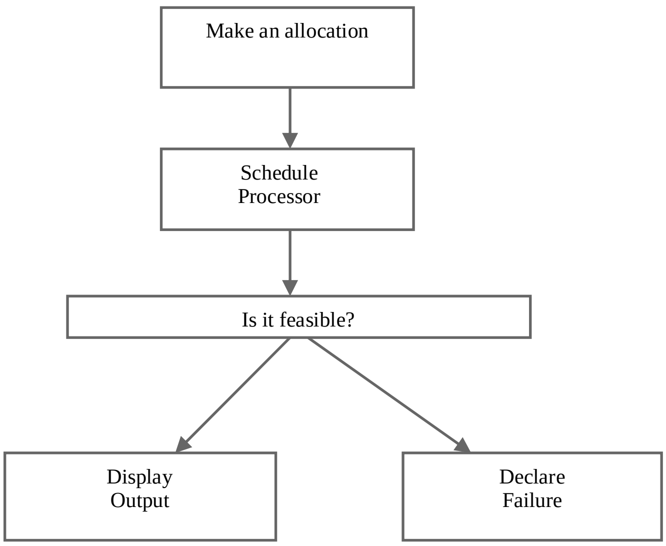

Figure 2.1: Basic Function of Scheduling Algorithm

B. Real Time Scheduling Algorithms:

In Real-time systems scheduling algorithms are classified into two categories: Static algorithm and Dynamic algorithm. Based on execution attributes of tasks, dynamic algorithm assigns priorities at runtime [28] [29] [30]. This algorithm allows switching of priorities between tasks. In contrast with dynamic algorithm, a static algorithm assigns priorities at design time. All assigned priorities remain fixed throughout the execution of task. Figure 2.2 gives the classification of available scheduling algorithms for real-time systems [31] [32].

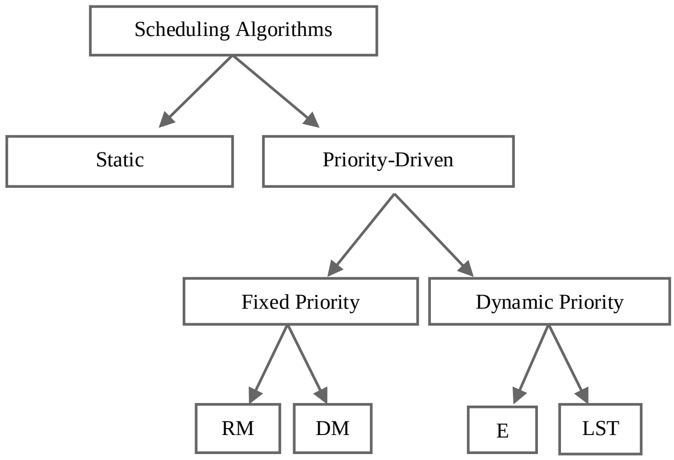

Figure 2.2: Real time scheduling algorithms

Following table 2.1 shows the comparison between the available real time algorithms.

Table 2.1: Comparison of Real time algorithms

Algorithms / Parameters	RM	DM	LST	EDF
Priority	Static	Static	Dynamic	Dynamic
CPU utilization	Average	Low	Low	High
No. of context switches	High	Less	High	Less
Optimal	No	No	No	Yes
Deadline miss chances	Average	Average	High	Less
Response time	Average	Less	Less	Average

The EDF algorithm is optimal compared with the other real-time algorithms and if task is not scheduled by EDF then all other algorithms will fail to schedule that task [33] [34] [35] [36]. As compared to other algorithms EDF is simple to implement and gives much better utilization of processor and also EDF having dynamic nature with less number of context switches. The deadline miss chances are less in EDF algorithm [37] [38] [39] [40].

III. HARDWARE IMPLEMENTATION

In this work we use hardware components like ARM LPC 2148 microcontroller, Radio Frequency (RF) modem, USB device, Temperature sensor, humidity sensor, moisture sensor, light sensor. Following figure gives the brief structure of hardware system.

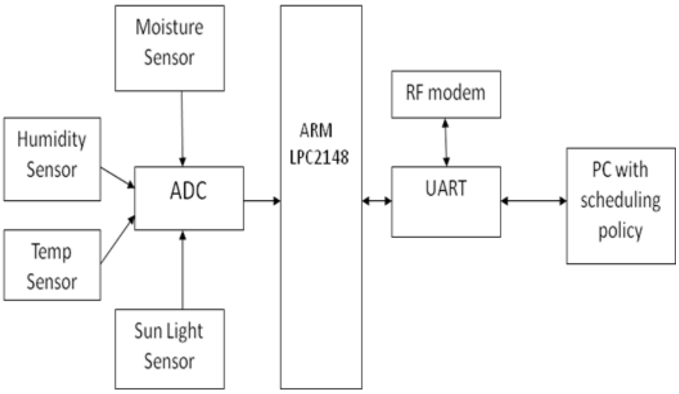

Figure 3.1: Block diagram of WSN

The above figure shows the working module of wireless sensor network. ARM LPC 2148 is the widely used Integrated Circuit (IC) from ARM-7 family. It is manufactured by Philips and it is pre-loaded with many inbuilt peripherals making it more efficient and a reliable option for the beginners as well as high end application developer. The LPC2148 microcontroller has 512KB of internal flash and 32+8K RAM.

A Universal Asynchronous Receiver Transmitter (UART) is usually an individual (or part of an) integrated circuit used for serial communications over a computer or peripheral device serial port. Radio modem can be used for applications that need two way wireless data transmission. It transfers data wirelessly across a range of up to tens of kilo meters'. It features adjustable data rate and reliable transmission distance. The communication protocol is self controlled and completely transparent to user interface. This module works in half-duplex mode. Means it can either transmit or receive but not both at same time.

a. ***Temperature Sensor:*** The measurement of temperature is one of the fundamental requirements for environmental control, as well as certain chemical, electrical and mechanical controls. Temperature sensors are vital to a variety of everyday products.
b. ***Humidity Sensor:*** Humidity is the presence of water in air. Humidity sensing is very important, especially in the control systems for industrial processes and human comfort. Controlling or monitoring humidity is of paramount importance in many industrial & domestic applications.
c. ***Moisture Sensor:*** Moisture refers to the presence of a liquid, especially water, often in trace amounts. Small amounts of water may be found, for example, in the air (humidity), in foods, and in various commercial products. Moisture also refers to the amount of water vapour present in the air.
d. ***Light Sensor:*** Visible light is electromagnetic radiation that is visible to the human eye, and is responsible for the sense of sight. Applications include smoke detection, automatic lighting control, and batch counting and burglar alarm systems.

IV. SOFTWARE IMPLEMENTATION

A. *EDF Scheduling Algorithm:*

EDF scheduler still remains an efficient option for online scheduling in these new generation computing systems.

a. Main Definitions:

a) ***Definition 1:*** A scheduling algorithm is optimal if it finds a valid schedule (where all deadlines are satisfied) whenever one exists.
b) ***Definition 2:*** A scheduling algorithm is online if it makes its decision at run-time.

EDF is an optimal scheduling algorithm on preemptive uniprocessor, in the following sense: if a collection of independent jobs, each characterized by an arrival time, an execution requirement and a deadline, can be scheduled (by any algorithm) in a way that ensures all the jobs complete by their deadline, the EDF will schedule this collection of jobs so they all complete by their deadline. While developing EDF algorithm we assume that all the tasks are having aperiodic nature means they can arrive at any instant of time. We implement this algorithm for uniprocessor where deadline is one of the important parameter because we assume those aperiodic tasks are hard real time.

(a). EDF with Array: Here we use an array for storing deadline values of task. When any parameter crosses threshold then at that time task arrives with their arrival time, execution time and deadline time. Now scheduler takes the decision which task will get service first using EDF scheduling policy which says that task having least deadline value will get service first.

Hence there is a need to sort deadline array so that we can assign a priority to the task depending on their deadline value. For sorting we are using algorithm which is given below:

i. Quick Sort
ii. Merge Sort
iii. Bubble Sort

With the help of this algorithm we can sort the deadline array and then assign priority to the task as per the EDF policy i.e. task having less deadline value will get highest priority.

Now in real time system the priority of task changes dynamically. For this reason there is a need to keep a track of deadline values. If any task changes deadline then we call sorting algorithm and assign priorities to the task. In array inserting a new deadline value of task is expensive; because existing elements have to shift. To overcome this problem a better method is to use a link list data structure.

(b). EDF with Link List: At first it is assumed that the list is sorted with the help of Quick sort algorithm. After sorting, scheduler assigns priority to the task which is having least deadline value. Now consider if any task crosses the threshold value then deadline of that task gets change and to identify that change in the deadline value, we set the flag (equal to 1) respect to that change deadline value. Following figure 4.1 represents the link list structure in which node contains task name, their deadline value with status of flag. When task crosses threshold then deadline value change and we set the flag equal to 1 and then can easily identify that change value. The representation of flag set is given in figure 4.2. For inserting that change value we call binary insertion sort algorithm which inserts a change deadline at its proper position. After arranging link list the scheduler identify highest priority task at index 0, second highest priority task at index 1 and so on.

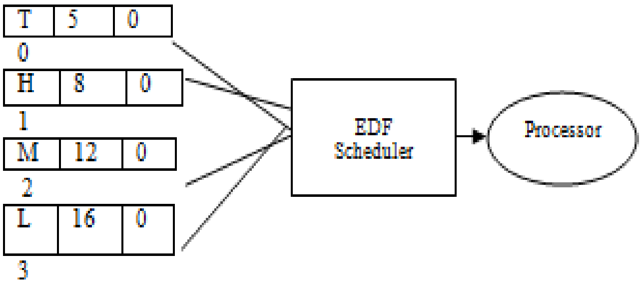

Figure 4.1: Representation of Link List with EDF scheduler

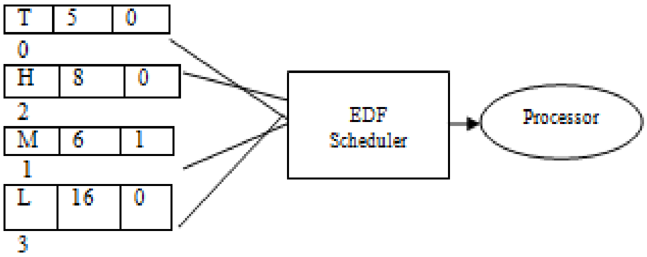

Figure 4.2: Representation of Link List with flag set

Binary search algorithm minimizes the comparison required to arrange the link list and also time required to sort is get minimized. Algorithm of binary search for insertion in link list is given below:

Step 1: Beg=LB
Step 2: End=UB
Step 3: MID = (Beg+End/2)
Step 4: If Item<Data (MID)
Step 5: Then End=MID-1
Step 6: Else Beg=MID+1

The algorithm divides the list and get middle index of the element. Now check that middle value is greater than or less than the Item that we want to insert. If item is greater than middle value, then right left part of list is get skipped and in second iteration the search starts on half of the list. This random access is possible only when we know the Upper bound (UB) and the Lower bound (LB) of the list. Here Item is nothing but the element that we want to insert in list at its proper position. After getting an index then we will insert our new element at its proper position.

V. RESULTS AND DISCUSSION

A. EDF algorithm for aperiodic task:

The experimentation result is considered after simulating number of task sets with variation in arrival time, deadline value and execution time. Finally after scheduling set of tasks we got the graph given below in figure 5.1. As all tasks are having aperiodic nature with hard deadline so main aim was to schedule task before deadline with minimum value of context switches, pre-emptions, miss rate and also minimized the response time of tasks. After scheduling number of task samples, we observed that in aperiodic system EDF algorithm performs well as compare to LST algorithm. Aperiodic task are schedulable with EDF algorithm so mostly all the tasks meet their deadline.

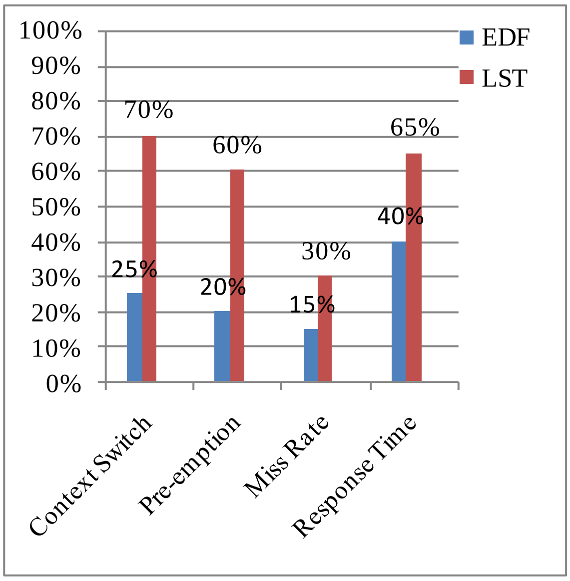

Figure 5.1: Graph shows the performance of EDF algorithm

B. Sorting Mechanism:

In this work we have used four sorting algorithms and compared their simulation results depend on their performance indicator parameter i.e., the number of memory references and required time to sort. Following figure 5.2 shows the comparison with running time required and the number of memory references. We found that quick sort algorithm is very efficient as compared to other sorting algorithm and also we have used this quick sort with binary insertion sort to get better results.

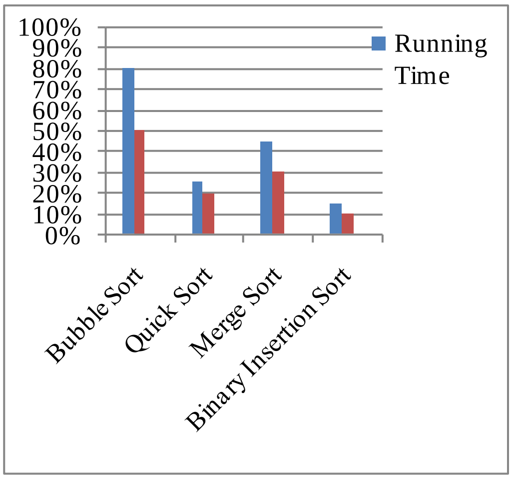

Figure 5.2: Comparison of sorting algorithm w.r.t. Running time and Counter

a. Comparisons of Time Complexity of Sorting Algorithms

In this table, *n* is the number of records to be sorted. The columns “Average”, “Best” and “Worst” give the time complexity in each case, and the memory requirements listed below should be understood to be inside big O notation.

Table 5.1 Comparison of sorting algorithm

Algorithms	Time Complexity		
	Average	Best	Worst
Quick Sort	O(n log n)	O(n log n)	$O(n^2)$
Binary Insertion Sort	O(log n)	O(1)	O(log n)
Merge Sort	O(n log n)	O(n log n)	O(n log n)
Bubble Sort	$O(n^2)$	$O(n^2)$	$O(n^2)$

VI. CONCLUSION AND FUTURE SCOPE

This work discussed the feasibility of EDF algorithm for aperiodic task of hard real time system. With the help of EDF algorithm scheduler schedules the entire set of aperiodic tasks with minimum number of context switches, pre-emptions, miss rate and at some level EDF helps to minimize the response time of task. The major part of this work concerned with the implementation of EDF scheduler using Link List with Binary Insertion Sort algorithm which helps to speed up the scheduler. We have compared sorting algorithms on the basis of their performance indicator parameters. With the help of binary insertion sort algorithm we can arrange the link list with in minimum time. The presented experimental results demonstrate the effectiveness of the implementation. This work can be extended in various directions. First, the proposed algorithm can be modified for multiprocessors. Second, there is need to use RTOS where we can actually implement EDF to schedule the task with their deadline value and burst time. This work assumed the set of aperiodic task with hard deadline; there are some applications in WSN which demand schedulability with periodic and sporadic task. Also practical implementation issues could be a subject of future work. Further study is required to improve efficiency of the proposed algorithm.

VII. ACKNOWLEDGMENT

It gives me immense pleasure to express my gratitude to Dr. D. G. Harkut, who provided me constructive criticism and a positive feedback during this work. I also express my sincere gratitude to respected Principal Dr. M. S. Ali for providing me necessary facilities.

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