A Dynamic Online Non Preemptive Soft Real Time Scheduling Algorithm – High Deadline Meeting Rate

by

ZAHEREEL ISHWAR BIN ABDUL KHALIB
(0940210391)

A thesis submitted
in fulfillment of the requirements for the degree of
Doctor of Philosophy

School of Computer and Communication Engineering
UNIVERSITI MALAYSIA PERLIS

2013

DECLARATION OF THESIS

Authors Full Name : **ZAHEREEL ISHWAR BIN ABDUL KHALIB**

Date of birth : **10 OCTOBER 1976**

Title : **A DYNAMIC ONLINE NON PREEMPTIVE SOFT REAL TIME SCHEDULING ALGORITHM – HIGH DEADLINE MEETING RATE**

Academic Session : **2011/2012**

I, hereby declare that this thesis becomes the property of Universiti Malaysia Perlis (UniMAP) and to be place at the University library. This thesis is classified as :

CONFIDENTIAL	☐	(Contains confidential information under the Official Secret Act 1972)
RESTRICTED	☐	(Contains restricted information as specified by the organization where research was done)
OPEN ACCESS	☐	I agree that my thesis is to be made immediately available as hard copy or on-line open access (full text)

I, the author, give permission to the Universiti Malaysia Perlis to reproduce this thesis in whole or in part of the purpose of research or academic exchange only (except during a period of ……. years, if so requested above).

Certified by

…….
SIGNATURE

…….
SIGNATURE OF SUPERVISOR

…….
(PASSPORT NO. / NEW IC NO.)

PROFESSOR DR. R BADLISHAH AHMAD
……
NAME OF SUPERVISOR

Date: ……..

Date: ……

NOTES: * If there is CONFIDENTIAL or RESTRICTED, please attach with the letter from the organization with period and reasons for confidentially or restriction.

GRADUATE SCHOOL
UNIVERSITY MALAYSIA PERLIS

PERMISSION TO USE

In presenting this thesis in fulfillment of a post graduate degree from the Universiti Malaysia Perlis, I agree that permission for copying of this thesis in any manner, in whole or in part, for scholarly purposes may be granted by my supervisor(s) or, in their absence, by the Dean of the Graduate School. It is understood that any copying or publication or use of this thesis or parts thereof for financial gain shall not be allowed without any written permission. It is also understood that due recognition shall be given to me and to Universiti Malaysia Perlis for any scholarly use which may be made of any material from my thesis.

Request for permission to copy or to make other use of material in this thesis whole or in part should be addressed to

Dean of Graduate School

Universiti Malaysia Perlis (UniMAP)

No. 112 & 114, Tingkat 1, Blok A, Taman Pertiwi Indah,

Jalan Kangar-Alor Setar,

Seriab, 01000 Kangar, Perlis.

Acknowledgement

First of all, I present my gratitude to the Most Gracious and Most Merciful for the infinite mercy and destiny showered on me that this work is finally completed and successful, also in every other countless aspect of life.

To my parents, I love and honor them, I owe them respect and care for all the hardship, love and affection, guidance and motivation, advice and warning since my early days of childhood up to this point of my life and what has to come in future.

To my wife and children, who may not understand the technicality of this work, but understand the significant and the load which I have to bare, the cup of drinks on the table, and the words of care… I thank, love and hug them for their pray and patience, understanding and concern, smile and laughter which wipe off the cob webs I have in mind… at certain points in digesting the project.

To my supervisors Prof Dr. R. Badlishah Ahmad and Dr. Ong Bi Lynn, many thanks for the guidance and assistance in handling the many '*sharp unexpected turning*' in the work which keeps the wheel running on track and the many guide and advice on do and don't, enough and not enough and helping '*leveling the unsmooth land*' I had paved.

Finally, special thanks to my OMNeT++ gurus Mr. Muhammad El Sheikh, Dr. Latifah Munirah Kamarudin and the OMNeT++ online discussion group for their guide and assistance in the implementation stage of the project. To all colleagues and clusters inmates thanks for all the cheers, motivation, drive and advice.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

RTS	-	Real Time System
HRT	-	Hard Real Time
RM	-	Rate Monotonic
EDF	-	Earliest Deadline First
RTOS	-	Real Time Operating System
DMTR	-	Deadline Meeting Rate/ Success Rate
DES	-	Discrete Event Simulator
ART	-	Average Response Time
NP	-	Non Deterministic Polynomial Time
RR	-	Round Robin
FIFO	-	First In First Out
RM	-	Rate Monotonic
DM	-	Deadline Monotonic
LLF	-	Least Laxity First
CPU	-	Central Processing Unit
MUF	-	Maximum Urgency First
M-EDF	-	Modified EDF
MMUF	-	Modified MUF
gEDF	-	Group EDF
SJF	-	Shortest Job First
MMF	-	Maximum Miss First

A-EDF	-	Accuracy Aware EDF
IDN	-	Input Data Noise
AD	-	Data Aged
gPEDF	-	Group Priority EDF
NP-Hard	-	Non Deterministic Polynomial Time Hard
GUI	-	Graphical User Interface
RTSIM	-	Real Time Simulator
Realtss	-	Real time scheduling simulator
gutEDF	-	Group, Utilization, Deadline Tolerance EDF

LIST OF SYMBOLS

τ_i	-	Task i
$\tau_{i,j}$	-	Job i of Task j
j	-	A job of a Task (note: an instance of a task is a job)
r_i	-	Release Time of Task i
e_i	-	Execution Time of Task i
D_i	-	Relative Deadline of Task i
d_i	-	Absolute Deadline of Task i
$d_i - t$	-	Dynamic Deadline of Task i
P_i	-	Period of Task i
γ	-	Deadline Meeting Rate / Success Rate
R	-	Average Response Time
U_t	-	System Load
G_r	-	Group Range
t	-	Time
T_r	-	Deadline Tolerance
Ω	-	Success Ratio Improvement / Deadline Meeting Ratio Improvement
σ	-	Average Response Time Improvement
φ	-	Average Response Time Ratio
δ	-	Deadline Tolerance Ratio
α	-	Describe the machine environment in convention of scheduling theory
β	-	Describes the details of the processing characteristic and its constraints in convention of scheduling theory

γ	-	Describes the objective of the scheduling problem in convention of scheduling theory
Pm		In convention of scheduling theory, it means Identical machine in parallel
Qm	-	In convention of scheduling theory, it means Machine in Parallel with different speeds
Rm	-	In convention of scheduling theory, it means unrelated machines in parallel

Satu Algoritma Penjadual Kerja Dinamik Atas Talian Tidak Boleh Henti bagi Sistem Masa Nyata Lembut - Kadar Tepati Masa Tamat Tinggi

ABSTRAK

Algoritma Earliest Deadline First (EDF) adalah sebuah penjadual kerja dinamik yang cemerlang untuk beban sistem normal. Namun, prestasinya dari segi kadar tepati masa tamat semasa beban kerja melebihi had tidak dapat ditentukan. Tesis ini membentangkan satu algoritma baru untuk penjadualan kerja Masa Nyata Lembut melalui skim Dinamik Tidak Boleh Henti, yang mampu mengekalkan kadar tepati masa tamat yang cemerlang semasa beban sistem normal, dan menghasilkan kadar tepati masa tamat yang lebih baik semasa beban kerja melebihi tahap normal. Dalam sistem masa nyata lembut, adalah penting bagi sesebuah algoritma penjadual untuk mengekalkan prestasi yang boleh diterima semasa beban kerja melebihi tahap normal, kerana sistem masa nyata lembut mampu bertolak ansur untuk tidak menepati masa tamat pada kadar tertentu bagi menghasilkan kecekapan dalam parameter prestasi kepentingan sendiri. Banyak usaha lain yang telah dilakukan untuk menangani isu tingkah laku yang tidak dapat ditentukan semasa beban kerja melebihi tahap normal. Namun, kebanyakan penyelididk menggunakan skim Boleh Henti, memerlukan pengesanan beban kerja melebihi tahap normal dan disesuaikan untuk aplikasi tertentu yang khusus. Algoritma yang dicadangkan ini, yang mengumpulkan kerja menggunakan parameter dinamik semata-mata dalam formula perkumpulannya adalah sesuatu yang baharu. Seterusnya, kerja-kerja di dalam sesebuah kumpulan akan dijadualkan dengan pendekatan baharu yang hampir sama dengan Kerja Pertama Terpendek, tetapi memberi sekurang-kurangnya dua faedah tambahan. Untuk menganalisis prestasi algoritma yang dibangunkan dan membandingkannya dengan algoritma lain, sebuah model simulasi bagi Sistem Masa Nyata Lembut yang Tiada Kekangan Sumber serta Tidak Boleh Henti telah dibangunkan menggunakan simulator diskret OMNeT++. Pensimulasi Penjadual Sistem Masa Nyata tersebut adalah bersaiz sederhana, tetapi mampu memenuhi tujuan simulasi. Model Pensimulasi Penjadual Sistem Masa Nyata tersebut kemudiannya disahkan berdasarkan kepada spesifikasi yang ditentukan. Bagi tujuan validasi, model simulasi tersebut diuji terhadap kes-kes yang diketahui untuk memastikan kesahihan operasi dan hasil yang dicapai didapati sama dengan teori. Analisis algoritma telah dijalankan menggunakan pendekatan simulasi berlebihan, di mana setiap penjanaan simulasi telah diulangi dengan benih yang berbeza. Prestasi algoritma telah dieksperimenkan dengan menggunakan pelbagai kombinasi parameter yang terdiri daripada Saiz Masa Tamat Relatif, Toleransi Masa Tamat dan Masa Pelaksanaan. Dapatan kajian menunjukkan bahawa algoritma yang dibangunkan yang dinamakan gutEDF sentiasa mencapai prestasi yang lebih baik dari segi Kadar Tepati Masa Tamat berbanding Tempoh Masa Tamat Terawal dan algorithm yang dikenali sebagai Kumpulan Tempoh Masa Tamat Terawal, di bawah kombinasi parameter input yang berbeza. Bukan itu sahaja, algoritma ini juga dinilai dari segi Purata Masa Tindakbalas, yang merupakan parameter prestasi bagi sesetengah Sistem Masa Nyata Lembut dan dapatan menunjukan bahawa gutEDF sentiasa menghasilkan Purata Masa Tindakbalas yang lebih cepat.

A Dynamic Online Non Preemptive Soft Real Time Scheduling Algorithm – High Deadline Meeting Rate

ABSTRACT

The evergreen Earliest Deadline First algorithm is an excellent dynamic real time job scheduler under normal System Load. However, its' performance in terms of deadline meeting rate is simply undeterministic under overload condition. This thesis presents a new algorithm in scheduling Soft Real Time Jobs by means of Dynamic Non Preemptive scheme, which is capable of maintaining excellent deadline meeting rate during normal System Load, while producing much better deadline meeting rate during overload. In a soft real time system it is critical that an algorithm is capable of maintaining acceptable performance during overload, because soft real time tolerates some level of missing deadline at the benefit of efficiency in its own parameter of interest. Many other works has been done to cater the issue of undeterministic behavior of Earliest Deadline First during overload. However, most of them uses preemptive scheme, requires overload detection and tailored to specific application. The proposed algorithm, which group jobs using purely dynamic parameters in its grouping formula is by itself novel. Next, the jobs in the group are schedule by another novel approach which is identical to shortest job first, but comes with a minimum of two extra benefits. To analyze the performance of the developed algorithm and compares it to other algorithms, a non preemptive, non resource constraint soft real time simulation model is developed on the OMNeT++ discrete event simulator. The Real Time Scheduling Simulator is rather moderate in size but is serve the simulation purpose. The Real Time Scheduling simulation model is then validated based on its specification. As for verification, the simulation model is tested against known cases to ensure correctness of operation and results achieved is found to be identical to theory. The analysis of the algorithm has been conducted by means of excessive simulation approach, where each simulation runs has been repeated with different seeds. The performance of the algorithms has been experimented with combinations of parameters which compose of Relative Deadline Size, Deadline Tolerance and Execution Time. Simulations results shows that, the developed algorithm, named gutEDF always achieved much better performance in terms deadline meeting rate compared to Earliest Deadline First and its immediate predecessor known as Group Earliest Deadline First, under different combinations of input parameters. Not only that, the algorithm is also evaluated in terms of Average Response Time, which is a Soft Real Time performance parameter for some application and results collected shows that gutEDF always achieved much better Average Response Time.

CHAPTER 1

INTRODUCTION

1.1 Overview

History of Real Time System (RTS) dated back to at least as early as 1960's. In those days RTS were developed using cyclic executives or simply known as 'the big while loop' and approached in a rather ad-hoc manner (Audsley, Burns, Davids, Tindell, & Wellings, 1995). During late 1970's and early 1980's, there was a wave of realization among researchers that this approach leads to inflexible, error prone and hard to maintain system(Audsley, et al., 1995). The need for flexible and maintainable system, while ensuring deterministic behavior had boost emergence of many scheduling approach. Tailored to the application of interest in those days, which mostly developed for safety critical system like military guided missiles and outer space exploration applications, which are of Hard Real Time (HRT) nature, most of the work had focus on preemptive priority scheduling class. Preemptive scheduling offers the benefit of zero CPU idle time. Combine with priority scheduling, which aims at ensuring highest priority task gets the CPU first, they both made a perfect match at ensuring deterministic behavior of HRT task. Among the work, the most renowned is the work by (Liu & Layland, 1973), which proposed Rate Monotonic (RM) algorithm as a fixed priority scheduler and Earliest Deadline First (EDF) as a dynamic priority scheduler.

Over the years, emergence of new application domains like high speed multimedia, telecommunications network, mobile robotics, virtual reality, internet streaming and interactive computer gaming, which are of Soft Real Time (SRT) nature

has boost new needs in the real time field. Such systems which are highly dynamic in behavior and timing requirements, tolerates some level of deterministicness at the benefit of efficiency in their own performance parameter of interest (Buttazo, Lipari, Abeni, & Caccamo, 2005).

1.2 The Problem @ Problem Statement

Due to lack of work on proper approach in handling emerging soft real time domains, hard real time technologies has also been used on these new domains area, which usually has less stringent timing requirements and more dynamic behavior. Hence, it is simply inappropriate to used HRT approach on SRT domains application because it would jeopardize efficiency at the cost deterministicness, which is not desirable in soft real time (Buttazo, et al., 2005). The author of Soft Real Time: Predictability vs. Efficiency book has listed out some desirable features of a SRT computing system and pointed out overload management as the first feature. The other features include temporal isolation, bounded priority inversion, aperiodic task handling and resource reclaiming.

As for scheduling mechanism, the evergreen hard real time EDF scheduler, which is claimed to be the most widely used scheduler for real time system (Anderson, Bud, & Devi, 2005; Balarin, Lavagno, Murthy, & Vincentelli, 1998) has been shown to face major performance problem during overload (Buttazo, Spuri, & Sensini, 1995). In this thesis, the main concern is to improve the deadline meeting rate (DMTR) of the EDF algorithm during overload.

In real time system, overload refers to the situation where the computational demand (the amount of time needed to execute all the ready jobs) exceeds the available

processing time (S. Baruah, Mok, & Rosier, 1990). For example, let's consider the following set of four jobs with execution time equals 5, 4, 3 and 6 units of time; and the deadlines of all jobs equal 14. Here, is an overload case, where the cumulative amount of execution time (18 units of time) exceeded the available amount of processing time (14 units of time).

Note, EDF is an excellent preemptive priority scheduler under normal load condition (Liu & Layland, 1973). Many works have been done to cater the overload issue of EDF. However, as will be explained later in chapter two, most of the work concern preemptive scheduling and requires overload detection. Despite the benefit of less context switching with non-preemptive scheduling, few indeed approaches overload handling with this scheme.

1.3 Scope of Works

A complete RTS is built up of many interesting field of knowledge. Figure 1.1 gives a thought of what it takes in building a complete real time system. Anyhow, existence of a Real Time Operating System (RTOS) or necessary features (very much application dependent) of an RTOS is a must in any RTS. Hence, for the purpose of this work, the scope will be narrowed down as depicted in Figure 1.2. The scheduling algorithm to be developed will be dynamic, non-preemptive and online as shown in Figure1.2.

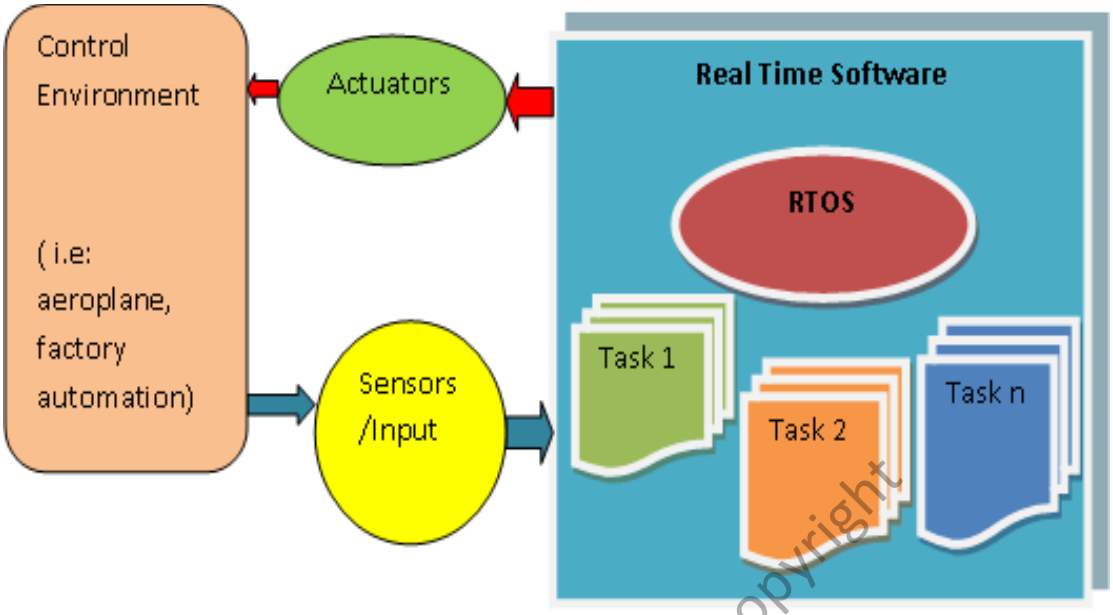

Figure 1.1: Possible Built up of a Real Time System

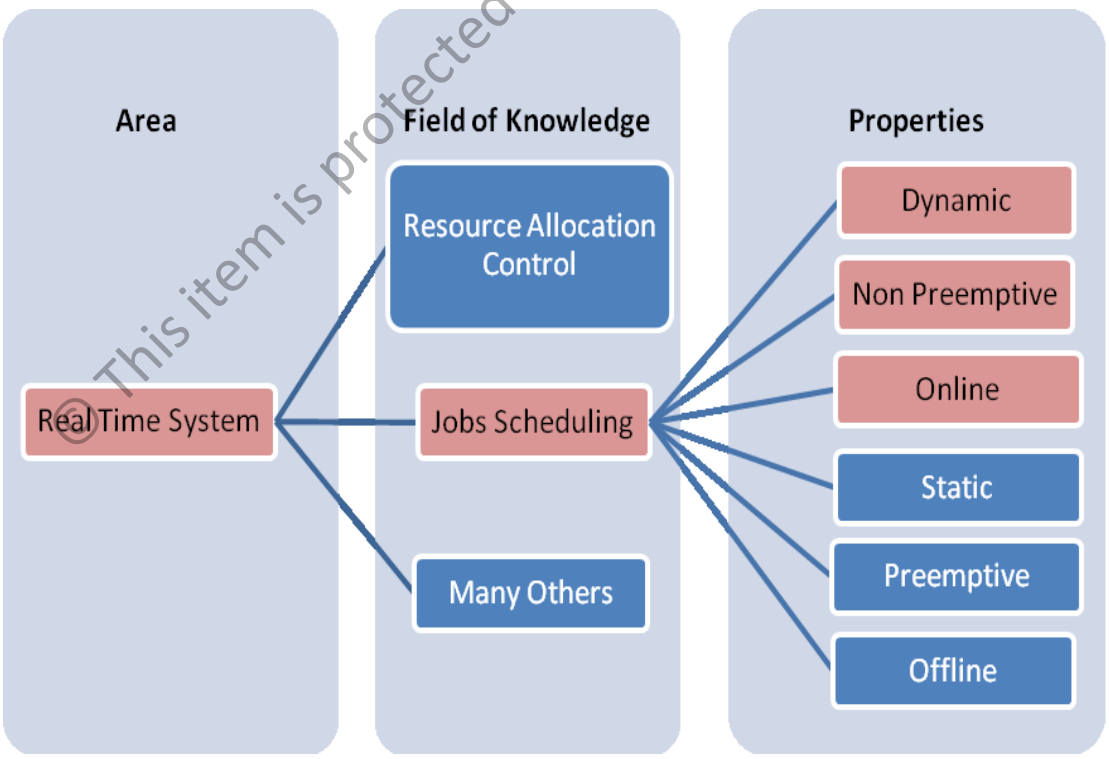

Figure 1.2: Properties of scheduling algorithm to be implemented