UNIVERSITI PUTRA MALAYSIA

NEW SYNCHRONIZATION PROTOCOL FOR DISTRIBUTED SYSTEM WITH TCP EXTENSION

PEYMAN BAYAT

FK 2013 125

NEW SYNCHRONIZATION PROTOCOL FOR DISTRIBUTED SYSTEM WITH TCP EXTENSION

By

PEYMAN BAYAT

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Doctor of Philosophy

August 2013

To my Parents and my Wife

For their Love

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

NEW SYNCHRONIZATION PROTOCOL FOR DISTRIBUTED SYSTEM WITH TCP EXTENSION

By

PEYMAN BAYAT

August 2013

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Process management is a fundamental problem in distributed systems. It is fast becoming a major performance and design issue for concurrent programming on modern architectures and for the design of distributed systems. One of the major duties in process management (synchronization) is mutual exclusion control.

Previous studies related to the topic do not use enough messages in the distributed system. Hence, the presented solutions are unable to identify active processes that are currently related to critical sections and dead in the network communication. Specially, if a fault happened for a process that has a coordinator role or in a critical section, the inability to detect the faults would cause the system to crash. Faulty processes may cause some other active processes to become inactive during the queuing or within the using a critical section time. In addition, the system requires adding some messages to avoid starvation and deadlock.

On the other hand, previous researches have focused only on time stamp, which is unfair because there are other critical parameters that are not being considered. The

thesis shows that it is possible to model the processes of distributed system in the form of a three dimensional matrix, so as to optimize fault-tolerant for mutual exclusion and critical section management. In this regard, the research also presents a new approach of the race models for distributed mutual exclusion. The new components such as participation of time stamp, time action, and other parameters such as special priority are introduced. The matrix is defined as such based on weight, which is able to solve problems of critical sections in order to obtain better state of fault-tolerance. After embedding the presented solution, a new protocol is created and applied. Thus, the new protocol is available to the communicating packets across all computer networks. The new messages and parameters could add to the available option part in the TCP packet header format, which has some free places.

Another aspect of distributed systems, which considered in the thesis, is process allocation to resources (such as critical sections). Optimization of process allocation causes to decrease the network traffic and fairer allocation, and therefore, optimization of fault-tolerance.

The new protocol is simulated with using the OPNET and the MATLAB software. According to previous researches that evaluated performance to measure fault-tolerance in this thesis, the network performances are evaluated and compared. The achieved results should continue to reach a steady state. These results show that the proposed algorithm, on average, has 7.97% higher fault-tolerance. In the worst condition, it optimized 3.99% higher than the most fault-tolerant previous works.

The resulting algorithm does not involve variability in the hardware type nor is it based on specific distributed application software or databases. Finally, in sensitive industries, this protocol is capable to offer services on a fault tolerant infrastructure.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PROTOKOL PENYEGERAKAN BARU UNTUK SISTEM TERAGIH DENGAN TCP TAMBAHAN

Oleh

PEYMAN BAYAT

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Proses pengurusan adalah masalah asas dalam sistem teragih. Ia pantas menjadi persembahan utama dan isu reka bentuk untuk pengaturcaraan serentak pada seni bina moden dan reka bentuk sistem teragih. Salah satu tugas utama dalam pengurusan proses (penyegerakan) adalah kawalan pengecualian bersama.

Kajian sebelum ini yang berkaitan dengan topik yang tidak menggunakan mesej yang cukup dalam sistem teragih. Oleh itu, penyelesaian yang dikemukakan tidak dapat mengenal pasti proses aktif yang kini yang berkaitan dengan bahagian-bahagian kritikal dan mati dalam komunikasi rangkaian. Khas, jika kerosakan yang berlaku untuk proses yang mempunyai peranan penyelaras atau di bahagian yang kritikal, ketidakupayaan untuk mengesan kesilapan akan menyebabkan sistem untuk kemalangan. Proses yang rosak boleh menyebabkan beberapa proses aktif yang lain untuk menjadi aktif semasa beratur itu atau dalam menggunakan seksyen kritikal masa. Di samping itu, sistem ini memerlukan menambah beberapa mesej untuk mengelakkan kebuluran dan kebuntuan.

Sebaliknya, kajian sebelum ini telah memberi tumpuan hanya pada setem masa, yang tidak adil kerana terdapat parameter kritikal lain yang tidak dipertimbangkan. Tesis ini menunjukkan bahawa ia adalah mungkin untuk model proses sistem teragih dalam bentuk matriks tiga dimensi, untuk mengoptimumkan kesalahan-toleran untuk pengecualian bersama dan kritikal pengurusan bahagian. Dalam hal ini, kajian ini juga memberi pendekatan baru model perlumbaan untuk pengecualian bersama diedarkan. Komponen baru seperti penyertaan setem masa, tindakan masa, dan parameter lain seperti keutamaan khas akan diperkenalkan. Matriks ditakrifkan sebagai apa-apa berdasarkan berat badan, yang mampu menyelesaikan masalah seksyen kritikal dalam usaha untuk mendapatkan keadaan yang lebih baik daripada kesalahan-toleransi. Selepas menerapkan penyelesaian yang dikemukakan, protokol baru dibuat dan digunakan. Oleh itu, protokol baru ini boleh didapati untuk paket berkomunikasi di semua rangkaian komputer. Mesej baru dan parameter boleh menambah pilihan bahagian yang terdapat di paket TCP header format, yang mempunyai beberapa tempat percuma.

Satu lagi aspek sistem teragih, yang dianggap dalam tesis, adalah proses untuk memperuntukkan sumber-sumber (seperti bahagian kritikal). Mengoptimumkan peruntukan menyebabkan proses untuk mengurangkan trafik rangkaian dan pengagihan lebih adil, dan oleh itu, pengoptimuman kesalahan-toleransi.

Protokol baru adalah simulasi dengan menggunakan Opnet dan perisian MATLAB. Menurut kajian sebelumnya yang dinilai prestasi untuk mengukur kesalahan-toleransi dalam tesis ini, persembahan rangkaian dinilai dan dibandingkan.

Keputusan yang dicapai perlu diteruskan untuk mencapai keadaan yang stabil. Keputusan ini menunjukkan bahawa algoritma yang dicadangkan itu, secara purata, mempunyai 7.97% lebih tinggi kesalahan-toleransi. Dalam keadaan yang paling teruk, ia dioptimumkan 3.99% lebih tinggi daripada kebanyakan karya kesalahan-bertoleransi sebelumnya.

Algoritma yang terhasil tidak melibatkan kepelbagaian dalam jenis perkakasan tidak juga berdasarkan perisian aplikasi khusus diedarkan atau pangkalan data. Akhirnya, dalam industri-industri sensitif, protokol ini mampu untuk menawarkan perkhidmatan di atas infrastruktur kesalahan toleran.

ACKNOWLEDGEMENT

The author wishes to express his gratitude to his supervisor, Assoc. Prof. Dr. Abd Rahman Ramli, who was abundantly helpful and offered invaluable guidance and support. Deepest gratitude is also due to the committee members, Assoc. Prof. Dr. Mohammad Iqbal Saripan and Dr. Syamsiah Mashohor whose advice, knowledge, and experience provided a path of success for this research.

I certify that a Thesis Examination Committee has met on 23th August, 2013 to conduct the final examination of Peyman Bayat on his thesis entitled "new synchronization protocol for distributed system with tcp extension" in accordance with the Universities and University College Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The committee recommends that the student be awarded the Doctor of Philosophy.

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DECLARATION

I hereby confirm that:

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LIST OF ABBREVIATIONS

IPC	Inter Process Communication
TCP	Transmission Control Protocol
DCS	Distributed Control Systems
PHP	Pigeon Hole Principle
ISO	International Standard Organization
MIMD	Multi Instruction Multi Data
OS	Operating System
OSI	Open Systems Interconnection
TSL	Test Set Lock
DMX/DME	Distributed Mutual Exclusion
LAN	Local Area Network
PDA	Personal Digital Assistant
MAC	Medium Access Control
STFQ	Start Time Fair Queuing
DCF	Distributed Coordination Function
NTP	Network Time Protocol
PTP	Precision Time Protocol
DTM	Dynamic synchronous Transfer Mode
GPS	Global Positioning System
WAN	Wide Area Network
RPC	Remote Procedure Call
CA	Cristian Algorithm
BMC	Best Master Clock
QoS	Quality of Service
CS	Critical Section
Ack	Acknowledgement
DBMS	Data Base Management System
AYA	Are You Alive?
Gb	Gigabit
LB	Laxity Based
COTRC	Channel Occupancy Time based Rate Control
BSS	Basic Service Set

BDP	Bandwidth Delay Product
NS	Network Simulator
IF	Initialization Function
IA	I'm Alive
IP	Internet Protocol

CHAPTER 1

INTRODUCTION

1.1 Introduction

Yearly, large numbers of people die due to machinery accidents such as aircraft and air flight control, train control, sensitive industrial in factories or electricity generations faulty (Giua and Seatzu, 2008). All crashes cost persons and their money and time. Today, most of these systems are computerized and network-based, therefore, sensitive networks (like mentioned systems) are needed to ensure survival and fairness resulting from fault-tolerant systems (Eger and Killat, 2007). Crash-free systems are possible through the design of distributed systems in sensitive networks (Lau, 2005). Fault-tolerance in general is the ability of a system to continue operating as expected, despite internal or external failures.

To achieve fault-tolerance, distributed systems should address different types of uncertainties: processor non-determinism, uncertain message delivery times, unknown message ordering in a queue, and processor/communication failures (Lodha and Kshemkalyani, 2000). Processor non-determinism is caused by process scheduling algorithms (Alonso et al., 2007). Processor and communication failures occur due to hardware and software failures.

Mutual exclusion algorithms for distributed systems are divided in three groups consist of: centralized algorithms, distributed algorithms and token ring algorithms

(Li et al., 2010). One of the most practical groups is centralized algorithms (Vincenzo et al., 1994; Agrawal and El-Abbadi, 1991), but they have disadvantages of having lower fault-tolerance and being a single point of failure in distributed systems, hence leading to the decrease in fault-tolerance of the entire system (Attiya et al., 2010; Simon et al., 2001).

In a centralized algorithm, in which a centralized machine or process performs synchronization and all other processes, should communicate with this process or machine. Each process has to get permission from this centralized coordinator to enter a critical section (Agrawal and El-Abbadi, 1991).

Centralized algorithms onto a special part of a distributed system to decide on mutual exclusion and on whose turn it is to enter the Critical Section (CS). These algorithms are divided into two types. First, those algorithms that have a central referee to decide and second those do not have central referee, in which rather they decide according to participating most of the workstations (Tanenbaum, 2008).

As a base and important protocol in TCP/IP protocol status, TCP has been extensively verified to data transmission on these networks (Biaz and Vaidya, 2005). TCP utilizes the technology of positive acknowledgement with retransmission to solve the instability under level IP protocol and offers reliable data transmission service for application protocols (Fu et al., 2004). For the networks that are based on TCP, there are two communication peers, which are client(s) and server(s) (Zabir et al., 2004). A TCP connection is normally initiated by client’s request and by server’s response messages. After establishing the TCP connection, the server will offer data service to clients through this connection (Casetti et al., 2002).

1.2 Problem statement

The following are problems that exist in centralized algorithms' fault-tolerance, which will be solved in this thesis:

The first problem statement is process crash, based on process synchronization's algorithms (IPC), including below different situations:

If the coordinator crashes, in this case, there is no process to manage or to control critical section, hence the past queue will be lost (De Sa et al., 2012; Attiya et al., 2010).

If a process in a critical section queue crashes, so, when the process reached to the critical section and entered the section, starvation will happen to other processes. Next, after this process, they will not know if the process inside the critical section is dead or otherwise (De Sa et al., 2012; Attiya et al., 2010; Ding et al., 2008).

If a process in the critical section crashes, a starvation happens for other processes in the related queue, because they never can enter the critical section ((De Sa et al., 2012; Attiya et al., 2010; Ding et al., 2008).

The second problem statement is a system crash due to lack of some parameters for critical section entrance (De Sa et al., 2012; Attiya et al., 2010). There are some other important parameters in addition to the timestamps in distributed systems, such as, time action (execution time), emergency priority or delay (Yaashuwanth and Ramesh, 2010; Li and Zhou, 2009; Alpcan and Bas, 2005; Iordache et al., 2002; Galli, 2000). Additionally, previous works did not consider these parameters together, which is important for aspect of fairness (De Sa et al., 2012; Attiya et al., 2010; Ding et al., 2008).

The third problem statement is process allocating to resources in distributed systems (Ding et al., 2008). A fault-tolerant distributed system need to be fair in process allocation to it's resources (Lodha and Kshemkalyani, 2000). For a critical section, an optimized process allocation can be fairer and keeps distributed system alive, because of avoid to some faults in such system (Yumin et al., 2010).

1.3 Objectives

The main goal is to optimize fault-tolerance. Of course, according to the previous researches, to evaluate fault-tolerant in a system, the system performance should be evaluated (Ekwall and Schiper, 2011; Wang et al., 2008; Wang and Wu, 2007; Yang et al., 2005; Wang et al., 2005; Pleisch and Schiper, 2003).

The first objective is optimization in the process crash problem of mutual exclusion and critical section in centralized algorithms. The new protocol in centralized approach should cover coordinator crash so that if a coordinator crashes, all of the processes in the past queue should be recoverable and the ordering problem should be solves by some addition messages in Inter Process Communication (IPC). Also, if any process in the critical section or in the related queue crashes, it should not to causes crash whole the system. In these cases, identifying the dead processes in critical and sensitive areas is important to ensure there will be no starvation.

The second objective is to propose additional parameters such as priority, time action (or duration of the activation process in critical section), and delay. These parameters complement the timestamp parameter especially when they cause a process into the critical section queue or coordinator does not crash, then the system will be more fault-tolerant. While previous researches only depend on one variable (time stamp) (De Sa et al., 2012; Attiya et al., 2010; Ding et al., 2008), the new approach is depend on additional variables .With this, at least one of four conditions of deadlock may be avoided and the system becomes a deadlock-free system (Li et al., 2008; Chu et al., 1997). In many cases, this also means that processes will need to grant mutual exclusive access to the critical section (Conga and Bader, 2006). Of course, the new obtained queue should be reordered according to the important parameters by using a fast sorter algorithm.

The third objective is optimization of process allocation into resources, especially for processes in a race condition to critical sections entrance in a distributed system. The presented solution for a resource is based on Pigeon Hole Principle (PHP) algorithm and in the case of extension, the approach should be conflict free, and it is based on induction lemma.

1.4 Contribution

The primary contribution of this thesis is fault-tolerant and efficient mutual exclusion algorithms. The new protocol has the following advantages:

- Identify a dead process whether it is in the critical section or it's queue, and if the dead process has a coordinator effect. This is to avoid starvation in the network and related to the first objective (Lawley and Reveliotis, 2001).

- Increase fairness with involve other important parameters beyond the timestamp depending on characteristics of a distributed system. This contribution is related to second objective, and causes to have a deadlock free and so, more fault-tolerant distributed system.

- Allocate jobs or processes better to the existing machine(s) based on mathematical proofs, and avoid to resource conflicting related to the third objective.

1.5 Scope of research

From the practical view, attention to characteristics in distributed systems is very important. Distributed systems are known to exhibit certain differences in a network. In this dissertation, the scope of the study lies within the software network and its related layers. The choosing of a protocol and tracking its changes in the open source condition (for example Linux OS) will achieve fairness and is able to extend beyond the single dimension of time space. This implies that adding new messages to the distributed system in suitable layer(s) is possible.

The proposed algorithm is scoped to areas related to a distributed operating system with a micro kernel and so, other distributed operating systems (based on monolithic kernel) are not in scope.

Hardware problems are not including to the project and also, assumed there are N processes in the distributed system. The system is based on asynchronous message passing and process assumed work correctly which they are not various (Joung, 2000). The distributed system has FIFO channels for data (packet) communications, (Lee et al., 2008; Leung and Li, 2003).

There are several errors can happen in a distributed system but in this research will focused only on errors related to the critical section.

1.6 Thesis organization

Chapter 2 details out the literature reviews of previous works related to the centralized algorithm, distributed mutual exclusion, as well as optimization. Optimizations are performed in the proposed algorithms and approaches in order to obtain better fault-tolerance in centralized algorithms and fault-tolerant process allocation.

Chapter 3 consists of the methodology including the system model, distributed system assumptions, identification of new message(s) and improvement to the previous algorithms.

Chapter 4 further deliberates on fault-tolerance, steps and points of the new protocol, extensions in the new DMX algorithm, race conditions as well as the competitive model for processes involving the new parameters. It also presents a simulation in two simulation software, OPNET and MATLAB using various Distributed Computing Toolbox and programming. Finally, this chapter presents the process allocation with Pigeon Hole Principle (PHP) and its related aspects to the entire distributed system using the Induction Lemma.

Chapter 5 illustrates the results of simulation with figures and considers in depth the effects of the new protocol and its parameters through comparison with findings using previous solutions.

Finally, Chapter 6 discusses the analysis from a comparison of result with previous algorithms. The chapter finally concludes with some indication for future practical works based on the proposed presented algorithm and approach.

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