UNIVERSITI PUTRA MALAYSIA

ADAPTABLE DECENTRALIZED ORCHESTRATION ENGINE FOR BLOCK STRUCTURED NON-TRANSACTIONAL WORKFLOW IN SERVICE ORIENTED ARCHITECTURE

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FSKTM 2011 32

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By

FARAMARZ SAFI ESFAHANI

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

April 2011

To

Sanaz Gilani who showed me a true love

My Parents who have devoted their life to their children

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

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April 2011

Chairman: Masrah Azrifah Azmi Murad, PhD

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In the Service Oriented Architecture (SOA), business processes are executed by non-scalable centralized orchestration engines. Nonetheless proliferation of business process applications in organizations raises scalability requirements. Decentralized orchestration engines are applied to address the scalability by decentralizing a process into design-time static fragments without considering runtime requirements. The fragments are then encapsulated into runtime components such as agents.

The SOA orchestration layer suffers from the lack of adaptability with runtime environment in decentralization of business processes. Accordingly, three aspects of runtime adaptability in decentralization are studied in this thesis. The first aspect is *frequent-path* adaptability, which is equal to detecting closely-interrelated activities and encapsulating them in the same fragment. Another aspect is *proportional-fragment* adaptability, which is analogous to the proportionality of produced fragments with number of machines. The last aspect is *available-bandwidth*

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adaptability, which is process fragmentation based on current circumstances of communication media.

An ever-changing runtime environment along with the mentioned adaptability aspects raises the following research problems: 1) there is no framework to support architectures, decentralization methods, and a feedback loop from runtime environment; 2) current decentralization methods do not consider the frequent-path and proportional-fragment adaptability aspects in creating fragments; 3) there is no algorithm to map runtime circumstances to a suitable decentralization method in order to satisfy the available-bandwidth adaptability. Accordingly, the following research objectives are considered: first, to propose a framework including architectures, decentralization methods, and a feedback loop from runtime environment; second, to improve response-time and throughput of decentralized business processes applying the frequent-path and proportional-fragment adaptability aspects; third, to improve bandwidth-usage of decentralized business processes applying the available-bandwidth adaptability.

The contributions of this research are also as follows: i) An Adaptable and Decentralized Workflow Execution Framework (ADWEF) is introduced that proposes an abstraction of a runtime adaptable decentralization in the SOA orchestration layer; ii) two architectures Type-1 and Type-2 are presented for the ADWEF that are able to support the execution of dynamically created fragments; iii) three aspects of runtime adaptability in decentralization namely frequent-path, proportional-fragment and available-bandwidth are introduced; iv) two decentralization methods called Hierarchical Process Decentralization (HPD) and Hierarchical and Intelligent Process Decentralization (HIPD) are presented, which are capable of providing various fragments. The latter considers the frequent-path

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adaptability and both of them together satisfy both frequent-path and proportional-fragment adaptability aspects; v) A Fuzzy Decentralization Decision Making algorithm (FDDM) is presented based on the fuzzy logic to choose a suitable method of decentralization that satisfies the three adaptability aspects frequent-path, proportional-fragment and available-bandwidth; and, vi) an algorithm is introduced for wiring of dynamic fragments.

Evaluations of the three adaptability aspects in the ADWEF demonstrate that the frequent-path adaptability greatly improves response-time, throughput, and bandwidth-usage of decentralized business processes. The proportional-fragment adaptability proves that number of fragments must be proportional to the number of workflow engines machines. The available-bandwidth adaptability which is realized by the FDDM algorithm unifies the mentioned adaptability aspects and reduces the number of exchanged messages compared to other methods.

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

PENGAGIHAN BOLEH SUAI ENJIN ORKESTRASI UNTUK ALIR KERJA BERSTRUKTUR BLOK TANPA URUS NIAGA DI DALAM SENI BINA BERASASKAN SERVIS

Oleh

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Dalam Seni Bina Berasaskan Servis (SOA), proses niaga tertentu BPEL dilaksanakan oleh enjin orkestrasi terpusat yang ketidakboleh skala. Perkembangan aplikasi proses niaga dalam organisasi meningkatkan keperluan skalabiliti. Enjin orkestrasi teragih diterapkan untuk mengatasi skalabiliti dengan mengagihkan proses BPEL menjadi serpihan statik pada waktu reka bentuk tanpa mempertimbangkan keperluan masa jalanan yang tidak mempunyai maklumat pada masa reka bentuk tersebut. Serpihan-serpihan kemudian dikemas ke dalam komponen masa jalanan seperti agen.

Lapisan orkestrasi SOA menderita daripada kekurangan kebolehsuaian dengan persekitaran masa jalanan di dalam pengagihan proses niaga. Oleh kerana itu, tiga aspek kebolehsesuaian masa jalanan dalam pengagihan dipelajari di dalam tesis ini. Aspek pertama adalah kebolehsuaian laluan-kerap bertujuan untuk mengesan aktiviti yang relevan dan melingkupinya dalam serpihan yang sama. Aspek lain adalah

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kebolehsuaian perkadaran serpihan yang analog dengan perkadaran serpihan yang dihasilkan dengan jumlah mesin. Aspek yang terakhir adalah kebolehsuaian dengan lebar jalur yang tersedia di mana proses serpihan adalah berdasarkan keadaan semasa bagi media komunikasi.

Persekitaran masa jalanan yang selalu berubah seiring dengan aspek kebolehsuaian yang disebutkan menimbulkan beberapa masalah kajian berikut: i) tiada rangka kerja untuk menyokong seni bina, kaedah pengagihan dan gelung maklum balas daripada sekitaran masa jalanan; ii) kaedah pengagihan terkini tidak mempertimbangkan aspek-aspek perkadaran serpihan dan laluan-kerap di dalam pembentukan serpihan-serpihan; dan iii) tiada algoritma untuk memetakan keadaan masa jalanan kepada kaedah pengagihan yang sesuai untuk memuaskan kebolehsuaian lebar jalur yang tersedia. Untuk menyelesaikan masalah-masalah yang dinyatakan di atas, beberapa objektif kajian berikut dipertimbangkan: pertama, untuk mencadangkan satu rangka kerja bagi menyokong pelaksanaan penghasilan serpihan-serpihan secara dinamik; kedua, untuk menambahbaik masa sambutan dan daya pemprosesan bagi proses niaga teragih dengan mengaplikasikan aspek-aspek kebolehsuaian laluan-kerap dan perkadaran serpihan; dan akhir sekali, untuk menambahbaik penggunaan lebar jalur proses niaga teragih dengan mengaplikasikan kebolehsuaian lebar jalur yang tersedia.

Selain daripada itu, sumbangan kajian ini adalah seperti berikut: i) satu rangka kerja pelaksanaan alir kerja teragih dan boleh suai (ADWEF) diperkenalkan yang mencadangkan suatu peniskalaan bagi pengagihan boleh suai masa jalanan dalam lapisan orkestrasi SOA; ii) dua seni bina Jenis-1 dan Jenis-2 digambarkan untuk ADWEF yang menyokong pelaksanaan penghasilan serpihan-serpihan secara dinamik; iii) tiga aspek kebolehsuaian masa jalanan dalam pengagihan termasuk

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laluan-kerap, perkadaran serpihan dan lebar jalur yang tersedia diperkenalkan; iv) dua kaedah pengagihan HPD dan HIPD dibentangkan yang mampu menyediakan pelbagai serpihan. Kaedah pengagihan yang kedua mempertimbangkan kebolehsuaian laluan-kerap dan kedua-dua kaedah memuaskan aspek-aspek kebolehsuaian laluan-kerap dan perkadaran serpihan; v) satu algoritma pembuat keputusan pengagihan kabur (FDDM) dibentangkan untuk memilih kaedah yang sesuai bagi pengagihan yang dapat memuaskan aspek-aspek laluan-kerap, perkadaran serpihan dan lebar jalur yang tersedia; dan vi) satu algoritma diperkenalkan untuk pendawaian serpihan dinamik.

Penilaian terhadap tiga aspek kebolehsuaian di dalam ADWEF menunjukkan bahawa kebolehsuaian laluan-kerap meningkatkan masa sambutan, daya pemprosesan dan penggunaan lebar jalur bagi proses niaga teragih. Kebolehsuaian perkadaran serpihan membuktikan bahawa jumlah serpihan mestilah berkadar dengan jumlah enjin alir kerja. Kebolehsuaian lebar jalur tersedia yang direalisasikan oleh algoritma FDDM menyatukan aspek kebolehsuaian tersebut dan mengurangkan jumlah pertukaran mesej jika dibandingkan dengan kaedah yang lain.

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ACKNOWLEDGEMENTS

First and foremost, my sincere gratitude and thanks to God for giving me the strength, patience, courage and determination in completing this work.

I would like to express my sincere thankfulness to my supervisor Dr. Masrah Azrifah Azmi Murad for giving me an opportunity to commence this project. Through the course of my study, I have had the great fortune to get to know and interact with her. Her comments and supports for further development as well as her assistance during writing this thesis are invaluable to me. Her teachings also provided me an opportunity to do research in my favorite area.

I would like to express my sincere thanks and appreciation to the supervisory committee members Associate Professor Dr. Md. Nasir B. Sulaiman and Dr. Nur Izura Udzir for their guidance, valuable suggestions and advice throughout this work in making this a success.

I cordially appreciate my wife Ms. Sanaz Gilani for her beautiful love and my warmest gratefulness for her support, patience and encouragement that paved the way for finishing my study. I also owe my parents for their kindness, love, encouragement and affirmation, which made it possible for me to achieve this work. My deepest gratitude is to them for devoting their life to their children. Finally, I appreciate my father and mother in low for their infinite patience and support during this study.

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APPROVAL

I certify that a Thesis Examination Committee met on **28th April 2011** to conduct the final examination of **Faramarz Safi Esfahani** on his **Doctor of Philosophy** thesis entitled "**Adaptable Decentralized Orchestration Engine For Block-Structured And Non-Transactional Workflows In Service Oriented Architecture**" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at University Putra Malaysia or other institution.

FARAMARZ SAFI ESFAHANI

Date: 28 April 2011

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