A Multi-tenant Database Framework for Software and Cloud Computing Applications

A Thesis Submitted for the Degree of
Doctor of Philosophy in Computing Sciences

By

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July 2014

CERTIFICATE OF AUTHORSHIP/ ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Haitham Yaish

Date: 14/07/2014

ACKNOWLEDGMENT

I wish to express my great thanks to all who gave me tremendous support and help during my PhD study primarily to the following.

First and foremost, I would like to express my ultimate acknowledgment to God, who has given me the inspiration and strength to accomplish this thesis beside the time that I spent working in the IT industry during the years of this study. Being a full-time PhD student and at the same time, full-time employee would be impossible without the assistance and the help of God.

I would like to express the deepest gratitude to my principal supervisor Dr. Madhu Goyal, and co-supervisor Dr. George Feuerlicht for their academic guidance, insight, and encouragement throughout every milestone in this study.

I would like to acknowledge my highest appreciation to my parents, Hashim and Sanaa, my brother Abdulatif, and my sisters Mona, Maha and May for their constant support, prayers, inspiration, and best wishes during this study and through all my life.

I would like to express my great appreciations to my wife, Heba. I could never have accomplished this thesis without her love, encouragement, patience, understanding, and prayers. She shared me all the good and difficult times during my study. I also would like to express my thanks and love to my sons, Yazan and Mohammad for doing their best to understand the situation of their father who had to be busy between study and work for such a long time.

I would like to express my appreciations of the support and help that I got from the Centre for Quantum Computation and Intelligent Systems (QCIS), School of Software, Faculty of Engineering and Information Technology (FEIT) at the University of Technology, Sydney.

Finally, I should not forget to thank all the teachers and lecturers who taught me during the school years, Bachelor degree, Master degree, and PhD degree. The knowledge that I gained from all of them was essential to complete this study.

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ABSTRACT

Cloud Computing is a new computing paradigm that transforms accessing computing resources from internal data centres to external service providers. This approach is rapidly becoming a standard for offering cost effective and elastic computing services that are used over the internet. Software as a service (SaaS) is one of the Cloud Computing service models that exploits economies of scale for SaaS service providers by offering the same software and computing environment for multiple tenants. This contemporary multi-tenant service requires a multi-tenant database design that can accommodate data for multiple tenants in one single database schema. Due to multi-tenant database resource sharing in this service, the multi-tenant schema should be highly secured, optimized, configurable, and extendable during runtime execution to fulfil the applications' requirements of different tenants. However, traditional Relational Database Management Systems (RDBMS) do not support such multi-tenant database schema capabilities, and it is a significant challenge to enable RDBMS to support these capabilities. Therefore, one solution is using an intermediate software layer that mediates multi-tenant applications and RDBMS, to convert multi-tenant queries into regular database queries, and to execute them in a RDBMS. Developing such a multi-tenant software layer to manage and access tenants' data is a hard and complex problem to solve and has significant complexities that involve longer development lifecycle.

There are two main contributions of this thesis. Firstly, a proposal for a novel multi-tenant schema technique called Elastic Extension Tables (EET). Secondly, a proposal for a multi-tenant database framework prototype to implement EET schema

in a RDBMS. This approach can be used to develop a software layer that mediates software applications and a RDBMS. This software layer aims to facilitate the development of software applications, and multi-tenant SaaS and Big Data applications for both cloud service providers and their tenants.

Extensive experiments were conducted to evaluate the feasibility and effectiveness of EET multi-tenant database schema by comparing it with Universal Table Schema Mapping (UTSM), which is commercially used. Significant performance improvements obtained using EET when compared to UTSM, makes the EET schema a good candidate for implementing multi-tenant databases and multi-tenant applications. Furthermore, the prototype of the EET framework was developed, and several experiments were performed to verify the practicability and the effectiveness of using this framework that based on EET multi-tenant database schema. The results of the experiments indicate that the EET framework is suitable for the development of software applications in general, and multi-tenant SaaS and Big Data applications in particular.