UNIVERSITI PUTRA MALAYSIA

DESIGN AND IMPLEMENTATION OF INTELLIGENT INTEROPERABILITY FRAMEWORK FOR HETEROGENEOUS SUBSYSTEMS IN SMART HOME ENVIRONMENT

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By

THINAGARAN PERUMAL

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

May 2011

Dedicated to,

My Family

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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May 2011

Chairman: **Associate Professor Abdul Rahman Ramli, Ph.D.**

Institute: **Advanced Technology**

Recent advances in computing and communication technologies paved the growth for applications and heterogeneous subsystems in smart home environment. A typical smart home is highly characterized by heterogeneity subsystems that need to perform joint execution of operation in an efficient manner. Significant growths of subsystems are visible especially with new services, applications and devices in smart home environment. Nevertheless the need for interoperability elements still seems elusive. In general, these subsystems are isolated and consist of different operating system and tier of services. Current implementation of interoperability in smart home is in the form of dry-contact, lacking of intelligent mechanism that solves dependencies of heterogeneous subsystems in performing their operation respectively. There is significant need for a cross-platform interoperability solution that could make the subsystems 'talk' each other

and operate in an interoperable manner within smart home environment. This brings forth the debate of choosing Web Services technology as premier interoperability platform. Being a distributed architecture, smart home environment requires certain degree of interoperability to manage subsystems comprising of different platforms. Web Services seems to be the emerging technology that could lead the way in providing greater interoperability. In this thesis, an intelligent interoperability framework is designed and implemented for managing heterogeneous subsystems in smart home environment. By inheriting the capabilities of XML SOAP technology and Web Services, three new algorithms based on Event-Condition-Action (ECA) paradigm have been developed to facilitate efficient interoperation of the heterogeneous subsystems.

The first algorithm, named as Framework Initialization algorithm, is developed to initialize the framework and discovering the subsystems configured in order to derive the interoperation tasks. The second algorithm, named as Asynchronous Event-Driven algorithm is derived to manage heterogeneous subsystems in smart home environment. Besides, this algorithm provides home users or application developers to implement their own event operators with bespoke syntax for their application purpose by defining cross-events corresponding to the event operators. The third algorithm, named as Pro-Active Intelligence algorithm has inspired autonomous action triggering for each event interoperation, using a control action statement that is generated by SOAP packets required for joint execution of tasks among heterogeneous subsystems. A Home Application Server (HAS) was configured for proof of concept. The framework implementation has been tested to clarify its outstanding advantages over the conventional interoperability solution as well as the performance of message

transactions for events in smart home environment corresponding with response time, heterogeneous ECA interoperation, and conformance reliability. Based on the response time result without load, it is evident that the average time utilization for single operation of subsystem is 25.87ms, validates the smart home requirement. For ECA interoperation test result, it is concluded that there are two significant performance drops with one at 10% and the other one at 30% of network load. The framework conformance testing also clearly stated that the stability range of the framework is visible from No Load till 50% load percentages. As a conclusion, this research contributes to the aspect of solving interoperability requirement for smart home environment in a federated manner.

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

REKA BENTUK DAN PELAKSANAAN KERANGKA KERJA SALING BOLEH KENDALI CERDIK UNTUK SUBSISTEM DALAM PERSEKITARAN RUMAH PINTAR

Oleh

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Kemajuan terkini dalam teknologi komputer dan komunikasi merangsang kepada pertumbuhan pesat pembangunan aplikasi dan subsistem majmuk dalam persekitaran rumah pintar. Pada amnya, rumah pintar terdiri dari subsistem majmuk yang perlu melaksanakan operasi bersama secara cekap. Pertumbuhan pesat subsistem sebegini tampak dengan jelas terutamanya perkhidmatan, aplikasi dan peranti dalam persekitaran rumah pintar, namun kebolehan mereka untuk saling boleh kendali masih sukar dicapai. Umumnya, subsistem dibangunkan secara berasingan dan terdiri daripada sistem pengendalian dan aras perkhidmatan yang berbeza. Pelaksanaan fungsi saling boleh kendali di persekitaran rumah pintar masa kini adalah dalam bentuk sentuhan kering dan tiada mekanisme pintar yang boleh menyelesaikan integrasi subsistem majmuk dalam operasi masing-masing. Keperluan kepada suatu penyelesaian pelantar saling boleh kendali yang boleh membuat subsistem 'berhubung' antara satu sama lain dan beroperasi

dalam keadaan saling boleh kendali di persekitaran rumah pintar amat signifikan. Ini menjurus kepada pemilihan teknologi perkhidmatan Web sebagai platform perdana dalam menyelesaikan saling boleh kendali antara subsistem dalam persekitaran rumah pintar. Sebagai satu seni bina teragih, persekitaran rumah pintar memerlukan peringkat tertentu yang saling boleh kendali untuk menguruskan subsistem berkaitan dengan pelantar yang berbeza. Perkhidmatan Web menonjol sebagai alaf teknologi baru yang boleh memberi penyelesaian dalam menyediakan saling boleh kendali dengan lebih meluas. Dalam tesis ini, satu kerangka kerja saling boleh kendali cerdik telah direkabentuk dan dilaksanakan untuk menguruskan subsistem majmuk di persekitaran rumah pintar. Dengan mewarisi ciri-ciri teknologi XML SOAP dan perkhidmatan Web, tiga algoritma berasaskan paradigma Peristiwa-Keadaan-Tindakan (ECA) telah dibangunkan untuk kemudahan pengendalian subsistem majmuk.

Algoritma yang pertama, dinamakan sebagai algoritma permulaan kerangka kerja adalah untuk memudahkan kerangka kerja serta menemukan subsistem untuk memperolehi operasi saling boleh kendali. Algortima kedua, yang dinamakan sebagai Pacuan Peristiwa Tak Segerak dibangunkan untuk pengurusan subsistem majmuk di persekitaran rumah pintar. Selain itu, algortima ini membolehkan tuan rumah atau jurutera aplikasi untuk melaksanakan operator kawalan dan sintaks yang diubahsuai untuk kegunaan aplikasi masing-masing. Algoritma yang ketiga, dinamakan sebagai Kecerdasan Proaktif telah menginsipirasikan tindakan autonomi untuk setiap peristiwa saling boleh kendali, dengan menggunakan paket SOAP yang bertujuan untuk operasi bersama subsistem majmuk. Sebuah pelayan applikasi rumah (HAS) telah dikonfigurasi

untuk membuktikan konsep yang dibincangkan. Pelaksanaan kerangka kerja ini telah diuji untuk menjelaskan kelebihannya berbanding dengan sistem saling boleh kendali konvensional, serta prestasi transkasi mesej untuk peristiwa persekitaran rumah pintar yang berkaitan dengan, masa sambutan operasi saling boleh kendali subsistem majmuk serta kepatuhan kebolehpercayaan kerangka kerja. Berdasarkan keputusan masa sambutan, purata penggunaan masa untuk transaksi sehala adalah 25.87ms, mengesahkan keperluan persekitaran rumah pintar. Bagi keputusan saling boleh kendali ECA, boleh disimpulkan bahawa terdapat dua kejatuhan prestasi, dalam lingkungan 10% dan 30% trafik beban jaringan. Keputusan kepatuhan kebolehpercayaan juga jelas menunjukkan kestabilan kerangka kerja tampak dari situasi tanpa beban sehingga 50% peratus beban. Sebagai kesimpulan, penyelidikan ini menyumbang kepada aspek penyelesaian keperluan saling boleh kendali untuk persekitaran rumah pintar secara berstruktur.

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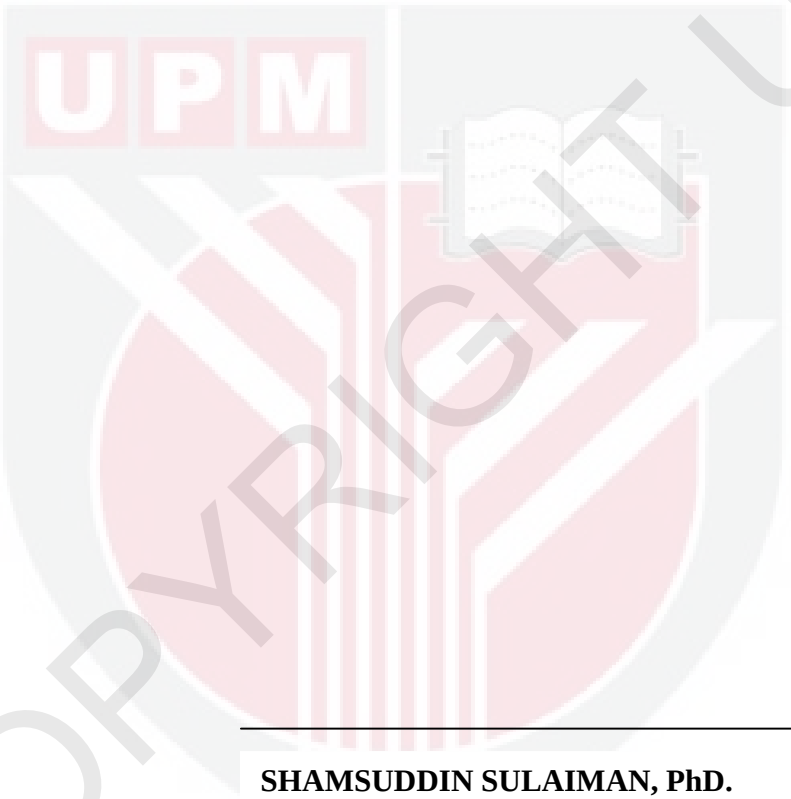
I certified that an Examination Committee met on _____to conduct the final examination of Thinagaran Perumal on his Doctor of Philosophy thesis entitled “Design and Implementation of Intelligent Interoperability Framework for Heterogeneous Subsystems in Smart Home Environment” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:



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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirements for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

_____

THINAGARAN PERUMAL

Date:

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