Wellness Protocol: An Integrated Framework for Ambient Assisted Living

A thesis presented in partial fulfilment of the requirements for the degree of

Doctor of Philosophy

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Abstract

Smart and intelligent homes of today and tomorrow are committed to enhancing the security, safety and comfort of the occupants. In the present scenario, most of the smart homes Protocols are limited to controlled activities environments for Ambient Assisted Living (AAL) of the elderly and the convalescents. The aim of this research is to develop a Wellness Protocol that forecasts the wellness of any individual living in the AAL environment. This is based on wireless sensors and networks that are applied to data mining and machine learning to monitor the activities of daily living. The heterogeneous sensor and actuator nodes, based on WSNs are deployed into the home environment. These nodes generate the real-time data related to the object usage and other movements inside the home, to forecast the wellness of an individual. The new Protocol has been designed and developed to be suitable especially for the smart home system. The Protocol is reliable, efficient, flexible, and economical for wireless sensor networks based AAL.

According to consumer demand, the Wellness Protocol based smart home systems can be easily installed with existing households without any significant changes and with a user-friendly interface. Additionally, the Wellness Protocol has extended to designing a smart building environment for an apartment. In the endeavour of smart home design and implementation, the Wellness Protocol deals with large data handling and interference mitigation. A Wellness based smart home monitoring system is the application of automation with integral systems of accommodation facilities to boost and progress the everyday life of an occupant.

Dedication

I primarily dedicate this research work to the occupants living alone.

To my parents

Late.Shri.Bhaskar Rao Ghayvat

Shrimati. Sadhana Ghayvat

To my brother

Basant Ghayvat

Acknowledgements

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My special gratitude to my beloved parents, Late Shri Bhaskar Rao Ghayvat and Mrs.Sadhna Ghayvat and sibling Basant Ghayvat for their constant encouragement, support and prayers for my success. I dedicate this thesis to my father who passed away recently, in the course of this research, who greatly longed to see me with a doctorate.

Table of Contents

List of Figures

List of Tables

List of Publications, Contributions and Achievements during the PhD study (2013-2016)

Journal papers: 6 (Published only)

1) **Ghayvat, H**., Mukhopadhyay, S., and Gui, X.: 'Issues and mitigation of interference, attenuation and direction of arrival in IEEE 802.15. 4/ZigBee to wireless sensors and networks based smart building', **Elsevier**: Measurement, 2016, 86, pp. 209-226.

2) **Ghayvat, H**., Mukhopadhyay, S., Liu, J., and Gui, X.: 'Wellness Sensors Networks: A Proposal and Implementation for Smart Home to Assisted Living' **IEEE Sensors** Journal, 2015, Volume: 15, Issue: 12, pp.7341 – 7348.

3) **H. Ghayvat**, S. Mukhopadhyay, X. Gui, and N. Suryadevara, "WSN-and IOT-Based Smart Homes and Their Extension to Smart Buildings," **MDPI:** Sensors, vol. 15, pp. 10350-10379, 2015.

4) **Ghayvat, H**., Liu, J., Alahi, M., Mukhopadhyay, S., and Gui, X.: 'Internet of Things for smart homes and buildings: Opportunities and Challenges', **Australian Journal** of Telecommunications and the Digital Economy, 2015, 3, (4), pp. 33-47

5) **H. Ghayvat,** A. Nag, N. Suryadevara, S. Mukhopadhyay, X. Gui, and J. Liu, "SHARING RESEARCH EXPERIENCES OF WSN BASED SMART HOME," International Journal on Smart Sensing & Intelligent Systems, vol. 7, 2014, pp. 1997-2013.

6) M. Khan, S. Din, S. Jabbar, M. Gohar, **H. Ghayvat**, and S. Mukhopadhyay, "Context-aware low power intelligent SmartHome based on the Internet of things," **Elsevier:** Computers & Electrical Engineering, ISSN No. 0045-79062016, pp.1-15.(Early access)

Book Chapter

7) U. Bakar, **H. Ghayvat**, F. Hasan, and S. Mukhopadhyay, "Activity and anomaly detection in smart home: A survey," in Next Generation Sensors and Systems, ed: Springer, 2016, pp. 191-220.

8) **H. Ghayvat**, S. C. Mukhopadhyay, and X. Gui, "Sensing Technologies for Intelligent Environments: A Review," in Intelligent Environmental Sensing, ed: Springer, 2015, pp. 1-31.

Refereed conference papers: 7 (published only)

9) **H. Ghayvat**, S. Mukhopadhyay, X. Gui, and J. Liu "Enhancement of WSN Based Smart Home to a Smart Building for Assisted Living: Design Issues," in Communication Systems and Network Technologies (CSNT), 2015 Fifth International Conference on, Gwalior India, 4-6 April 2015, pp. 219-224.

10) J. Liu **H. Ghayvat**, and S. Mukhopadhyay, "Introducing Intel Galileo as a development platform of smart sensor: Evolution, opportunities and challenges," in Industrial Electronics and Applications (ICIEA), 2015 IEEE 10th Conference on, Auckland NZ, 15-17 June 2015, pp. 1797 - 1802.

11) **H. Ghayvat**, S. Mukhopadhyay, and X. Gui, " Addressing Interference issues in a WSN based smart home for ambient assisted living," in Industrial Electronics and Applications (ICIEA), 2015 IEEE 10th Conference on, Auckland NZ, 15-17 June 2015, pp. 1661 - 1666.

12) Md. E. E Alahi, S. C. Mukhopadhyay, **H. Ghayvat**, R. Wang, L. Jie, " Comparative Studies of Embedded Platform For IoT Based Implementation," in International Conference on Sensing Technology (ICST), 2015 IEEE 9th Conference on, Auckland NZ, 8-10 Dec 2015. pp. 748-752.

13) **H.Ghayvat**, Liu.Jie, A.Babu, M.E.Alahi, U.A.B.U.A.Bakar, S.C.Mukhopadhyay and X.Gui, " Simulation and Evaluation of ZigBee-based Smart Home using Qualnet Simulator," in International Conference on Sensing Technology (ICST), 2015 IEEE 9th Conference on, Auckland NZ, 8-10 Dec 2015. pp. 579-585.

14) Sadia Din, **Hemant Ghayvat**, Anand Paul, Awais Ahmad, M. Mazhar Rathore, Imran Shafi, " An Architecture to Analyze Big data in the Internet of Things," in International Conference on Sensing Technology (ICST), 2015 IEEE 9th Conference on, Auckland NZ, 8-10 Dec 2015. pp. 677-682.

15) David Morton, **H. Ghayvat,** S. C. Mukhopadhyay, Steve Green. “Sensors and Instrumentation to Measure sap Flow in Small Stem Plants”. Proceeding of the IEEE: International Instrumentation and Measurement Technology Conference (I^2MTC) 2016, Taipei, Taiwan, 23-26 May 2016. pp. 1088- 1093.

IEEE Sensors Council

November 24, 2015

TO:
Mr. Hemant Ghayvat, Massey University
Mr. Jie Liu, Massey University
Prof. Subhas Chandra Mukhopadhyay, Massey University
Mr. Xiang Gui, Massey University

Dear Mr. Ghayvat, Mr. Liu, Prof. Mukhopadhyay, Mr. Gui,

On behalf of the IEEE Sensors Council I am pleased to congratulate you as a coauthor of the paper *Wellness Sensor Networks: A Proposal and Implementation for Smart Home for Assisted Living,* IEEE Sensors Journal, Vol. 15, No. 12, December 2015, for your paper being one of the 50 most downloaded Sensors Journal papers in the month of September 2015. It is exciting to note that included in this count are all Sensors Journal papers published since the Journal's foundation, about 4500 papers in total, and that last year, 439,609 Sensors Journal papers were downloaded from IEEE Xplore. You can view the latest Top 50 papers at:

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Thank you for your contribution to the IEEE Sensors Journal!

Best regards,

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President, IEEE Sensors Council

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Glossary

AAL	Ambient Assisted Living
ADL	(Basic) Activities of Daily Living
WSN	Wireless Sensor Network
IoT	Internet of Things
HMS	Home Monitoring System
ISM	Industrial Scientific and Medical
DOA	Direction of Arrival
RSSI	Received Signal Strength Indicator
SNR	Signal to Noise Ratio
WDKG	Wellness Dynamic Key Generation