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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

In

Electronics, Information and Communication Systems

At

School of Engineering and Advanced Technology,

Massey University,

Manawatu Campus,

New Zealand

HEMANT GHAYVAT

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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

Words can never describe my sense of gratitude to my supervisor Professor Subhas Mukhopadhyay. Prof. Subhas has not only been my Ph.D. supervisor but also a mentor who supported me all the way from my home country India to New Zealand for higher studies. In the course of research, there were some difficult days, in those days, he inspired me to be focused and sincere to the research. This work would not have been possible without his kind support, expert guidance, the trenchant critiques, and most of all his remarkable patience. My sincere thanks to my co-supervisor Dr. Xiang Gui, for his guidance and support throughout the academic program.

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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

Abstract……..II

Dedication…….III

Acknowledgements……...……...IV

Table of Contents…….……...……..V

List of Figures……...……...……IX

List of Tables……...……..…XV

List of Publications, Contributions and Achievements during the PhD study(2014-2016)…….…...…..…XVII

Glossary……..……..…....XXI

Chapter 1. Introduction……..…….…….…….1

1.1 Introduction…….…….…….……..…..1

1.2 Motivation of Designing Homes for Tomorrow……..……...…..1

1.2.1 Independent Living ……...……...…1

1.2.2 Enhance the Comfort and Lifetime……...……....3

1.2.3 Health Services……..……...….4

1.2.4 Efficient Use of Electricity……..…….…….....4

1.2.5 Safety and Security……..……...…5

1.3 Problem Formulation…….……..……...……..5

1.4 Problem Solution…….……..……7

1.5 Reasoning of Wellness Protocol and Approach……...……...……..8

1.6 Scope of Thesis……..…….……..……9

1.7 Novel Contribution…….…….……..……...……9

1.8 Thesis Overview……..…….……..….10

Chapter 2. Literature Survey…….……13

2.1 Introduction…….…….……...……..13

2.2 Smart Home for Wellness…….……...……..….15

2.3 Entities of Smart Home Systems…….……...……...….16

2.3.1 Sensors and Actuators…….....17

2.3.2 Controller and Processing Unit……....19

2.3.3 Defined Wireless Networking Protocols……..……..…….19

2.3.4 Local Home Gateway and Server……...….23

2.4 Smart Home Around the World…….……....…23

2.5 Activity Recognition Algorithms and Approaches 36

2.6 Issues of Deployment …….....…..….41

2.7 Large Data Handling…….…….……44

2.8 Introducing Internet of Things and Cloud Computing…….…….……45

2.9 Conclusion…….……..…….....…….46

Chapter 3. Wellness Protocol Development and Implementation……..…….....47

3.1 Introduction…….……....……..……...47

3.2 A Brief About Wellness Protocol System…….…..……..……47

3.3 Wellness Approach to Protocol Development……..……..…….....……..48

3.3.1 Intelligent Sampling and Transmission Control Algorithm…….…...52

3.3.2 Interference Mitigation……..…….....……..58

3.3.3 Wellness Dynamic Key Generation for Security…….……..…..60

3.4 Wellness Sensing Units for Home Monitoring and Control…….....……64

3.5 Wireless Topology, Network Formation for Smart Home System….…….…….70

3.6 Deployment of Heteregeneous Wireless Sensing Units in a Home……...…71

3.7 Healthcare……...…….……..….74

3.7.1 Software Description…….……...…….….75

3.7.2 Angle Calculation Algorithm……...…….……76

3.8 Desired Number of Wireless Sensing Units for AAL…...……...….....76

3.9 Software Data Extraction, Storage and User Interface…….…….....…..….76

3.10 Evaluation of Wellness Protocol Data Reliability…….…….....…..…..82

3.11 Software Required for Wellness system…….……..……..…86

3.12 Comparison of Wellness over ZigBee…….…….……...…..…87

3.13 Conclusion…….…….…..……..…..88

Chapter 4. Issues and Mitigation of Wireless Sensor and Networks (WSNs) Based Smart Building System…….....89

4.1 Introduction…….……..……89

4.2 Description of Smart Building System…….…….…..….…….……90

4.3 Methodology to Measure Interference and Attenuation Loss…..……..….……...92

4.3.1 Latency…….……..…..…93

4.3.2 Data-Packet Delivery Parameters……...….94

4.3.3 Link Quality Metrics …….…....96

4.4 Experimental Observations, Analysis, and Mitigation…….…....……99

4.4.1 Fundamental Tests…….…….....…….……99

4.4.2 Analytical and parametric tests……..…..102

4.4.3 Signal Attenuation inside Smart Building…….....……104

4.4.4 Direction of arrival (DOA)…….…….109

4.4.5 Mitigation of Interference and Suggestions …….....….117

4.5 Conclusion……...……..…….….125

Chapter 5. Activity Detection and Wellness Pattern Generation……..….127

5.1 Introduction……..……..…..127

5.2 Classification of Events and Activities……..……..……128

5.3 Activity Annotation…….…….….131

5.4 Wellness Belief Model…….…….134

5.4.1 Methodology……..135

5.4.2 Modelling the wellness belief ……....….135

5.5 Wellness Determination of An Occupant……..…..138

5.5.1 Old Wellness Function……..…...139

5.5.2 Modified Wellness Function ……..….139

5.5.3 Measurement of Maximum Active and Inactive Object Usage Duration …….……..….141

5.6 Experimental Analysis, Observation, and Results…….……..143

5.7 Web-Based results…….…..150

5.8 Conclusion…….…..152

Chapter 6. Wellness Pattern Generation and Forecasting...……..….153

6.1 Introduction……..……..…..153

6.2 Modelling Trends and Forecasting…...……..……..……153

6.3 Behavioural Pattern Generation and Forecasting…..…….….155

6.4 Comparative Results...…….…….160

6.5 Conclusion……..…….…….164

Chapter 7. Conclusion and Future Works……..….165

References……..…….…..167

List of Figures

Figure 1-1 Single-person households..... 2
Figure 1-2 One person households by Age and Sex, 1970 to 2012 in the US..... 3
Figure 1-3 Trend of living alone in the US..... 4
Figure 2-1 General functioning block diagram of smart home system 17
Figure 2-2 (a) Iron Press heating system attached to the context aware arrangement, (b) Medicine dosage and time reminder machine “Tabsafe” 26
Figure 2-3 Mum's Wine Cellar 27
Figure 2-4 Camera based monitoring 27
Figure 2-5 Sensor deployment and activity recognition layout 29
Figure 2-6 Block diagram representation smart home for assisted living and care..... 30
Figure 2-7 Camera installed at Tiger place Missouri..... 30
Figure 2-8 (a) Force sensor deployed below the mattress and (b) Appliances are connected to usage monitoring logic 30
Figure 2-9 Sensing technology applied in home monitoring..... 31
Figure 2-10 Home Care Lab Bedroom (5th October 2012, Stirling)..... 32
Figure 2-11 Home Care Lab Kitchen (5th October 2012, Stirling)..... 32
Figure 2-12 Home Care Lab Lounge (5th October 2012, Stirling) 32
Figure 2-13(a)User is evaluating gestural input via a watch-like device (6th November 2008, Glasgow, © University of Glasgow and (b) Front of the 'MATCH Box' developed by the University of Glasgow team (27th September 2007, Glasgow) ..... .33
Figure 2-14 The Ubiquitous Communicator (UC) is used as remote control all over the home..... ……33
Figure 2-15 Toyota PAPI house at Japan 34
Figure 2-16 Green car charger and power supply in the home if needed 34
Figure 2-17 Wide open window space for natural light and a big fireplace..... 35
Figure 2-18 Fireplace in the room 35
Figure 2-19 Fire hazard control caused by the fireplace..... 36
Figure 3-1 Representation of Wellness Protocol Based Home System. 48
Figure 3-2 Functional Description of the Developed Smart home Monitoring System ... 49
Figure 3-3 Representation of IEEE 802.15.5.ZigBee Stack Fields and Auxiliary Security Header in Detail 49

Figure 3-4 Representation of IEEE 802.15.5.ZigBee Stack Fields and Data Payload in Detail 50
Figure 3-5 Event-priority based packet creation for WSNs for smart home solution 52
Figure 3-6 Snapshot of XCTU to show the periodic sampling rate selection 53
Figure 3-7 Snapshot of XCTU to show the cyclic sleep period 53
Figure 3-8 Intelligent sampling and transmission control algorithm 55
Figure 3-9 Comparative graph on data collection between Zigbee and Wellness protocol for E & E sensing unit 56
Figure 3-10 Comparative graph on data collection of Smart Home system for House 1 ..57
Figure 3-11 Comparative graph on data collection of Smart Home system for House 2 ..... …57
Figure 3-12 XCTU snapshot for channel selection 58
Figure 3-13 Other household device functioning over the same channel where zigbee device is operating 59
Figure 3-14 XCTU snapshot to show the ZigBee encryption 61
Figure 3-15 Wellness Dynamic Key Generation based Security Algorithm 62
Figure 3-16 Performance benchmark according to CPU cycles 63
Figure 3-17 Performance benchmark according to Execution time 64
Figure 3-18 Prototype of Wireless Sensing Unit design 69
Figure 3-19 Image of a real house where smart home monitoring and control system are installed 71
Figure 3-20 Layout structure of the house with sensor deployment and household objects 72
Figure 3-21 Outdoor sensing unit for outside temperature measurement 72
Figure 3-22 E & E sensing unit, which is monitoring and controlling (a) Water kettle, (b) Washing machine, (c) Microwave and (d) Television. 73
Figure 3-23 Represents the force sensing unit deployment to monitor (a)Sofa, (b) Dining Chair, (c) Bed and (d) Toilet seat. 73
Figure 3-24 CRespresents the PIR sensing unit deployment to monitor (a) Living room and (b) Entry door 74
Figure 3-25 : (a) Contact sensing unit connected to fridge door and (b) Manual push button indicator 74
Figure 3-26 The MPU-60X 0 Motion Processing Units 75
Figure 3-27 Block diagram of software system 76

Figure 3-28 Tthe steps of low-level sensor data analysis 77
Figure 3-29 Local home gateway for Intel Galileo Coordinator 78
Figure 3-30 Wellness protocol system architecture..... 78
Figure 3-31 Hierarchical representation of WellnessSF (Wellness standard format) tree diagrams for smart home system, (S-UNIT: SENSING UNIT)..... 79
Figure 3-32 Snapshot of Home Monitoring Website which presents the sub-sections of monitoring..... 82
Figure 3-33 Packet error rate of Wellness protocol Vs ZigBee with change in spacing between Tx and Rx 83
Figure 3-34 Packet delivery ratio of Wellness protocol Vs ZigBee with change in spacing between Tx and Rx 84
Figure 3-35 Packet loss rate of Wellness protocol Vs ZigBee with change in spacing between Tx and Rx. 85
Figure 3-36 Packet success rate of Wellness protocol Vs ZigBee with change in spacing between Tx and Rx 85
Figure 3-37 : Average Delay of Wellness protocol Vs ZigBee with change in spacing between Tx and Rx 86
Figure 4-1 Layout of big building heterogeneous sensing system 91
Figure 4-2 Arrangement of sensor nodes for experimental investigation..... 100
Figure 4-3 Delay as a function of hopping distance 101
Figure 4-4 PDR as a function of hopping distance..... 101
Figure 4-5 PER as a function of hopping distance 102
Figure 4-6 (a) Layout of attenuation loss test..... 105
Figure 4-6 (b) RSSI as a function of different building materials, where STx-AS is varied from .5 m to 6 m 106
Figure 4-7 (a) PDR as a function of different building materials, where STx-AS is varied from 0.5 m to 6 m, ... 107
Figure 4-7 (b) Close-up view PDR as a function of different building materials, where STx-AS is varied from 0.5 m to 6 m..... 107
Figure 4-8 (a) PSR as a function of different building materials, where STx-AS is varied from 0.5 m to 6 m, ... 108
Figure 4-8 (b) Close-up view PSR as a function of various building materials, where STx-AS is varied from .5 to 6m 108
Figure 4-9 Schematic setup for IS location for DOA 110

Figure 4.10: RSSI as a function of the angle between Rx and IS in the line of sight, STx-Rx=3m……...……..…..….111

Figure 4.11: PDR as a function of the angle between Rx and IS in the line of sight, STx-Rx=3 m……...…….….111

Figure 4.12: PSR as a function of the angle between Rx and IS in the line of sight, STx-Rx=3 m…….……..…..112

Figure 4.13: RSSI as a function of the angle between Tx and IS in the line of sight, STx-Rx=3m……..……..…..….112

Figure 4.14: PDR as a function of the angle between Tx and IS in the line of sight, STx-Rx=3 m…….…….……...……...…..113

Figure 4.15: PSR as a function of the angle between Tx and IS in the line of sight, STx-Rx=3 m…….……...…….……...……..113

Figure 4.16: RSSI as a function of angle between Rx and IS in multipath fading, STx-Rx=5m……...…….…….114

Figure 4.17: PDR as a function of angle between Rx and IS in multipath fading, STx-Rx=5 m…….…….…….…….115

Figure 4.18: PSR as a function of angle between Rx and IS in multipath fading, STx-Rx=5 m…….……..……...……115

Figure 4.19: RSSI as a function of angle between Tx and IS in multipath fading, STx-Rx=5 m……...……...……116

Figure 4.20: PDR as a function of angle between Tx and IS in multipath fading, STx-Rx=5 m……...…...….116

Figure 4.21: PSR as a function of angle between Tx and IS in multipath fading, STx-Rx=5 m……...……117

Figure 4.22: The XBee smart building system is operating at frequency 2.430 MHz…….....119

Figure 4.23: Shows the Wi-Fi functioning over the same frequency 2.430 MHz, which degraded the XBee RF link quality……...……...…….120

Figure 4.24: Shows the Bluetooth functioning over the same frequency 2.430 MHz, which degraded the XBee RF link quality……...……121
Figure 4.25: Microwave oven distributed all ZigBee channels, and the microwave signal are dissipated across the whole ZigBee spectrum…….……..….122
Figure 4.26: PSR as a function of the distance between IS and Rx, SIS-Rx = 1m to 16m……..…….123
Figure 4.27: PDR as a function of distance between Tx and Rx, SIS-Rx = 1m to 16……....…..123
Figure 4.28: Difference in average RSSI between the highest and lowest levels of each factor…….……...….124
Figure 4.29: Difference in average packet delivery parameter between the maximum and minimum levels for each factor……..……..124
Figure 4.30: Offset frequency measurement by RF spectrometer…….....…...125
Figure 5.1:Activities of daily living. …….....…..129
Figure 5.2: Modeling sub-activity for ADLs……..…..129
Figure 5.3: Sample of Sensor activation logged…….……..…132
Figure 5.4: Representation of sensor activation, object usage, and activity…….133
Figure 5.5: Smart home room temperature actual and expected for 24 hours…….….137
Figure 5.6: Probability of movement in different locations of home based on PIR sensing unit…….……..…….138
Figure 5.7: Probability of occupancy in different locations of home based on Force sensing unit……..…….138
Figure 5.8: Comparison of β1,old and β1,new wellness functions (with two cases with wellness belief and without wellness belief)…… ……...….140
Figure 5.9: Comparison of β2,old and β2,new wellness functions (with two cases with wellness belief and without wellness belief)……... ……..…..141
Figure 5.10: Object usage for one day for house-1……...……..……144
Figure 5.11: Object usage for one day for house-2…….....……145
Figure 5.12: Object usage for one day for house-3……...…….…..145
Figure 5.13: Object usage for one day for house-4…….....…..…146
Figure 5.14: β1,old at four different elderly houses……..……..147
Figure 5.15: Wellness Indices for sleeping activity for four different houses up to one week…….....…..…148
Figure 5.16: The ADLs throughout the day……..151

Figure 5.17: The ADLs of having medicine and meal throughout the day…….....…151
Figure 6.1: Functional block diagram of Wellness learning algorithm for time series analysis…….……...….154
Figure 6.2: Actual shower usage and its trend…….……..….155
Figure 6.3: Actual dining chair usage and its trend…….…….…..156
Figure 6.4: Actual dining bed usage and its trend…….……...…156
Figure 6.5: Actual dining toilet usage and its trend…….…….…...157
Figure 6.6: Shower usage duration and forecasting for upcoming week…….…….....157
Figure 6.7: Dining chair usage duration and forecasting for upcoming week….…….158
Figure 6.8: Bed usage duration and forecasting for upcoming week…….....158
Figure 6.9: Toilet usage duration and forecasting for upcoming week…….…. 159

List of Tables

Table 1-1: The statistic of householders living alone; it includes all age groups 2
Table 2-1: The criteria filter for selecting the research in literature survey 14
Table 2-2: The keyword used on google scholar and other research article search engine to find research studies.....14
Table 2-3: Ambient Sensors to Smart Environment Monitoring.....18
Table 2.4: Wireless Network based on IEEE standard 20
Table 2-5: Wireless Network Standards Not Based on IEEE Standards 22
Table 2-6: represents limitations and drawbacks of the recent and current research on the smart home protocol development…….……25
Table 2.7: General classification of anomaly detection techniques.....38
Table 1.8: Traditional Activity Classification (modeling) approaches.....38
Table 3.1: Priority of events in descending order 51
Table 3.2: The layer features and functions are presented.....65
Table 3.3: Technical description and functioning of Sensing units.....66
Table 3.4: The reasons to select Intel board on the top of RPI.....69
Table 3.5: ZigBee device modes and their functions.....70
Table 3.6. More description of user, location unit, mobile unit and annotation of tree diagram of WSL (Wellness Standard format) 80
Table 4.1: The issues and their range in the experiments……..……103
Table 4.2: Obstruction-material details of building environment.....104
Table 4.3: Optimum value recorded at STx-AS=6 m 109
Table 5.1: Selection and deployment location of sensing units.....130
Table 5.2: Activity Annotation process at different portion of the day 134
Table 5.3: Number of sensor activation and activity detection for four different houses equipped with hydrogenous sensing units 146
Table 5.4: Improved Wellness indices for different activities to four different houses……..….149
Table 6.1: Wellness function indices of object usage and forecast of the ADLs.....…...159

Table 6.2: Annotation used in confusion matrix table.....161
Table 6.3: Confusion matrix to show the accuracy of ADLs detection for different object usage by Naïve Bayes method.....162
Table 6.4: Confusion matrix to show the accuracy of ADLs detection for different object usage by HMM method……...…….162
Table 6.5: Confusion matrix to show the accuracy of ADLs detection for different object usage by CRF method…….…..…...163
Table 6.6: Confusion matrix to show the accuracy of ADLs detection for different object usage by Wellness method……..……...…….…..….163
Table 6.7: Accuracy of different machine learning methods……164

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:

http://ieeexplore.ieee.org/xpl/topAccessedArticles.jsp?punumber=7361

Thank you for your contribution to the IEEE Sensors Journal!

Best regards,

H. Troy Nagle

H. Troy Nagle
President, IEEE Sensors Council

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Measurement

Certificate of publication for the article titled:

"Issues and Mitigation of Interference, Attenuation and Direction of Arrival in IEEE 802.15.4/ZigBee to Wireless Sensors and Networks Based Smart Building "

Authored by:

Hemant Ghayvat

S.C.Mukhopadhyay

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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