AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Computer and Systems Engineering Department

Wireless Communication Protocols for Smart Home Applications

Thesis

Submitted in Partial Fulfillment of the Requirements of the Degree of
Master of Science in Electrical Engineering

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STATEMENT

This thesis is submitted to Ain Shams University for the degree of Master of Science in Electrical Engineering (Computer and Systems Engineering).

The work included in this thesis was carried out by the author at the Software Engineering Competence Center (SECC), Information Technology Industry Development Agency (ITIDA), Cairo, Egypt.

No part of this thesis was submitted for a degree or a qualification at any other university or institution.

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ABSTRACT

Smart home technologies are gaining more and more attention as their emerging applications day-after-day demonstrate high value when it comes to yielding resource-thriftiness, and providing comfort, convenience, security, and entertainment to individuals in general and to elderly and sick people in particular. This thesis tackles two major challenges facing such applications.

First, as smart home applications are getting more and more complex, it is required to find an effective tool to model such complexity in order to make smart home realization simpler and systematic. The thesis proposes utilizing the famous Petri net tools to model, simulate, analyze, control, and supervise the activities found in a smart home. They offer many advantages over state-based models; the initial efforts towards formality. They overcome the state explosion problems of representing complex smart home scenarios. Modularity is another key improvement when compared to state-based models where any design flaws or mistakes could invalidate the entire model and any system specification changes could require tremendous effort to modify the design. In addition, it can explicitly model concurrency of the various systems existing in the home.

Second, as the indoor-positioning application plays a vital role in automating homes and providing energy thriftiness, the thesis develops a new fuzzy-based indoor positioning technique. The new technique uses the low-cost ZigBee wireless communication protocol and its link quality indicator (LQI) metric to accurately determine room-level positions. It considers environment characteristics when specifying different fuzzy sets, with K-means algorithm is utilized in order to specify the different fuzzy ranges based on the LQI histogram in the specific environment. The new fuzzy-based technique is compared to two other popular techniques, namely, the highest LQI technique and the environment adaptive technique. When the three techniques are implemented using Jennic JN5148 ZigBee PRO evaluation kit, the developed technique demonstrates superior performance under the typical memory and time constraints.

Keywords: Smart home, Home automation, Petri net, Wireless communication, ZigBee, LQI, Fuzzy logic, Indoor positioning

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TABLE OF CONTENTS

List of Abbreviations

AES	Advanced Encryption Standard
AF	Application Framework
AoA	Angle of Arrival
AP	Access Point
APDU	APS Protocol Data Unit
APL	Application Layer
APS	Application Support Sub-layer
BPSK	Binary Phase Shift Keying
BSS	Basic Service Set
BT	BlueTooth
CCK	Complementary Code Keying
CCM	Cipher block Chaining Message authentication protocol
COFDM	Coded Orthogonal Frequency Division Multiplexing
CRC	Cyclic Redundancy Check
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
DE-SAP	Data Entity Service Access Point
DS	Distribution System
DSSS	Direct Sequence Spread Spectrum
DU	Data Unit
EDR	Enhanced Data Rate
ESS	Extended Service Set
FFD	Full Function Device
FHSS	Frequency Hopping Spread Spectrum
FSK	Frequency Shift Keying
GFSK	Gaussian shaped Frequency Shift Keying
GTS	Guaranteed Time Slot
HVAC	Heat, Ventilation, and Air Conditioning
IBSS	Independent Basic Service Set
IEEE	Institute of Electrical and Electronic Engineering
ISM	Industrial, Scientific, and Medical
KNN	K Nearest Neighbor
LAN	Local Area Networks
LOS	Line Of Sight
LQI	Link Quality Indicator
MAC	Media Access Control layer
MAC	Message Authentication Code

MED	Minimum Euclidean Distance
ME-SAP	Management Entity Service Access Point
MIC	Message Integrity Code
MIMO	Multiple Input Multiple Output multiplexing
MPDU	MAC Protocol Data Unit
M-QAM	M-ary Quadrature Amplitude Modulation
NLOS	Non Line Of Sight
NPDU	Network Protocol Data Unit
NWK	Network layer
OEM	Original Equipment Manufacturer
OFDM	Orthogonal Frequency Division Multiplexing
OQPSK	Offset Quadrature Phase Shift Keying
OSI	Open System Interconnect
PAN	Personal Area Networks
PHY	PHYsical layer
PLC	Power Line Control
PN	Petri Net
PPDU	PHY Protocol Data Unit
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
RFD	Reduced Function Device
RSS	Received Signal Strength
RSSI	Received Signal Strength Indicator
SAP	Service Access Point
SBPI	Supervision Based on Place Invariants
TdoA	Time Difference of Arrival
ToA	Time of Arrival
UWB	Ultra WideBand
UWM	Ultra Wideband Multiplexing
WAN	Wide Area Networks
Wi-Fi	Wireless Fidelity
WKNN	Weighted K Nearest Neighbor
WLAN	Wireless Local Area Networks
WPAN	Wireless Personal Area Networks
ZB	ZigBee
ZDO	ZigBee Device Object

LIST OF FIGURES