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A NOVEL RADIOMETRIC SIGNATURE IDENTIFICATION SCHEME FOR INDOOR ENVIRONMENT

BY

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ABSTRACT

With an always changing technological world, the advancement of inexpensive and basic Wireless Sensor Network (WSN) devices can possibly replace many different technologies for low energy consumption and low data rate environmental monitoring, smart homes and security applications. Radio frequency devices have the characteristic of reporting their signal level through radio signal strength indicator (RSSI). In this dissertation, changes in RSSI levels of IEEE 802.15.4 transceivers are used as indicators of the presence of an individual in indoor environment. Furthermore, with the proposed scheme, the idea of determining the identity of a particular individual by the increase of the number of devices that send their RSSI levels is introduced. To prove the concept of utilizing radiometric fingerprinting for human identification in indoor condition, raw RSSI data is processed first using filters to remove out of range data. Then statistical profiles are created from all the participating vertically aligned transmitters and associated with each human individual using the indoor space. Then a matching decision is determined after the newly generated statistical profiles are then compared with pre-stored statistical profiles (e.g., RSSI samples of same size referred to a radiometric signatures in this dissertation) in the database and a decision of matching or mismatching is given in view of RMSE threshold. To test the newly developed methodology, sets of tests were performed on total of 27 subjects for 4 predetermined static positions in Communications Protocols Laboratory in Block E-2, Kulliyyah of Engineering. The scheme was tested for two groups that emulate members of family and office groups in addition to testing based on the position of the subject in relation to the link. The outcomes demonstrated a sensitivity and specificity of 100% for a family testing group of 4 members and 5 members office group. On account of testing the best positions for subjects that gives the best performance, sitting positions showed better performance with 100% accuracy for both in-link and out-of-link positions for a resolution of 7 transmitters using the optimum decidability model. While for standing positions, the in-link position achieved 0% false positive alarms for both models and only 2.4% false negative alarms using optimum decidability model and 3.6% false negatives for the in-order of heights model. Such performance, uncovers the capability of the proposed radiometric scheme in security and home automation applications where real-time identification of occupant is a demand. Likewise, this work is an important step in empowering non-invasive recognition systems that make sensor networks more widely accepted.

خلاصة البحث

مع التغير الدائم في العالم التقني، فإن التطور في الأجهزة التي تعمل بتقنية شبكة الاستشعار اللاسلكية (WSN) والتي تتسم بانخفاض اسعارها وبساطتها يزيد امكانية احلالها محل غيرها من الأجهزة في تطبيقات الرصد البيئي والمنازل الذكية والتطبيقات الأمنية،وهذا يرجع إلى انخفاض معدل استهلاكها للطاقة ومعدل ارسالها للبيانات. وتتميز أجهزة التردد الراديوي بخاصية الإبلاغ عن مستوى الإشارة من خلال مؤشر قوة الإشارة(RSSI). في هذه الأطروحة، يتم استخدام التغيرات في مستويات مؤشر قوة الإشارة من أجهزة الإرسال والاستقبال التي تعمل بتقنيةIEEE802.15.4 كمؤشرات على وجود فرد في بيئة داخلية. وعلاوة على ذلك، في هذا المخطط المقترح، يتم تقديم فكرة تحديد هوية فرد معين من خلال زيادة عدد الأجهزة التي ترسل مستويات مؤشر قوة الإشارة الخاصة بها. ولإثبات مفهوم استخدام بصمات موجات الراديو لتحديد هوية أشخاص في بيئة داخلية، أجريت مجموعة من الاختبارات على مجموع 27 شخصا في 4 مواقع محددة سلفا في مختبر بروتوكولات الاتصالات في مبنى E-2 بكلية الهندسة. وقد تم اختبار المخطط لمجموعتين تحاكي أحداها أسرة و الأخرى لمجوعة من الأفراد في بيئة عمل مكتبية ،بالإضافة إلى اختبار يستند إلى موقع الشخص بالنسبة للشبكة. ويحدد قرار المطابقة بعد استخراج قيم مؤشر قوة الإشارة التي تم استقبالها من عدة مرسلات تعلق على الجدار. بعد ذلك يتم جمع قراءات مؤشر قوة الإشارة ومقارنتها مع عينات تم تخزينها مسبقا من نفس الحجم في قاعدة البيانات ويتم إعطاء قرار تطابق أو عدم تطابق استنادا إلى القيمة الفاصلة للجذر التربيعي لمتوسط مربعات الخطأ (RMSE). أظهرت النتائج حساسية وخصوصية بنسبة 100٪ لمجموعة اختبار الأسرة ذات 4 أفراد و مجموعة بيئة العمل المكتبي ذات 5 أفراد. أما في حالة اختبار أفضل المواقع للأشخاص التي تعطي أفضل أداء، أظهرت النتائج أن موضع الجلوس أظهر أفضلية في الأداء مع دقة تبلغ 100٪ سواء أكان الشخص جالسا في موقع يتقاطع مع خط الوصل المباشر للشبكة أو في موقع محيط بهذا الخط باستخدام 7 أجهزة للارسال بناءا على نموذج تحقيق قيمة التحديد المثلى. بينما في وضعيات الوقوف، فإن الوقوف في موقع يتقاطع مع خط الوصل المباشر للشبكة حقق 0٪ إنذارا إيجابيا كاذبا لكلا النموذجين و 2.4٪ فقط من الإنذارات السلبية الكاذبة باستخدام نموذج تحقيق قيمة التحديد المثلى و 3.6٪ من الإنذارات السلبية الكاذبة لنموذج الترتيب حسب الارتفاع. هذا الأداء، يكشف إمكانية استخدام مخطط بصمات موجات الراديو المقترح في تطبيقات الأمن والتشغيل الآلي للمنازل حيث يكون التعرف الآني على الاشخاص المتواجدين ضرورة. وبالإضافة إلى ذلك، يعتبر هذا العمل خطوة هامة في تمكين نظم التعرف اللامتدخلة التي تجعل من شبكات الاستشعار ذات قبول على الصعيد العام.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Communication Engineering).

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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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LIST OF ABBREVIATIONS

API	Application Programming Interface
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BS	Base Station
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
DFL	Device Free Localization
FAR	False Accept Rate
FFD	Full Function Devices
FN	False Negative
FP	False Positive
FRR	False Reject Rate
GUI	Graphical User Interface
HEC	Header Error Check
ID	Identification
IDE	Integrated Development Environment
IEEE	Institute of Electrical and Electronics Engineers
ISM	Industrial, Scientific and Medical
LLC	Logical Link Control
LOS	Line of Sight
LQI	Link Quality Indicator
LR-WPAN	Low Cost –Low Rate Wireless Personal Area
LSB	Least Significant Byte
MAC	Medium Access Control

MSB	Most Significant Byte
NIC	Network Interface Card
PAN	Personal Area Network
PARADIS	Passive Radiometric Device Identification System
PC	Personal Computer
POS	Personal Operating Space
RF	Radio Frequency
RFD	Reduced Function Devices
RFID	Radio Frequency Identification
RMSE	Root Mean Square Error
RSSI	Received Signal Strength Indicator
SFD	Frame Delimiter
SNR	Signal-To-Noise Ratio
SOHO	Small Office Home Office
TN	True Negative
TP	True Positive
UI	Uniqueness Identification
WPAN	Wireless Personal Area Network
WSN	Wireless Sensor Network
ZC	Zigbee Coordinator
ZED	Zigbee End Device
ZR	Zigbee Router

LIST OF SYMBOLS

μ_D	Mean of Inter-Class Distribution
μ_S	Mean of intra-class distribution
d'	Decidability
$\lceil x \rceil$	Ceil of the value x
σ_D	Standard deviation of inter-class distribution
σ_S	Standard deviation of intra-class distribution
$\sum$	Sum of
Hz	Hertz
%	Percentage
M_s	Millisecond
μ	Micro
G_t	Antenna Gains of the Transmitter
G_r	Antenna Gains of the Receiver
λ	Signal Wavelength
f	Signal Frequency
d	Distance from the Transmitter
dBm	Power ratio in decibels (dB) in referenced to one milliwatt (mW)
P_r	Received Power
P_t	Transmitted Power
Rx	Receiver
T_x	Transmitter
α	Alpha, the coefficient used in Alpha trimmed filters

CHAPTER ONE

1 INTRODUCTION

1.1 OVERVIEW

Human identification is a public concern all over the time. The current advances in technologies and automated systems that rely on recognizing the user to operate have opened new challenges regarding feasibility and cost effectiveness of human identification systems. Technologies such as radio frequency identification and wireless sensor networks encourage the discovery and identification of items that are not viably recognizable by utilizing customary sensor advancements. Ubiquitous facilities have been an achievement in dealing with tackling real world's issues (Juels, 2006; Xie et al., 2014). Radio frequency identification innovation has been utilized for multiple applications which incorporate logistic applications, toll system applications, E-ticketing applications, Healthcare applications and Security and identification systems (Wu et al., 2009).

RF likewise is utilized as a part of Identification and recognition techniques exploiting some of its unique attributes, this is called Radiometric Signature or RF fingerprinting. A Radiometric Signature is a system where properties of the signal are extracted and used to differentiate between the sources of these signals in light of the variation and change of these properties (Polak & Goeckel, 2011).

Radiometric Signature techniques are for the most part classified either based on their transmission channel characteristics. Radio Signal Strength Indicator (RSSI) and change of Multi path correlation are systems utilized for RF fingerprinting and they all under channel characteristics classification. The other recognition approach is built on exploiting hardware imperfection characteristic of every device where it is found that

there are no two devices are identical and have exactly the very same hardware architecture (Kennedy et al, 2008). In this dissertation, the first technique will be utilized which is using RSSI in Radiometric Signature. The choice of RSSI for human detection and recognition is valid because it satisfies these conditions:

- ***Universality:*** it indicates that each person in group tested should have his /her specific own characteristics e.g. Height, weight gait and the moving and walking style which accordingly will influence the readings of RSSI.
- ***Uniqueness:*** that the mentioned unique characteristics have to be unique and different enough to be measured, classified and then two persons distinguished accordingly.
- ***Permanence:*** The characteristics use for recognition should be stable or stable enough and not significantly changes with time and environment. In the case of RSSI the change with environment actually is the case, however the tests will be performed indoors so there will be no main change in environment condition.
- ***Collectability:*** The distinctive criteria can be measured in quantity (RSSI measured in dB).
- ***Performance:*** The accuracy of the system or scheme where the system should have high accuracy considering the working environment.
- ***Acceptability:*** People who are using this system are willing to accept it operating in their environment without being a source of discomfort.
- ***Circumvention:*** It refers to the fact if the system can be fooled or deceived by some techniques which may led to system failing to produce the desired output (Schuckers, 2001 and Rahultech, 2010).

RSSI Radiometric Signature method was chosen to be applied because RSSI readings have the requirement that any identification metric should have as in Figure 1.1. It is unique, universal, can be measured and easy to use.

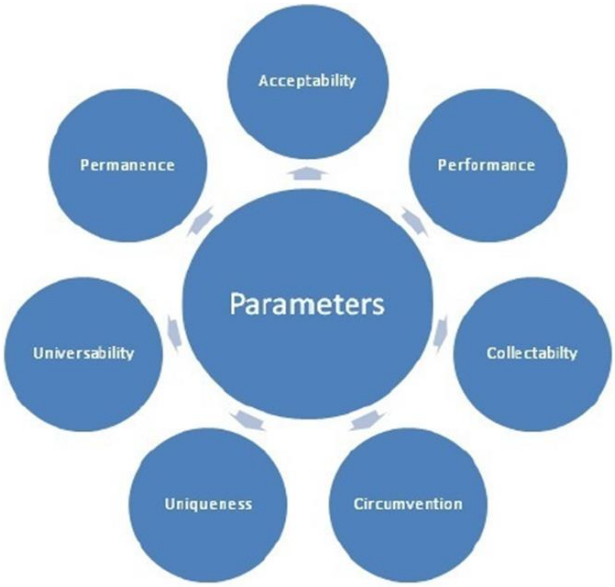

Figure 1.1Basic Criteria for Human Identification System (Rahultech, 2010)

When a connection starts there will be an exchange of messages between transmitter and a receiver, by analysing RSSI variations, the system can predict the change in the surrounding environment, based on humans entering or leaving the area where this communication system is built. The suggested technique is mainly based on the fact that the presence of objects between the two ends of the connection will produce a shadowing effect. RSSI usually fluctuates by the change of environments by increasing or decreasing in level compared to a mean value. However, RSSI fluctuation over a given time is highly influenced by the presence of a human body. When the room is empty the value of RSSI will be almost constant.

For a limited set of individuals, they will vary in their height, weight and body gait, this will result in variation of the medium that the signal moves through while crossing the human body. Accordingly with installing nodes at different heights the measurements of RSSI levels will defer from an individual to another (Mitchell & Chen, 2014).

1.2 PROBLEM STATEMENT AND ITS SIGNIFICANCE

Human detection, recognition and identification is one of the most needed technologies in our daily life. Security, home automation and medical monitoring systems are known applications based on human detection techniques. Nonetheless, most of the current commonly used human detection systems are known to be costly, hard to operate, bulky and most of the time require a specific action from the user such as iris recognition and finger prints systems. Users for tag based identification system need to wear tag to identify them among others, however, the presence of new person to the environment who is not wearing tag cannot be recognized by such systems besides the inconvenience of the need to wear a tag all the time to be identified. Moreover, users of camera based identification systems, view these systems as invasive to their privacy and could be utilized to gather more information than just the information needed for user identification. Camera based identification systems present another drawback related to the relatively high bandwidth needed for these devices to function properly. The proposed system which is based on radiometric fingerprinting will be non-invasive and passive, so it will not bring and inconvenience of carrying objects and it will not interfere with users' daily activity.

In view of all these concerns, the proposed method in this research work is able to detect any human presence and to compare the change of the current signal to the

previously logged signals. The suggested system utilizes RF technology characteristics to fulfil its planned objective. Because radio frequency systems are cheap, easy to use and provide accurate identification wirelessly, the suggested scheme is economical, has low power consumption, quick response, easy to use, with low cost for maintenance.

In the recent years many researches have been done in the field of using radiometric signature in human detection, however there are still many open issues related to the accuracy and performance of similar systems to be investigated. Furthermore, none has attempted to use such radiometric signatures in human identification yet.

1.3 RESEARCH OBJECTIVES

The primary objective of this research work is to produce a human identification scheme for indoor environments using RF radiometric fingerprinting. The specific objectives may be detailed as follows:

1. To develop an offline training phase to collect and record RF signatures for a limited set of individuals in a contained indoor environment (e.g., home, office, or laboratory).
2. To develop an online identification algorithm for the RF signature profile under examination by comparing it to the limited set of profiles available in the database and to produce a matching score.
3. To verify the results against several human samples from students (male/female) and children by producing a false alarm statistics.

1.4 OPEN ISSUES

Based on the reviewing of the works done in the field of Human identification using Radio frequency fingerprinting, it is completely clear that the accuracy of systems using RSSI as mean for detecting people is still an open issue. However there are other open issues that can be summarized in these points:

- ***Sensing noise:*** Noise power which is generated by the presence of big objects other than the study sample (human) in the environment of sensing can affect the quality of the system due to diffraction and scattering which will cause the signal to be distorted. Basically, the presented approach overcomes these obstacles utilizing Alpha trimmed filters.
- ***Environmental variations:*** the rapid variation in environment condition can cause the readings to change in disproportional way of the parameter to be measured. This issue will be tackled by limiting he scheme to indoor environment.
- ***Similarity to background signal:*** It is quite clear that extracting the human body's physical properties from the properties of background is not an easy task, however it still the core task in human-sensing. This separating of properties is almost impossible task in outdoor environments. Hence, the proposed scheme makes use of multiple sensors to detect the change is signal.
- ***Appearance variability and unpredictability:*** human bodies are different in their height, weight and mass to height distribution. Although these characteristics can be determining factors in the case of RSSI, the change of appearance can be an obstacle while trying to recognize a person wearing

heavy clothes in winter and relate these characteristics to same person with light clothes in summer.

- ***Active deception:*** In advanced systems especially for military applications, it is important to put in consideration the possibility of attack like jamming signals, where the system is deceived or fooled.
- ***Human-sensing purposes:*** the use of human sensing can be for many purposes, these purposes are: Presence, Counting, Location-detection, or localization, Tracking and identification.
- ***Power Efficiency management strategies:*** these systems are implemented to be running for continuous, long time so it should be designed power efficient.
- ***Modulation schemes:*** to reduce power consumption and for usability some modulation schemes are needed, they can be baseband or passband modulation technique.
- ***Sensor Node Architecture, link-layer topology and routing algorithm:*** the design of the node and the topology also the routing algorithm can be used to increase the accuracy and lower the power consumption of the system.

1.5 SCOPE

In this proposed scheme, the design was based on using channel characteristics only as mean of radiometric signatures, the use of other radiometric techniques is out of the scope of this research.

Sensing noise effect, nodes distribution, filtering techniques and sampling size variation were used to produce radiometric signature scheme in indoor environments.