DESIGN AND IMPLEMENTATION OF ENERGY EFFICIENT LARGE-SCALE TRACKING SYSTEM

BY

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A Thesis Presented to the
DEANSHIP OF GRADUATE STUDIES

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

COMPUTER ENGINEERING

DECEMBER 2017

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN- 31261, SAUDI ARABIA

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To my loving

I dedicate this thesis to my parents, my wife, my brothers, sisters and my advisor.

Thank you for supporting me along the way.

Without your help, I could not have completed this work.

ACKNOWLEDGMENTS

I thank Allah for granting me the guidance, health, patience, and determination to successfully accomplish this work.

I would like to express my deep appreciation to my research supervisor, **Dr. Uthman Baroudi**, for guidance me throughout the research. I also would like to thank the members of my thesis committee, **Dr. Tarek Sheltami**, and **Dr. Hesham Alfares**, for their help in accomplishing this work.

I would also like to thank the King Fahd University of Petroleum and Minerals for creating excellent research environment for the students and for supporting them until they accomplish their objectives.

I also would like to thank my parents, and my wife who always support me with their love, encouragement, and constant prayers. I would like to thank my brothers and sisters for their love and support throughout my study.

Finally, I would like to say thanks to all my friends, especially those in the King Fahd University of Petroleum and Minerals and all others who helped in this work.

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LIST OF ABBREVIATIONS

Wi-Fi	:	Wireless Fidelity
RFID	:	Radio-Frequency Identification
IOS	:	IPhone Operating System
WSN	:	Wireless Sensor Networks
IoT	:	Internet of Things
ITS	:	Intelligent Transportation System
BLE	:	Bluetooth low energy
LF	:	Low frequency
HF	:	High frequency
UHF	:	Ultra High frequency
GPS	:	Global Positioning System
WLAN	:	Wireless Local Area Network
LAN	:	Local Area Network
GAMS	:	General Algebraic Modeling System
QoS	:	Quality of Service
FER	:	Frame Error Rate

PDR	:	Pedestrian Dead Reckoning
MANAL	:	Mobile Anchor Node Assisted Localization
BAG	:	Bandwidth Aggregation
RAPS	:	Rate Adaptive Position System
CH	:	Cluster Head
CM	:	Cluster Member
AP	:	Access Point
MT	:	Mobile Terminals
MANET	:	Mobile Ad hoc NETworks
ADHS	:	Adaptive Distributed Hierarchical Sensing
HCC	:	Hierarchical Control Clustering
SCORT	:	Synchronous Connection Oriented with Repeated Transmission
SAFH	:	Smooth Adaptive Frequency Hopping
ISM	:	Industrial, Scientific, and Medical
CSMA	:	Carrier Sense Multiple Accesses
WLANS	:	Wireless Local Area Networks
HRW	:	Hybrid RFID and WSN
PDA	:	Personal Data Assistant

RSSI	:	Received Signal Strength Indicator
REMA	:	RSSI Environment and Mobility Adaptive
API	:	Application Interface
BSN	:	Body Sensor Network
OCB	:	Offset CodeBook
BL	:	Battery Level
GFSK	:	Gaussian frequency shift keying
SCO	:	Synchronous Connection Oriented
ACL	:	Asynchronous Connection Less
RFS	:	Reduced-Function Sensor
RFRR	:	Reduced-Function RFID Reader
UDP	:	User Datagram Protocol
LP	:	Linear Programming
NLP	:	Nonlinear Programming
MIP	:	Mixed Integer Programming
MINLP	:	Mixed Integer Nonlinear Programming
RHS	:	Right Hand Side

RSA : Rivest-Shamir-Adleman

SRTHMATS : Smart Real-Time Healthcare Monitoring and Tracking System

ABSTRACT

Full Name : Abdulrahman Abdalla Abu-Elkhail

Thesis Title : Design and Implementation of Energy-Efficient Large-Scale Tracking System

Major Field : Computer Engineering

Date of Degree : December, 2017

The Hajj season is one of the biggest annual events in the world, where millions of people from all over the world gather to perform religious rituals over several days. The main challenge during Hajj season for organizers and participants is to ensure safety, health and comfort during Hajj. Given such a large-scale event such as Hajj; the pilgrims are usually in a bounded area and in large number.

Several existing tracking systems based on mobile clustering are available in the literature. However, very few of these solutions are suitable for the problem at hand (large scale tracking problem; e.g. tracking pilgrims during Hajj seasons) that addresses a very hugely crowded area. Therefore, there is a need for a new approach that tackles this problem and be able of tracking and monitoring health conditions of the crowd and providing their locations and movement directions. Additional benefits include reducing the energy consumption, transmission delay and maximizing the whole network throughput and the network lifetime.

We propose a novel technique to design an energy-efficient large-scale tracking system based on mobile clustering. The newly proposed method of mobile clustering ensures energy efficiency in a large-scale tracking system that can be used in large public events such as the annual Muslim pilgrimage (Hajj), airports, train stations, etc. This method considers random movement of large number of people in a bounded area by adaptively and collaboratively constructing networks of smart phones clusters exploiting Bluetooth, Wi-Fi and 3G/4G technologies. In order to eliminate the operating systems limitations (i.e. ios does not support a friendly establishment of Bluetooth network, while android does so), we have integrated our approach with RFID technology.

In order to evaluate the proposed method, we first formulate the problem as a linear program and we compute the optimal number of clusters and their members. Second, a Matlab/Simulink simulation is developed to simulate the proposed method under realistic operational conditions. Third, an android application is developed to experiment the proposed method under realistic operational conditions. Finally, a smart RFID node is integrated with our approach to test the proposed method under real experiments. The results demonstrate the outstanding performance of the proposed method compared to contemporary methods.

ملخص الرسالة

الاسم الكامل : عبدالرحمن عبدالله ابوالخيل

عنوان الرسالة : تصميم وتنفيذ نظام تتبع ذو نطاق واسع كُفْء في استهلاك أمثل للطاقة

التخصص : هندسة الحاسب الألي

تاريخ الدرجة العلمية : ديسمبر ، 2017

يعد موسم الحج أكبر الأحداث السنوية في العالم، حيث الملايين من الناس من جميع أنحاء العالم يجتمعون لأداء الشعائر التعبدية على مدى عدة أيام، يتنقلون فيها بين عدة أماكن متباعدة. إن التحدي الرئيس خلال موسم الحج للمنظمين والمشاركين هو ضمان السلامة والصحة والراحة أثناء الحج. وقد جاء هذا البحث ليقدم علاجا لهذه المسالة وذلك عن طريق تصميم نظام يتتبع حركة المشاركين وحالتهم الصحية وتوفير مواقعهم واتجاهات الحركة. وتشمل المزايا الإضافية تحقيق دقة تحديد المواقع، والحد من استهلاك الطاقة وتعظيم الإنتاجية من الشبكة بأكملها وتعظيم عمر الشبكة.

وقد درسنا العديد من التقنيات القائمة لأنظمة التتبع على أساس تجميع المحمول وبيان عيوبها الرئيسية. ومع ذلك، فلم نجد طريقة لديها نهج مناسب لحل المشكلة في متناول اليد (تتبع الحجاج أثناء الحج) الذي يعالج منطقة مزدحمة جدا مع حركة عالية وتوفي بالشروط الآنفة الذكر.

قدمت هذه الدراسة نهجا جديدا لتصميم نظام تتبع على نطاق واسع كفوء في استخدام الطاقة على أساس تجميع المشاركين بمجموعات صغيرة متغيرة وبناء شبكة فعالة مستخدمة الهواتف الذكية ومعتمدة على تقنية بلوتوث (Bluetooth)، واي فاي (Wi-Fi) و (RFID) الذكية. وتضمن الطريقة المقترحة للتكتل المتنقل كفاءة استخدام الطاقة في نظام تتبع واسع النطاق يمكن استخدامه في المناسبات العامة الكبيرة مثل الحج والمطارات ومحطات القطارات، وما إلى ذلك. وكذلك تم دمج تكنولوجيا (RFID) مع الطريقة السابقة للتقليل من الاعتماد على التوافق بين الهواتف الذكية وتقنيات بلوتوث (Bluetooth)لأن الاتصالات عن طريق البلوتوث (Bluetooth) تدعم الهواتف الذكية المعتمدة على نظام التشغيل (Android) للتواصل مع بعضها البعض، ولا تسمح للتواصل مع نظم التشغيل الأخرى مثل الهواتف الذكية (ios).

من أجل تقييم الطريقة المقترحة، قمنا أولا بصياغة المشكلة كبرنامج خطي. ثانيا، تم تطوير محاكاة للطريقة مستخدمين (Matlab/Simulink) في ظل ظروف عملية واقعية. ثالثا، تم تطوير تطبيق (Android) لتجربة الطريقة المقترحة في ظل ظروف عملية واقعية. وأخيرا، تم دمج عقدة (RFID)الذكية مع نهجنا لاختبار الطريقة المقترحة تحت التجارب الحقيقية. أظهرت النتائج الأداء المتميز للطريقة المقترحة مقارنة بالطرق المعاصرة.

CHAPTER 1

INTRODUCTION

1.1 Overview

Bluetooth, Radio-Frequency IDentification (RFID), Wireless Sensor Networks (WSN) and Internet of Things (IoT) technology became efficient in smart environments and applicable to a wide variety of applications; such as tracking systems, medical treatment, environmental monitoring, Intelligent Transportation System (ITS), public health, smart grid, and many other areas [1]. Bluetooth and Radio-Frequency IDentification (RFID) systems are considered to be the strategic enabling components for such tracking and healthcare systems due to the energy autonomy of Bluetooth low energy (BLE) and battery-less tags as well as their low cost [2, 3]. However, these devices are energy constrained. Therefore, optimizing the energy consumption in the network that is composed from such devices is essential. In this work we are proposing to use clustering scheme in order to maximize life time of the network.

The rest of the chapter is organized as follows. In section 1.2, the background and terminology is reviewed. In section 1.3, the research motivation is described. The problem statement is presented in section 1.4. Sections 1.5 and 1.6 present the research methodology and research objectives, respectively. Sections 1.7 and 1.8 present the thesis contributions and the thesis outline, respectively.

1.2 Background and Terminology

1.2.1 Bluetooth

Bluetooth is a low-power wireless protocol used to transfer and broadcast data between devices. It occupies the frequency range 2402-2480 MHz .Most mobile Bluetooth devices use just 1mW to save batteries to achieve only a 10 m range and have the built-in security that the device can't connect unless it obtains authorization. The connection between two Bluetooth devices is called pairing. When two Bluetooth devices notification each other; they construct a network – called a piconet; it is a small network consisting of one master and up to seven slaves. But in standard the number can be extended by creating a scatternet. The master in one piconet can be a slave in another piconet so linking the two networks together. All devices connecting to a piconet use the same frequency hopping and are controlled by the master. The channel is divided into 625 microsecond time slots and it's shared between the master and the slaves using the simple law that the master transfers on even time slots and the slaves send in odd time slots [4].

The recent Bluetooth version 4.2 (also known as Bluetooth Low Energy (BLE) or Bluetooth Smart) which introduces a number of new features that improve speed (250 % faster), more secure also allowing only reliable owners to track device location and self-confidently pair devices also has IoT capabilities also can transmit the data over internet [4].

1.2.2 Radio-Frequency IDentification (RFID)

Radio-Frequency IDentification (RFID) is a technology which uses radio frequency waves to transmission data between a reader and a mobile item to identify, classify, track…, etc.

(RFID) tags are small transponder that respond to requests from a reader by wireless transferring and consists of microchip, antenna, case, battery (for active tags only) [5].There are three types of tags, the first type is passive tags, those tags do not have an internal power source, and they therefore rely on the power induced by the reader. This means that the reader has to keep up its field until the transaction is completed. Because of the lack of a battery, these tags are the smallest and cheapest tags available. The second type is semi-passive tags, those tags have an internal power source that keeps the microchip powered at all times. This is advantage; because the chip is always powered it can respond faster to requests, therefore increasing the number of tags that can be queried per second which is important to some applications. The third type is active tags, those tags have an internal power source but they use the energy supplied for both, to power the microchip and to generate a signal on the antenna. Also there are three regions in respect to frequency deals with RFID tags, the first region is low frequency (LF) region which is between 30 to 500 kHz, and the second region is high frequency (HF) region which is between 10 to 15 MHz and the third region is ultra-high frequency (UHF) region which is between 850 to 950 GHz and between 2.4 to 2.5 GHz and 5.8 GHz.

1.3 Research Motivation

We have several motivations regarding the smartphones and RFID that give us incentive to use them in our research that ensures energy efficient for a large scale tracking system such as (Hajj). First, the recent smartphones are capable of activating tracking systems by exploiting GPS and WLAN technologies for positioning and communication. Second, all smartphones don't require any modifications in their equipment and all smartphones support the Bluetooth and WLAN interface and have different properties such as Bluetooth range, WLAN range, etc. Third, tracking information needed to be sent to the server by each smartphone is small in size and it doesn't require high data rate. Fourth, the RFID tags are very simple, easy to install, low cost and low power consumption. Finally, the RFID tags can store a lot of information up to 2KB [6]; also they can be combined with sensors to provide real time information and data access.

1.4 Problem Statement

The main challenge during Hajj season for organizers and participants is to ensure safety, health and comfort during Hajj. The pilgrims are usually in a bounded area and in large number with random movement of people in a bounded area.

In this work we aim to propose a novel method for monitoring health conditions of pilgrims and providing location and directions using smart phones/devices with low energy consumption and integrating it with a smart RFID node.

The recent smartphone's technologies that capable of positioning and communication give a great incentive to use the smartphone's in tracking systems. However, implementing these systems in the real world has many issues that must be considered because positioning and communication require high power, the first issue is the smartphone's energy constrained which is limited to the battery equipped on the phones. In addition, using each smartphone's GPS and Wi-Fi is not energy efficient, so the solution is grouping the nearby smartphone's to form a cluster to attain energy efficient large-scale tracking system instead of using smartphone's GPS and Wi-Fi. However, clustering smart devices into groups come with many technical challenges. First of all, achieve accuracy of positioning. Secondly, collect information in each cluster and reported this information from clusters head (masters) to the server for processing it.

There are also many challenges related to mobile clustering it is very important to manage the transmission to avoid the interference between Bluetooth itself and Bluetooth/Wi-Fi. Moreover, it is important to determine the optimal cluster size to achieve maximum throughput for the whole network and to achieve maximum lifetime of the network.

On other hand, there are also many challenges related to RFID technology; firstly, it is very important to manage the transmission to avoid the interference and channel access congestion during the data transmission. Secondly, it is very important to manage transmission to reduce the long distance transmission interference. Thirdly, the RFID tag is susceptible to malicious attack. Finally, it is very important to manage the collected data to avoid the duplicate information

1.5 Research Methodology

This section describes the research approach as follows:

Phase 1: Comprehensive Literature Review

Review the current technical issues of positioning using smartphones and study the current clustering algorithms especially those that address with high mobility and study the practical issues of network using multiple radio interfaces.

Phase 2: Formulation of the proposed solution into mathematical models.

Formulation of the proposed solution into mathematical models that ensures efficient energy consumption and good quality of service and solved it by GAMS simulator.

Phase 3: Develop a dynamic algorithm of energy efficient large-scale tracking system.

Develop a dynamic algorithm of energy efficient large-scale tracking system which assure the reduction of energy consumed by positioning and communicating and guarantee good quality of service and implemented it by Matlab/Simulink simulator.

Phase 4: Implementing the proposed algorithms through developing mobile applications on android smartphones.

Develop android application that ensures the reduction of energy consumed by positioning and communicating and guarantee good quality of service. In addition, a firebase server developed to process the collected data from smartphones.

Phase 5: Develop a smart RFID node.

Develop a smart RFID node that consists of RFID tag, small RFID reader and sensors such as pulse sensor and muscle sensor.

Phase 6: Integrate the android application with a smart RFID node.

Integrate the android application with a smart RFID node by using Bluetooth shield.

1.6 Research Objectives

The main objective of our work is to design and implement an energy efficient large scale tracking system using smartphones and integrates it with a smart RFID node. User location and information of interest are reported to the server periodically. The other sub objectives as follows:

1. Survey the literature of exiting methods for tracking large crowd systems.
2. Formulate and optimize the proposed solution as mathematical model.
3. Development of a clustering algorithm that can dynamically configure clusters in such a way it can guarantee a reliable and energy efficient.
4. Studying the effect of the proposed tracking system on the QoS; such as energy, throughput and efficiency of the whole network.
5. Comparing the proposed algorithms with the existing energy-inefficient algorithms.
6. Develop android application that ensures the reduction of energy consumed by positioning and communicating and guarantee good quality of service.
7. Develop a smart RFID node.
8. Integrate the android application with a smart RFID node by using Bluetooth shield.
9. Experiment the proposed method using a small scale testbed.

1.7 Thesis Contributions

As an expected result of the work presented in this thesis, the following contributions can be highlighted:

Design an energy efficient large scale tracking system using smartphones and integrates it with a smart RFID node: User location and information of interest are reported to the server periodically

Positioning accuracy via short-range radio: The total distance between masters and slaves is minimized because communicating via short-range radio interfaces such as Bluetooth is more accurate than communicating via long-range radio interfaces.

Reducing the energy consumption and transmission delay of Bluetooth clusters: Reducing the total distance between masters and slaves reduces the energy consumption and the transmission delay for Bluetooth networks.

Reducing interference between Bluetooth and Bluetooth/Wi-Fi: Minimizing the number of clusters reduces the volume of transmissions, such that interference within the Bluetooth network itself and between Bluetooth and Wi-Fi signals is minimized. In addition, this results in reducing channel access congestion that leads to minimize the frame error rate (FER) which leads to maximize the throughput of the whole network.

Maximizing Network lifetime: Minimizing the number of clusters reduces energy consumption, thus maximizing the lifetime of the network.

Efficient large-scale data collection using a smart node: each node replicates their tag data to its neighbor node. The RFID reader receives all information of nodes from the nodes when they move into the RFID reader range instead of reading every tag. This reduces channel access congestion and long distance transmission interference, also collects the information between nodes in efficient way for a large-scale system such as (Hajj).

1.8 Thesis Outline

The reminder of this work is structured as follows. Chapter 2 presents the literature review. Efficient technique based on mobile clustering of the Bluetooth network that ensures energy-efficient for a large-scale tracking system is presented in Chapter3. Chapter 4 describes the efficient technique that ensures energy-efficient for a large-scale tracking system based on a smart RFID node. Finally, Chapter 5 concludes the thesis, lists the limitations of the approach proposed, and recommends a set of directions in which future work can be conducted.

CHAPTER 2

LITERATURE REVIEW

This chapter summarizes the previous work related to energy-efficient tracking systems based on clustering approach. Many researchers approached the problem by using Bluetooth, Wi-Fi or RFID as the short-range radio interfaces. However, no existing solutions used Bluetooth and Wi-Fi is suitable for the problem at hand (tracking applications for a large-scale system such as Hajj) that addresses a very hugely crowded area with high mobility which certainly makes the design and the optimization even harder.

S. Jamil et al. considered the Hajj season crowd, sensing in a hybrid participating sensing approach to investigate the information of group dynamics, the study implemented using wearable Bluetooth Low Energy tags (BLE tags) and pre assigned smartphone's during Hajj days; using the mentioned hybrid approach data was collected from the groups of BLE tags with the assistance of GPS locations. The results pointed out the activity of groups (not individuals) while moving around the holy places and whether they stay together or not and provides analysis of the movements and their timing. Also the beacon is one way communication [7].

Moreover, the study uses a system to categorize hajj social networks and apply study to examine the group topology, especially in prayer times, and identifies group leaders and their followers as well as the peaks of users' density, besides refreshing groups' changes. The system merges ANT+ and Bluetooth, two heterogeneous systems and utilizing GPS, wearable BLE devices. Proposed approaches are applied to collect information from 41 applicants during their 8 days Hajj [8]. However the study only focuses on collecting data in the two holy mosques on prayer times. Also the beacon is one way communication.

Furthermore, a promising study discusses employing smartphones based on localization method called Pedestrian Dead Reckoning (PDR) which depends on the previous location, walking length and walking direction to determine the current position. The PDR model provides high accuracy in a short range, but it will drift with mobile distance [9]. However, the beacon is one way communication.

Z. Chen et al. focus on combining smartphone sensors and beacons for accurate indoor localization. The Pedestrian Dead Reckoning (PDR) can be applied for localization using smart phone sensors. Unfortunately, it will drift with walking distance. Therefore, beacons are introduced to correct the drift of the PDR approach. A particle filter is performed for the correction. Experiments show a significant improvement of the localization accuracy with sparse beacons deployment in a 47.3m× 15.9m area [10]. However, the beacon is one way communication.

Omijeh et al. presented a promising study discusses the analysis of Bluetooth-based ad-hoc network for voice transmission over Local Area Network. The aim is to analyze the performance of Bluetooth technology when applied to communication between Bluetooth-enabled devices such as smart phones and personal computers connected over Local Area Network (LAN) in order to communicate with other users or devices which are out of the immediate Bluetooth range. The use of Bluetooth in voice and data transmission could produce high data and audio rates while not producing a corresponding rise in error rates. [11]. However, they didn't do an analysis of the Bluetooth-based ad-hoc network via a large-scale area.

Kim et al. introduced BLE mesh approach based on wireless mesh network protocol for BLE which utilizes the broadcasting ability of wireless communications and their results showed decreasing the energy consumption within the network [12]. However; they study focused only on the navigation. Also the beacon is one way communication.

Han et al. surveyed several Mobile Anchor Node Assisted Localization (MANAL) algorithms in wireless sensor network. They categorized MANAL algorithms into two sets: localization based on mobility scheme and localization based on path planning model [13]. However; the study didn't consider for tracking purposes.

Oh, H et al. study energy-efficient in heterogeneous Wi-Fi access networks by considering the bandwidth aggregation (BAG) is to be a capable solution to achieve the energy-efficient in a heterogeneous network. They proposed energy-efficient algorithm for wireless heterogeneous networks, which achieve reduction of the power consumption in mobile devices with Wi-Fi access networks [14]. However; the study didn't consider for tracking purposes.

Paek, J and his colleges present a rate adaptive position system for smartphone applications (RAPS) based on GPS positioning for smartphone. GPS is known as accurate and extremely power consumption. Hence their approach has been to frequently duty cycle GPS which trades off position accuracy for lower energy consumption. RAPS use a set of techniques to smartly decide when to turn on the GPS. It uses the position, time record of the user to approximate the user velocity and turn on GPS only if the predictable doubt in location exceeds the accuracy threshold. It also approximates user movement, and uses Bluetooth communication to reduce location with neighboring devices. They implemented their approach in real experiments on recent smartphone and showed the enhancement of lifetime of battery level where GPS is always on [15]. However, using each smartphone's GPS and Wi-Fi is not energy efficient because require higher power, especially for a very crowded area systems such as Hajj.

Leem et al. proposed a mobile clustering procedure based on cooperation. This solution takes into account three costs for clustering: the residual battery energy, wireless local area network, physical data rate, and the number of members in the estimated group. Every node sends broadcast message with a cost every 200 ms .The device which has highest cost will be chosen as a cluster head (CH) and the other devises act as cluster members (CMs). The CH collects the information from CMs via its Bluetooth and transmits the data to WLAN access point (AP) by using its WLAN interface [16]. This approach is inefficient for saving energy with a high mobility especially when the number of nodes in the WLAN Ap coverage is larger than threshold of WLAN AP which leads to high interference.

Abbasi et al. presented a classification of clustering schemes. They surveyed multiple clustering approaches for wireless sensor networks (WSN), and compared these based on several costs such as convergence rate, stability, overlapping, energy efficiency, failure recovery, balanced clustering, locations, and support for node mobility [17]. However, they didn’t consider for tracking purposes.

A promising study presents a full approach on the area of energy efficient through wireless networks with mobile devices to mobile devices collaboration. It is implicit that a number of mobile terminals (MTs) that are physically close to each other are attracted in downloading the same contented from a server via a back end server using a long-range wireless technology. And send it to other mobile using a short-range of Wi-Fi. This approach leads to great performance because the communication via short-range Wi-Fi technologies is energy efficient more than using a wide range Wi-Fi technology. They formed mobile cluster to reduce energy consumption [18]. However, they didn’t consider for tracking purposes.

The authors focus on study the impact of network parameter on the energy consumption and clustering of a set of mobile terminals that are interested in downloading cooperatively the same content. The optimal of mobiles clusters size to reduce energy consumption is a very hard problem. So they considered a grid network, which is a frequently used model in ad hoc and sensor networks, where it is sufficient to develop the optimal energy consumption as a function of the variety of network parameters [19]. However, they did not consider the optimal size of mobile clusters to minimize the energy consumption.

Basu, P et al. proposed a mobile clustering procedure which called by mobile ad hoc networks (MANET) based on the power ratio between the receivers and transmissions at any node from all its adjacent nodes. This cost used in cluster formation. Each node broadcasts its own mobility cost, within period and then compares its own cost with its neighbors. The node which has the lowest cost will be assigned as a Cluster Head; otherwise a cluster member. If a node exists between two cluster heads it becomes a gateway node [20]. However, they didn't consider for tracking purposes.

Chen, G et al. proposed several clustering algorithms for nodes in a mobile ad hoc network. The connectivity and minor ID as cost for choosing cluster heads. One of the nodes broadcast invitation for clustering to all the other nodes. The node which has lowest cost will be assigned as a Cluster Head. Every node can define its cluster and belong to only one cluster. The aim is to reduce the number of clusters, which leads to controlling sets of minor sizes [21]. However, they didn't consider for tracking purposes.

Maleki, S. et al. proposed a hybrid wired and wireless sensor network technique to find the optimum positions of cluster heads and access points based on wireless network energy consumption cost and wired network cost. They formulated the problem as a mixed integer nonlinear programming (MINLP) model and solved by BARON with considering the constraints of data rate for each cluster, limitations of communication radius for every sensor, cluster and access points , the amount of battery level in each cluster, the lifetime of the network, and the location for CHs. They results showed that their model is more energy effective than the wireless networks and leads to maximize the life time of the network [22]. However; their approach is inefficient for saving energy in a high scalability system such as Hajj which needs large infrastructures of wired and wireless sensor network.

The authors proposed a voting clustering algorithm in wireless sensor network. The selection of cluster head based on a sensor that has a high energy and more neighbors, the optimal cluster number is considered based on learning the correlation of cluster and energy consumption based on their geometry locations [23]. However, they didn't consider for tracking purposes.

A promising study proposed a trustworthy energy efficient algorithm in wireless sensor network .They consider for cluster construction the remaining energy and number of adjacent of each node, the chosen of cluster head based on Knowledge inference approach .Finally, selected the reliable cluster heads to ensure connectivity, reduces the energy consumption and maximize the life time of the network [24]. However they didn't varying the number density of nodes, therefor their approach is inefficient for saving energy in a high mobility system such as Hajj.

The authors proposed a two tier clustering approach based on the residual energy and number of adjacent of each node for cluster construction. Their approach provides to equilibriums the energy load of each node with packet loss free for the whole network [25]. However, they didn't consider for tracking purposes.

The authors proposed a hierarchical topology for smart homes to guaranteeing secure communication, and consuming small calculating and storage resources [26]. However, they have some problems, such as platform compatibility and security policies regarding to the importance of data also their scheme efficient with fewer resources in the smart home sensor network while their approach inefficient for saving energy in a high mobility system such as Hajj.

Oren et al. proposed the Adaptive Distributed Hierarchical Sensing (ADHS) algorithm. This algorithm changes the rates of the cluster heads (CHs) based on the difference of the sampled data without damaging the accuracy of the sensed data. Each node sends their sensed data to a master node which forwards the new calculated data to the sink node then to the base station. They presented an optimization to the energy consumption of the CHs in a hierarchical wireless sensor network (WSN) topology by using proximity-traversing-based algorithm which named by Hierarchical Control Clustering (HCC) which Consists in two main sub-processes, the first is the Tree Discovery process and the second is the Cluster Formation process. If the sub-tree size is less than 2k, it will form a single cluster for the whole sub-tree. Otherwise, it will form multiple clusters.

This two steps process has a time complexity of O (n), even though it has managed to obtain balanced clustering [27]. However, they didn't consider for tracking purposes.

Bandyopadhyay et al. proposed algorithm that minimized the total energy consumed in the system by forming sensors into a hierarchy of clusters that communicate together to transmit the data to the data processing center. They implemented their approach in the environment that assumed the environment of the communication is contention and errors free which made the algorithm fit for networks of enormous number of nodes [28].However; their proposed clustering schemes are inaccurate for saving energy for a large-scale system especially their implementation in the environment that assumed the communication environment is contention and errors free.

The work of [29]-[33] deals with avoiding interference between Bluetooth and Wi-Fi. The first study investigates these interference issues by simulating the Bluetooth Full duplex communication model in MATLAB Simulink which consists of a sender and a receiver and one of them assigned as master and the other assigned as slave and they also generated 802.11b packet block as an interference source. They used a new Bluetooth voice packet which named by synchronous connection oriented with Repeated Transmission (SCORT) to study the enhancement in performance. By using SCORT packets they could reduce the interference [29]. However, the study focused only on one piconet and they didn't matter about multiple piconets existing in the same area.

The second study focuses on interference avoiding between Bluetooth and Wi-Fi by simulating the Bluetooth Full duplex communication model of the network in MATLAB Simulink. The model consists of a Transmitter and Receiver and one of them should be assigned as master and the other as the slave. They also generated an 802.11b packet block as an interference source; they used the SCORT voice packet as a good solution to reduce the interference [30]. However, the study focused only on one piconet and they didn't matter about multiple piconets existing in the same area.

SejalD'mello et al. proposed a smooth adaptive frequency hopping (SAFH) algorithm that avoids the congested portions of the industrial, scientific, and medical (ISM) band to improve the performance of frequency hopping in the presence of interference by simulating the Bluetooth Full duplex communication model of the network in MATLAB Simulink which consists of master device, slave device and 802.11b packet block as an interference source. Their approach assigns equal probability to all the channels then measures the frame error rate (FER) of all the channels and calculates the average FER. After that updates the hopping probability and generates a new hop set when the average FER exceeds the predefined threshold and at least one of channels has FER below the threshold [31]. However, the study only focuses on one piconet doesn't matter about multiple piconets in a bounded area. Also they did not use any clustering algorithms to improve performance in a large-scale system.

Moreover, study focuses on the outcome when multiple piconets on a carrier sense multiple accesses (CSMA) which based on wireless local area network.

The CSMA protocol is measured for wireless local area networks (WLANS), and the probability of mistake of a WLAN packet is considered in the existence of interfering Bluetooth packets. They simulated the scatternet of Bluetooth devices by using the Bluetooth Full duplex communication model of the network in MATLAB Simulink which consists of master device, slave device and 802.11b packet block as an interference source. The simulation used to analysis the results, which show that the existence of multiple piconets reduces the throughput with larger packet transmissions [32]. However, they didn’t study how to improve the performance in a large-scale area such as Hajj.

Furthermore, the study focuses on interference avoiding between Bluetooth and Wi-Fi and they proposed two interference aware approaches. The first approach minimizes the interference by skipping the frequencies which occupied by Wi-Fi. The second approach to improve throughput of the piconet by restructuring the piconet when master suffers from interference. They used the Bluetooth Full duplex communication model of the network in MATLAB Simulink which consists of master device, slave device and 802.11b packet block as an interference source. They simulated their approaches by Bluetooth Full duplex communication model on four devices, one master, three slaves and 802.11b packet block as an interference source. They could avoid the interference during Bluetooth link construction by skips the channels occupied by Wi-Fi. Also, they could reduce the network overheads by restructuring the piconet when the master suffers from interference which applies the role switching's to restructure a new piconet and will choose a new master when the retransmission rate reaches the threshold and reconstructs the piconet topology during data transmission. Also, they could reduce the energy consumption and the transmission delay for Bluetooth networks [33]. However, the study focused only on one piconet and they didn't matter about multiple piconets existing in the same area.

The Authors proposed a solution for efficient data collection in a large-scale monitoring mobile application based on two approaches. They proposed a hybrid RFID and WSN system (HRW) which has smart nodes that consists of RFID tags, small RFID readers, and wireless sensors. The first approach (the replication approach) that each node replicates its tag data to the neighbor's node. The RFID reader receives all information of nodes from the nodes when they move into the RFID reader range. The second approach (the clustering approach) that each node replicates its tag data to the cluster head node. The RFID reader receives all information of nodes from the cluster heads instead of reading every tag when they move into the RFID reader range. This reduces channel access congestion and long distance transmission interference, also collects the information between nodes in efficient way for a large-scale system such as (Hajj) [6]. However, they approaches are efficient for data collection for a large-scale system and using the smart nodes led to great results, Therefore, in this work, we will simulate the (Smart node) that was proposed by Shen et al. [6].Also we tested it in the laboratory as a real experiments.

Sun Microsystems in collaboration with the University of Fribourg [34] have proposed a web-based application called (RFID-Locator) to enhance the quality of services. RFID-Locator tracks the patients and goods in the hospital to build a smart hospital. All patients in the hospital are given an RFID based on wristband resembling a watch with a passive RFID tag in it. All patients' history and treatment records are stored in a secure centralized database. Doctors have RFID-enabled personal data assistant (PDA) devices to read the patients data determined on the patients RFID bangles.

DSouza et al. [35] have proposed a wireless localization network to follow the location of patients in indoor environments as well as to monitor their status i.e. walking, running, etc. Authors deploy static nodes at different locations of the hospital that interact with the patients mobile units to determine the patient position in the building. Each patient carries a small mobile node that is consisting of a small sized Fleck Nano wireless sensor and a three-axis accelerometer sensor in order to monitor their physical status.

Chandra-Sekaran et al. [36] have proposed a location-aware WSN to track people in a disaster site using a ranging algorithm. The ranging algorithm is based on received signal strength indicator (RSSI) environment and mobility adaptive (REMA) filter. The REMA filter can estimate the real-time localization of people at the disaster site using RSSI and Global Positioning System (GPS).

Xiaoguang and Wei [37] have proposed an adaptive communication framework to build a smart hospital warehouse based on integration between RFID and

WSN. The main components of the proposed solution include RFID tags, sensors, reader and center data platform. Authors evaluate their solution based on three network architectures Heterogeneous network architecture, Smart sensor tag network architecture, and smart reader network architecture.

Charalampos and Ilias [38] have developed a Cloud-based system consists of sensors, sensors getaway, and communication APIs provided by the Cloud platform the system manage and collect the data (bio signals, motion data and contextual data) forward this data to the cloud using wireless technology then to external application which provides the necessary real-time data monitoring and management. The results are promising but too much work is needed in the security and encryption of the collected data also in energy efficiency area.

Similar to [38], authors in [39] focused on healthcare area and provided a survey shows the current study on RFID sensing from the viewpoint of IoT for individual healthcare also prove that (RFID) technology is now established to be part of the IoT. On the other hand, the paper reveals many challenging issues, for example, the reliability of the sensors and the true dependence of the reader's node.

There are even more advanced solutions provided in [40] the authors proposed iHome approach which consists of three key blocks, the iMedBox, the iMedPack, and the Bio-Patch. RFID tags are used to enable communication capabilities to the iMedPack block also flexible and wearable biomedical sensor devices are used to collect data (Bio-Patch).

Another Smart Healthcare System proposed in [41] to monitor and track patients, personnel, and biomedical devices automatically using deferent technologies RFID, WSN, and smart mobile. In order to allow these different technologies to interoperate a complex network communications relying on a CoAP, 6LoWPAN, and REST paradigms have been implemented two use cases implemented and the result proved a good performance not only to operate within hospitals but to provide power effective remote patient monitoring.

Gope and Hwang [42] have proposed a secure IOT healthcare application using body sensor network (BSN) to monitor patient's health using a collection of wireless sensor nodes. In addition, the system can efficiently protect patient's privacy by utilizing a lightweight anonymous authentication protocol, and the authenticated encryption scheme offset codebook (OCB). The lightweight anonymous authentication protocol can achieve mutual authentication, preserve anonymity, and reduce computation overhead between nodes. The OCB block cipher encryption scheme is well-suited for secure and expeditious data communication as well as efficient energy consumption.

Table 1 show the summary of the literature survey which consists of the references and their approaches and the limitations and gaps of the related work.

Reference #, Year	Approach	Type of Analysis	Limitations and Gaps
[23],2017	A clustering algorithm in wireless sensor network.	Simulation	General clustering algorithms without focusing on tracking purposes.
[27],2017	Adaptive Distributed Hierarchical Sensing (ADHS) algorithm.	Simulation	They didn't consider for tracking purposes.
[13],2016	Mobile Anchor Node Assisted Localization (MANAL) algorithm.	Simulation	The study didn't consider for tracking purposes.
[26],2016	Hierarchical topology for smart homes to guaranteeing secure communication.	Experiment	However, they have some problems, such as platform compatibility and security policies regarding to the importance of data.
[33],2016	They proposed approach to minimize the interference by skip the frequencies which occupied by Wi-Fi. The second approach to improve the throughput of the piconet by restructuring the piconet when master suffers from interference.	Simulation	However, the study focused only on one piconet and they didn't consider multiple piconets existing in the same area.
[42],2016	A secure IOT healthcare application using body sensor network (BSN) to monitor patient's health using a collection of wireless sensor nodes.	Experiment	However; their approach needs more infrastructures.

[7] , 2015	Hybrid approach of BLE tags (beacon) with assistance of smartphone GPS.	Experiment	The beacon is one way communication. Also it was not possible in their deployment to restrict the location of smartphones within the groups. They used 732 pilgrims as volunteers in their experiment.
[9],2015	Localization method by using BLE tags with assistance of GPS.	Experiment	The beacon is one way communication.
[10],2015	Localization method by using smartphone sensors and beacons.	Experiment	The beacon is one way communication.
[11],2015	Bluetooth-based ad-hoc network for voice transmission over Local Area Network.	Simulation	They didn't do an analysis of the Bluetooth-based ad-hoc network via a large-scale area.
[12],2015	BLE mesh approach.	Experiment	Focused only on the navigation. Also the beacon is one way communication.
[25],2015	The authors proposed a two tier energy efficient clustering approach.	Simulation	They didn't consider for tracking purposes.
[41],2015	Monitor and track patients, personnel, and biomedical devices automatically using deferent technologies RFID, WSN, and smart mobile.	Experiment	However; their approach needs more infrastructures of wired and wireless sensor network.
[8],2014	Wearable BLE devices utilizing GPS.	Experiment	The beacon is one way communication. Also the network size is very small, only 41 applicants.
[22],2014	A hybrid wired and wireless sensor network technique to find the optimum positions of cluster heads.	Simulation	Their approach is inefficient for saving energy in a high scalability system such as Hajj which needs more infrastructures of wired and wireless sensor network.

[24],2014	A trustworthy energy efficient algorithm in wireless sensor network.	Simulation	However they didn't varying the number density of nodes, therefor their approach is inefficient for saving energy in a high mobility system such as Hajj.
[39],2014	A survey shows the current study on RFID sensing from the viewpoint of IoT for individual healthcare.	Experiment	They reveal many challenging issues, for example, the reliability of the sensors and the true dependence of the reader's node
[40],2014	IHome approach which consists of three key blocks, the iMedBox, the iMedPack, and the Bio-Patch.	Experiment	The study didn't consider for tracking purposes.
[14],2013	Eenergy-efficient algorithm for wireless heterogeneous networks.	Simulation	The study didn't consider for tracking purposes.
[18],2013	Energy efficient algorithm.	Simulation	Didn't consider for tracking purposes.
[19],2013	They presented energy efficient algorithm.	Simulation	Did not consider the optimal size of mobile clusters to minimize energy consumption.
[28],2013	Energy efficient algorithm by forming sensors into a hierarchy of clusters.	Simulation	However, their hierarchy clustering schemes are not suitable for saving energy for a large-scale system especially their implementation that assumed the communication environment with error free.
[38],2012	A Cloud-based system which provides the necessary real-time data monitoring and management.	Experiment	The results are promising but too much work is needed in the security and encryption of the collected data also in energy efficiency area.

[16],2011	A mobile clustering procedure based on cooperation.	Simulation	This approach is inefficient for saving energy with a high mobility especially when the number of nodes in the WLAN Ap coverage is larger than threshold of WLAN AP.
[30],2011	They focused on interference avoiding between Bluetooth and Wi-Fi.	Simulation	However, the study focused only on one piconet and they didn't matter about multiple piconets existing in the same area.
[31],2011	They proposed a smooth adaptive frequency hopping (SAFH) algorithm to improve the performance of the interference.	Simulation	However, the study focused only on one piconet and they didn't matter about multiple piconets existing in the same area.
[32],2011	They study focused on the outcome when multiple piconets on a carrier sense multiple accesses (CSMA) which based on wireless local area network.	Simulation	However, they didn't study how to improve the performance in a large-scale system such as Hajj.
[15],2010	A rate adaptive position system for smartphone applications (RAPS) based on GPS positioning for smartphone.	Experiment	Using everybody's smartphone's GPS and Wi-Fi is not energy efficient solution because require higher power.
[29],2009	Synchronous connection oriented with Repeated Transmission (SCORT) to study the performance of the interference.	Simulation	However, the study focused only on one piconet and they didn't matter about multiple piconets existing in the same area.

[36],2009	They proposed a location-aware WSN by using a ranging algorithm.	Experiment	However, using everybody's GPS is not energy efficient solution because require higher power.
[35],2008	They proposed a wireless localization network to follow the location of patients in indoor environments as well as to monitor their status.	Experiment	However, using everybody's smartphone's GPS and Wi-Fi is not energy efficient solution because require higher power.
[37],2008	They proposed an adaptive communication framework to build a smart hospital warehouse based on integration between RFID and WSN.	Experiment	They revealed to many challenging issues, for example, the reliability of the sensors and the true dependence of the reader's node.
[17],2007	They surveyed multiple clustering approaches for wireless sensor networks.	Simulation	They didn't consider for tracking purposes.
[34],2006	They proposed RFID-Locator that tracks the patients in smart hospital.	Experiment	The results are promising but too much work is needed in the security and encryption of the collected data also in energy efficiency area.
[21],2002	They proposed several clustering algorithms for nodes in a mobile ad hoc network.	Simulation	They didn't consider for tracking purposes.
[20],2001	They proposed a mobile clustering procedure which called by mobile ad hoc networks (MANET).	Simulation	They didn't consider for tracking purposes.

Table 1: The summary of the literature survey

CHAPTER 3

EFFICIENT TECHNIQUE BASED ON MOBILE CLUSTERING OF THE BLUETOOTH NETWORK

In this chapter, efficient technique based on mobile clustering of the Bluetooth network that ensures energy-efficient for a large-scale tracking system is presented as follows: the first section presents the efficient technique based on 1st-level mobile clustering of the Bluetooth network. The efficient technique based on 2nd-level mobile clustering of the Bluetooth network is presented in the second section. Finally, the third section describes the android application that ensures energy-efficient for a large-scale tracking system

3.1 1st-level mobile clustering of the Bluetooth network

The recent smartphones are capable of activating tracking systems by exploiting GPS and WLAN technologies for positioning and communication. However, for large-scale tracking systems, which track the random movement of people, the continuous usage of a person smartphone's GPS and Wi-Fi is not an energy-efficient solution. In this section, an energy-efficient solution is proposed for large-scale tracking systems without using everybody's smartphone's GPS and Wi-Fi by grouping nearby smartphones to form a cluster. A cluster, also called a piconet, is a small network that consists of a cluster head and cluster members that communicate locally via Bluetooth. In Bluetooth specifications [4], we can form a cluster, which consists of one master (cluster head) and up to seven slaves (cluster members).The master is responsible for providing positioning information as well as sharing information with the rest of the slaves and also with the back-end server.

3.1.1 Proposed solution

The main goal of our approach is to build a cooperative mobile clustering for tracking purposes with reduced energy consumption. It is assumed that we have a large group of moving nodes, (each with their own cell phone) that will be divided into small clusters (groups). The cluster, also called a piconet, consists of one master and up to seven slaves (according to standard [4]). The master is responsible for positioning and sharing information with the rest of slaves and with the back-end server. Clusters reside within small areas, so communication within clusters can be done via a short-range radio interface that consumes low power such as Bluetooth.

We used in our approach Bluetooth version 4.2 which introduces a number of new features that improve speed (250 % faster), ten more capacity and more secure also allowing only reliable owners to track device location and confidently pair devices also has IoT capabilities because low power consumption also can transmit the data over internet [4].

Figure 1 illustrates the concept of the piconet. The construction of the piconet depends on the choice of a master node from the set of devices in the same range. Each device will broadcast specific information to all devices in its range, such as its battery level and Wi-Fi connection availability. This information is important for sustain ability of the piconet. All users will initiate a table containing nominees to be the master of the new constructed piconet. The device that has the highest battery level and Wi-Fi connection will be chosen as the master of this particular piconet. Then, it will start communicating with other devices to join its cluster (i.e. these users are considered slaves).

Afterward, the process of data exchange will start between the slaves and the master, which is responsible for transferring all data to the back-end server, where this data will be stored and processed. Then, after specific period, new clusters are formed and new masters will be selected along with their children (i.e. slaves).The ranking of the list will be refreshed periodically and the new highest ranked user will be assigned as master. This procedure guarantees fair load distribution among multiple devices to attain maximum lifetime of the network and avoiding draining the battery of any individual device.

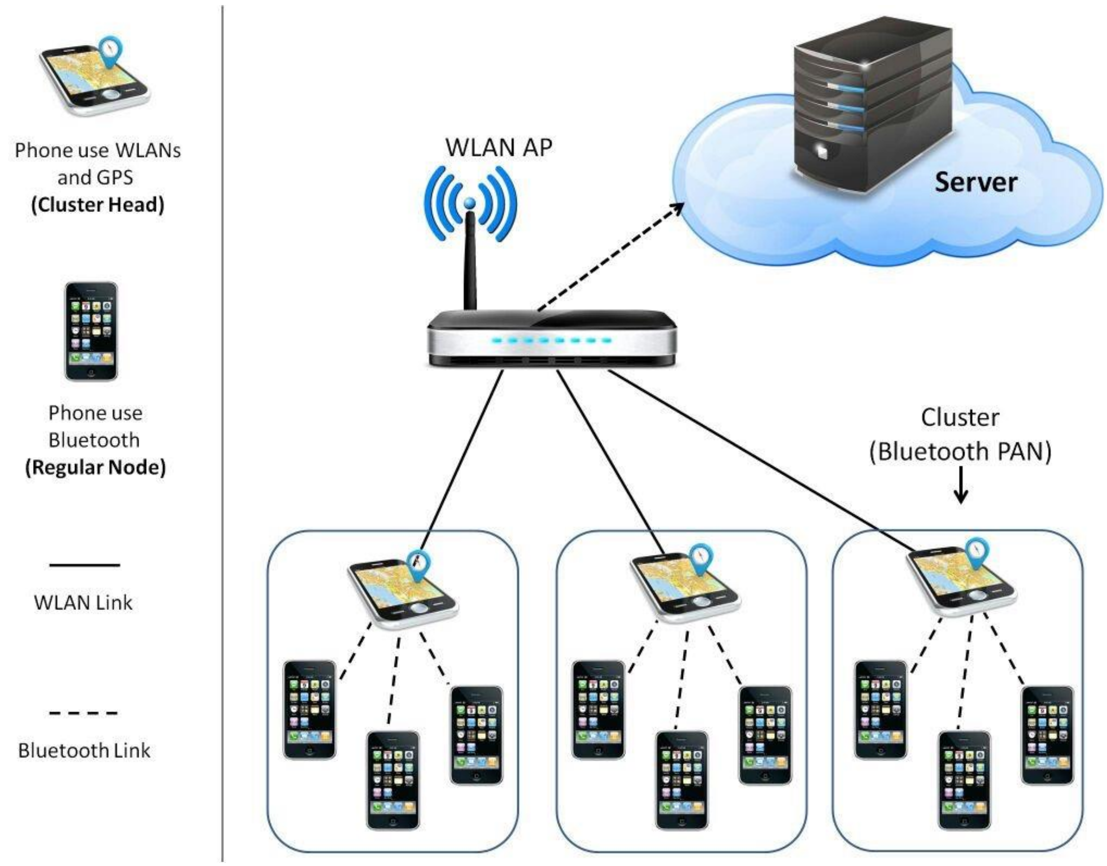

Figure 1 Proposed solution (1st-Level Clustering Bluetooth Network); slaves use Bluetooth technology while masters use Wi-Fi to exchange information with back-end server.

Distribution Clustering Algorithm

Our goal is to design an energy-efficient, low-interference tracking system based on mobile clustering that satisfies the requirements of large-scale environments. To accomplish this goal, the cost function of our clustering algorithm focuses specifically on node battery level and Wi-Fi connection availability. In order to achieve our goal the following requirements must be met:

- Each node creates its decision based on its local information.
- Each node can be either a cluster head (master) or cluster member (slave) that belongs to exactly one cluster.
- Clusters must include all nodes, without any overlap (common nodes) between different clusters.
- Message exchange should be efficient in order to meet clustering processing requirements.

Pseudo Code and Flow Chart

Pseudo Code

```
Boot Up
Broadcast data
If N>0 (N: Number of nodes)
 For i= 1: N /clustering Bluetooth Network
  IF (i has Wi-Fi)
         Update possible Master
  Else
         Update possible Slave
  End if
  IF (i has highest battery level {BL})
         Update become Master
  End if
```

```
    For j = 1: possible Slave
     IF (Dij<= 10)// Bluetooth range
           Update M-possible Slave
     End if
     IF (M<= 7)
           Update become Slave
     Else
           Update closest 7 to become Slave
     End if
    Update N = N- cluster size
  Else
 End if
```

Figure 2 describes our algorithm in detail. When all nodes are booted up, each node will broadcast its battery level and Wi- Fi connection availability to all nodes in its range. After that, all nodes that have Wi-Fi connection availability are eligible to be cluster head, and the nodes that don’t have Wi-Fi are eligible to be cluster members. Next, the node, which has the highest battery level, will be chosen as the master node (cluster head) of the particular piconet, and the closest (up to seven) nodes can join as slaves (cluster members). The construction process continues until each node is assigned either as a cluster head or a cluster member that belongs to exactly only one cluster at the end of the clustering procedure.

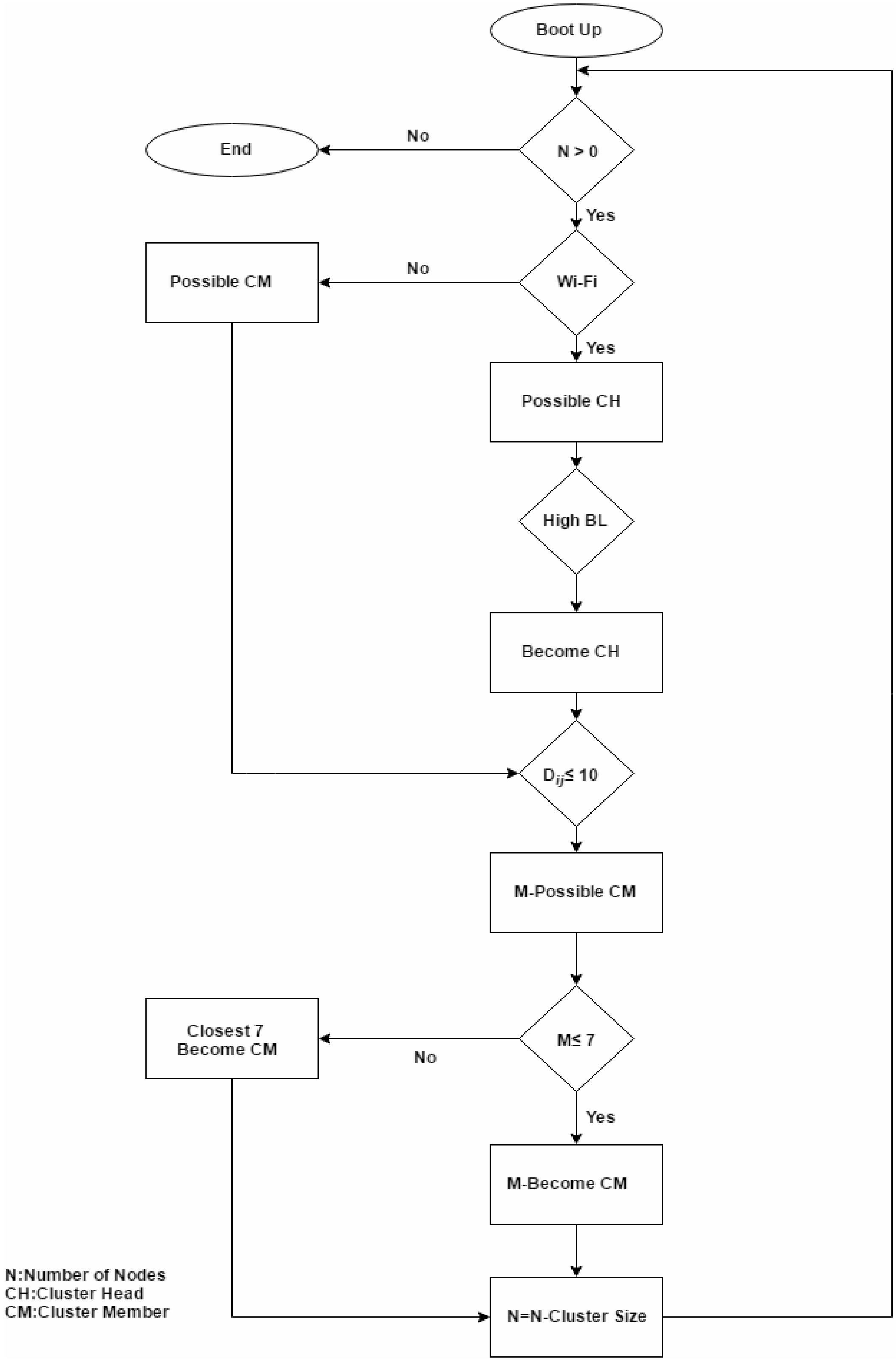

Figure 2 Flow Chart of 1st-Level Clustering Algorithm

3.1.2 The Mathematical Model

In order to achieve the goals of efficient energy consumption and good quality of service, the following objectives must be optimized:

- Minimizing the number of clusters.

- Minimizing the total distance between masters (cluster head) and slaves (cluster members)

The first objective is sought because minimizing the number of the clusters leads to reducing the energy consumption, which leads to maximize network lifetime. Moreover, minimizing the number of clusters reduces channel access congestion, which reduces the interference among Bluetooth- based clusters as well as Bluetooth/Wi-Fi connections when they are employed in the same area.

The second objective, minimizing the total distance between masters (cluster heads) and slaves (cluster members), leads to higher accuracy of positioning. Since the master node will represent all its children in respect to the positioning in- formation, communicating via short-range radio interfaces such as Bluetooth< 10m)is more accurate than communicating via long-range radio interfaces. The expected error is ±10m. Furthermore, it reduces the energy consumption and the transmission delay for Bluetooth networks, since communicating via short-range radio interfaces such as Bluetooth consumes lower power than communicating via long-range radio interfaces.

Let i=1 to n denote the slave number, j=1 to n denote the master number and Cij denote the distance between node i and node j.WF denote the availability of Wi-Fi service in user's smartphone as in (1). The user's battery level (BL) is defined as in (2). The terms 3 and 4 deals with the decision variables of our model, that equal one if slave i is connected to a master j and zero otherwise and that equal one if the device j is assigned as a master and zero otherwise, respectively.

$$WF = \begin{cases} 1, & \text{if device has Wi} - \text{Fi} \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

$$BL = \begin{cases} 1, & \text{if batterylevel} \geq 50\% \\ 0, & \text{otherwise} \end{cases} \tag{2}$$

$$X_{ij} = \begin{cases} 1, & \text{if slave } i \text{ is in the cluster of master } j \\ 0, & \text{otherwise} \end{cases} \tag{3}$$

$$Y_j = \begin{cases} 1, & \text{if node } j \text{ is a master.} \\ 0, & \text{otherwise} \end{cases} \tag{4}$$

The mathematical model for this problem is given by (5). The objective is to minimize Z, which consists of two terms , the first term deals with minimizing the total distance between masters (cluster heads) and slaves and the second term deals with minimizing the number of clusters (masters) for the clustering Bluetooth network.

The objective function is to minimize Z, subject to five constraints. The first constraint (I) is to ensure every slave has a master. Constraints II and III limit the cluster size to 8 (i.e. one master besides 7 slaves) and ensure that clusters are within the Bluetooth range of 10m, respectively. The last constraints IV and V ensure that the master has Wi-Fi and a battery level of greater than or equal to 50%, respectively. The fixed cost of each master is denoted by F and it is equal to 100.

$$\text{Min } Z = \sum_{i=1}^{n}\sum_{j=1}^{n}\left(C_{ij}X_{ij}\right) + F\sum_{j=1}^{n} Y_j \text{, subject to:}$$

$$\begin{array}{ll} \text{I.} & \sum_{j=1}^{n} X_{ij} = 1\,, i = 1 \ldots n \\ \text{II.} & \sum_{i=1}^{n} X_{ij} \leq 8\,Y_j, j = 1 \ldots n \\ \text{III.} & \sum_{j=1}^{n} C_{ij}X_{ij} \leq 10\,, i = 1 \ldots n \\ \text{IV.} & Y_j \leq WF \\ \text{V.} & Y_j \leq BL \end{array} \tag{5}$$

3.1.3 The performance evaluation experiments and discusses the achieved results

In this section, we evaluate the performance of the proposed approach by finding the optimal solution and via simulation. We begin by describing the optimal solution and then discuss the simulation results.

Optimization Solution

The General Algebraic Modeling System (GAMS) is designed for modeling and solving linear programming (LP), nonlinear programming (NLP), and mixed integer programming (MIP) optimization problems [43]. Since the above model described in (5) is a binary integer program, it was solved by the MIP feature of GAMS. GAMS Version 24.3.3 was used, and the problem was setup with four different scenarios.

The first and second scenarios tackle the problem by solving each term in the objective function separately. The first case solves for minimizing the first term (total distance) by reading the input data (*WF*, *BL* and *Cij*). The second scenario solves for minimizing the second term (number of clusters) of the objective function.

The third and fourth scenarios consider both terms of the objective function together. The fourth scenario applies the sensitivity analysis by fixing the number of nodes first to 700, and then 800. This is done by changing the maximum distance between master and slave (changing the RHS) in constraint III in (5). In addition, sensitivity analysis is applied to 700 and 800 nodes, respectively, by changing the fixed cost of each master, *F*, and calculating the optimal value of the objective function (the number of the clusters).

All above scenarios are studied under the following environment. The size of the service region is set as 10×20 m2. We have calculated the optimal value (the total minimum distances and number of clusters) of the objective function by using GAMS (MIP) solver of 100, 200, 300, 400, 500, 600, 700, and 800 nodes, respectively. In order to achieve 95 % confidence interval, each simulation experiment was repeated ten times using different random topologies.

Figure 3 shows the results for scenario 1 (minimizing total distance). As the number of nodes increases, it can be observed that the total distance between masters and slaves is reduced on average. For example, with 100 nodes, the minimum distance is 1m, whereas with 800 nodes it is about 0.6m. Therefore, clustering is very efficient, especially for a large-scale system. A higher accuracy of positioning can be achieved, since short-range radio interfaces are more effective than long-range radio interfaces for localization. Shorter distances can also reduce the energy consumption and the transmission delay of Bluetooth networks.

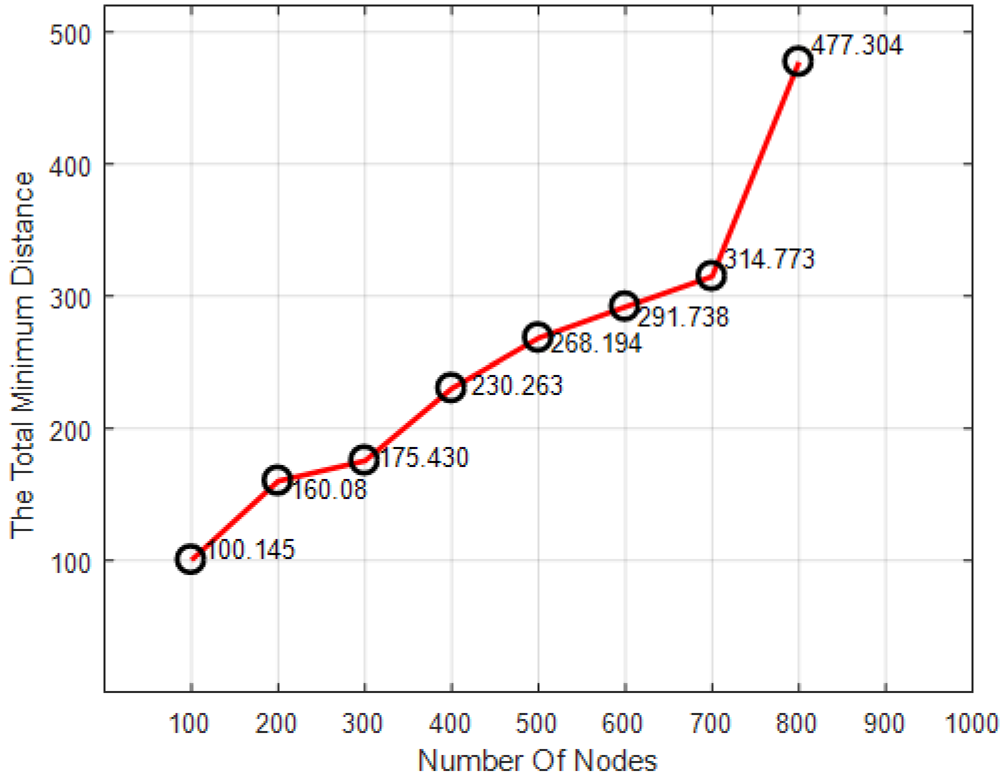

Figure 3 The total minimum distance (for scenario 1)

Figure 4 illustrates the results for scenario 2 (minimizing the total number of clusters). It can be observed that for up to 600 nodes, one cluster can handle between 6-7 nodes. However, when there are 800 nodes, each cluster can consist of up to 8 nodes so there can be more slaves per master. Once again, this is very efficient for a large-scale system, because there will be less channel access congestion. Furthermore, interference among Bluetooth signals of different nodes or between Bluetooth and other 2.4 GHz technologies such as Wi-Fi can be reduced. Lastly, energy consumption is reduced, thus maximizing network lifetime.

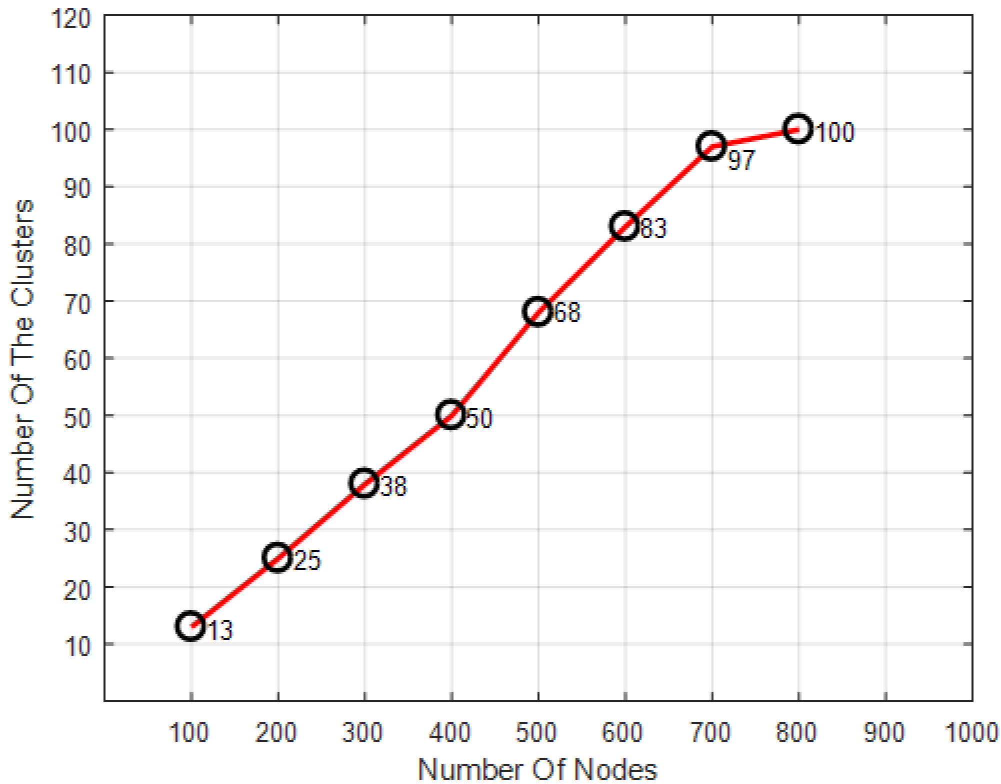

Figure 4 Optimal numbers of the clusters (for scenario 2)

Figure 5 and Figure 6 display the results for scenario 3 that combines the two objectives together (total distance and number of clusters). It is clear that the number of the clusters increases when the number of nodes increases in the model. Figure 5 shows for a small number of nodes (such as 500 and 600), we can still have 8 nodes per cluster. More benefits of combining both terms of the objectives will appear in the sensitivity analysis. The value of the fixed cost per master (*F*) as in (5) is set to 100 to have an effective balance between both terms of the objective function.

Figure 6 shows that the total minimum distance allowed can be increased. In Figure 3 the total distance of 100 nodes is equal to 100.145, whereas in Figure 6 the total distance of 100 nodes is equal to 140.768 (1540.768 – F*number of clusters (100*14)).

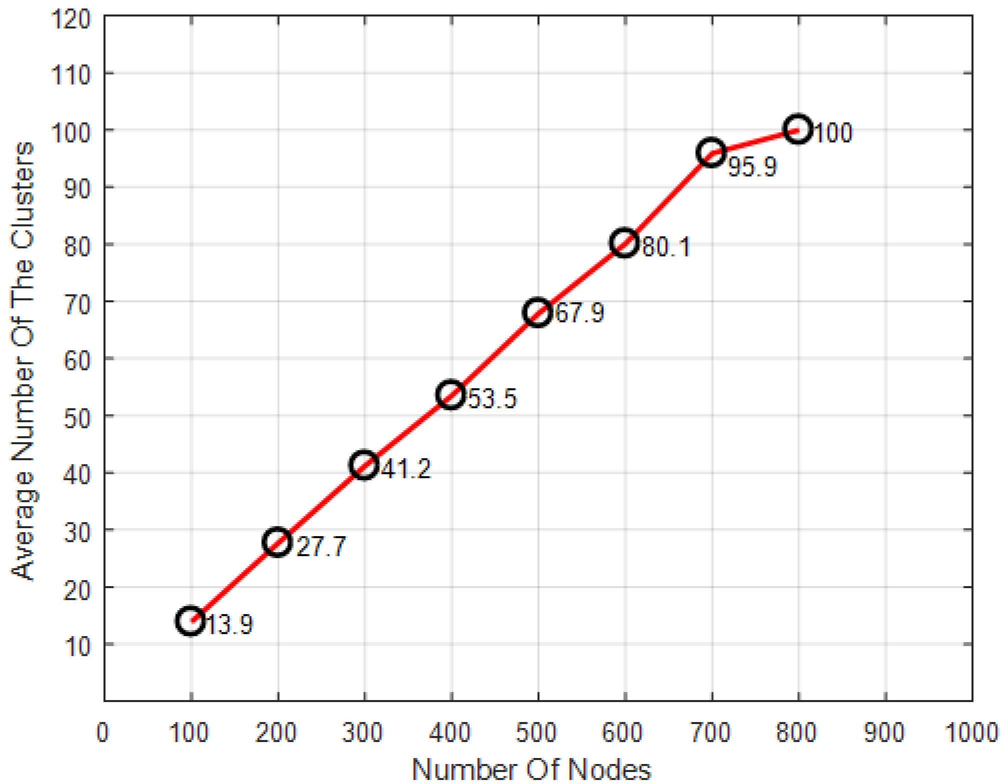

Figure 5 Optimal numbers of clusters (for scenario 3)

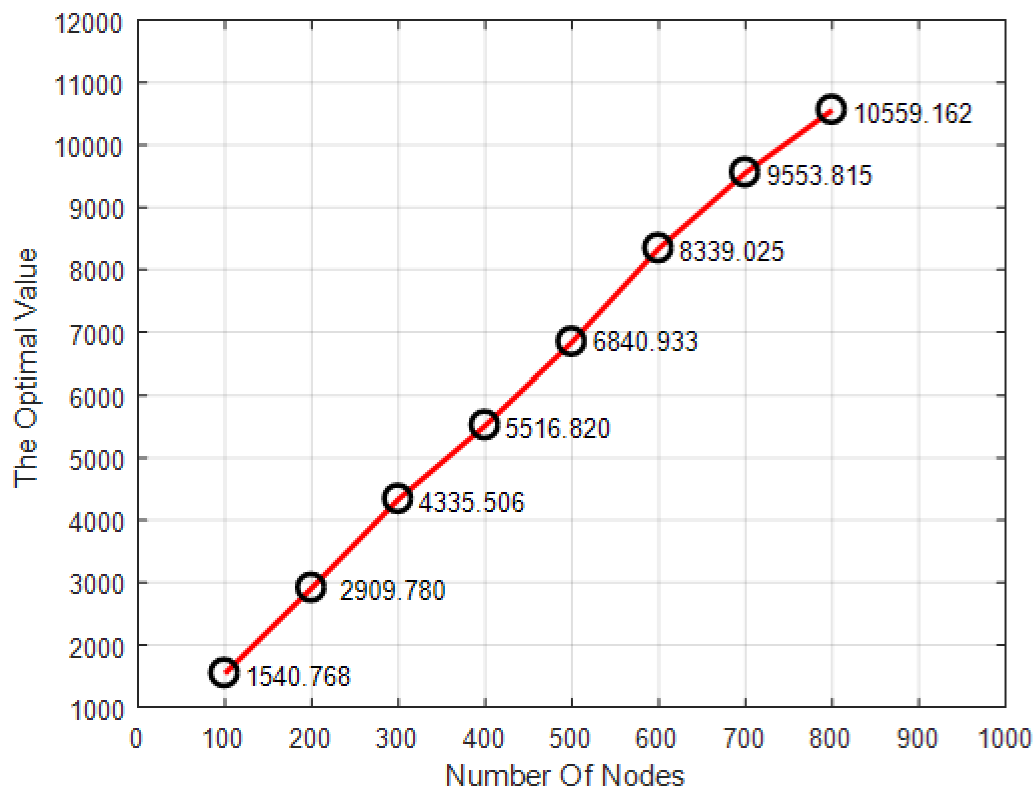

Figure 6 The optimal objective function value of model (for scenario 3)

Figures 7-9 present the results for the sensitivity analysis applied to a system of 700 and 800 nodes, respectively. Figure 7 shows the optimal number of clusters; the distance between master and slave is varying between 2m to 10m. For 700 nodes, the number of the clusters will be optimal when the distance between master j and slave i is equal to 6m, which implies 88 clusters. For the case of 800 nodes, the number of clusters stays the same when the distance between master j and slave i is changed. Therefore, the clustering is very efficient, especially for highly populated areas.

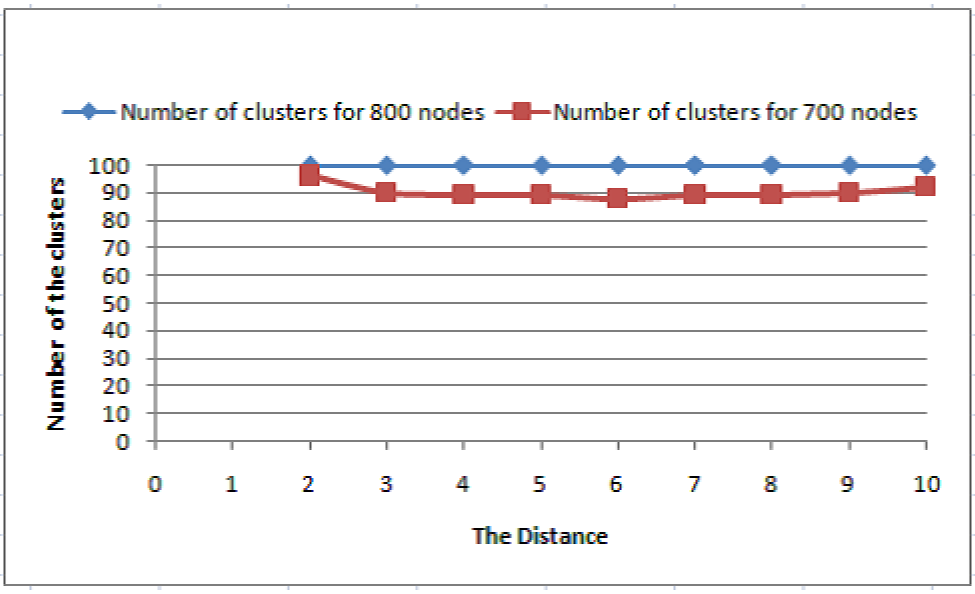

Figure 7 Optimal numbers of clusters versus the maximum allowable distance between a master and slave nodes

Figure 8 displays the total distance of the model when the value of fixed cost (*F*) is equal to 10E where E = 0, 1, 2…, 10. For 700 nodes, the optimal (minimum) total distance is 353m, which is obtained when *F* is equal to 100. For the case of 800 nodes, the optimal total distance is 559m, which is also obtained when *F* is equal to 100.These numbers seem to be well-suited for a large-scale system.

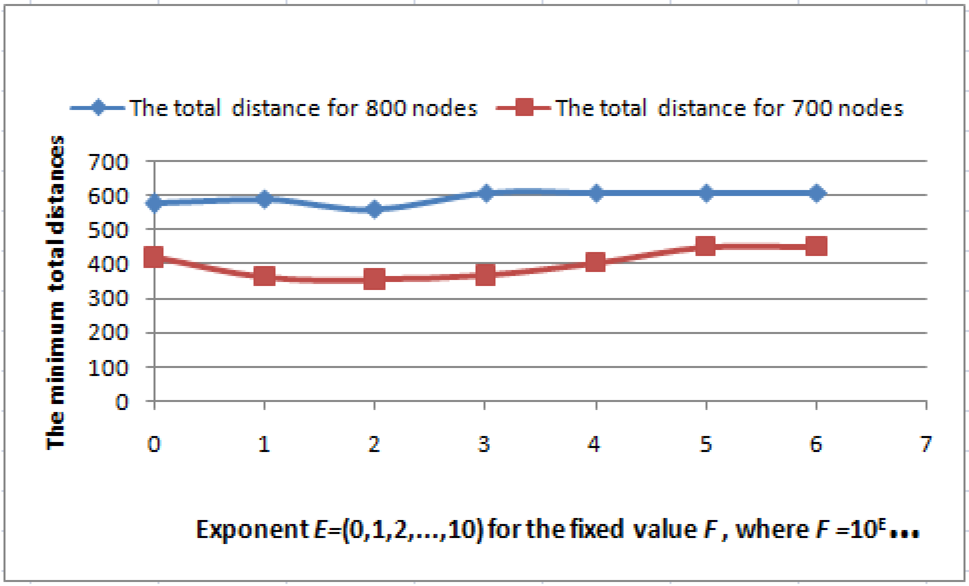

Figure 8 The total distance when changing F

Figure 9 shows the optimal number of the clusters when the value of fixed cost (F) is equal to 10^E where E = 0, 1, 2…, 10. For 700 nodes, the optimal (minimum) number of the clusters is 88 clusters, which is obtained when E = 5, or F is equal to 10^5. However, when this value (F= 10^5) is used, the performance significantly deteriorates for the other objective function (the total distance). As discussed before in Figure 8 the best total distance with 700 nodes is 353, which is achieved when F is equal to 100. On the other hand, the total distance increases to 449 when F is equal to 10^5. If we simply sum the values from Figures 8 and 9 for 700 nodes, the best value of F would be equal to 100 to attain the effectively for both terms. For the case of 800 nodes, the optimal number of clusters remains the same while F is varying. This shows that the clustering method is quite effective for large-scale systems.

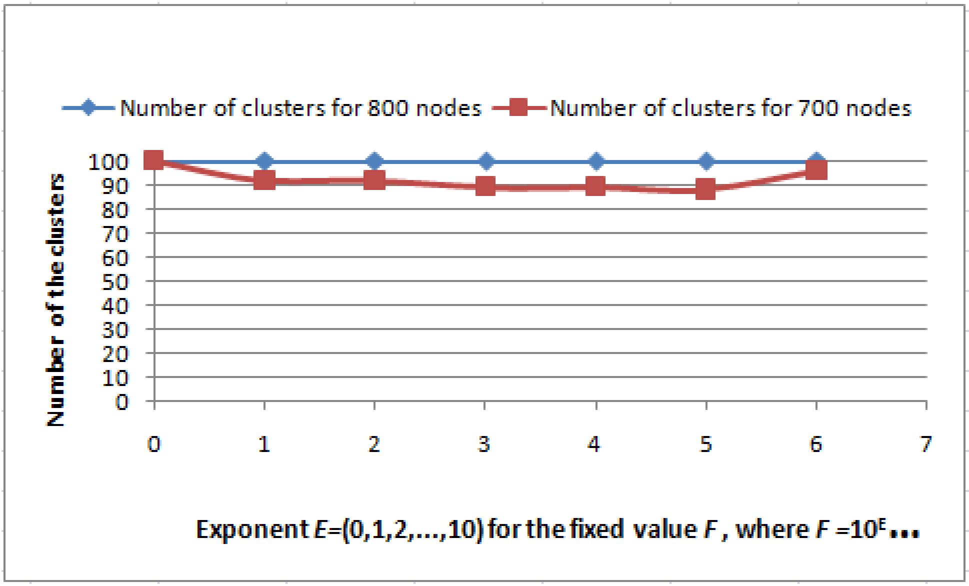

Figure 9 Optimal numbers of clusters when changing F

Simulation Experimental Setup

We evaluate the performance of our approach by using MATLAB Simulink. MATLAB Simulink is a leading tool used to study the properties of the Bluetooth and WLAN. Our study models the radio frequency mechanism of the Bluetooth full duplex voice and data transmission model (transceiver) [44][45]. Each transceiver consists of binary data generator, Gaussian frequency shift keying (GFSK), pseudo-random number generator to create frequency hopping, and matching receiver [46][47][48]. As an interference source, the 802.11 packet block is generated by a separate independent block. We have used the Bluetooth full duplex voice and data transmission model, which is more realistic for the standard Bluetooth.

Figure 10 depicts the full duplex communication between two Bluetooth devices. The model consists of a sender and a receiver, where one of them should be assigned as the master and the other one as slave. Furthermore, an 802.11b packet block is created as an interference source by a separate independent block. The data packets and voice packets can be transferred between the two devices: Supported voice packet types are HV1, HV2, HV3 and SCORT and Supported data packet types: DM1 [49][50].

The model shown in Figure 10 helps us to do the performance evaluation of Bluetooth network: scatternet and piconet in the existence of interference. As an interference source, the 802.11 packet block is generated by a separate independent block to be able to measure the interference between Bluetooth/Wi-Fi when existence in the same area. we know the Bluetooth uses 79 radio frequency channels in this ISM band, starting at 2402 MHz end up with 2480 MHz [4] .Therefore to be more accurate we also need to measure the interference between Bluetooth itself so we modified the model by adding the transmitting power signal as we see in Figure 11 to be able to measure the interference between Bluetooth itself. The flow data volume of each Bluetooth device is assumed to be stable in the piconet.

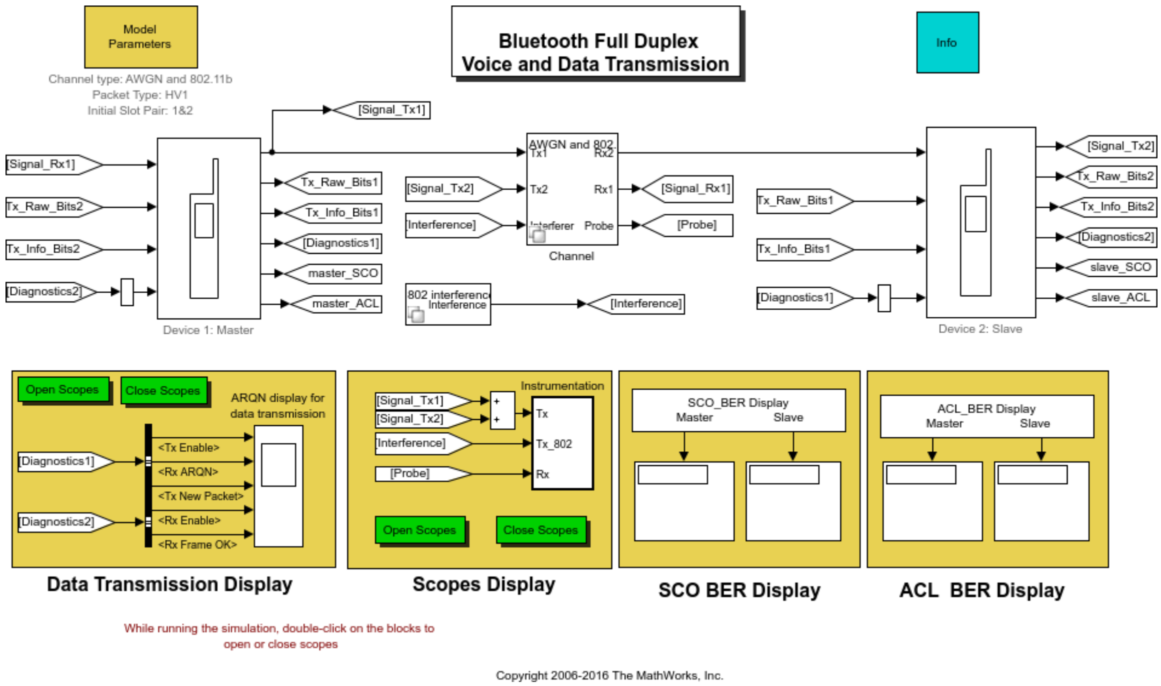

Figure 10 Bluetooth Full Duplex Voice and Data Transmission model

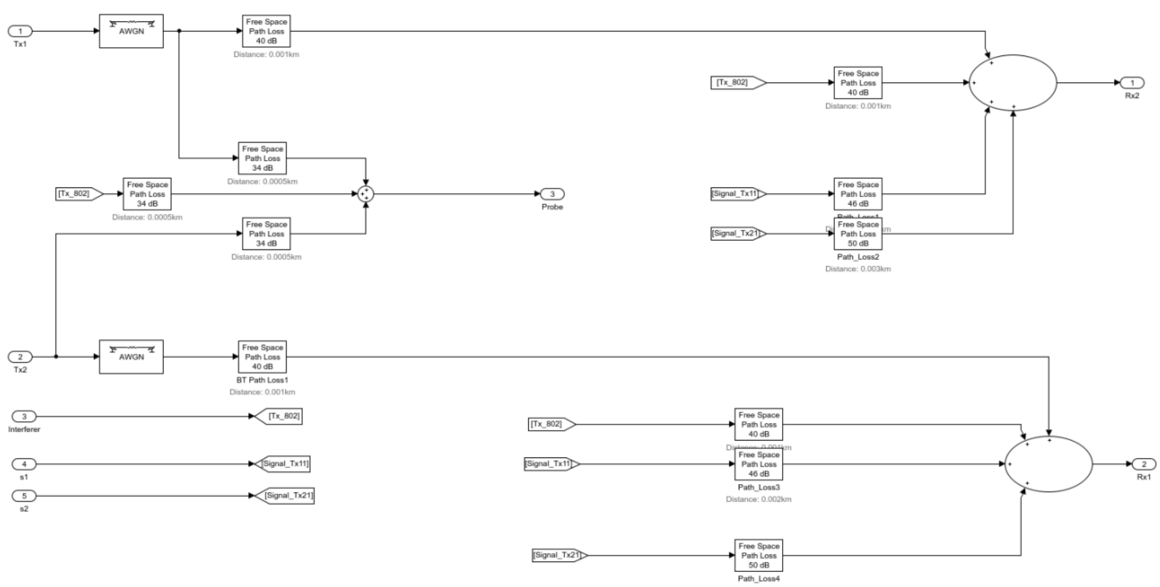

Figure 11 Adding the transmitting power signal to the model

Since we are interested in study Bluetooth piconets for highly populated area, this model considers N Bluetooth piconets existing together in an area of 10×10 m^2. Therefore, each piconet experiences interference by N-1 possible interfering piconets. If two or more piconets (clusters) send out a packet on the same frequency band at any time, the corresponding packets collide and are considered lost. As per Bluetooth standard, all clusters employ frequency-hopping technique where a random channel is selected among 79 frequency channels. This model is able to capture the interference between Bluetooth piconets and between a Bluetooth piconet and Wi-Fi when both exist in the same range [51][52]. Figure 12 shows the average frame error rate for one piconet, which consists of one master and one slave1that are affected by N-1 piconets.

We used DM1 data packet type and we calculated the average Frame Error Rate (FER) of the piconet for each master and slave with different number of piconets. We also changed the distance to surrounding piconets randomly from (0.1 to 10 meters) and calculated the average frame error rate for twenty times in order to achieve 95 % confidence interval. We assumed that the flow data volume of each Bluetooth device is fixed in the piconet with frame size 20 byte (160 bits).

Figure 12 illustrates that the average FER of the master is greater than the average FER of the slave. It also shows as expected that the average FER increases when the number of the clusters (piconets) increases and causes higher interference. Therefore, our approach minimizes the number of clusters to reduce the channel access congestion, thus reducing the interference within the Bluetooth itself also between Bluetooth and Wi-Fi.

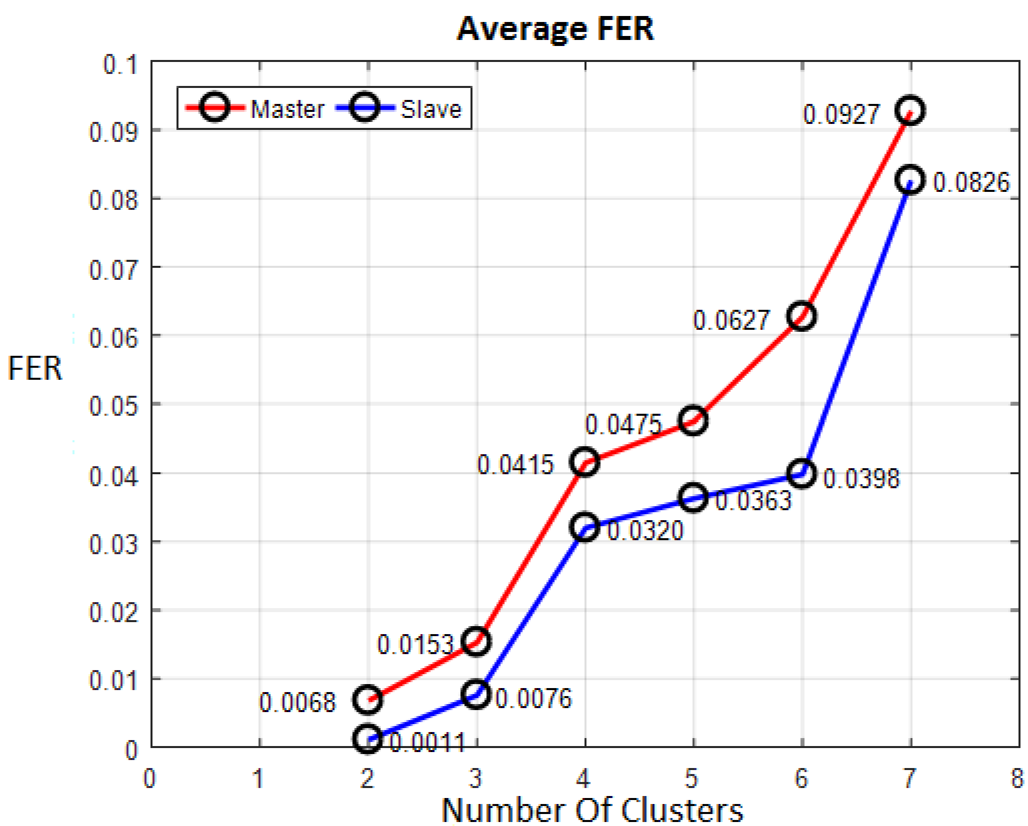

Figure 12 Average frame error rate of Simulink experiments for multiple Bluetooth coexisting piconets

Performance Metrics

We have evaluated the performance of the direct approach, the proposed clustering approach, and the optimal GAMS solution. We have evaluated the performance of the algorithm using Matlab. The total energy consumption and throughput in each round were calculated for different number of nodes, up to 800 nodes. Each node can send data traffic at a rate of 1,000 kbps and it can send frames with sizes up to 20 bytes which is sufficient to send health information messages. For the hardware (Bluetooth/Wi-Fi) energy consumption, we use the same values as in [53]; the simulation parameters are summarized in Table 2. In order to achieve 95 % confidence interval, each simulation experiment was repeated ten times using different random topologies.

$$TE = TE_{CH} + TE_{CM} + TE_{idle} \tag{6}$$

$$Throughput = N * CS * FS * Pc \tag{7}$$

$$Efficiency = Throughput/TE \tag{8}$$

TE is the total energy consumption of all nodes, which is the sum of energy consumption by cluster heads TE_{CH}, energy consumption by cluster members TE_{CM}, and energy consumption by idle nodes TE_{idle}.

Throughput is defined as the total number of successfully received bits, *N* is the number of rounds, cluster size *CS*, frame size *FS*, and frame correction rate *Pc*, where (*Pc* = 1 – FER).

Efficiency which is defined as the throughput divides by the total energy consumption.

Parameters	**Values**	**Comments**
P^WA	1100 mW	Active Tx/Rx power of WLAN
P^WI	880 mW	Idle listening power of WLAN
P^BA	220 mW	Active Tx/Rx power of Bluetooth
P^BI	120 mW	Idle listening power of Bluetooth
R^W	54 Mbps	Maximum bit rate of WLAN
R^B	2 Mbps	Maximum bit rate of Bluetooth
P^{GPS}	1500 mW	Power of GPS

Table 2: Simulation Parameters and Values

Simulation Results

We have presented the performance of the direct approach, the proposed clustering approach, and the optimal GAMS solution.

Figure 13 shows the average throughput of the proposed approach for different values of the total number of nodes. It is assumed that the frame size is equal to 20 bytes, which is sufficient to send health information messages.

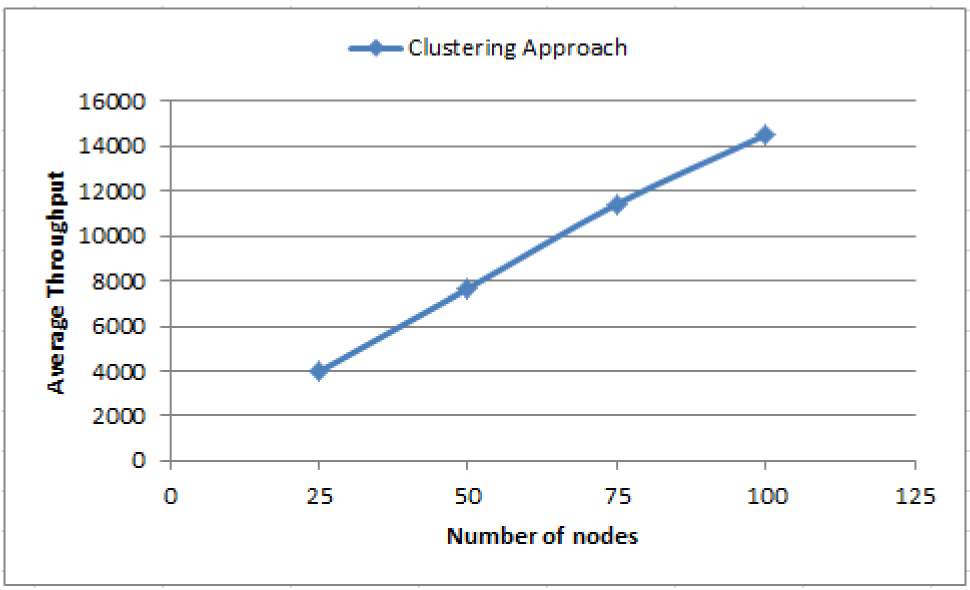

Figure 13 Average throughput of the clustering approach

Figure 14 and Table 3 show the average total energy consumption of the direct approach, the proposed clustering approach, and the optimal GAMS solution for different values of the total number of nodes. Figure 14 shows that the average total energy of the proposed approach is closer to the average total energy of optimal solution obtained by GAMS. In fact, the total energy of the proposed clustering approach becomes closer to optimality as the number of nodes increases. This is clear from Table 3, which shows a difference of only 1.8% between the performance of our approach and the optimal GAMS solution when the number of nodes is equal to 100, while the difference is zero when number of nodes is equal to 800.This shows that the proposed clustering approach is capable of producing high-quality, near-optimum solutions for large-scale tracking problems.

For the direct approach, the total energy increases as the number of nodes increases. This is because in the direct approach each node has Wi-Fi and GPS for transmission of the data to the back-end server. Since all nodes transmit data over long- range, the direct approach consumes more energy than the proposed clustering approach. As observed from Table 3, the energy consumption of the direct approach is 377.8% higher than the optimal consumption specified by GAMS when the number of nodes is equal to 100, and 409.4% higher when the number of nodes is equal to 800.Clearly,the direct approach is a very inefficient solution method for large-scale high-mobility tracking systems.

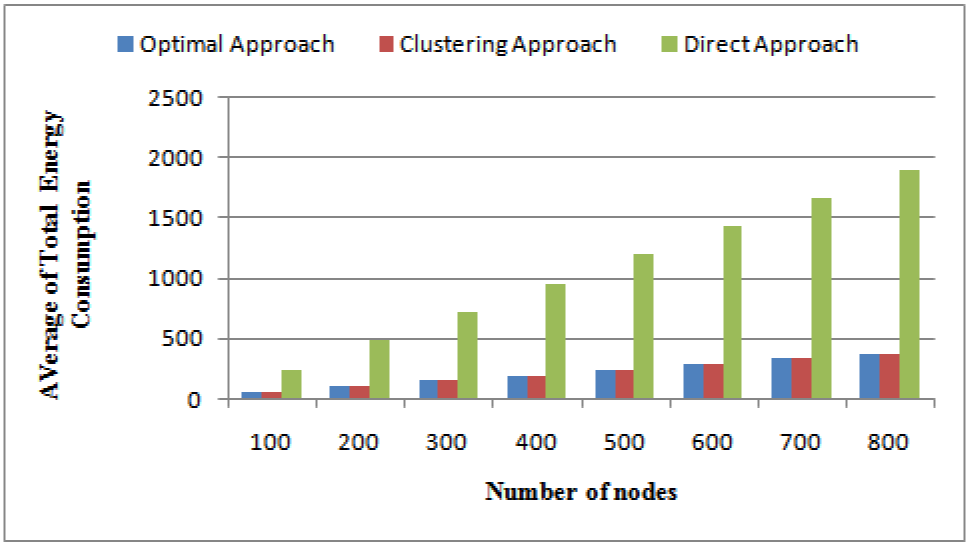

Figure 14 Comparison of the average Energy Consumption

#of nodes	1st-Level Clustering Approach (Joule)	Direct Approach (Joule)	Optimal Approach GAMS (Joule)	Comparison vs GMAS	
				1st-Level Clustering Approach	Direct Approach
100	50.8	238.41	49.9	1.8%	377.8%
200	97.9	476.82	96.4	1.6%	394.6%
300	145.9	715.23	144.2	1.2%	395.9%
400	191.2	953.64	189.5	0.9%	403.2%
500	237.8	1192.05	236.6	0.5%	403.8%
600	284.1	1430.46	283.2	0.3%	405.1%
700	330.1	1668.87	329.7	0.1%	406.2%
800	374.4	1907.28	374.4	0%	409.4%

Table 3: Comparison of total energy consumption for three solution methods

Figure 15 and Table 4 show the average efficiency packet per Joule for the direct approach and the proposed clustering approach for different values of the total number of nodes. Figure 15 shows that the efficiency packet per Joule of the proposed approach increases slightly when the number of nodes increases. This can also be seen from Table 4, which shows that the efficiency of clustering increases as the number of nodes increase.

On the other hand, in the direct approach, the efficiency packet per Joule remains constant as the number of nodes increases. The reason is that in the direct approach each node has Wi-Fi and GPS to transmit data to the back-end server. Therefore, the probability that each node has to transmit its data to the back- end server is the same. This is another reason to conclude that the direct approach is not suitable for handling high-data requirements of a large-scale tracking system.

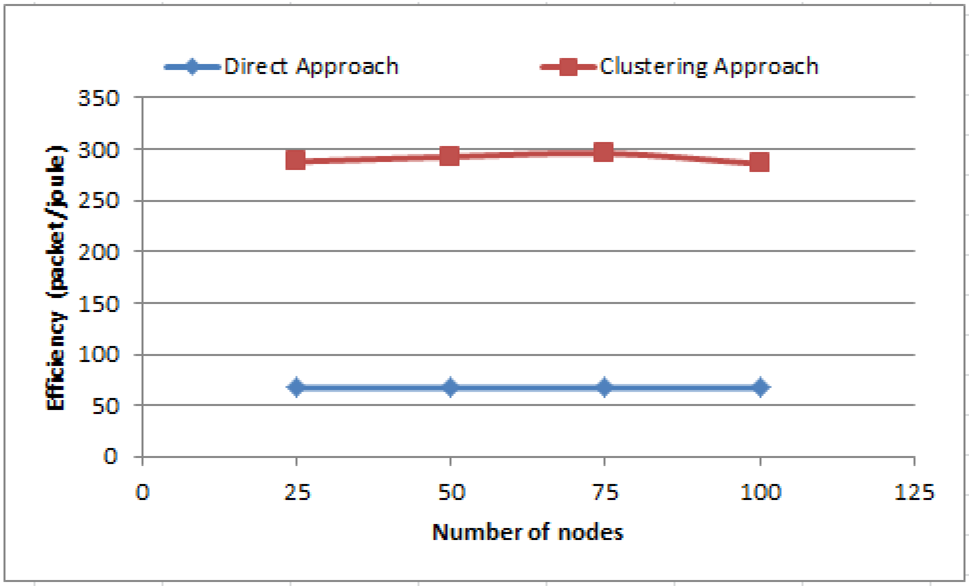

Figure 15 Comparing the efficiency of direct approach and clustering approach

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#of nodes	Throughput of (bps)		Energy Consumption of (Joule)		Efficacy of (packet/joule)	
	Clustering Approach	Direct Approach	Clustering Approach	Direct Approach	Clustering Approach	Direct Approach
25	3972.8	4000	13.8	59.6	287.9	67.1
50	7668	8000	26.2	119.2	292.7	67.1
75	11430	12000	38.6	178.8	296.1	67.1
100	14516.8	16000	50.8	238.41	285.8	67.1

Table 4 : Comparison of energy and efficiency of the direct approach and the clustering approach

3.2 2nd-level mobile clustering of the Bluetooth network

The recent smartphones are capable of activating tracking systems by exploiting GPS and WLAN technologies for positioning and communication. However, for large-scale tracking systems, which track the random movement of people, the continuous usage of a person smartphone's GPS and Wi-Fi is not an energy-efficient solution. In this paper, an energy- efficient solution is proposed for large-scale tracking systems without using everybody's smartphone's GPS and Wi-Fi by grouping nearby smartphones to form a cluster based on two hierarchy levels of Bluetooth clustering. A cluster, also called a piconet, is a small network that consists of a cluster head and cluster members that communicate locally via Bluetooth. In Bluetooth specifications [4], we can form a cluster, which consists of one master (cluster head) and up to seven slaves (cluster members). But in principle the number can be extended in another way by creating two hierarchy levels of Bluetooth clustering which called a "Scatternet".The master in one piconet in the first level of Bluetooth clustering can be a slave in the second level of Bluetooth clustering so linking the two networks together. The master in the second level hierarchy of Bluetooth clustering which called (super master) is responsible for providing positioning information as well as sharing information with the rest of all its children and also with the back-end server.

3.2.1 Proposed solution

The main goal of our approach is to optimize energy for large-scale Bluetooth networking based on hierarchical mobile clustering that can be used for tracking purposes for a large-scale system. It is assumed that we have a large group of moving nodes, (each with their own cell phone) that will be divided into small clusters (groups).By grouping nearby smartphones to form a cluster based on two hierarchy levels of Bluetooth clustering. The cluster, also called a piconet, consists of one master and up to seven slaves (according to standard [4]). But in principle the number can be extended in another way by creating two hierarchy levels of Bluetooth clustering which called a “Scatternet”.The master in one piconet in the first level of Bluetooth clustering can be a slave in the second level of Bluetooth clustering so linking the two networks together. The master in the second level hierarchy of Bluetooth clustering which called (super master) is responsible for providing positioning information as well as sharing information with the rest of the slaves (masters in the first level hierarchy of Bluetooth clustering) and also with the back-end server. The clusters reside within small areas, so communication within clusters can be done via a short-range radio interface that consumes low power such as Bluetooth.

Figure 16 illustrates the concept of the two hierarchy levels of Bluetooth clustering. The construction of the first-level cluster (piconet) depends on the choice of a master node from the set of devices in the same range. Each device will broadcast specific information to all devices in its range, such as its battery level and Wi-Fi connection availability. This information is important for sustainability of the cluster. All users will initiate a table containing nominees to be the master of the new constructed cluster. The device that has the highest battery level and Wi-Fi connection will be chosen as the master of this particular cluster. Then, it will start communicating with other devices to join its cluster (i.e. these users are considered slaves).After that, the construction of the second-level cluster depends on the choice of a master which called (super master) from the set of first-level masters in the same range. The master that has the highest battery level will be chosen as super master of this particular cluster. Then, it will start communicating with other first-level masters to join its cluster via Bluetooth (i.e. these first-level masters are considered slaves for the second-level masters).

Afterward, the process of data exchange will start between the slaves and the first-level master’s end up with super master that is responsible for transmitting all data to the back-end server, where this data will be stored and processed. Then, after specific period, new clusters are formed and new masters will be selected along with their children (i.e. slaves) and new super master will be selected along with their children (i.e. first-level masters).The ranking of the list will be refreshed periodically and the two-level hierarchy of Bluetooth clustering will be constructed. This procedure guarantees fair load distribution among multiple devices to attain maximum throughput and lifetime of the network and avoiding draining the battery of any individual device.

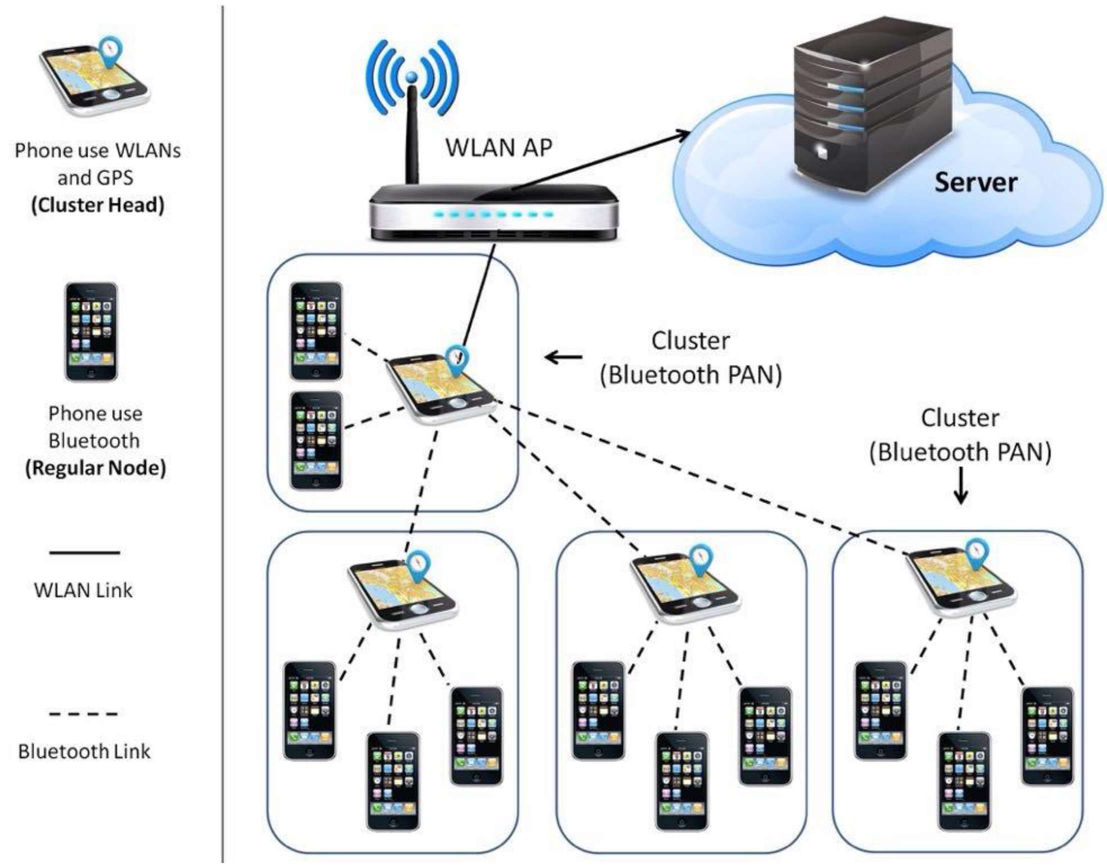


Figure 16 Proposed solution (Hierarchy Clustering Bluetooth Network); slaves use Bluetooth technology while super masters use Wi-Fi to exchange information with back-end server.

Hierarchical Clustering Algorithm

Our goal is to optimize energy; low-interference for large-scale Bluetooth networking based on hierarchical mobile clustering that can be used for tracking purposes that satisfies the requirements of large-scale environments. To accomplish this goal, the cost function of our clustering algorithm focuses specifically on node battery level and Wi-Fi connection availability. In order to achieve our goal the following requirements must be met:

- Each node makes its decision based on its local information.
- Each node can be either second-level master (super master) or first-level master (slave for the super master) or cluster member (slave for first-level master) that belongs to exactly one cluster.
- Clusters must include all nodes, without any overlap (common nodes) between different clusters.
- Message exchange should be efficient in order to meet clustering processing requirements.

Pseudo Code

```
Boot Up
Broadcast data
If N>0 (N: Number of nodes)
 For i = 1: N // first-level clustering
  IF (i has Wi-Fi)
         Update possible Master
  Else
         Update possible Slave
  End if
  IF (i has highest battery level {BL})
         Update become Master
  End if
  For j = 1: possible Slave
   IF (Dij<= 10)// Bluetooth range
         Update M-possible Slave
   End if
```

```
      IF (M<= 7)
            Update become Slave
      Else
            Update closest 7 to become Slave
      End if
     Update N = N- cluster size
   Else
    For i= 1: Master//second-level clustering
      IF (i has highest battery level {BL})
            Update become super master
      Else
            Update possible master
      End if
      For j = 1: possible master
       IF(Dij<=10)// Bluetooth range
            Update M-possible Master
       End if
       IF (M<= 7)
            Update become Master
       Else
            Update closest 7 to become Master
       End if
      Update Master=Master- cluster size
    End if
```

The pseudo code describes our algorithm in detail. When all nodes are booted up, each node will broadcast its battery level and Wi- Fi connection availability to all nodes in its range. Firstly, (the construction of first-level cluster) all nodes that have Wi-Fi connection availability are eligible to be cluster head (master), and the nodes that don't have Wi-Fi are eligible to be cluster members (slaves).

Next, the node, which has the highest battery level, will be chosen as the master node (first-level cluster head) of the particular piconet, and the closest (up to seven) nodes can join as slaves (cluster members). The construction process continues until each node is assigned either as a master or a slave that belongs to exactly only one cluster at the end of the clustering procedure. After that, (the construction of 2nd-level cluster) the first-level master which has the highest battery level, will be chosen as the super master node (2nd-level cluster head) of the particular piconet, and the closest (up to seven) first-level masters can join as cluster members (slaves for the second-level cluster). The construction process continues until each node is assigned either as a super master or a master or a slave that belongs to exactly only one cluster at the end of the clustering procedure.

Time Scheduling for Efficient Data Transmission

The Bluetooth forms two types of data transmissions between devices in a piconet synchronous connection oriented (SCO) and asynchronous connection less (ACL). SCO is point to point transmission data between the master and a single slave. The master reserves time slots to ensure that the capacity is existing for an SCO link while ACL connection can use any time slot. Also it can be used as one to one connection but the master can broadcast the data to multiple slaves and the slave can only send data when invited to do so by the master.

All of the devices connect to a piconet use the same frequency hopping schedule and are controlled by the master. The channel is divided into 625 microsecond time slots and it's shared between the master and the slaves using the simple law that the master transfers on even time slots and the slaves send in odd time slots [4]. Therefore, we need two time slots (1250 microsecond) for each slave to transmitting its data to the master. So to avoid the interference from other ISM Bluetooth devices that split into 79 channels each 1MHz wide we uses scheduling time as the figure below for each device in the second level of Bluetooth cluster. The figure below illustrates the scheduling time for each device in the second level of Bluetooth cluster into two modes active mode and sleep mode and the time for each of them is 1250 microsecond and each device can only send its data when it's in active mode.

Master	Slave 1	Slave 2	Slave 3	Slave 4	Slave 5	Slave 6	Slave 7
active	sleep	sleep	sleep	sleep	sleep	sleep	sleep
sleep	active	sleep	sleep	sleep	sleep	sleep	sleep
sleep	sleep	active	sleep	sleep	sleep	sleep	sleep
sleep	sleep	sleep	active	sleep	sleep	sleep	sleep
sleep	sleep	sleep	sleep	active	sleep	sleep	sleep
sleep	sleep	sleep	sleep	sleep	active	sleep	sleep
sleep	sleep	sleep	sleep	sleep	sleep	active	sleep
sleep	sleep	sleep	sleep	sleep	sleep	sleep	active

Figure 17 Time Scheduling for the 2nd Level of Clustering Bluetooth Network

Figure 18 as an example to illustrate the time scheduling for the first hierarchy level of clustering Bluetooth network. As shown in Figure 18 the first hierarchy level of clustering Bluetooth network consists of three clusters (piconets) and each cluster consists of one master and seven slaves .The master that responsible for transmitting data via Wi-Fi for processing to the back-end server. We observed from Figure 18 the delay time is constant when number of clusters increases. While the frame error rate (FER) increases when number of clusters increases that leads to loss some of data that may be critical especially for tracking purposes.

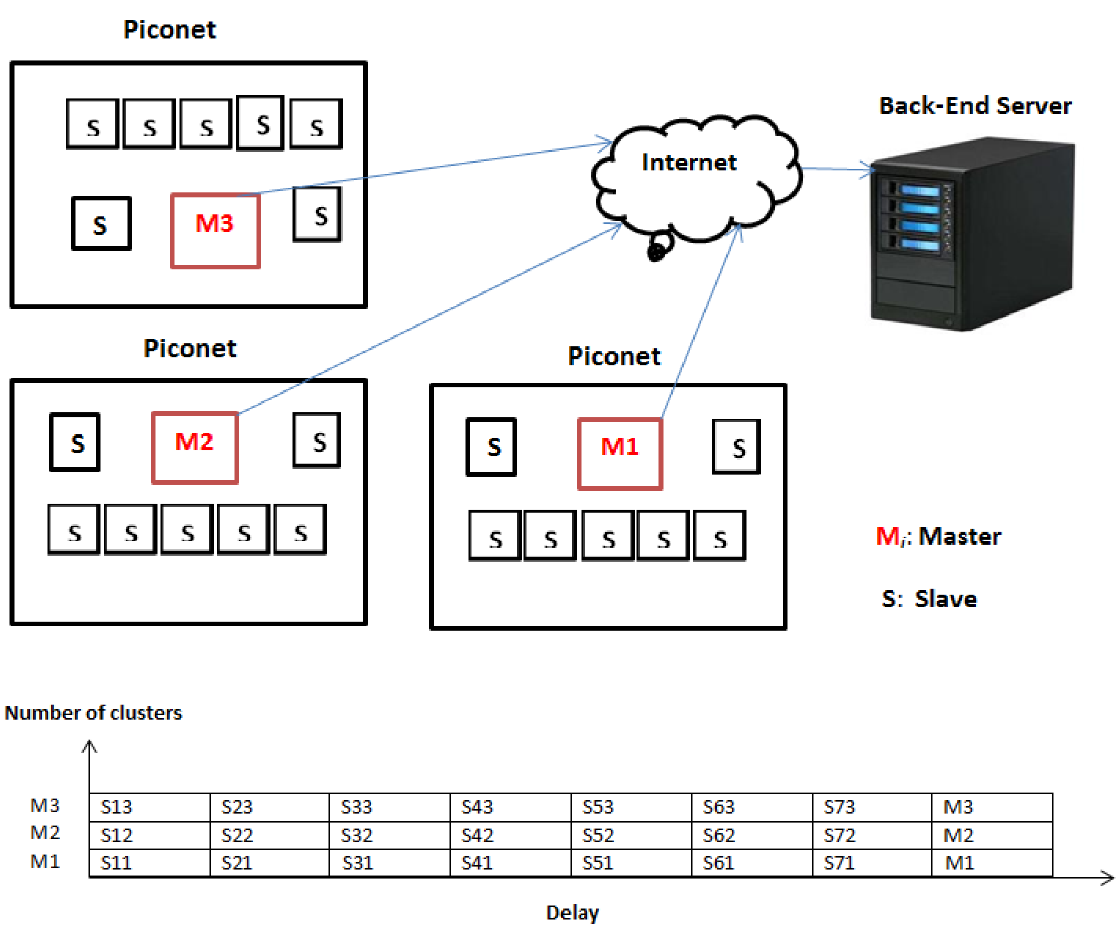


Figure 18 Example of Time Scheduling for the first Hierarchy Level of Clustering Bluetooth Network

$$TTSi = (Ni) * T \quad (9)$$

$$Dmax = (max\ Ni) * T \quad (10)$$

$$Total\ Delay = Dmax \quad (11)$$

The equations of (9-11) deals with the time scheduling for the first hierarchy level of clustering Bluetooth network.

TTSi is the time of cluster *i* to transmit data to the server, which is the number of nodes in the cluster *i* (*Ni*) multiply by the constant *T (1250 µs).*

Dmax is the maximum delay for the first hierarchy level of clustering Bluetooth network, which is equal the maximum number of nodes for the first hierarchy level of clustering Bluetooth network *(Ni)* multiply by the constant *T (1250 µs).*

Total Delay is the total delay of all clusters for the first hierarchy level of clustering Bluetooth network which is equal the *Dmax.*

Figure 19 as an example to illustrate the time scheduling for the second hierarchy level of clustering Bluetooth network. As shown in Figure 19 the second hierarchy level of clustering Bluetooth network consists of three clusters (piconets) and each cluster consists of one master and seven slaves .The super master that responsible for transmitting data via Wi-Fi for processing to the back-end server. We observed from the Figure 19 the delay time increases when number of clusters increases. The second hierarchy level of clustering Bluetooth network decreases number of the clusters that leads to decreases the frame error rate (FER).Therefore; it is very efficient, especially for highly populated areas.

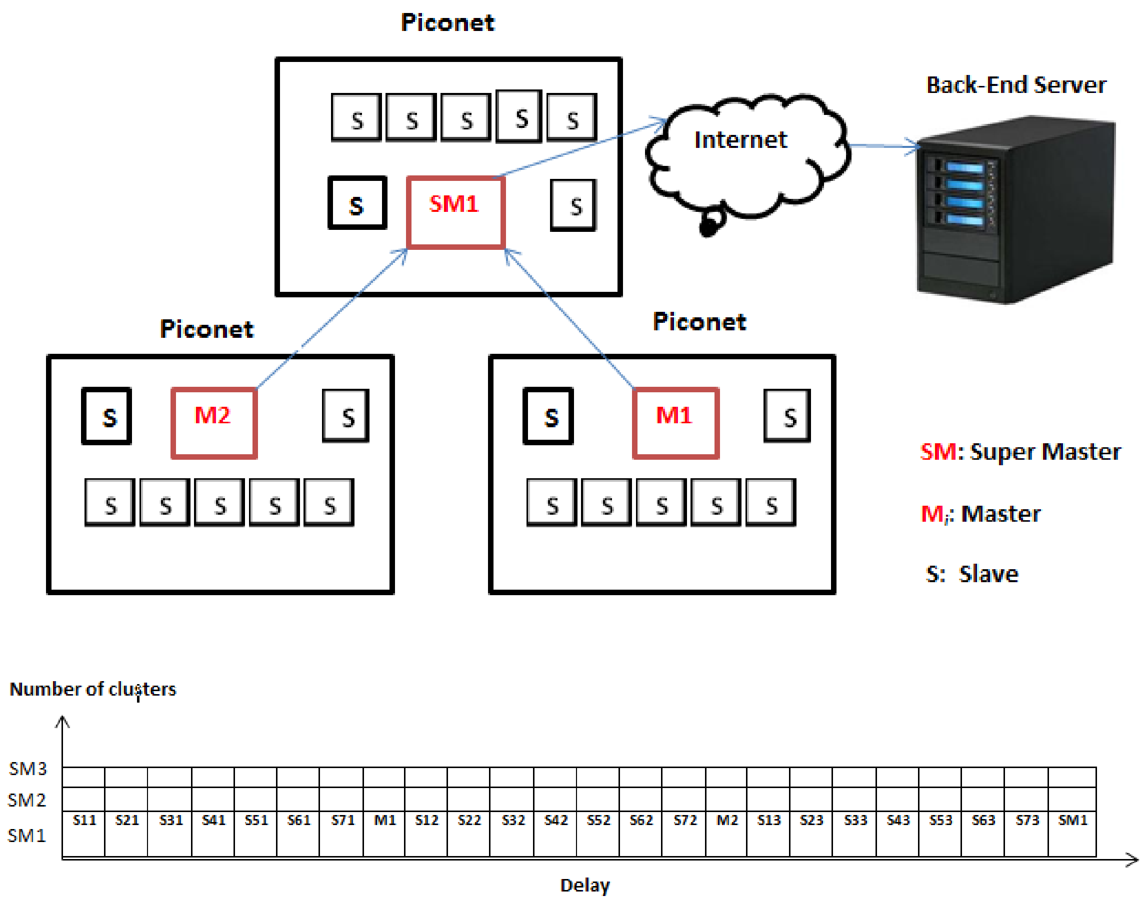


Figure 19 Example of Time Scheduling for the second Hierarchy Level of Clustering Bluetooth Network

$$TTSi = (1+Ni) * T \tag{12}$$

$$Dmax <= (\max Ni)(\max Nj) * T \tag{13}$$

$$Total\ Delay = \sum TTSi \tag{14}$$

The equations of (12-14) deals with the time scheduling for the second hierarchy level of clustering Bluetooth network

TTSi is the time of cluster *i* to transmit data to the server, which is the number of nodes in the cluster *i* (*Ni*) adding to one (super master) multiply by constant *T (1250 µs).*

Dmax is the maximum delay for the second hierarchy level of clustering Bluetooth network, which is less than or equal the maximum number of nodes for the first hierarchy level of clustering Bluetooth network *(Ni)* multiply by the maximum number of nodes for the second hierarchy level of clustering Bluetooth network *(Nj)* multiply by the constant *T (1250 µs).*

Total Delay is the total delay of all clusters for the second hierarchy level of clustering Bluetooth network where *(i=1, 2, 3..., I.).*

3.2.2 The Mathematical model

In order to achieve the goals of efficient energy consumption and good quality of service, the following objectives must be optimized:

- Minimizing the number of clusters (masters) for the first hierarchy level of clustering Bluetooth network.
- Minimizing the total distance between masters (cluster heads) and slaves (cluster members) for the first hierarchy level of clustering Bluetooth network.
- Minimizing the number of clusters (super masters) for the second hierarchy level of clustering Bluetooth network.
- Minimizing the total distance between super masters (cluster heads) and slaves (first-level masters) for the second hierarchy level of clustering Bluetooth network.

The first objective is sought because minimizing the number of the clusters leads to reducing the energy consumption, which leads to maximize network lifetime. Moreover, minimizing the number of clusters reduces channel access congestion, which reduces the interference among Bluetooth based clusters as well as Bluetooth/Wi-Fi connections when they are employed in the same area.

The second objective, minimizing the total distance be- tween masters (cluster head) and slaves (cluster members), leads to higher accuracy of positioning.

Since the master node will represent all its children in respect to the positioning information, communicating via short-range radio interfaces such as (Bluetooth< 10m) is more accurate than communicating via long-range radio interfaces. The expected error is ±10m. Furthermore, it reduces the energy consumption and the transmission delay of Bluetooth networks, since communicating via short-range radio interfaces such as Bluetooth consumes lower power than communicating via long-range radio interfaces.

The third objective is sought because minimizing the number of the super masters leads to reducing the energy consumption, which leads to maximize network lifetime. Furthermore, reduces channel access congestion, which reduces the interference among Bluetooth based clusters as well as Bluetooth/Wi-Fi connections when they are employed in the same area which leads to maximize the throughput for the whole network.

The forth objective, minimizing the total distance be- tween super masters and slaves (first-level masters), leads to higher accuracy of positioning. Since the super master node will represent all its children in respect to the positioning in- formation, communicating via short-range radio interfaces such as (Bluetooth< 10m) is more accurate than communicating via long-range radio interfaces. The expected error is ±10m. Furthermore, it reduces the energy consumption and the transmission delay of Bluetooth networks, since communicating via short-range radio interfaces such as Bluetooth consumes lower power than communicating via long-range radio interfaces. Let i=1 to n denote the slave number, j=1 to n denote the master number and Cij denote the distance between node i and node *j*. *WF* denote the availability of Wi-Fi service in user's smartphone as in (15). The user's battery level *(BL)* is defined as in (16).The terms (17-20) deals with the decision variables of our model, 17 and 18 deals with the decision variables for the first hierarchy level of clustering Bluetooth network that equal one if slave *i* is connected to a master *j* and zero otherwise and that equal one if the device *j* is assigned as a master and zero otherwise, respectively. 19 and 20 deals with the decision variables for the second hierarchy level of clustering Bluetooth network that equal one if master *i* is connected to a super master *j* and zero otherwise and that equal one if the master *j* is assigned as a super master and zero otherwise, respectively.

$$WF_j = \begin{cases} 1, & \text{if device } j \text{ has Wi} - \text{Fi} \\ 0, & \text{otherwise} \end{cases} \tag{15}$$

$$BL_j = \begin{cases} 1, & \text{if battery level of device } j \; is \geq 50\% \\ 0, & \text{otherwise} \end{cases} \tag{16}$$

$$X_{ij} = \begin{cases} 1, & \text{if device } i \text{ is connected to master } j \\ 0, & \text{otherwise} \end{cases} \tag{17}$$

$$Y_j = \begin{cases} 1, & \text{if device } j \text{ is assgined as a master.} \\ 0, & \text{otherwise} \end{cases} \tag{18}$$

$$V_{ij} = \begin{cases} 1, & \text{if master } i \text{ is connected to super master } j \\ 0, & \text{otherwise} \end{cases} \tag{19}$$

$$W_j = \begin{cases} 1, & \text{if master } j \text{ is assgined as a super master} \\ 0, & \text{otherwise} \end{cases} \tag{20}$$

The mathematical model for this problem is given by (21). The objective function is to minimize Z, which consists of four terms , the first two terms deals with minimizing the number of clusters (masters) and the total distance between masters (cluster heads) and slaves for the first hierarchy level of clustering Bluetooth network. The third and fourth terms deals with minimizing the number of clusters (super masters) and the total distance between super masters (cluster heads) and slaves (first-level masters) for the second hierarchy level of clustering Bluetooth network.

The objective function is to minimize Z, subject to nine constraints. The first constraint (I) is to ensure every slave has a master. Constraints II and III limit the cluster size to 8 (i.e. one master besides 7 slaves) and ensure that clusters are within the Bluetooth range of 10m, respectively. The constraints IV ,V and VI ensure every master has a super master and ensure that limit the cluster size to 8 (i.e. one super master besides 7 masters) and ensure that clusters are within the Bluetooth range of 10m, respectively. The constraint VII ensure that the super master must be already a master .The last two constraints VIII and IX ensure that the master has Wi-Fi and a battery level of greater than or equal to 50%, respectively. The fixed cost of each master and super master is denoted by F and it is equal to 100.

$$\text{Min } Z = \sum_{i=1}^{n}\sum_{j=1}^{n} C_{ij} X_{ij} + \sum_{j=1}^{n} F_j Y_j + \sum_{i=1}^{n}\sum_{j=1}^{n} C_{ij} V_{ij} + \sum_{j=1}^{n} F_j W_j$$

subject to:

I. $$\sum_{j=1}^{n} X_{ij} = 1 , i = 1 \dots n$$

II. $$\sum_{i=1}^{n} X_{ij} \leq 8\, Y_j, j = 1 \dots n$$

III. $$\sum_{j=1}^{n} C_{ij} X_{ij} \leq 10 , i = 1 \dots n$$

(21)

IV. $$\sum_{j=1}^{n} V_{ij} \leq Y_i , i = 1 \dots n$$

V. $$\sum_{i=1}^{\mathrm{n}} \mathrm{V_{ij}} \leq 8W_j , j = 1 \dots \mathrm{n}$$

VI. $$\sum_{j=1}^{n} C_{ij} V_{ij} \leq 10Y_j , i = 1 \dots n$$

VII. $W_j \leq Y_j$

VIII. $Y_j \leq WF$

IX. $Y_j \leq BL$

3.2.3 The performance evaluation experiments and discusses the achieved results

In this section, we evaluate the performance of the proposed approach by finding the optimal solution and via simulation. We begin by describing the optimal solution and then discuss the simulation results.

Optimization Solution

The General Algebraic Modeling System (GAMS) is designed for modeling and solving (LP), (NLP), and (MIP) optimization problems [43]. Since the above model described in (21) is a binary integer program, it was solved by the MIP feature of GAMS. GAMS Version 24.3.3 was used, and the problem was setup with three different scenarios.

The first scenario tackles the problem only by solving the first two terms in the objective function that deals with minimizing the number of clusters (masters) and the total distance between masters (cluster heads) and slaves for the first hierarchy level of clustering Bluetooth network by reading the input data *(WF, BL and Cij).* The second scenario tackles the problem by solving all terms in the objective function deals with minimizing the number of clusters (super masters) and the total distance between super masters (cluster heads) and slaves (first-level masters) for the second hierarchy level of clustering Bluetooth network by reading the input data *(WF, BL and Cij).*

The third scenario considers all terms of the objective function together and applies the sensitivity analysis by fixing the number of nodes first to 700, and then 800. This is done by changing the cluster size of the second hierarchy level of clustering Bluetooth network (changing the RHS) in constraint V in (21).

All above scenarios are studied under the following environment. The size of the service region is set as 10×20 m^2. We have calculated the optimal value of the objective function by using GAMS (MIP) solver of 100, 200, 300, 400, 500, 600, 700, and 800 nodes, respectively. In order to achieve 95 % confidence interval, each simulation experiment was repeated ten times using different random topologies.

Figure 20 shows the results for scenario 1 minimizing the number of clusters (masters) for the first hierarchy level of clustering Bluetooth network. It can be observed that for up to 600 nodes, one cluster can handle between 6-7 nodes. However, when there are 800 nodes, each cluster can consist of up to 8 nodes so there can be more slaves per master. Once again, this is very efficient for a large-scale system, because there will be less channel access congestion. Furthermore, interference among Bluetooth signals of different nodes or between Bluetooth and other 2.4 GHz technologies such as Wi-Fi can be reduced. Lastly, energy consumption is reduced, thus maximizing network lifetime.

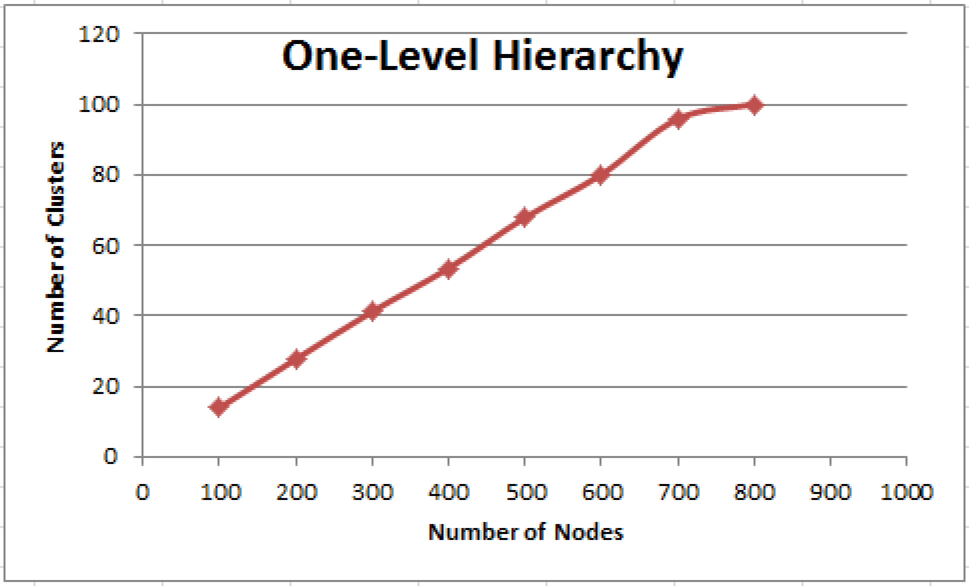


Figure 20 Optimal number of clusters (for scenario 1)

Figure 21 shows the results for scenario 2 minimizing the number of clusters (super masters) for the second hierarchy level of clustering Bluetooth network. It can be observed that for 100 nodes, two clusters can handle all their children's. However, when there are 800 nodes, only thirteen clusters can handle all their children's. Therefore, this is very efficient for a large-scale system, because there will be less channel access congestion. Furthermore, interference among Bluetooth signals of different nodes or between Bluetooth and other 2.4 GHz technologies such as Wi-Fi can be reduced that leads to minimize the frame error rate (FER) that leads to maximize the throughput for the whole network. Lastly, energy consumption is reduced, thus maximizing network lifetime.

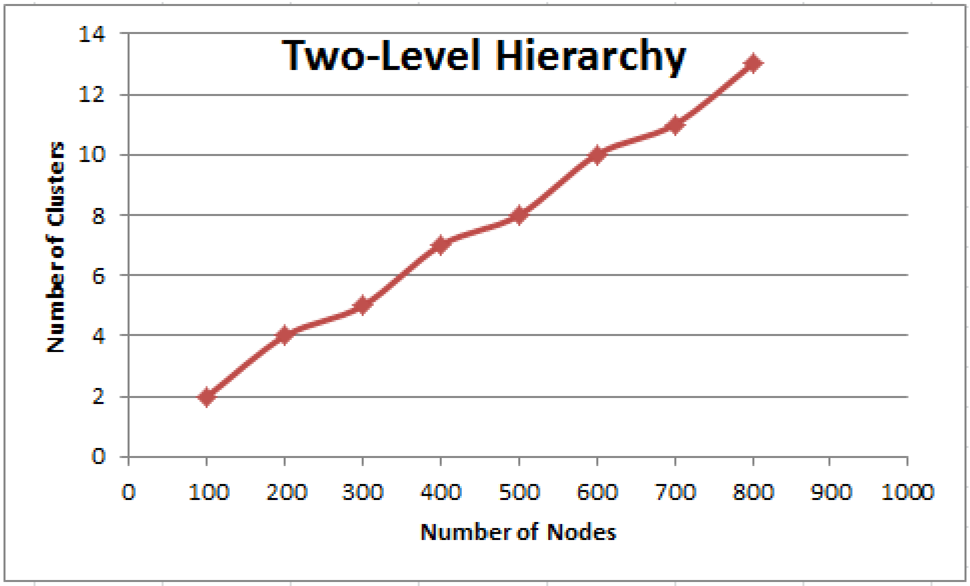


Figure 21 Optimal number of clusters (for scenario 2)

Figure 22 illustrates the comparison of number of the clusters for the first and second hierarchy levels of clustering Bluetooth network. It can be observed that the results of the second hierarchy level better than the results of the first level hierarchy level. For example, for 100 nodes, only two clusters can handle all their children's in the second hierarchy level while in the first hierarchy level fourteen clusters can handle all their children's. However, when there are 800 nodes, only thirteen clusters can handle all their children's in the second hierarchy instead of one hundred clusters in the first hierarchy level of Bluetooth network. Therefore, the second hierarchy level more efficient than the first hierarchy level especially for a large-scale system, because there will be less channel access congestion.

Furthermore, interference among Bluetooth signals of different nodes or between Bluetooth and other 2.4 GHz technologies such as Wi-Fi can be reduced that leads to minimize the frame error rate (FER) that leads to maximize the throughput for the whole network. Lastly, energy consumption is reduced, thus maximizing network lifetime

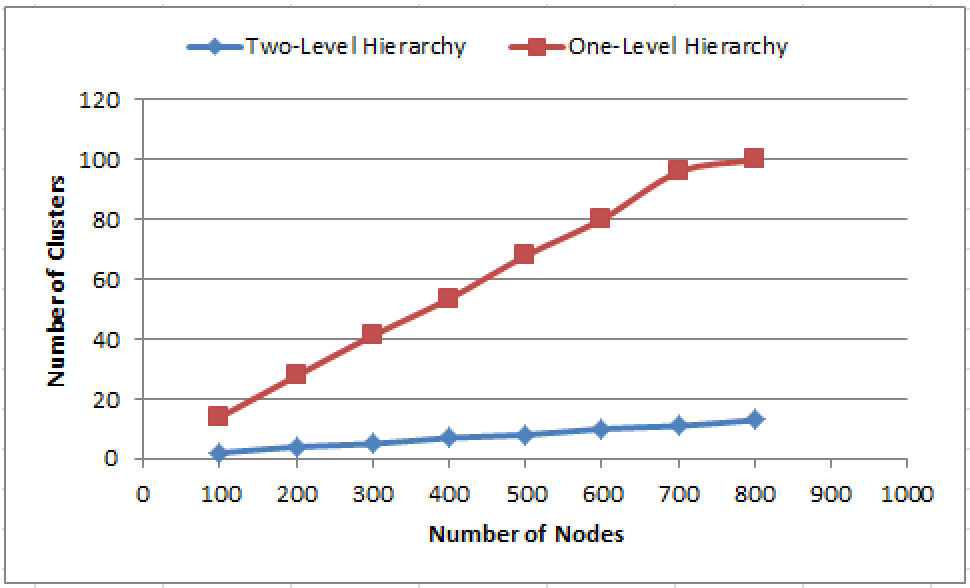


Figure 22 Optimal number of clusters for 1st-Level VS 2nd-Level

Figure 23 present the results for the sensitivity analysis applied to a system of 700 and 800 nodes, respectively. Figure 23 shows the optimal number of clusters; the cluster size of the second hierarchy level of clustering Bluetooth network (changing the RHS) in constraint V in (21) is varying between one to eight. For 700 nodes, the number of the clusters will be optimal when the cluster size is equal to 8, which implies 11 clusters. For the case of 800 nodes, the number of the clusters will be optimal when the cluster size is equal to 8, which implies 13 clusters. Therefore, the second hierarchy level of clustering Bluetooth network is very efficient, especially for highly populated areas.

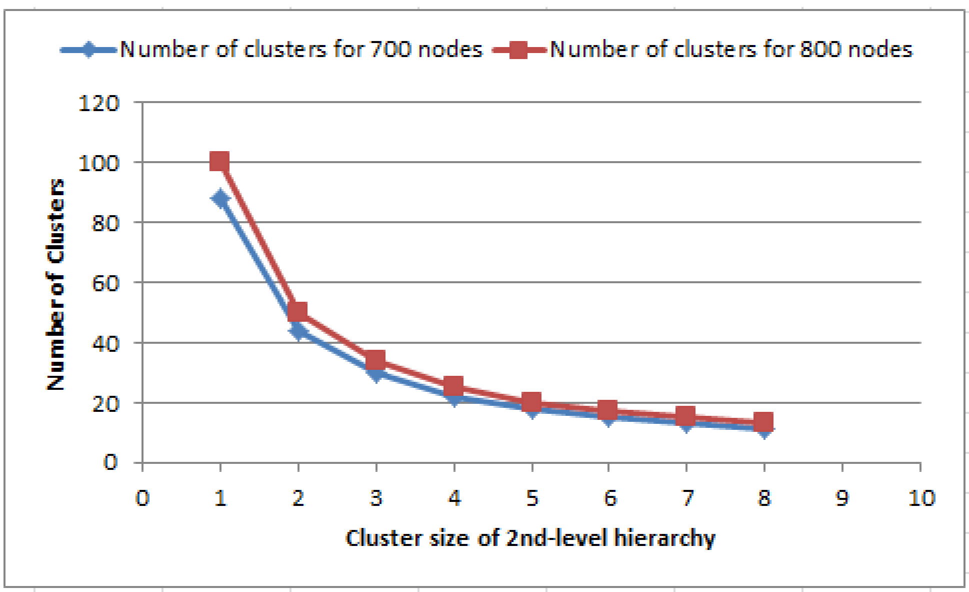


Figure 23 Optimal number of clusters (for scenario 3)

Simulation Results

We have presented the performance of the direct approach, the 1st-level clustering approach, the 2nd-level clustering approach, and the optimal GAMS solution.

We have evaluated the performance of the algorithm using Matlab/Simulink. We used the same simulation experimental setup and performance metrics that we used in the section 3.1.3.2 and the section 3.1.3.3, respectively. The total energy consumption, throughput and efficiency in each round were calculated for different number of nodes, up to 800 nodes. Each node can send data traffic at a rate of 1,000 kbps and it can send frames with sizes up to 20 bytes which is sufficient to send health information messages. For the hardware (Bluetooth/Wi-Fi) energy consumption, we use the same values as in [53]; the simulation parameters are summarized in Table 1. In order to achieve 95 % confidence interval, each simulation experiment was repeated ten times using different random topologies.

Figure 24 shows the average throughput of the first and second hierarchy level of clustering Bluetooth network approaches for different values of the total number of nodes. It is assumed that the frame size is equal to 20 bytes, which is sufficient to send health information messages. We observed from Figure 24 the throughput for the second hierarchy level better than the throughput for the first hierarchy level mainly when number of nodes increases that is very efficient, especially for highly populated areas.

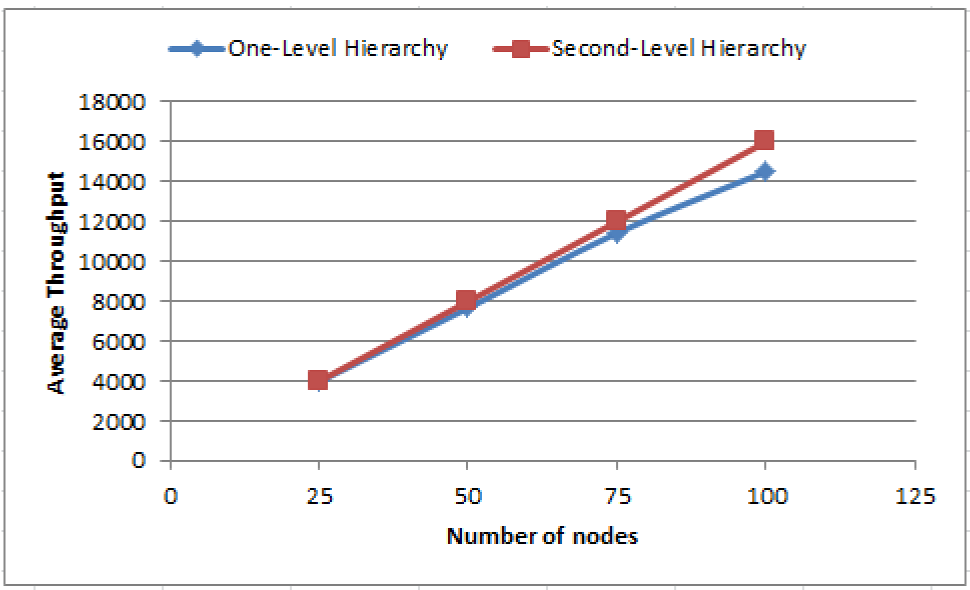


Figure 24 Optimal Average throughput of the first and second hierarchy level of clustering Bluetooth network approaches.

Figure 25 and Table 5 show the average total energy consumption of the direct approach, the proposed 2nd-Level Clustering, and the optimal GAMS solution for different values of the total number of nodes. Figure 25 shows that the average total energy of the 2nd-Level Clustering is closer to the average total energy of optimal solution obtained by GAMS. In fact, the total energy of the proposed 2nd-Level Clustering becomes closer to optimality as the number of nodes increases. This is clear from Table 5, which shows a difference of only 5% between the performance of our approach and the optimal GAMS solution when the number of nodes is equal to 100, while the difference is 0.54% when number of nodes is equal to 800.This shows that the proposed 2nd-Level Clustering is capable of producing high-quality, near-optimum solutions for large-scale tracking problems.

For the direct approach, the total energy increases as the number of nodes increases. This is because in the direct approach each node has Wi-Fi and GPS for transmission of the data to the back-end server. Since all nodes transmit data over long- range, the direct approach consumes more energy than the 2nd-Level Clustering approach. As observed from Table 4, the energy consumption of the direct approach is 993.6% higher than the optimal consumption specified by GAMS when the number of nodes is equal to 100, and 1042.1% higher when the number of nodes is equal to 800.Clearly,the direct approach is a very inefficient solution method for large-scale high-mobility tracking systems.

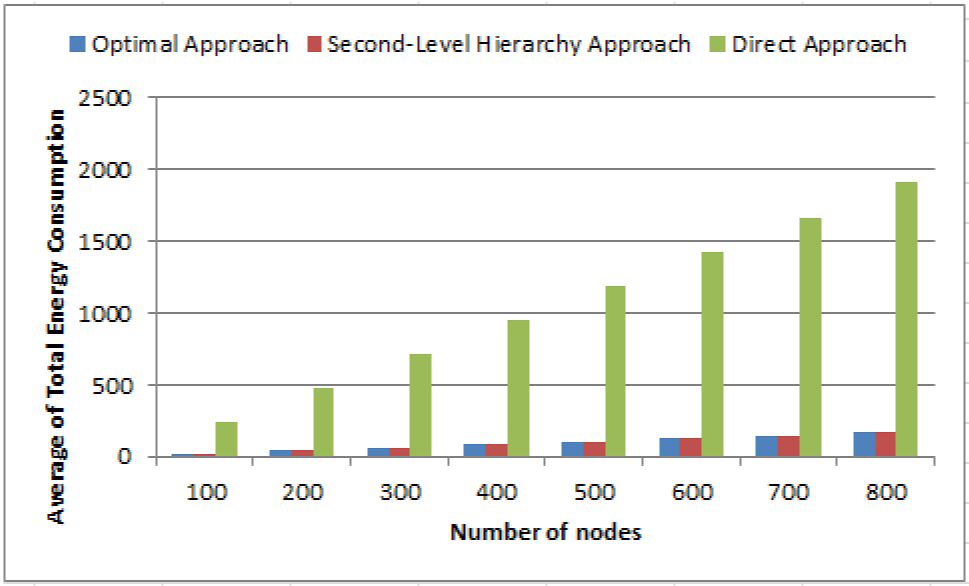


Figure 25 Comparison of the average Energy Consumption

#of nodes	2nd-Level Clustering Approach (Joule)	Direct Approach (Joule)	Optimal Approach GAMS (Joule)	Comparison vs GMAS	
				2nd-Level Clustering Approach	Direct Approach
100	22.9	238.41	21.8	5%	993.6%
200	45.6	476.82	43.5	4.80%	996.1%
300	65.6	715.23	62.9	4.29%	1037.1%
400	87.9	953.64	84.7	3.78%	1025.9%
500	107.3	1192.05	104.1	3.07%	1045.1%
600	128.8	1430.46	125.8	2.38%	1037.1%
700	147.5	1668.87	145.2	1.58%	1049.4%
800	167.9	1907.28	167	0.54%	1042.1%

Table 5 : Comparison of total energy consumption for three solution methods

Figure 26 and Table 6 show the average efficiency packet per Joule for the direct approach, 1st and 2nd level clustering approaches for different values of the total number of nodes. Figure 26 shows that the efficiency packets per Joule of 2nd-level clustering approach better than the efficiency packet per Joule of 1st-level clustering approach especially when the number of nodes increases. This can also be seen from Table 6, which shows that the efficiency of 2nd - level clustering approach better than the efficiency of 1st-level clustering. On the other hand, in the direct approach, the efficiency packet per Joule remains constant as the number of nodes increases. The reason is that in the direct approach each node has Wi-Fi and GPS to transmit data to the back-end server. Therefore, the probability that each node has to transmit its data to the back-end server is the same. This is another reason to conclude that the direct approach is not suitable for handling high-data requirements of a large-scale tracking system.

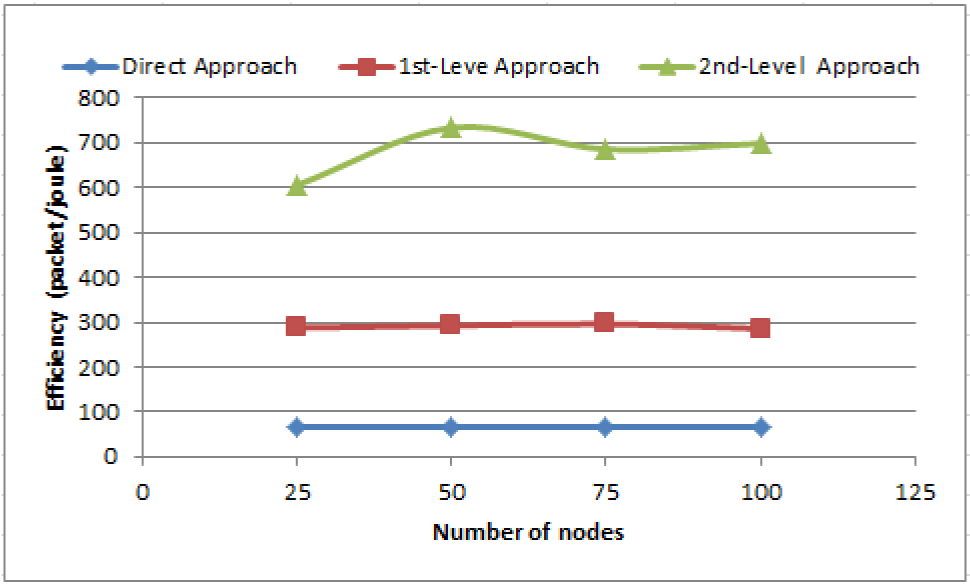


Figure 26 Comparing the efficiency of direct, 1st and 2nd clustering approaches

#of nodes	Throughput of (bps)			Energy Consumption of (Joule)			Efficacy of (packet/joule)		
	Direct Approach	1st-Level Approach	2nd-Level Approach	Direct Approach	1st-Level Approach	2nd-Level Approach	Direct Approach	1st-Level Approach	2nd-Level Approach
25	4000	3972.8	4000	59.6	13.8	6.6	67.1	287.9	606.1
50	8000	7668	8000	119.2	26.2	10.9	67.1	292.7	733.9
75	12000	11430	12000	178.8	38.6	17.5	67.1	296.1	685.7
100	16000	14516.8	16000	238.41	50.8	22.9	67.1	285.8	698.7

Table 6: Comparison of energy and efficiency of the three approaches

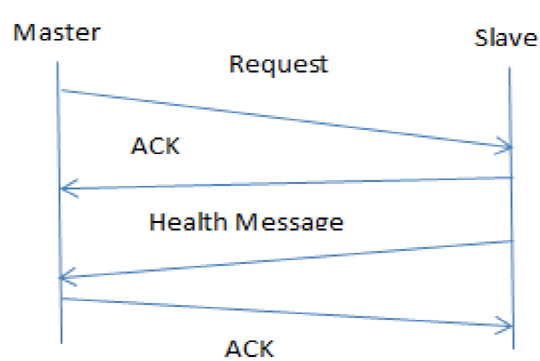
3.3 Android Application

In this section, we present the architecture of the developed android application for energy-efficient large-scale tracking system by using a combination of smart phone Bluetooth and Wi-Fi connections based on mobile clustering. We evaluate the performance of our android application in two different real experiment scenarios: mobile users and stationary users.

3.3.1 Proposed solution

Figure 27 illustrates the architecture of our android application for energy-efficient large-scale tracking system by using a combination of smart phone Bluetooth and Wi-Fi connections based on mobile clustering .Each cluster consists of cluster head (master) and up to seven cluster members (slaves).The construction of the piconet (cluster) depends on the choice of the master (cluster head) from devices in the same range (ten meters range). The device which has the highest cost (battery level and Wi-Fi connection) will be chosen as the master of this particular piconet (cluster) and it will start communicating with other devices and they will be paired as slaves. Afterward, the process of data exchange will start between the slaves and the master which is responsible for transferring all the data for processing to the firebase server. Our approach which is called “Smart Real-Time Healthcare Monitoring and Tracking System” (SRTHMATS APP) consists of firebase server and android application. Every user must download the application on it’s smart phone after that each user should create his/her user name (email) and password to be able to login to the application .When a user login to the application, the Bluetooth will turn on automatically after that each android device will check it's status like battery level and availability of Wi-Fi connection ,then based on some variables and cost function such as minimum battery level from the firebase server ; the android application can decide either the device should be a master or a slave. After that the slave must be connected to the master which is responsible for transmitting all the data for processing to the firebase server .The master is also responsible for the connection and it should keep refreshing it's piconet to ensure all the devices are nearby to it based on delay thread cost function.

After the application determines who is a master and who is a slave; the GPS will be enable automatically on the device that is chosen as a master to determine the location of its cluster then as the time diagram below, the master will send request message to communicate with its paired devices to join its piconet and the acknowledgement message should come from slaves that accept the master's request. Then, the slaves use the drop health check list such as (heartbeat, temperature and other emergency messages) to send health message to the master which is responsible for transmitting all data to the firebase server.



Then, after a predefined time frame the master should reconstruct it's piconet to ensure all devices are nearby to it based on delay thread parameter because all devices are moving. The master should keep refreshing its piconet until its battery drop more than battery percentage parameter then it will be switched to play the role of the slave. Then, a new master has to be chosen for the piconet to avoid draining of one individual device. The algorithm will check for other candidates to handle the data transfer for the next period of time in order to balance the load among multiple devices to attain the maximum possible lifetime of the network.

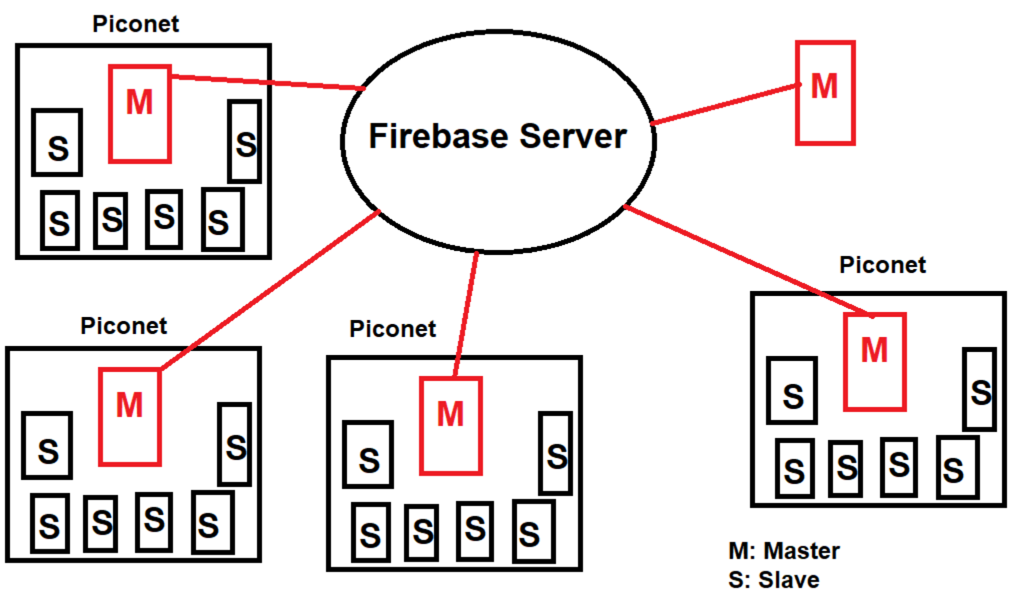


Figure 27 Android Application (SRTMHATS APP); slaves use Bluetooth technology while masters use Wi-Fi to exchange information with firebase server.

The cost functions and the parameters that is used in our approach

Battery Level Min: 80

This means that any device should have at least 80 battery levels to be a master.

Battery Percentage: 20

This means the master will switch to play the role of a slave when it's battery level dropped below 20% to avoid the draining of one individual device.

Delay Thread: 60000 ms

This means after 60000 ms the master should keep refreshing its piconet to ensure all the devices are nearby to it. In another way the piconet must reconstruct after 60000 ms.

Piconet Size: 7

This specifies the piconet size for each master (number of the slaves in each cluster that will be up to 7 slaves in each cluster).

List Sleep Disconect: 8000 ms

This means the time that the slave will be waiting for an open connection with another Bluetooth device before disconnecting it.

3.3.2 The performance evaluation experiments and discusses the achieved results

In this section, we evaluate the performance of the proposed approach by implementing our android application (SRTHMATS APP) that ensures energy-efficient large-scale tracking system by using a combination of smart phone Bluetooth and Wi-Fi connections based on mobile clustering. We evaluated the performance of our android application (SRTHMATS APP) in two different real experiment scenarios. The first scenario tackles the experiment of our (SRTHMATS APP) of twelve users (nodes) without mobility and the second scenario tackles the experiment of our (SRTHMATS APP) of twelve users (nodes) with mobility.

Both scenarios are studied under the following environment. The size of the service region (the classroom) is fixed as 9×9 m^2 within the Bluetooth range. Each experiment has been tested for ten minutes. Each user (node) can send data traffic (frames) with sizes up to 20 bytes which is sufficient to send health information messages. In the first experiment of the first scenario, the number of the delivered messages is equal 50 out of 66. In the experiment of the second scenario, the number of the delivered messages is equal 58 out of 72.

Experimental Setup

We will show the experimental setup of our (SRTHMATS APP); android application and firebase server console.

Figure 28 shows the login page of our android application for energy-efficient large-scale tracking system by using a combination of smart phone Bluetooth and Wi-Fi connections based on mobile clustering that allows creating new user with (username and password) also allows to login to the application which connect to the firebase server.

Figure 29 shows the home page of our android application (SRTHMATS APP); that allows changing email, changing password, resetting password, removing user, using the messenger in the application, stopping and exiting from the application.

Figure 30 and Figure 31 show the messenger page of our android application (SRTHMATS APP); that allows sending health information messages such as (Blood pressure, Diabetes, Heart beat, Temperatures and other critical health messages) of the master and the slave, respectively. Figure 30 shows the messenger page of the master which use Bluetooth to communicate with its children (slaves), GPS to determine its location and Wi-Fi to transfer its cluster information to the firebase server for management and processing. While Figure 31 shows the messenger page of the slave which use only Bluetooth to communicate with its parent (master).

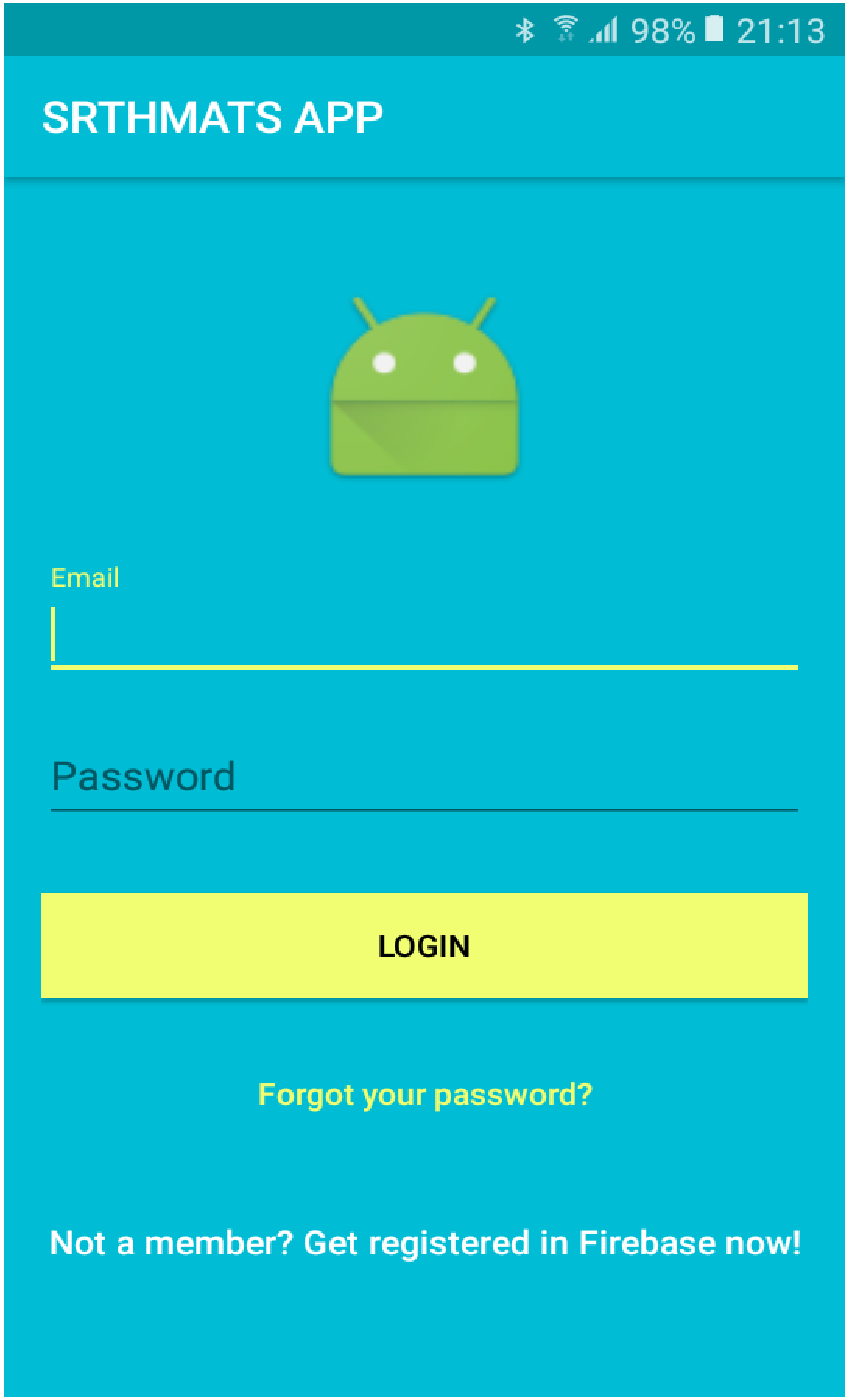


Figure 28 The login page of our android application (SRTMHATS APP).

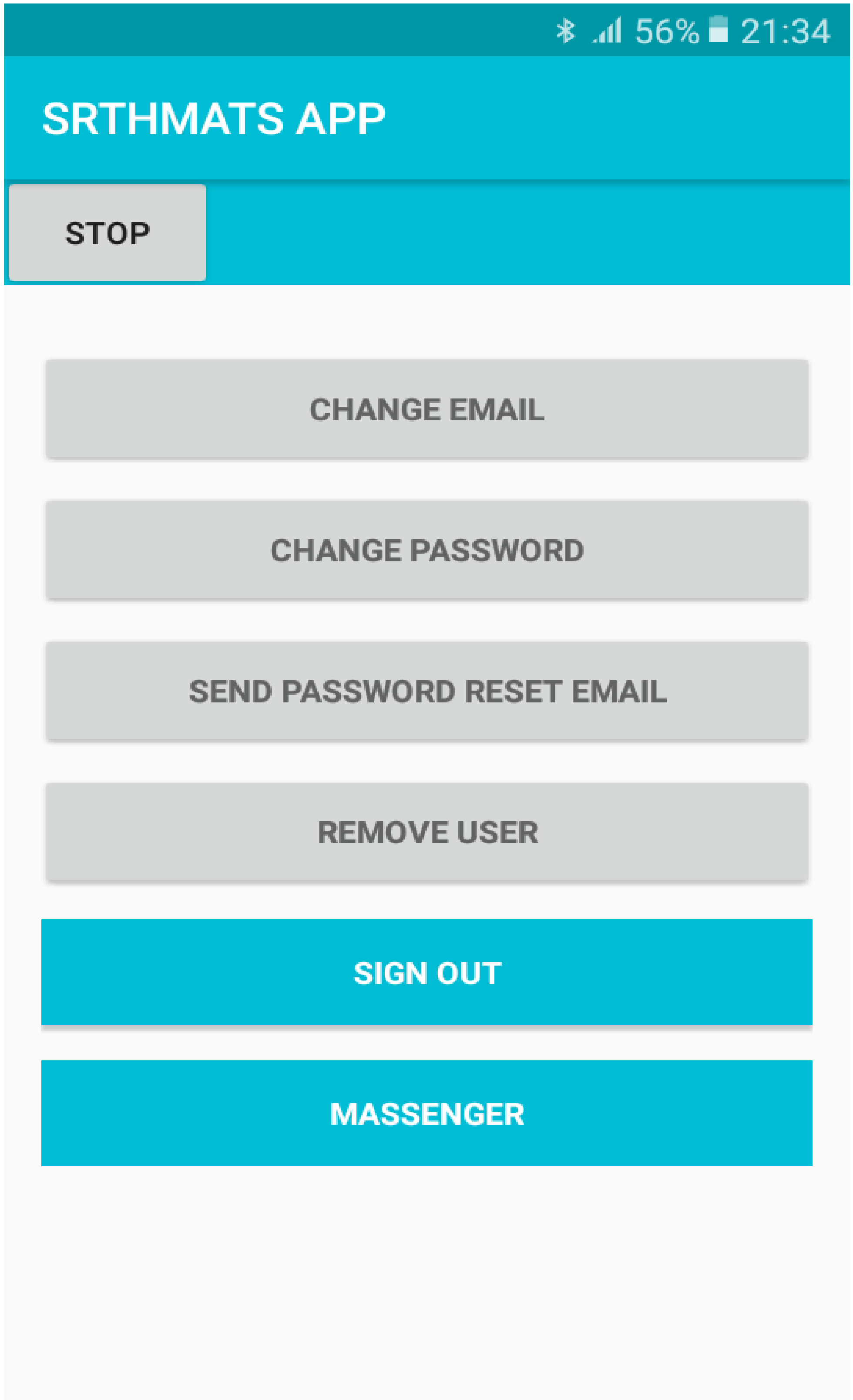


Figure 29 The home page of our android application (SRTMHATS APP).

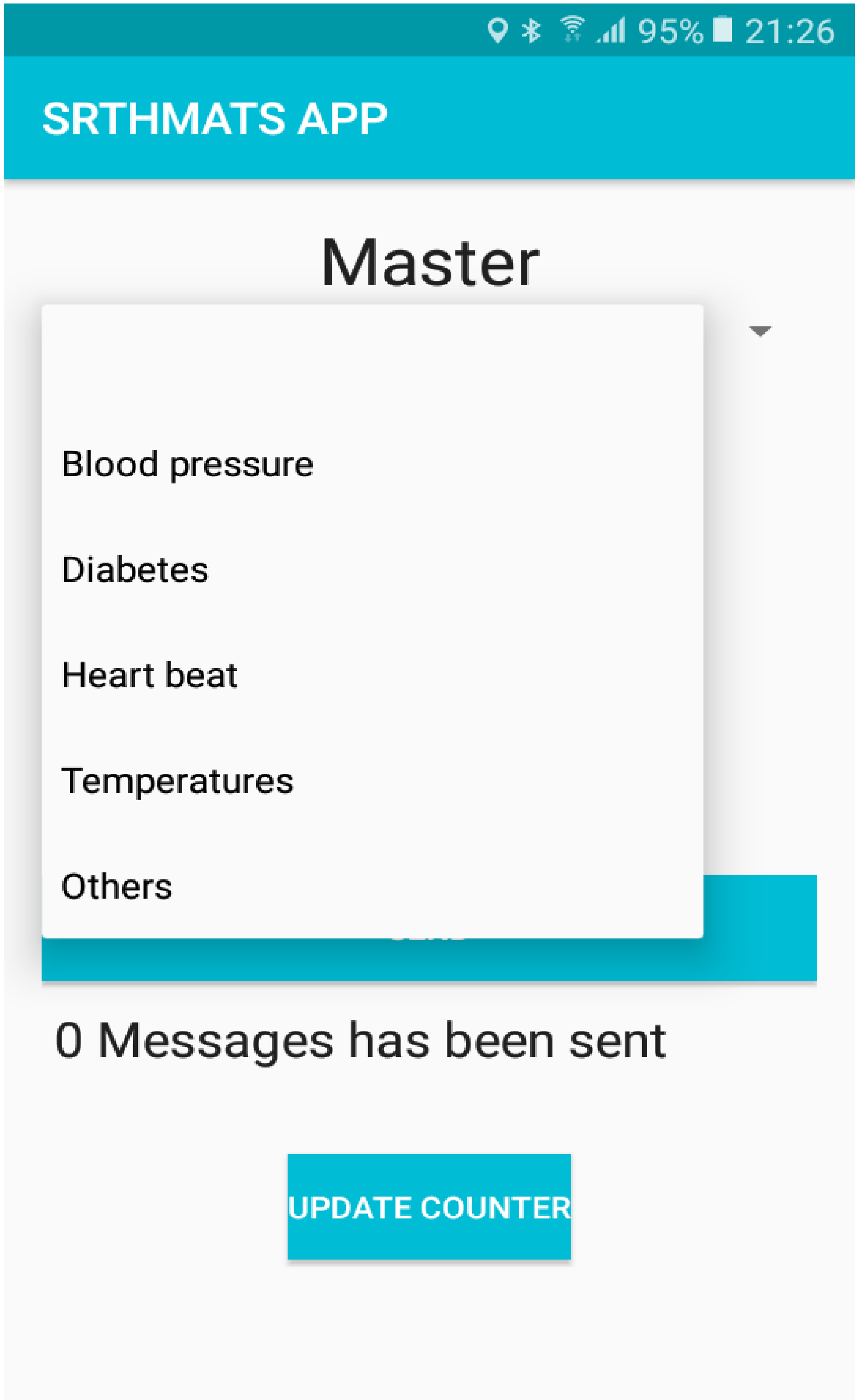


Figure 30 The messenger page of our (SRTMHATS APP) of the master.

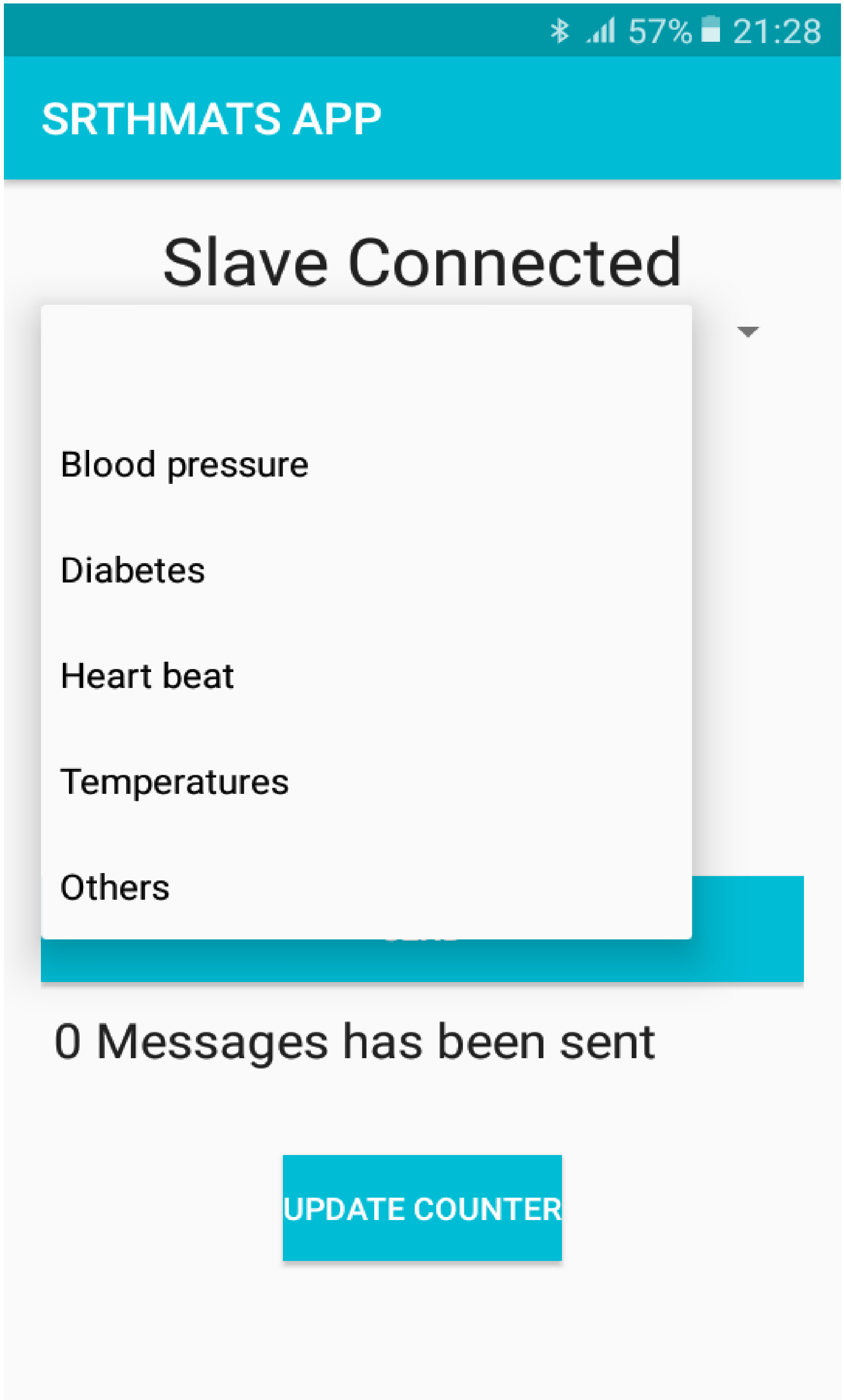


Figure 31 The messenger page of our (SRTMHATS APP) of the slave.

The firebase server shows the data of our android application (SRTMHATS APP); devices (all devices using the app with their battery level, mac address and login time), number of clusters, messages that contain health information message and cluster location , number of undelivered messages and the setting of our app as follows:


```
"Devices" : {
  "352412098034060" : {
    "Battery" : "89",
    "Network" : "true",
    "UUID" : "352412098034060",
    "mAddress" : "7C:1C:68:C8:B5:55",
    "time" : "Sun Dec 17 08:18:43 GMT+03:00 2017"    },
"Number of Clusters" : 5,
"Messages" : {
  "3C:05:18:E8:3C:8D"    : "Help~Blood pressure~~Location~50.1460572:26.3056239",
  "7C:1C:68:C8:B5:55"    : "Help~Heart beat~~Location~50.1460773:26.3056489",
},
"Undelivered Mesg" : 14,
"settings" : {
  "BatteryLevelMin" : 50,
  "BatteryPercentage" : 80,
  "DelayThread" : 60000,
  "ListSleepDisconect" : 8000,
  "PicoNetSize" : 7  },
```

Experimental Results

We have presented the performance of the direct approach, the 1st-level clustering approach and the android application (SRTHMATS APP). We used the same simulation experimental setup and performance metrics that we used in the section 3.1.3.2 and the section 3.1.3.3, respectively. The total energy consumption, throughput and efficiency in each scenario were calculated for twelve nodes.

Figure 32 shows the construction of the piconets (clusters) of the android application (SRTHMATS APP) for scenario 1. The first scenario tackles the experiment of our (SRTHMATS APP) of twelve users (nodes) without mobility in the service region (the classroom) $9 \times 9 \text{ m}^2$ within the Bluetooth range. The experiment has been tested for ten minutes. Each user (node) sent data traffic (frames) with sizes up to 20 bytes which is sufficient to send health information messages. The results show the number of the delivered messages is equal 50 out of 66 and the number of clusters is equal 3. This shows that the proposed app is capable of producing high-quality for large-scale tracking problems.

Figure 32 The construction of the piconets of our (SRTHMATS APP) for scenario1

Figure 33 shows the construction of the piconets (clusters) of the android application (SRTHMATS APP) for scenario 2. The second scenario tackles the experiment of our (SRTHMATS APP) of twelve users (nodes) with mobility in the service region (the classroom) 9×9 m^2 within the Bluetooth range. The experiment has been tested for ten minutes. Each user (node) sent data traffic (frames) with sizes up to 20 bytes which is sufficient to send health information messages. The results show the number of the delivered messages is equal 58 out of 72 and the number of clusters is equal 5. This shows that the proposed app is capable of producing high-quality for large-scale tracking problems.

Figure 33 The construction of the piconets of our (SRTHMATS APP) for scenario2

Figure 34 and Table 7 show the energy consumption of the direct approach, the 1st-level clustering approach and the android application (SRTHMATS APP) for the both scenarios. Figure 34 and Table 7 show that the energy of the proposed approach (SRTHMATS APP) is lower than the energy of the 1st-level clustering approach (theoretical approach). This is because the number of the clusters of our app is three and five for scenario 1 and scenario 2, respectively.

For the 1st-level clustering approach the number of clusters is two for both scenarios. While for the direct approach the total energy increases as the number of nodes increases. This is because in the direct approach each node has Wi-Fi and GPS for transmission of the data to the back-end server. Since all nodes transmit data over long- range, the direct approach consumes more energy than the 1st-level clustering approach and the android application (SRTHMATS APP) in both scenarios. Clearly, the direct approach is a very inefficient solution method for large-scale high-mobility tracking systems.

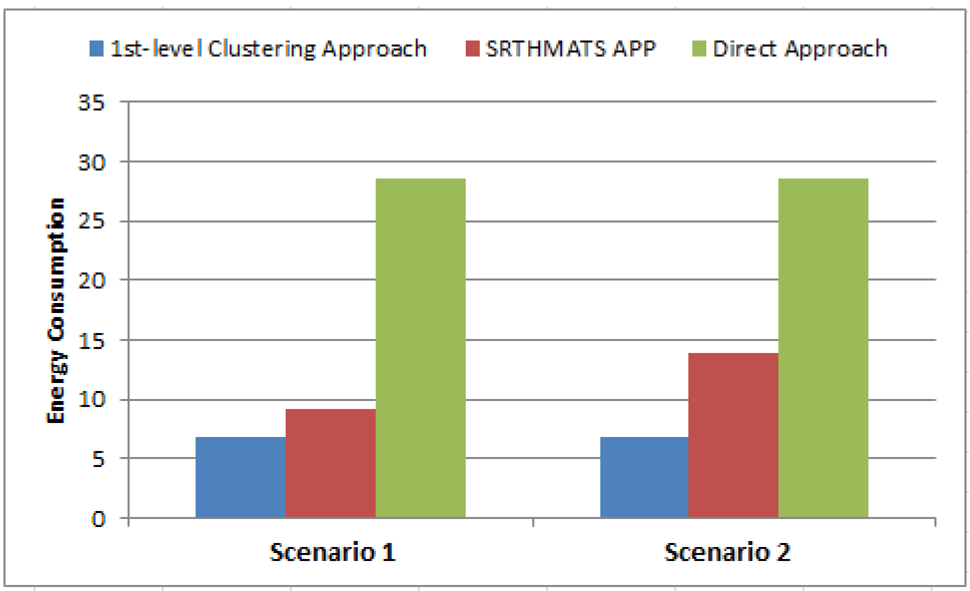


Figure 34 The comparison of the energy consumption of the both scenarios.

Figure 35 and Table 7 show the throughput of the direct approach, the 1st-level clustering approach and the android application (SRTHMATS APP) for the both scenarios. We observed from Figure 35 and Table 7 the throughput of the scenario 2 is higher than the throughput of the scenario 1; mainly this is because the number of sent packets (72 messages) for scenario 2 is greater than the number of sent packets (66 messages) for scenario 1. On the other hand, the throughput of our android application (SRTHMATS APP) is lower than the throughput of the direct approach and the 1st-level clustering approach.

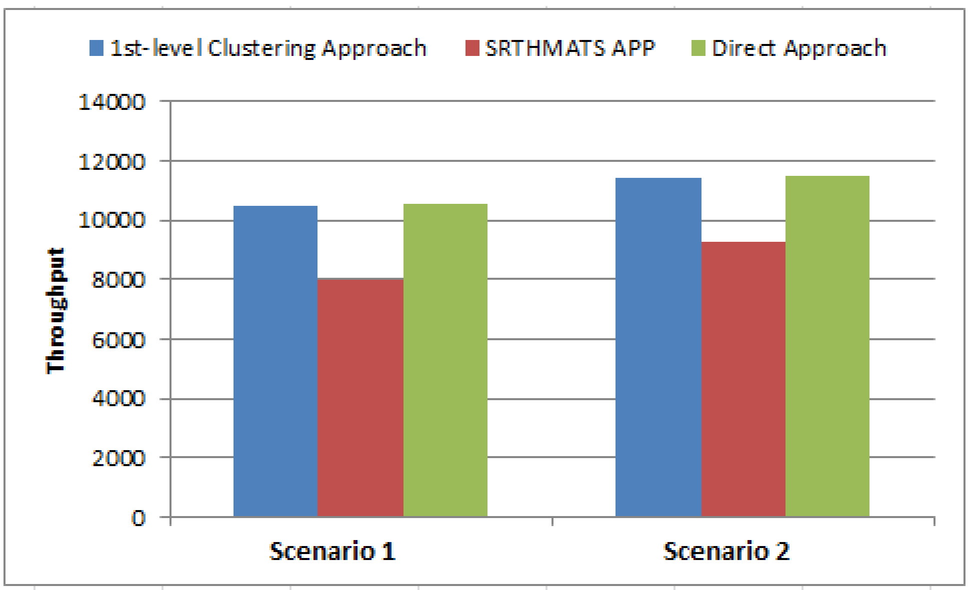


Figure 35 The comparison of the throughput of the both scenarios.

Figure 36 and Table 7 show the efficiency packet per Joule of the direct approach, the 1st-level clustering approach and the android application (SRTHMATS APP) for the both scenarios. Figure 36 and Table 7 show that the efficiency packet per Joule of the proposed approach (SRTHMATS APP) is lower than the efficiency of the 1st-level clustering approach (theoretical approach). This is because number of the clusters of our app is three and five for scenario 1 and scenario 2, respectively. For the 1st-level clustering approach the number of clusters is two for both scenarios. While the efficiency packet per Joule of the proposed approach (SRTHMATS APP) is higher than the efficiency of the direct approach. This shows that the proposed app is capable of producing high-quality for large-scale tracking problems. On the other hand, Figure 36 and Table 7 show the efficiency of the direct approach of scenario 2 is higher than the efficiency of the direct approach of scenario 1; mainly this is because the number of sent packets (72 messages) for scenario 2 is greater than the number of sent packets (66 messages) for scenario 1. In the fact, the efficiency packet per Joule of the direct approach remains constant as the number of nodes increases. The reason is that in the direct approach each node has Wi-Fi and GPS to transmit data to the back-end server. Therefore, the probability that each node has to transmit its data to the back- end server is the same. This is another reason to conclude that the direct approach is not suitable for handling high-data requirements of a large-scale tracking system.

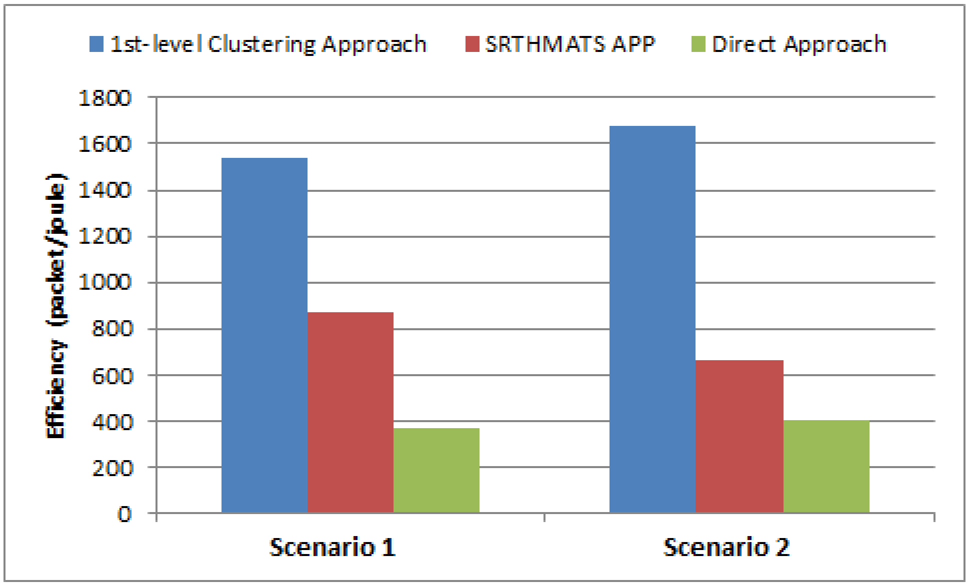


Figure 36 The comparison of the efficiency of the both scenarios.

Scenario #	Throughput of (bps)			Energy Consumption of (Joule)			Efficacy of (packet/joule)		
	1st-Level Approach	Direct Approach	SRTHMATS APP	1st-Level Approach	Direct Approach	SRTHMATS APP	1st-Level Approach	Direct Approach	SRTHMATS APP
1	10488	10560	8000	6.808	28.6092	9.192	1540.5	369.11	870.32
2	11441	11520	9280	6.808	28.6092	13.960	1680.5	402.67	664.76

Table 7: The Comparison of energy, throughput and efficiency of the three approaches

CHAPTER 4

EFFICIENT TECHNIQUE BASED ON A SMART RFID NODE

In this chapter, efficient technique based on a smart RFID node that ensures energy-efficient for a large-scale tracking system is presented as follows: the first section presents the simulator of the efficient technique based on a smart RFID node. The real experiment solution of the efficient technique based on a smart RFID node is presented in the second section.

4.1 Simulator Solution

In this section we simulated the (Smart node) that was proposed by Shen et al. [6]. The smart node is developed for collection data efficiently in a large-scale monitoring application. It combines the function of RFID readers (the reduced function of RFID reader), RFID tags, and Wireless Sensor Network (WSN). Thus, each node can read other’s sensed data in its own tag, and all information can be sent to an RFID reader through the node that reaches first to its range. Then, the RFID readers send the collected information to the back-end server for data management and processing. The system essentially consists of three components; smart nodes, RFID readers and the back-end server. In our system; we intend to develop a security scheme in order to protect our data from potential attacks; we applied Rivest-Shamir-Adleman (RSA) Algorithm to protect the collected data [54]. We implemented the data collection system for monitoring the health parameters using Cisco Packet Tracer 7.0 since it supports IoT, RFID, and many other functions as in the cisco specification [55].

4.1.1 Proposed solution

In this section, we discuss the proposed data collection technique that can efficiently collect the human being's health parameters (e.g. temperature, heartbeat…etc.) and make them available to the back-end server in real-time. The proposed approach uses Hybrid RFID and WSN (smart node) system based on clustering scheme that allows for both efficient data collection and data communication.

The main components in the data collection system architecture (clustering approach) are smart nodes, RFID readers, and the back-end server as shown in Figure 37 the smart node integrates the functionalities of RFID and WSN. It consists of Reduced-Function Sensor (RFS), RFID tag, and Reduced-Function RFID Reader (RFRR). RFS does not have wireless transmission function unlike the normal sensors. It is responsible for collecting the body temperature.

The smart node uses RFRR for the data transmission with other smart nodes; it reads other smart nodes' tags and writes the data into its own tag. RFID tag works as traditional packet memory buffer for data storage. The construction of the cluster depends on the choice of the cluster head from nodes in the same range. Each node read the tag id of all nodes in its range. The node which has the lowest id will be chosen as the cluster head of this particular cluster. The cluster consists of cluster head and cluster members; each member in the cluster replicates their tag information to the cluster head. The RFID reader receives all packets of nodes from the cluster head instead of reading every tag when they move into the RFID reader range. The RFID readers send the collected information to the back-end server for data processing and management.

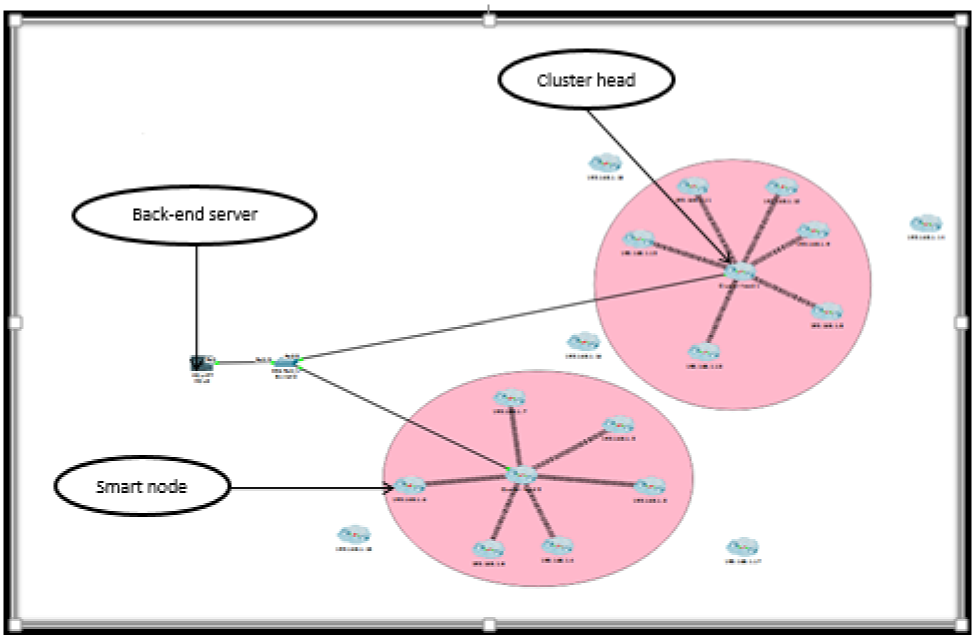


Figure 37 The architecture of the data collection system

4.1.2 The performance evaluation experiments and discusses the achieved results

In this section, we evaluate the performance of our approach that ensures efficient data collection system for monitoring the health parameters by using Cisco Packet Tracer 7.0 since it supports IoT, RFID, and many other functions as in the cisco specification [55].

Simulation Experimental Setup

We will show the experimental setup of our approach; smart nodes, RFID readers and the back-end server. Also we will show the experimental setup of Rivest-Shamir-Adleman (RSA) Algorithm in order to protect the collected data.

Figure 38 shows the implementation of a smart node in Cisco Packet Tracer. RFRR has been programed to perform two tasks; read the temperature from the RFS and store it into its tag, and read the data from other smart nodes within its transmission range and store it into its tag. The heating element is used to make diverse readings in the RFS. The heating element will be controlled using switch to turn it on and off. On the other hand, the microcontroller unit is used to monitor and verify the smart node readings.

When the smart node collects the sensed data, it appends it with a timestamp and stores this information in its own tag through RFRR. Subsequently, the transmitted data between smart nodes and RFID readers has three fields, namely, smart node ID which belongs to specific user, the sensed data, and the timestamp when the data was collected.

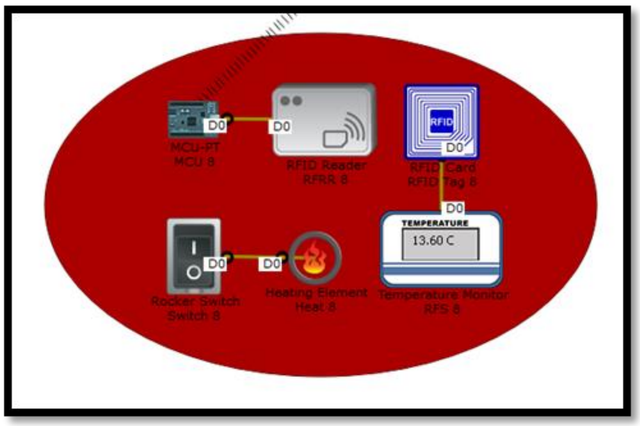


Figure 38 The Smart node components

Figure 39 shows the components of the RFID reader and its connectivity with the back-end server. The RFID readers are responsible for collecting the data from the smart nodes and deliver it to the back-end server. The transmission range of the RFID reader is much greater than that of the RFRR. When reading the data of the smart node tag, it sends that data directly to the back-end server wirelessly using UDP socket.

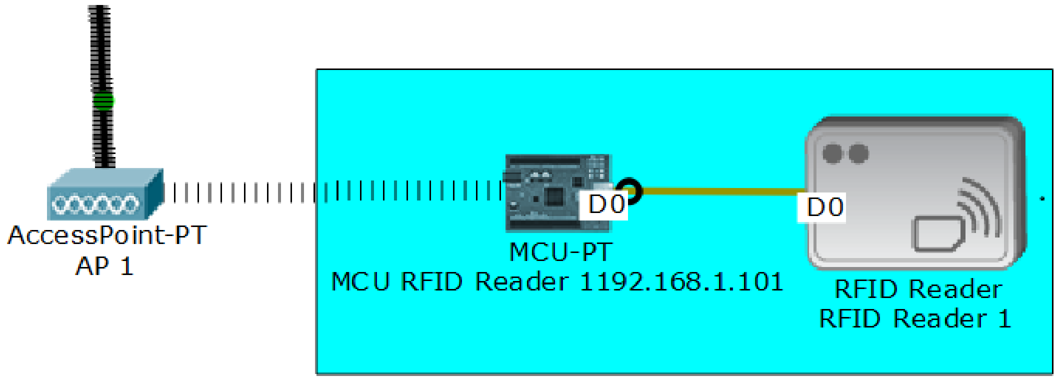


Figure 39 The RFID Reader

Figure 40 shows a sample of the collected data at the back-end server. The smart node can replicate its data to several other nodes in the system. Later, any one of these nodes that meets an RFID reader can send the data to the RFID reader. In this way, the probability that the data is delivered to the RFID reader is significantly increased and reduces the number of readers that needed for quickly data delivery.

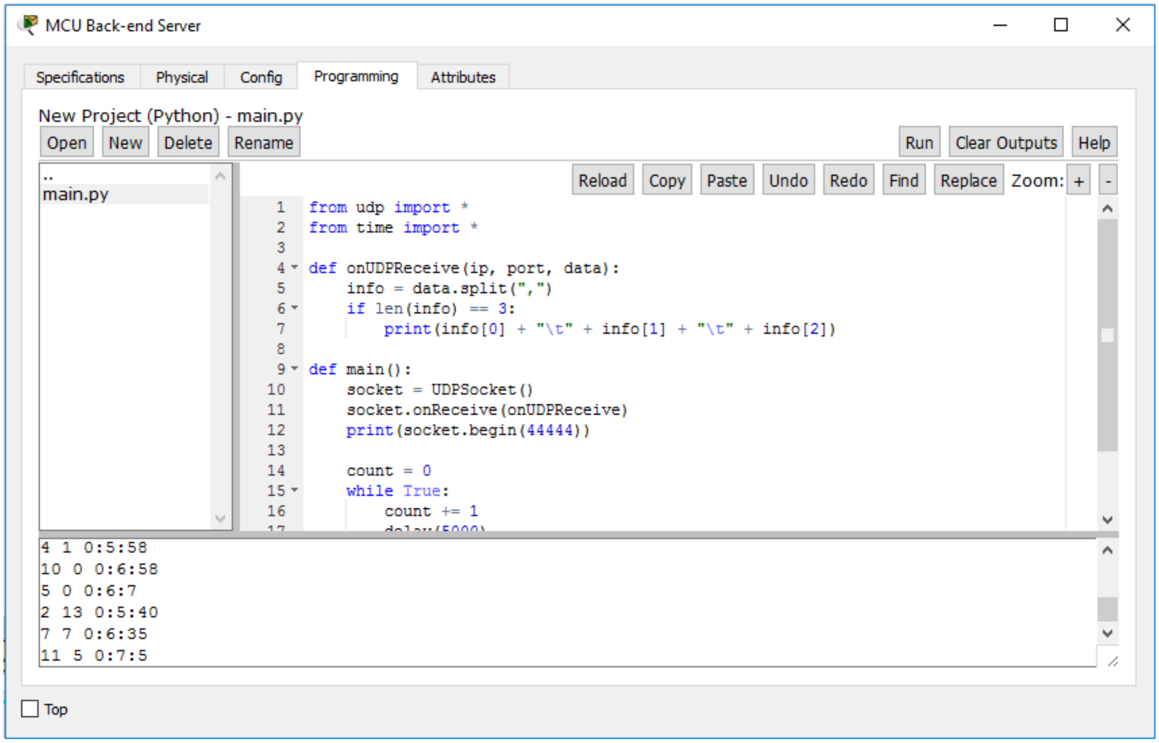


Figure 40 The Sample of the collected data at the back-end server

The main goal of our approach is designing and implementing a framework that integrates RFID with wireless sensor systems to gather information efficiently. The main challenge is collecting and protecting a real time data and management it especially in health related system that has important and critical data. As we know that the RFID nodes are deployed in open area therefore the attackers can simply access and take control and manage of these nodes. Thus, to protect our data from potential attacks we applied Rivest-Shamir-Adleman (RSA) Algorithms security against threats arising from node attacks. Figure 41 shows a sample of the collected data at the back-end server after implemented Rivest-Shamir-Adleman (RSA) Algorithm.

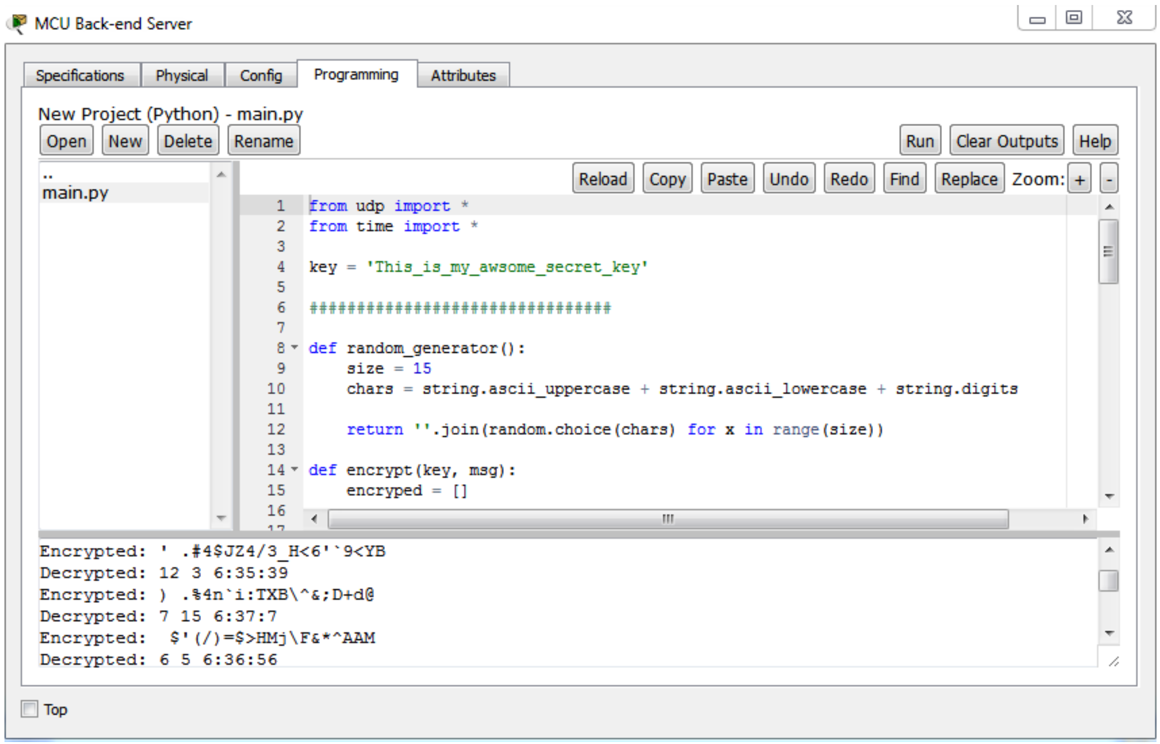


Figure 41 The Sample of the secure collected data at the back-end server

Simulation Results

We discuss the simulation results of our proposed system which based on clustering scheme (clustering approach) and the traditional approach (direct approach). We used Packet Tracer 7.0 and python as programming language in our simulation. We implemented both approach with different number of nodes for 10 minutes (600 seconds).

Figure 42 shows the average transmission delay per packet of the clustering approach decreases slightly when the number of nodes increases, this because when the number of nodes increases; the density will be increased also the number of cluster heads will be increased. Therefore, the probability of meeting cluster heads to forward their packets to the RFID reader then to the backend server will be increased, that leads to reduce the transmission delay. While in the direct approach the transmission delay per packet almost fixed. This because the probability of the each node to meets an RFID reader to forward its packets is the same.

On the other hand, in the direct approach every node has packets which can be transmitted to an RFID reader when each one meets an RFID reader. In the clustering approach the cluster head has all the packets of the cluster and forward them to an RFID reader at one time when it meets an RFID reader, which significantly reduces the transmission delay per packet.

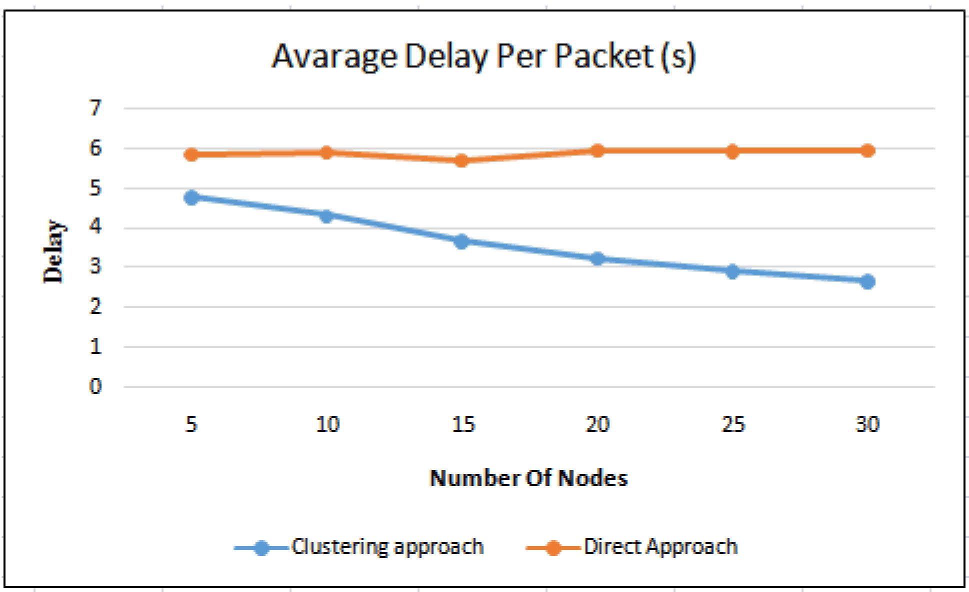


Figure 42 The Comparison of the average transmission delay

Figure 43 shows the average transmission delay per packet after included the RSA algorithm that ensures the security of the data during the transmission between nodes and RFID readers end up with the backend server. We are assuming the server environment is secure. Figure 43 shows the average transmission delay per packet in both approaches with RSA algorithm greater than the average transmission delay per packet without the RSA algorithm as we see in the Figure 42. This because the encryption and the decryption of the data taken more time during the security process.

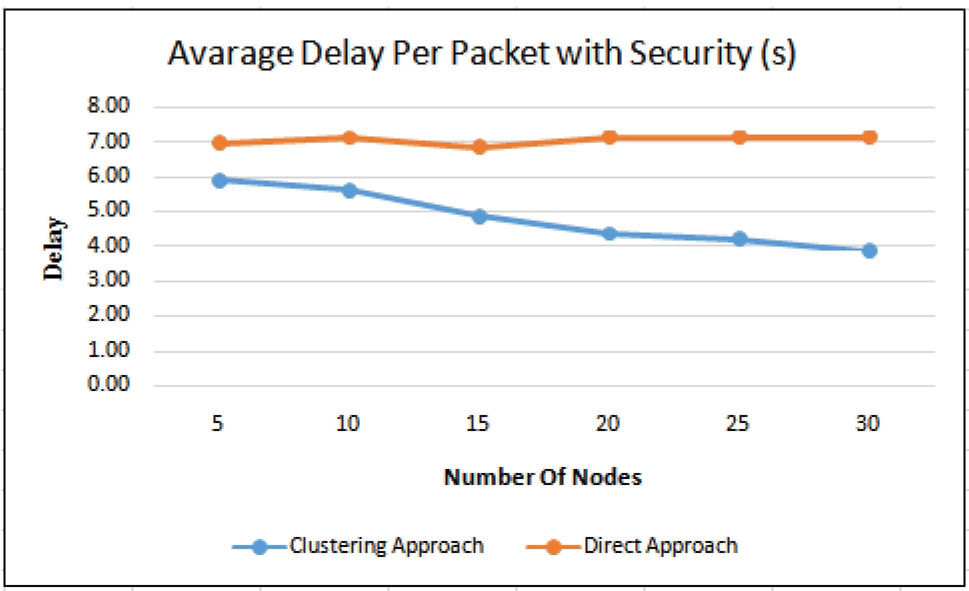


Figure 43 The Comparison of the average transmission delay with security

Figure 44 shows the average transmission delay decreases when the cluster size increases, this is because the cluster head has a lot of packets for all nodes in the cluster. Therefore, when the cluster head meets an RFID reader, all packets of the cluster is delivered to the RFID reader at one time. This significantly reduces the transmission delay per packet.

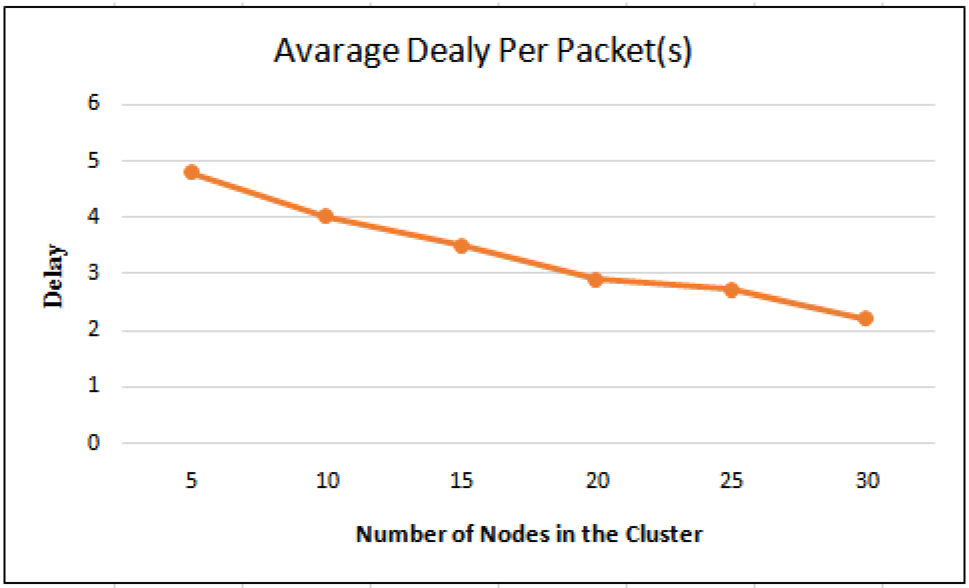


Figure 44 The average of transmission delay vs. cluster size

Figure 45 shows the number of the delivered packets in the clustering approach increases when the number of node increases. This because when the number of nodes in the same region area increases the density will be increased that leads to send more packets. Therefore; the probability of deliver packets will be increased. While in the direct approach the number of the dropped packets increases when the number of nodes increases. This because when the number of node increases the channel access congestion will be increased that leads to drop some of the packets during the transmission process.

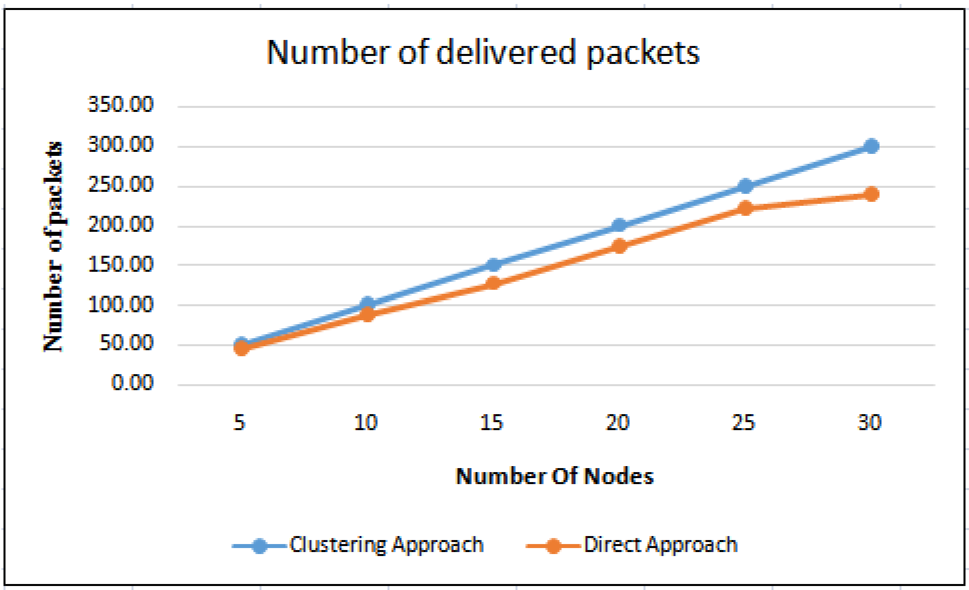


Figure 45 Comparison of number of the delivered packets

4.2 Real Experiment Solution

In this section, we present the implementation of the (Smart node) that was proposed by Shen et al. [6] along with few real experiment scenarios. The smart node is developed for collecting data efficiently in a large-scale monitoring application. It combines the function of RFID readers (the reduced function of RFID reader), RFID tags, and Wireless Sensor Network (WSN). In addition; we develop a security scheme in order to protect our data from potential attacks; we applied Advanced Encryption Slandered (AES) Algorithm to protect the collected data as well as authenticity RFID.

4.2.1 Proposed solution

In this section, we discuss the proposed data collection technique that can efficiently collect the human being's health parameters (e.g. muscle, heartbeat…etc.) and make them available to the back-end server in real-time. The proposed approach uses Hybrid RFID and WSN (smart node) system based on replication scheme that allows for both efficient data collection and data communication. The smart node consists of reduce function sensor (RFS), RFID tag, and reduce function RFID reader (RFRR). RFS does not have wireless transmission function unlike the normal sensors. It is responsible for collecting the body sensed data. The RFRR is RFID reader with a small range. It reads other smart nodes' tags and writes the data into its own tag. RFID tag works as traditional packet memory buffer for data storage.

Figure 46 shows our proposed solution based on replication approach .Each node can read other's sensed data and store it on its own tag, and all information can be sent to an RFID reader through the node that reaches first to its range. Then, the RFID readers send the collected information to the back-end server for data management and processing. As observed from Figure 46 node 1 replicates the sensed data of node 2 and node 4 and store these data on its own tag also node 2 replicates the sensed data of node 1 and node 3 and store these data on its own tag and so on.

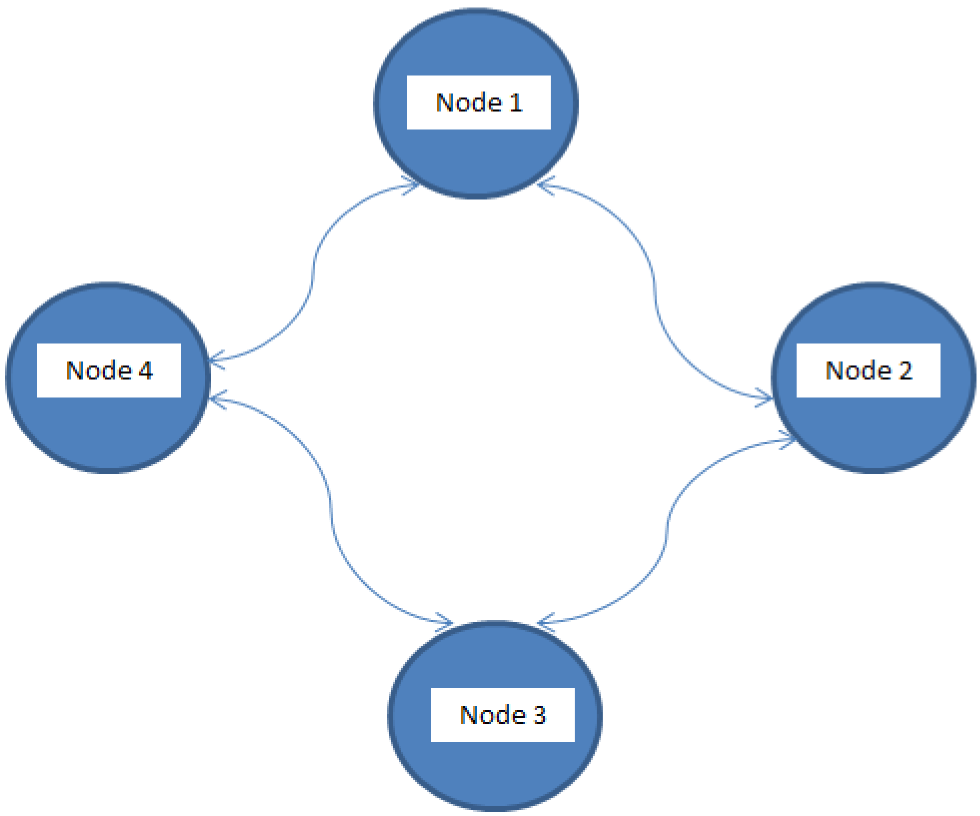


Figure 46 The proposed solution (Replication Approach)

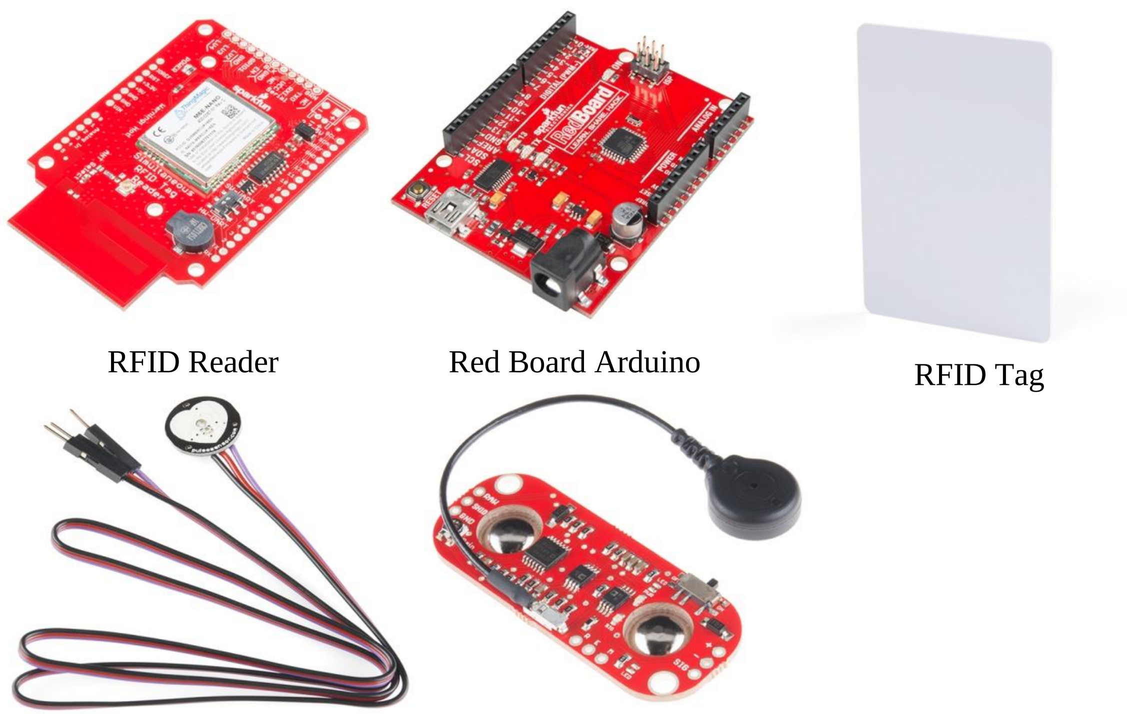
4.2.2 The performance evaluation experiments and discusses the achieved results

In this section, we present the experiment setup that is used for carry out the experiment. Then, we discuss the results.

Experimental Setup

Figure 47 shows the smart node component which consists of RFRR (small RFID reader), RFS (pulse sensor and muscle sensor), red board arduino and RFID tag. The RFRR can read within a small range from ten to fifteen cm as in the sparkfun specification [56]. The RFRR has been programed to perform two tasks; the first task is to read the heart beat and the muscle sensed data from the RFS (pulse sensor and muscle sensor), respectively and store these data into its tag. The second task is to read the data from other smart nodes within its transmission range and store it into its tag. On the other hand, the red board arduino is used to monitor, verify and process smart nodes readings.

When the smart node collects the sensed data, it appends it with a timestamp and stores the information in its own tag through RFRR. Subsequently, the transmitted data between smart nodes and RFID readers has three fields, namely, smart node ID which belongs to a specific user, the sensed data, and the timestamp when the data was collected.



RFID Reader

Red Board Arduino

RFID Tag

Pulse Sensor

Muscle Sensor

Figure 47 The Smart node components

Figure 48 shows our smart node which connects with heart beat sensor.

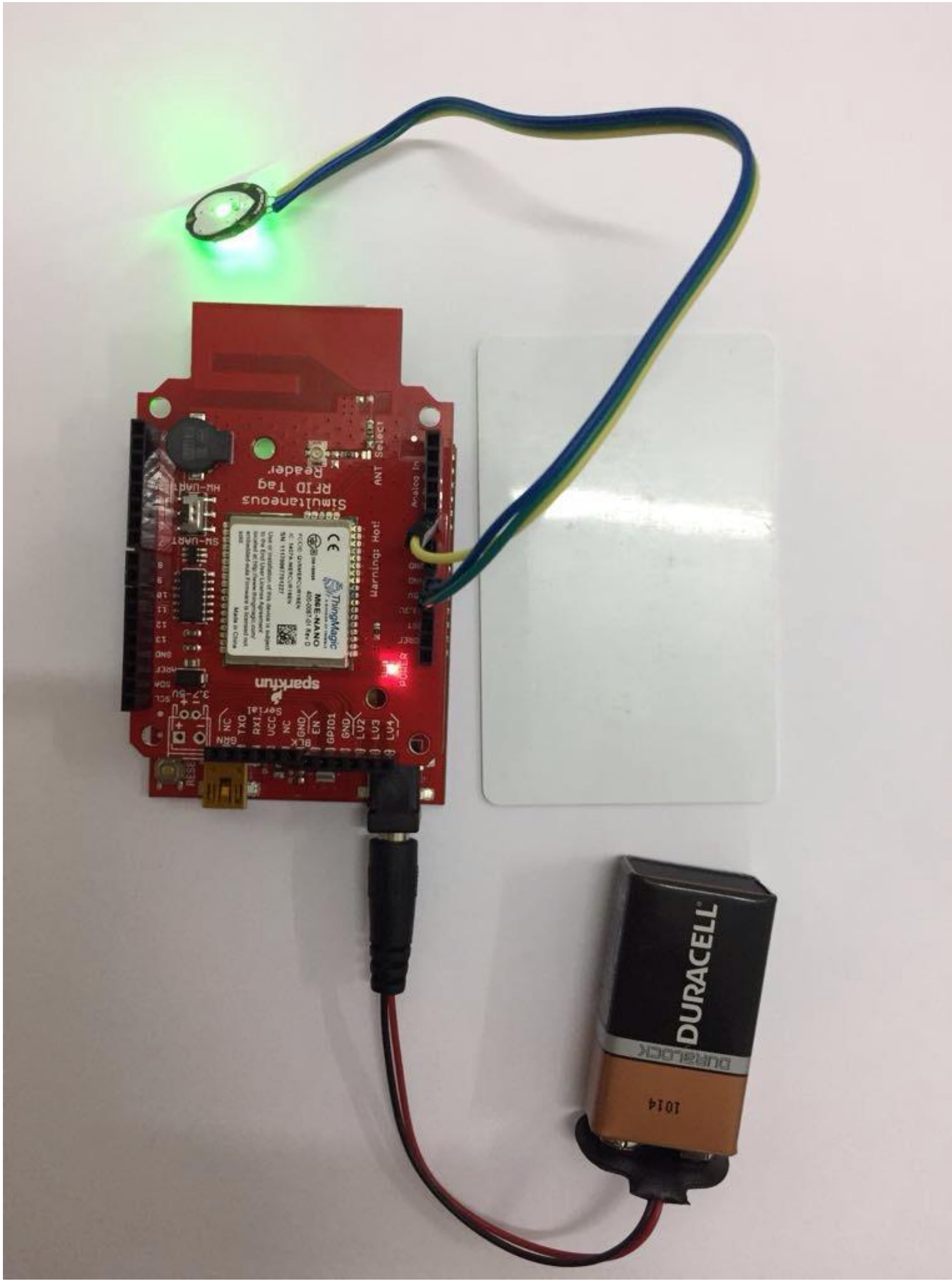


Figure 48 The Smart node with heart beat sensor

Figure 49 shows our smart node which connects with muscle sensor.

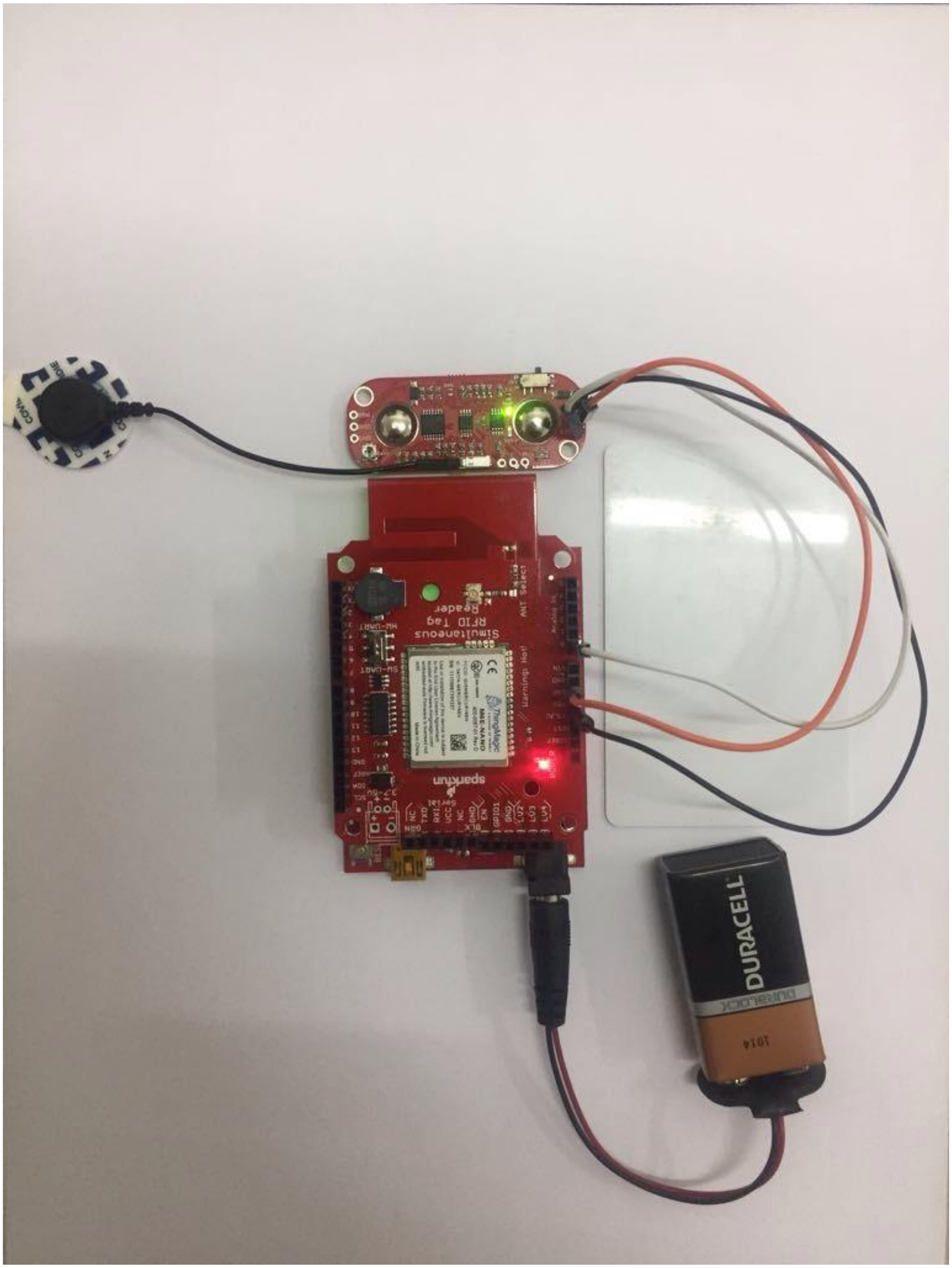


Figure 49 The Smart node with muscle sensor

Figure 50 shows our smart node which connects with Bluetooth shield in order to integrate the smart node with the android application (SRTHMATS APP).

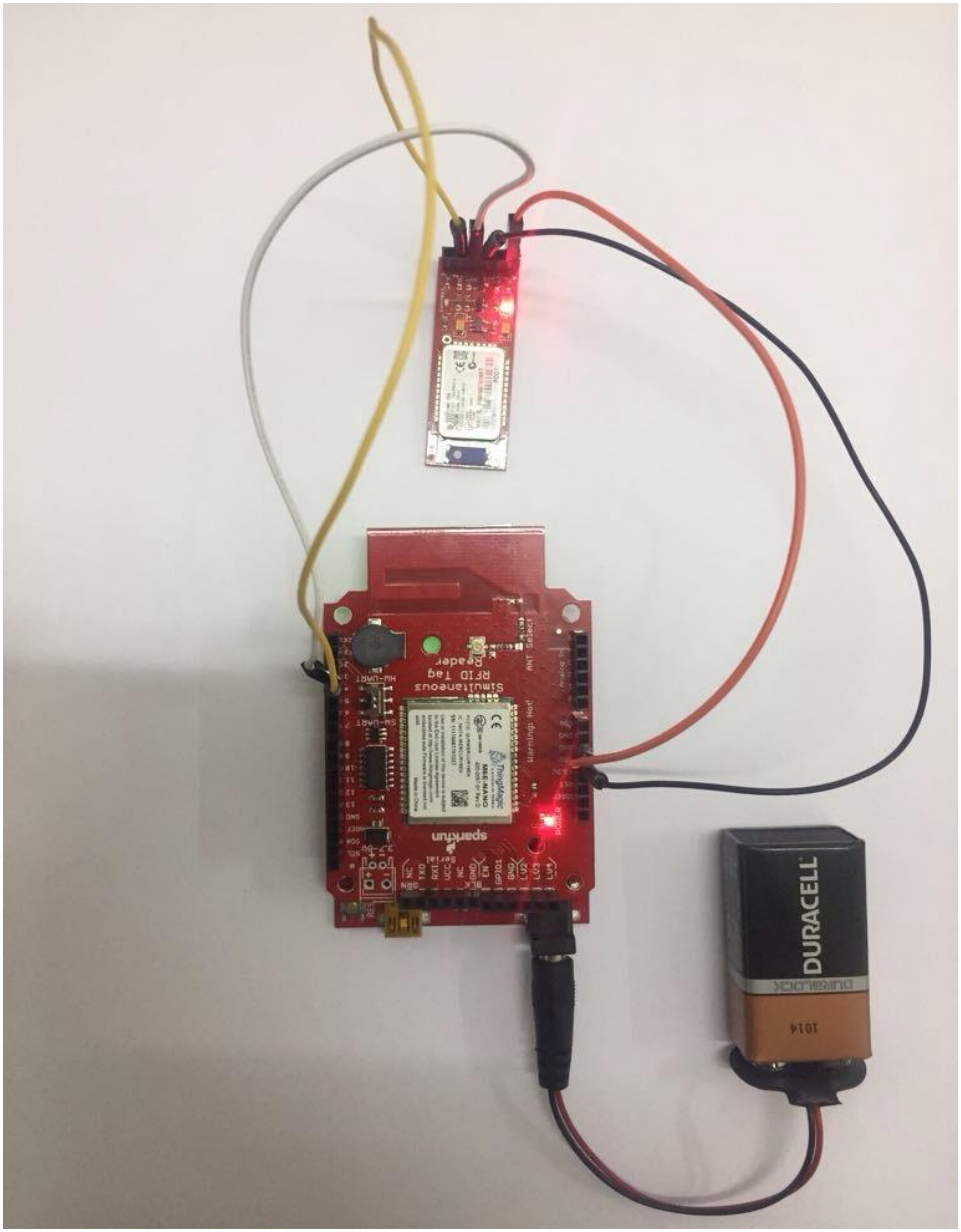


Figure 50 The Smart node with Bluetooth shield

Experimental Results

We discuss the experimental results of our proposed system which based on replication scheme.

Figure 51 and Figure 52 show a sample of the collected data of the pulse sensor that includes the beat per minute, live heart beat and the analog signal on the serial monitor and the serial plotter, respectively. The normal readings of the beat per minute of the pulse sensor should be between 60 and 100 otherwise, will be considered as emergency case.

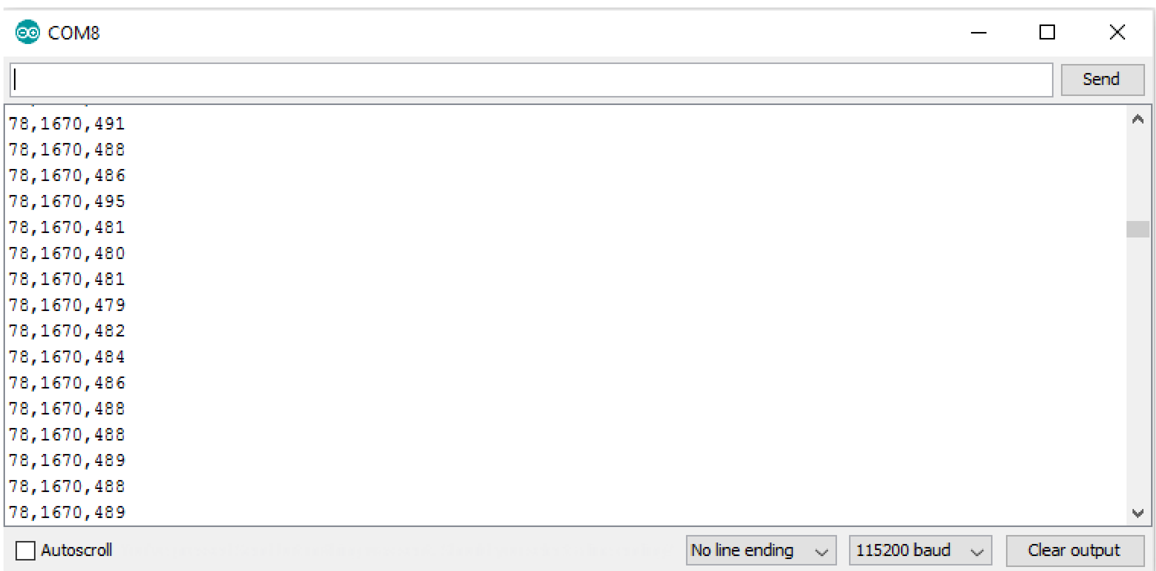


Figure 51 a sample of the collected data of the pulse sensor on the serial monitor

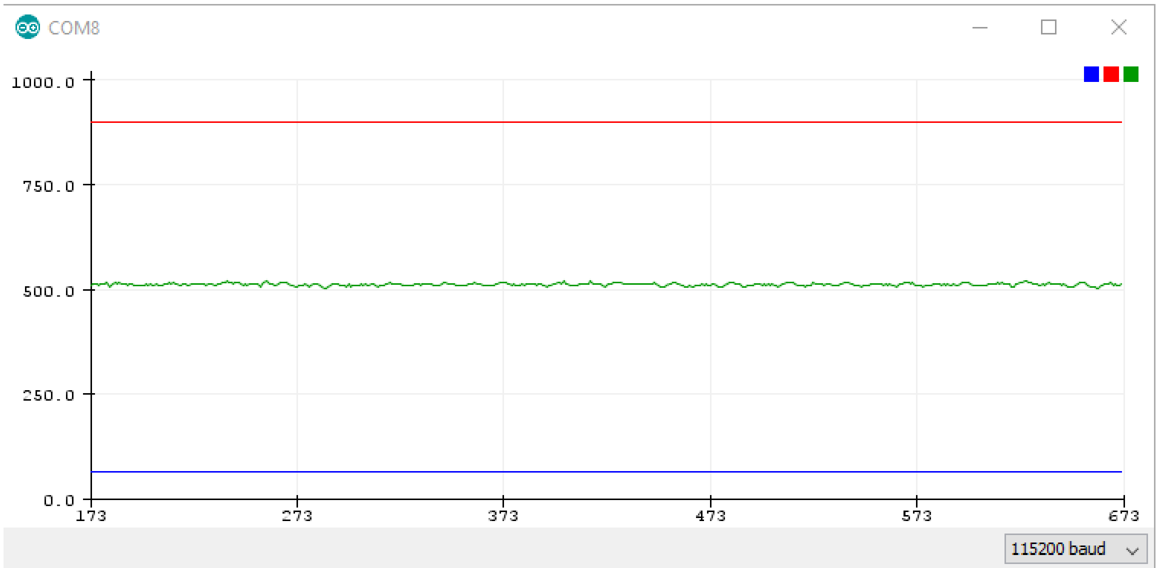


Figure 52 a sample of the collected data of the pulse sensor on the serial plotter

Figure 53 and Figure 54 show a sample of the collected data of the muscle sensor that includes the muscle state on the serial monitor and the serial plotter, respectively. The reading of the muscle sensor should be between 0 and 5 and it will be considered as emergency case when the reading of the muscle sensor will be between 0 and 1.

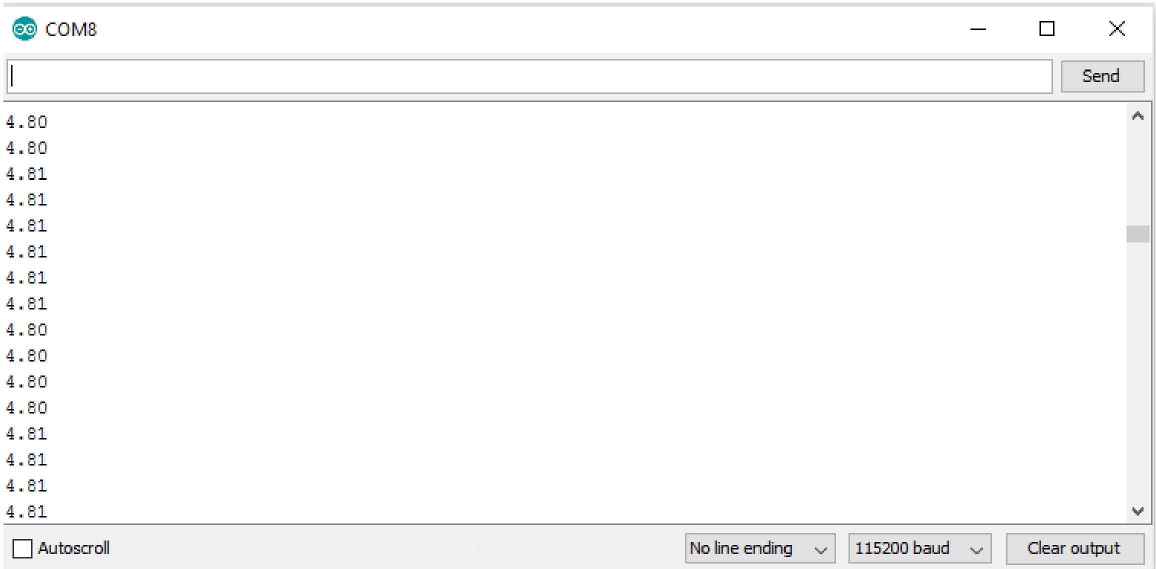


Figure 53 a sample of the collected data of the muscle sensor on the serial monitor

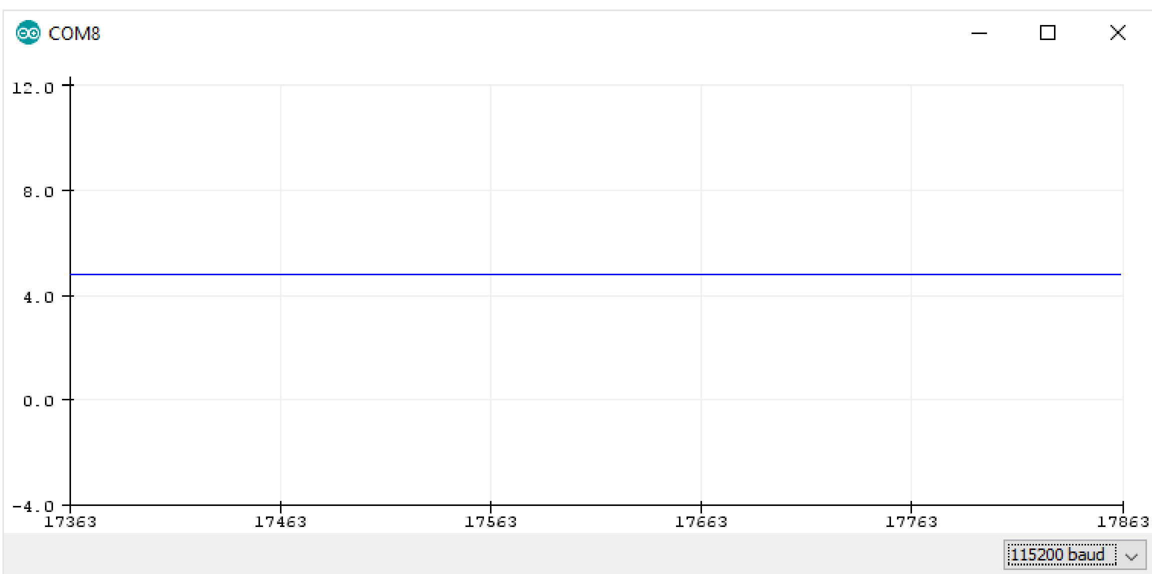


Figure 54 a sample of the collected data of the muscle sensor on the serial plotter

Figure 55 shows our experimental scenario which consists of three smart nodes and one RFID reader. Each node can read other's sensed data and store it on its own tag and all information can be sent to an RFID reader through the node that reaches first to its range. Then, the RFID readers send the collected information to the back-end server for data management and processing. It can be observed from Figure 55 the RFID reader is attached with external antenna to increase the transmission range of the RFID reader than that of the RFRR. The RFID readers are responsible for collecting the data from the smart nodes and deliver it to the back-end server. As our scenario each node one, two and three can read other's sensed data and store it on its own tag and all information can be sent to an RFID reader through the node three that reaches first to its range.

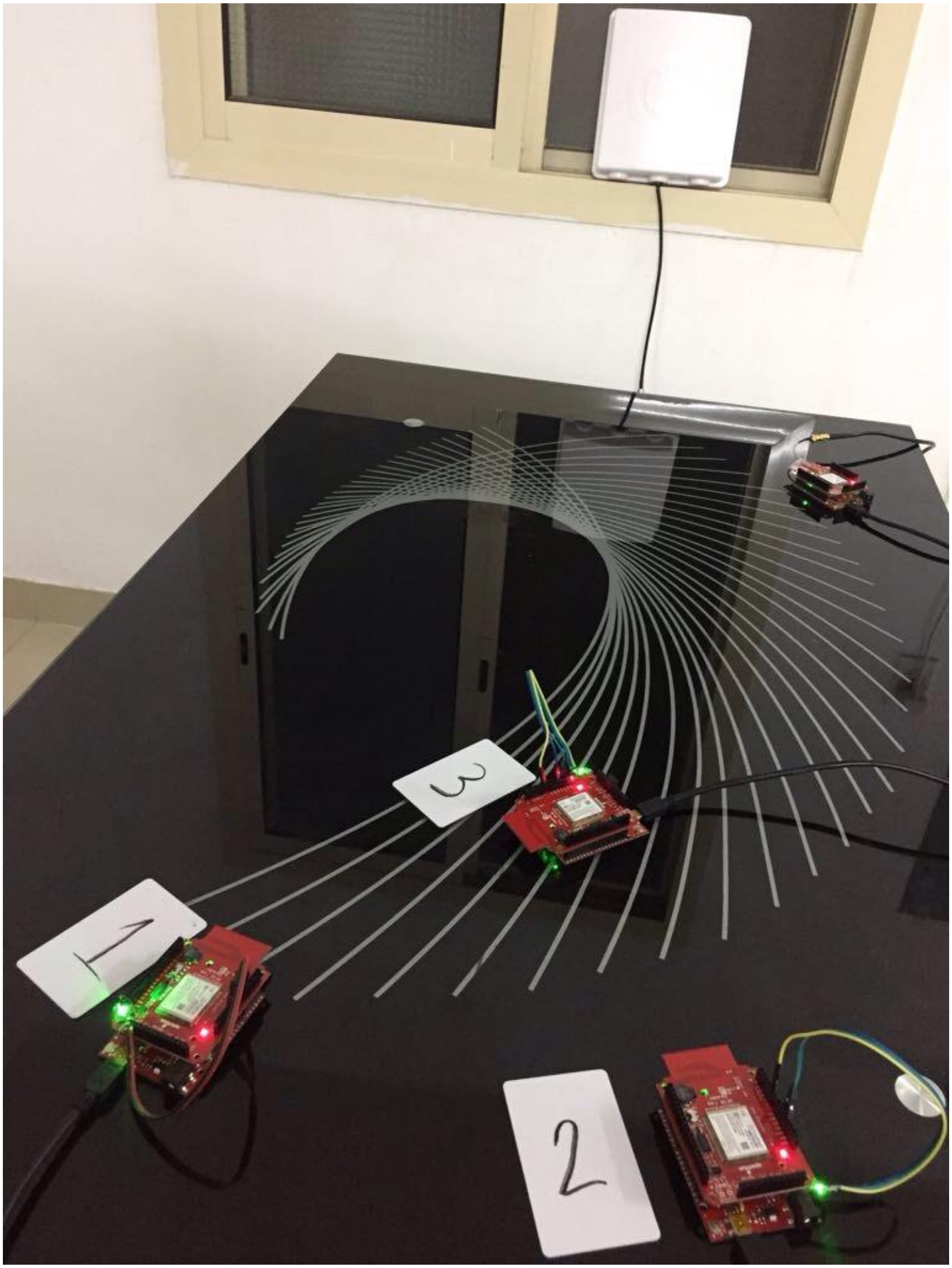


Figure 55 the experimental scenario which consists of three smart nodes and one RFID reader

Figure 56 shows the result our experimental scenario which consists of three smart nodes and one RFID reader. Node three read the sensed data of node one and node two and stores these data on its own tag and all information are sent to an RFID reader through node three that reaches first to its range.

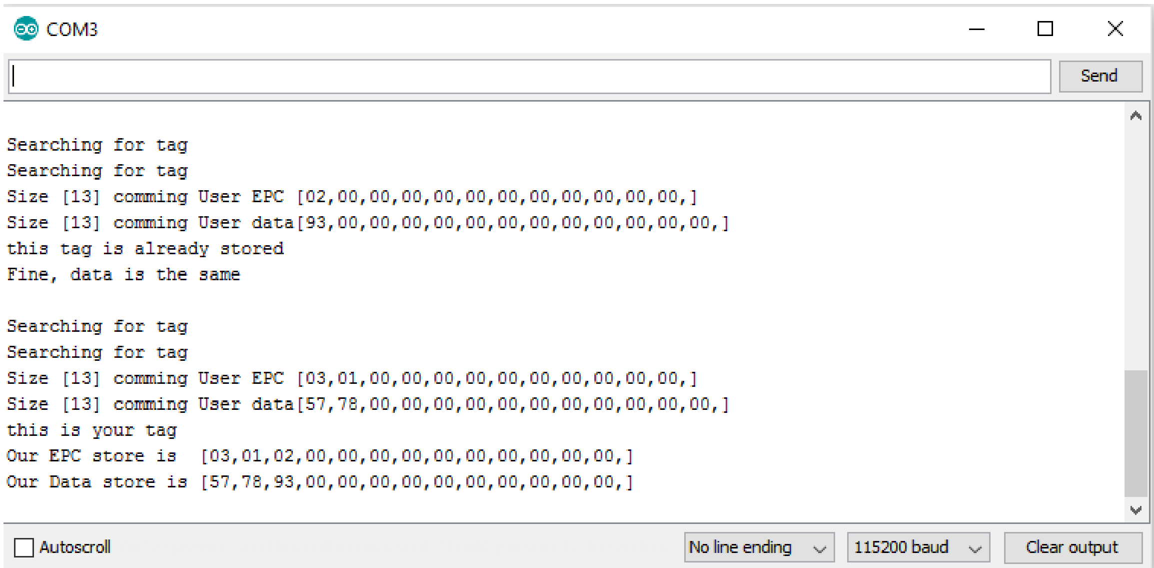


Figure 56 the results of our experimental scenario

Figure 57 shows the result our experimental scenario from the side of the RFID reader that received all information of all nodes from the node three that reaches first to its range.

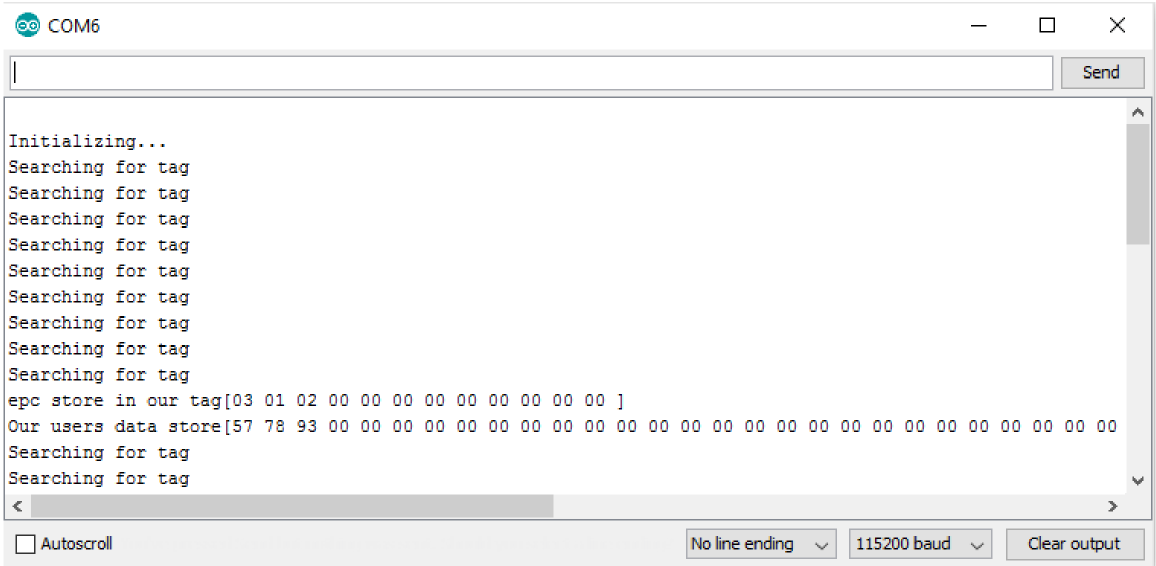


Figure 57 the results of our experimental scenario from the side of the RFID reader

Figure 58 shows the connection between the Adriano and the android application via Bluetooth by using the Bluetooth terminal application.

Figure 59 and Figure 60 show the results of the communication between the android application and the Adriano via Bluetooth by using the Bluetooth terminal application, respectively.

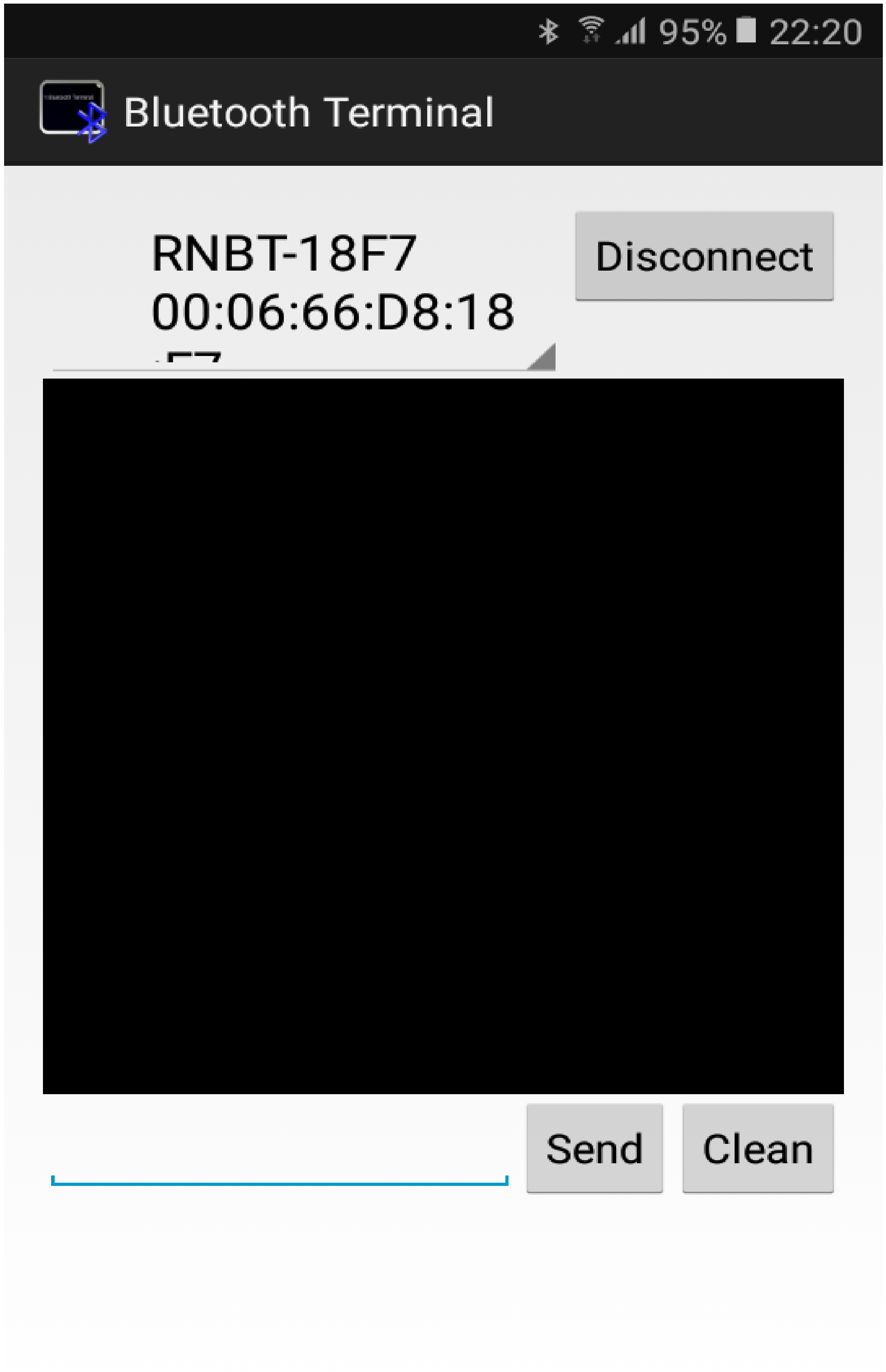


Figure 58 the connection between the Adriano and the android via Bluetooth

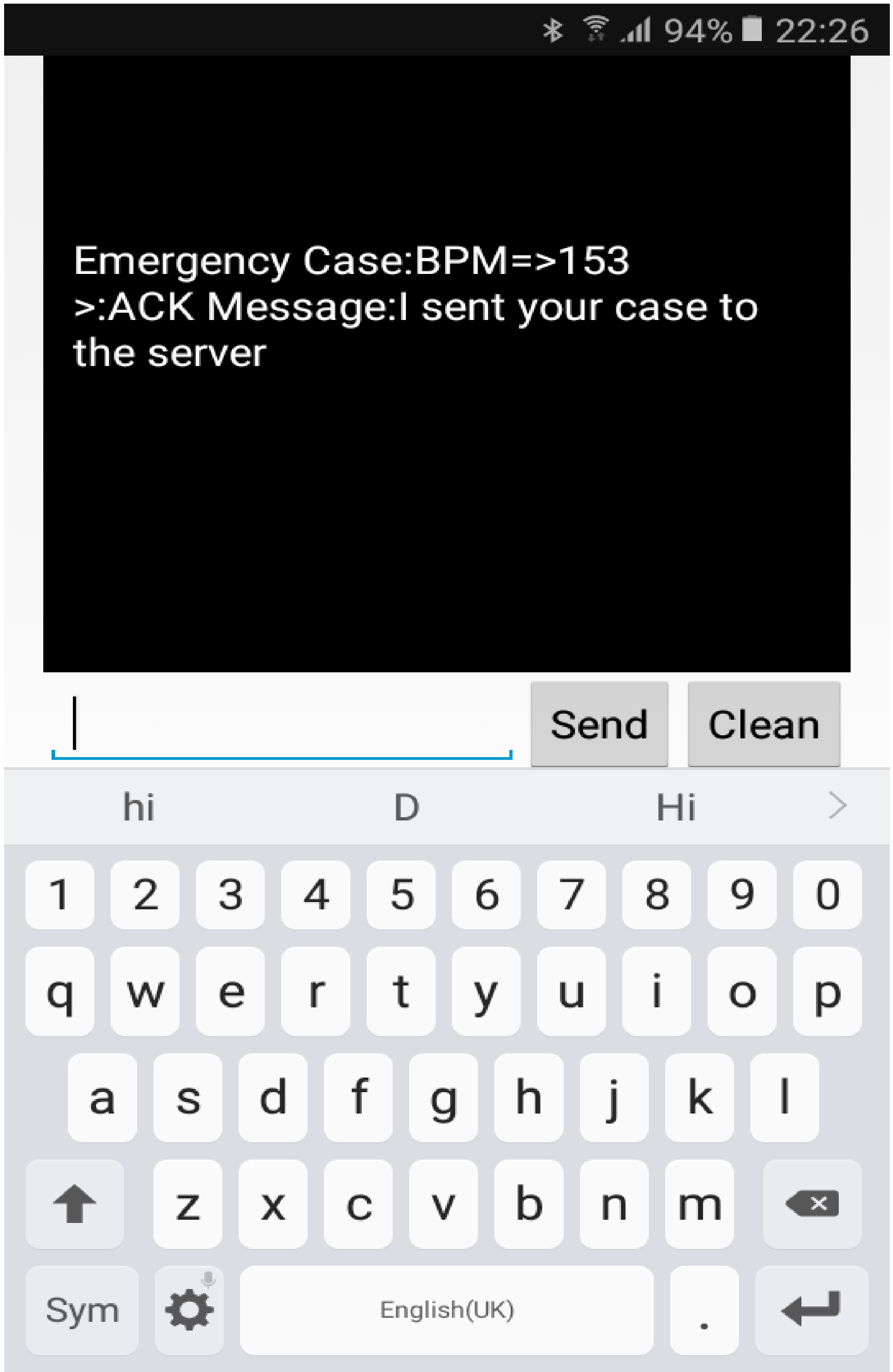


Figure 59 the results of the Bluetooth terminal

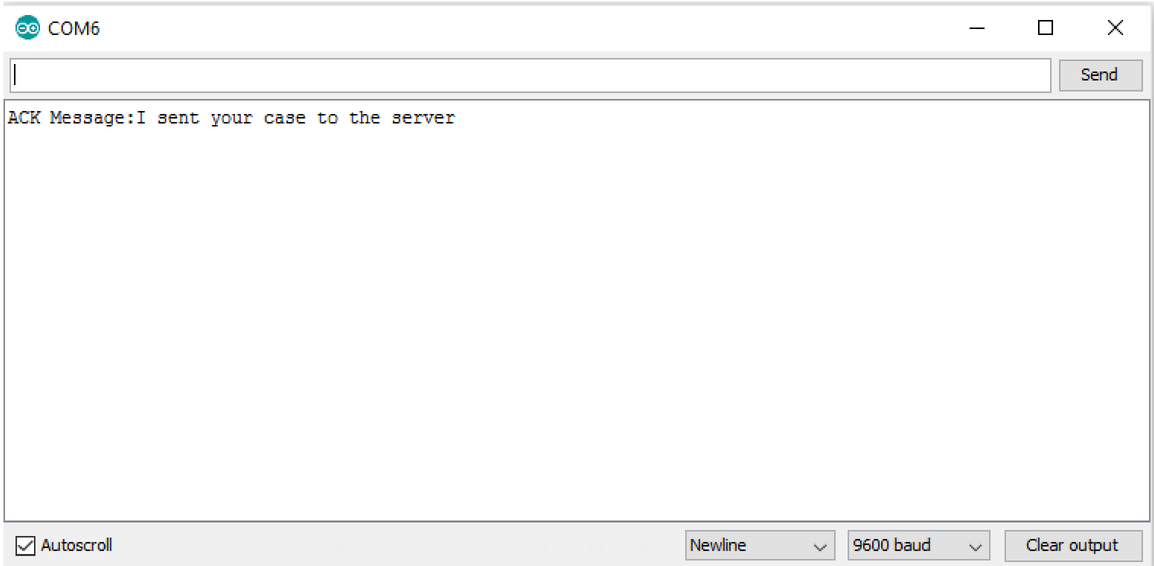


Figure 60 the results of the serial monitor

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CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 Conclusion

The thesis work presented a novel technique for optimization of Bluetooth clustering in order to design energy-efficient large-scale tracking systems based on mobile clustering. We minimized the total distance between masters and slaves and the number of clusters. Our proposed solution improves the accuracy of positioning, reduces the energy consumption and the transmission delay for Bluetooth networks. It also maximizes the throughput of the whole network and maximizes the lifetime of the network, and decreases the level of interference between Bluetooth itself also between Bluetooth and Wi-Fi. Experimental results show that the proposed solution ensures optimality, especially in the context of applying in a large-scale system.

On the other hand, a smart RFID node is implemented for ensuring healthcare monitoring applications based on RFID technology by integrating RFID with wireless sensor systems to gather information efficiently. We show the difference between our proposed architecture and the traditional architecture. In the traditional architecture only the nodes in the range of the RFID readers can send their tag data to the RFID readers. That leads to channel access congestion and therefore the process of collection data will be slow. While the nodes in the proposed architecture are smart nodes that each node can replicates their tag data to the cluster head which is responsible of transmit the data to the RFID reader then to the back-end server for processing it. Thus, the cluster head has all the packets of the cluster and forward them to an RFID reader when it meets an RFID reader, which significantly make the process of collection data fast. Experimental results show that the proposed solution ensures optimality, especially in the context of applying in a large-scale system.

5.2 Future Work

Our work has produced an energy-efficient large-scale tracking system using smartphones, in which user locations and information of interest are reported to the server periodically. There are other areas still not tackled in this research such as optimizing with respect to some other objectives.

In addition, there is a need to develop improved algorithms to design energy-efficient large-scale tracking systems that assure the reduction of energy consumed by the processes of positioning and communication and to guarantee good quality of service.

On the other hand, a smart RFID node is implemented for ensuring healthcare monitoring applications based on RFID technology by integrating RFID with wireless sensor systems to gather information efficiently. There are other areas still not tackled in this research such as the synchronization between smart RFID nodes that decreases the transmission delay, decreases the long transmission delay and the traffic overhead that improve the performance of the whole network. In addition, there is a need to develop improved algorithms to design energy-efficient large-scale tracking systems, to assure the reduction of energy consumed by the processes of positioning and communication and to guarantee good quality of service.

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