A Case Study of Internet of Things Using Wireless Sensor Networks and Smartphones

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Abstract — **In the state of the art, Internet of Things (IoT) tends to be touted as a future technology. Based on that concept and the constant development of Wireless Sensor Networks (WSNs), this paper explains and implements a case study of a converged Internet of Things based on a WSN and a smartphone.**

The implementation integrates the networking capabilities of a WSN, a wireless local area network and a smartphone device, in order to achieve a monitoring service and tracking mobility of objects for the purposes of future Internet of Things services. The scenario is to create a service, or a way that one will be able to "understand" and monitor an individual's movement inside a house. At the end new concepts and ideas for future work will be presented. The paper is part of the WMN Research Group ongoing research to implement a futuristic service for monitoring elderly residents under the concept of smart homes.

Index Terms— **IoT, iPhone, Smartphone, WSNs, Zigbee.**

I. Introduction

Wireless networks have massively and rapidly become a part of people's lives while the emerging technology of Wireless Sensors Networks (WSNs) has attracted significant research interest during the last years. This growing interest can be largely attributed to new applications enabled by large-scale networks of small devices capable of harvesting information from the physical environment, performing simple processing on the extracted data and transmitting it to remote locations [1]. The small devices, known as sensors or motes, have made possible this wide spread impact, as they continuously grow in processing power and bandwidth and at the same time minimising in size.

The radical changes that WSNs have brought in the daily life are just the beginning of a very highly sophisticated technology, which eventually will inter-connect houses, cities and even countries, as a part of the Internet of Things (IoT) scheme. This paper uses the *Crossbow platform*, depicted in Fig. 1. The platform includes the MICAz/MICA2 motes and the Base Station (BS) that collects all the data from the sensors and via a USB connection passes them to a laptop.

Also a smartphone device, an iPhone 4, is used for localisation purposes of the individual within the realm of the IoT. As the scenario uses two types of hardware and also tries to merge two technologies, it is essential to give a thorough presentation of each of the parts and fields.

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Fig. 1. Crossbow Platform, BaseStation (BS) and sensors.

II. Wireless Sensor Networks

Although the WSN paradigm goes back decades, only lately it has attracted many engineers and scientists as a part of a bigger and more crucial concept. Their use ranges from simple HVAC (Heating Ventilation Air-Conditioning) Systems in company buildings to advanced defence systems and even biological and chemical attack detection and reconnaissance. WSNs have two types of deployment:

- *Structured*, the sensors are deployed in a standard, fixed, pre-determined way that has thoroughly been decided.
- *Unstructured*, implies a dense random deployment within an area.

In an unstructured WSN, network maintenance such as managing connectivity and detecting failures is difficult due to several nodes. On the other hand, the advantage of a structured network is that fewer nodes can be deployed with lower network maintenance and management cost [2].

The two ways of communication in WSNs are the single-hop and the multi-hop, as seen in Fig. 2. Both of them are designed based on the energy conservation of the sensors.

- *Single-hop*: in that way all the sensors send the information collected, directly to the BS (red circle in Fig. 2).
- *Multi-hop*: in that case the sensors send the data to a neighbour node (called aggregation node, light blue

circle in Fig. 2), and then those nodes collect the information and finally send them to the BS.

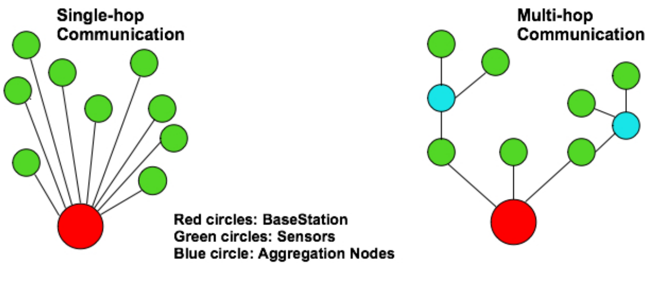


Fig. 2. Single-hop and multi-hop wireless sensor networks.

The easy way of establishing single-hop WSNs makes them the most commonly used and widely known type. In multi-hop, even though the sensors consume more energy as more processing power is needed they are more appropriate for large scale WSNs where the BS is located in distance from the nodes.

As mentioned before, the use of WSNs varies a lot, and the range of applications is increasing rapidly. The fields and some of the most important applications are:

- *Military Applications*, such as battlefield management, defence systems, military command and control, communications. Also the area of interest extents from collection of information, in general, to enemy tracking, battlefield surveillance or target classification [3].
- *Environmental Applications*, include applications mainly for environmental monitoring, like humidity and temperature in order to observe and record how a rainforest grows. Applications to monitor extinct species and even make sure their population increases or stays steady (protect them from any kind of danger). Last but not least application for fire precautions or prevention.
- *Traffic Control and Monitoring Applications,* a range of applications all designed to provide ease and convenience in journeys and the most important safety in the streets and highways. Applications for traffic lights monitoring, traffic monitoring, bridge and high way monitoring, which all give a better awareness to the drivers.
- *Commercial Applications*, as mentioned before HVAC systems fall into this category. Mainly implemented in the industrial and business world. Systems able to monitor and control the workspaces; equipment management services that will minimize or even prevent maintenance thus minimizing expenses.
- *Health/ Medical Applications*, projects and ideas that have radically change and will change the way the hospitals and doctors work. Applications like health care, monitoring of elderly house, monitoring of chronic diseases with specific body worn sensors, like heart beat sensors, or sensors, which can measure and pass information to the doctors regarding blood pressure, glucose levels, any body reactions to medication on vaccines and etc., will help get better understanding and even prevent infections and any kind of illnesses occurring.
- *Residential Applications,* a field that is related with the project presented in this paper, which includes habitant monitoring, habitant sensing, advanced intrusion alarm systems, applications for energy control and management, which will be able to minimize the cost of living (quite efficient for hotels as well) and many more.

The main focus of this paper is the smart home service scenario. Throughout the years of development, WSNs face an important drawback that is the energy consumption and conservation in the sensors. It has to be noted, that the sensors are working with simple batteries and even in the simple scenarios with single-hop communication (where no processing of the data is needed to be done), the collection and transmission of the data can be expensive in terms of energy consumption. Although, that was and in most cases still is an issue, more problems are faced, such as *node deployment*, *data reporting method*, *fault tolerance*, *scalability, transmission media*, *data aggregation* and *Quality of Service (QoS) provision*.

In the following we have summarized some specific routing protocols and algorithms that have been designed to overcome such difficulties depending on:

1. how the network is structured:
   - *Flat based or data-centric routing*, all the nodes perform the same functions and processes. In flat networks, each sensor node collaborates together to perform the sensing task it is not feasible to assign a global identifier to each node. This consideration has led to flat routing, where the BS sends queries to certain regions and waits for data from the sensors located in the selected regions [4].
   - *Hierarchical based or cluster based routing*, each node has a different role. In a hierarchical architecture, higher energy nodes can be used to process and send the information while low energy nodes can be used to perform the sensing in the proximity of the target. This means that creation of clusters and assigning special tasks to cluster heads can greatly contribute to overall system scalability, lifetime, and energy efficiency [4].
   - *Location based*, where nodes are positioned in a way to route the data in the network. The destination of each node can be calculated by taking into consideration the strength of the signal received.
2. the protocol operation, the following techniques can be specified,
   - *Multi-path based.*
   - *Query-based.*
   - *Negotiation-based.*
   - *QoS-based or coherent-based.*
3. how the source finds a route to the destination,
   - *Proactive*
   - *Reactive*
   - *Hybrid*

Each category defines a different type of algorithm or routing protocol. For the purposes of this paper we have used the ZigBee technology towards the implementation of our smart home application.

ZigBee provides device control and energy management. These include neighbourhood area networks for energy, using ZigBee for sub-energy within a home or apartment, and using ZigBee to communicate to devices within the home. The IEEE 802.15.4 standard was created for low-power devices that operate in the 868 MHz, 915 MHz, and 2.45 GHz frequency bands. The data rates supported by this standard are 20, 40, and 250 kbps; rather modest compared to other protocols such as IEEE 802.11 (e.g., IEEE 802.11a offers data rates of up to 54 Mbps) [5]. Before this standard was developed, the ZigBee Alliance worked on a low-cost communication technology for low data rates and low power consumption. The IEEE and the ZigBee Alliance ultimately joined forces and ZigBee has become the commercial name for the IEEE 802.15.4 technology.

The protocol can be categorised into two topologies: *star* and *peer-to-peer*. In the star topology a device, called *Personal Area Network (PAN) coordinator* is used to enact all the communications. On the contrary in peer-to-peer, the devices communicate straight with each other. However, they still must associate with the *PAN coordinator* before they can participate in peer-to-peer communication.

In the star topology, there are two types of modes: the *synchronized* (or beacon-enabled) mode and the *unsynchronized* mode. In the synchronized mode, the PAN coordinator periodically broadcasts beacon messages for synchronization and management purposes. The synchronization is used to perform slotted channel access, so that a device performs a random back off before the channel is sensed. If there is no channel activity, the device waits until the next slot and senses the channel again until no activity has been detected for two consecutive slots (after the initial back-off time). If activity has been detected, the back-off procedure is repeated; otherwise the channel can be accessed. The only difference in the unsynchronized mode is that the device can access the channel immediately when no activity has been detected during the first initial back-off time [6]. ZigBee is the most well-known protocol that can be used for implementing residential applications.

III. INTERNET OF THINGS (IOT)

As technological advances are daily being developed, so do wireless sensor networks and so does the Internet. Internet started as a way to provide communication between computers established in distanct locations, when every other sort of communication system is non-operable. It was later on developed in order to provide infinite information on a global level. Moreover with a great hand from the wireless technology the information is now able to be accessed remotely (over 3G, satellites, etc.) from everywhere around the world with the use of smart devices that have wireless access and an Internet browser (smartphones, laptop, tablets, netbooks etc.).

That concept can be extended to the formation of an interconected network, in which every day objects and people take part in it, that is the Internet of Things (IoT). It includes self-configuring wireless networks of sensors that create a world where every of its entities sends information to other objects and to people. This world, in which everything is tagged and communicating, provides information and knowledge that enables ease and convenience in every day living [7].

All the WSNs under one network, connected with each other, enable objects and devices from each environment (network) to be active participants and communicate with each other, exchange data, monitor various areas all around the globe, record and understand events and actions, be able to sense changes (sensing) and react autonomously and accordingly (actuating).

Services will be able to interact with these smart objects using standard interfaces that will provide the necessary link via Internet, to query and change their state and retrieve any information associated with them, taking into account security and privacy issues [8].

IV. SCENARIO, AIMS AND OBJECTIVES

In this paper, the scenario is designed under the scheme of *Smart Home applications* and a service is built to provide information for future work .We also carry out simulations to assess the impact of mobility in our proposed solution.

Each sensor node is identified by a specific number (*id*) in the network, which can be used as an address to its location. Those *ids* can be used for topology-localization purposes, meaning that they can be used to assign each node individually in different, yet specific spots in the area that is being monitored. The present scenario will use this concept and will monitor the movement of an individual inside a house. Sensors have been deployed throughout the house in different rooms (as see in Fig. 3) and each node's id specifies the room (for example the node with id 5767 means the kitchen). Also a smartphone is used (e.g. iPhone) for purposes of monitoring the mobility of a person and how the data are transmitted (over wireless network) while he moves. Assuming that the person will carry the smartphone on him at all times, the device will be able to give live information of the exact location inside an area. Those two notions together will result in a monitoring service, which will try to fully map a person’s movement within an area.

The concept for this scenario is to use the individual’s action in order to record and find in which room he entered. Thinking of the first action that a person does when entering a room is to switch on the light that will give the clue that is needed to understand the location inside the house. In the figure below, which is the scenario visually represented, the sensors are placed in a way to be close to the doors and in a high level so that they can receive the luminance of the light as soon as the source is off. The red circles represent the sensor nodes with their ids, and the pictures next to them, is how they are placed in reality (inside each room). Even though the scenario seems to be simple, there is a slight drawback that makes the entire scenario look for alternatives routes or more advanced networking and sensing. To be more precise, when the person leaves the room it does not necessarily means that he will switch off the light. So when he comes back to that room, there will be no change in sensing of the nodes (luminance is

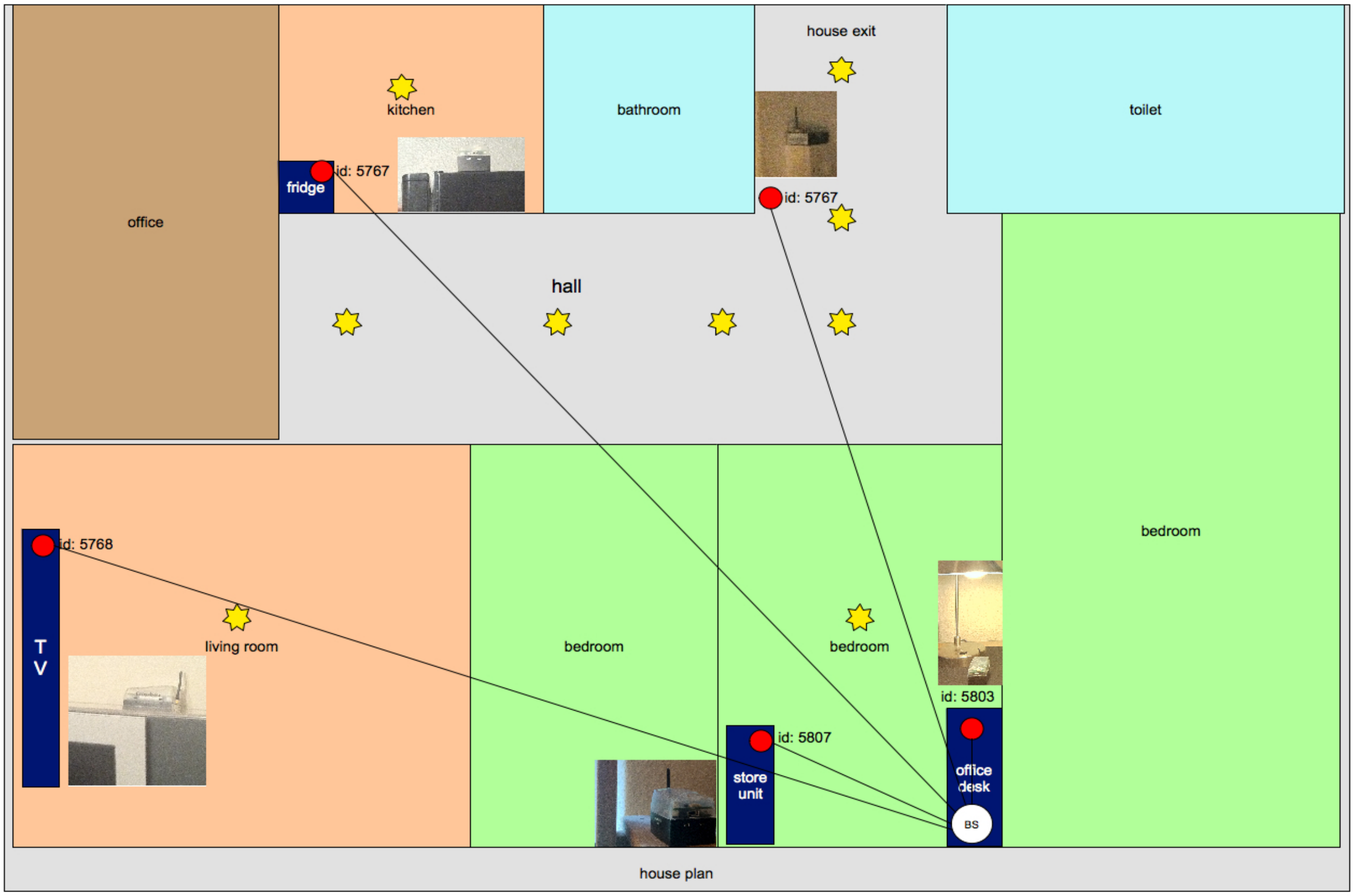


Fig. 3. The scenario established in the house plan.

on the same level) thus there will not be any track of his movement. And that is where the second part of the scenario comes into play and addresses such mobility cases.

The iPhone will be used as a localisation tool, which will give the specific coordinates of where the person is inside the house. The accelerometer of the iPhone is used to understand the way that the phone is held by the user and respectively turn the screen around to meet his needs (turn vertically or horizontally). In the current scenario, assuming that the user will have the device on him whilst moving around, it will continuously send a signal with his coordinates over the wireless network.

The main objective of the project is to shed light into the way mobility affects a WSN and how the data can efficiently and safely be transmitted to the BS or a computer, providing high quality of service (QoS). Also one of the aims is the use of the service as a reference for a future implementation with the use of hardware, as in actuators. Such architecture can provide efficient and innovative home automation for the every day life of people. Additional information will be gained in regards to how smart homes work and why are of such importance. Furthermore, this paper discusses the methods that are used and also the challenges that are faced when it comes to implementing smart home applications.

To summarise, objective of this work is to propose a non-complex WSN solution for smart home services. This will be achieved through detailed analysis, expirementation and in depth research on wireless sensor networking with emphasis on advanced and mobile WSNs.

V. Hardware and Methodology

There are two types of hardware used, one is the enviromental sensing platform designed by Crossbow technology, which uses five sensors, with a MICAz/MICA2 processor radio module and an MTS400 basic environmental sensor board each. The sensors are Full Function Devices (FFD) meaning that they can be implemented in any topology fully functional; they are capable of co-ordinating and communicating towards any device in the entire network. A Base Station (BS), that communicates with all sensors and has an MIB520 USB programming board. MoteView 2.0, monitoring software provided by Crossbow Technology. Also the motes use the 802.15.4 standard defined in 2003, though they do not use the network and application layers defined by the Zigbee Alliance's network and application layers. Also they use TinyOS 1.1.7 and Crossbow's mesh networking stack. The second one, which is an iPhone 4, uses the iOS, and its built-in sensors, which are the accelorometer and gyroscope.
The sensing platform is using the light function to understand whether a person entered or left a room. The reason why that function is used, will be explained thoroughly later on with testing and expirements.

The smartphone on the other hand uses more sophisticated technology as it uses enchanced sensors such as accelerometer and gyroscope. Also they both can be used along with advanced mathematics to result in monitoring mobility of an object or an individual. Both of the sensors give data in the three dimensional chart (3D Axis) as seen in Fig. 4.

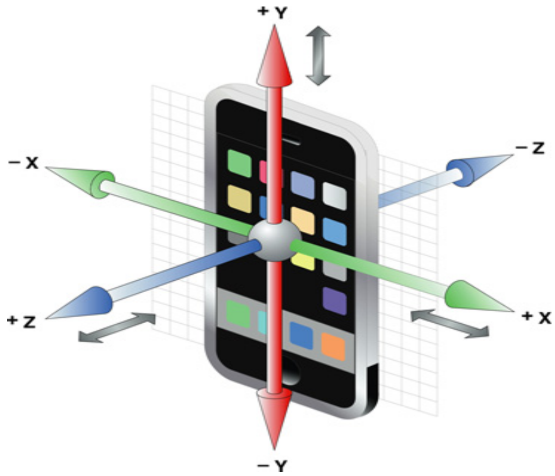


Fig. 4. 3D axis of the iPhone.

The 3D accelerometer returns acceleration in the X, Y, Z chart and reports data. The total acceleration of the device is equal to gravity plus the acceleration that the user imparts to the device, and those two can be separated with another sensor of the smartphone, which is called 3D gyro sensor and creates gyro enhanced motion data. Those data include the Euler angles of the device pitch, which is the X, roll, which the Y and yaw, which the Z in the chart. The three acceleration data can be used to understand how the individual moves and in which direction. The smartphone has a central point from which the 3D axis is drawed, so in accordance with that, one can understand if the individual is moving forward to one direction. Also it will be possible to understand if the person is moving up and down, jumping or falling down (something that could be used in hospital or elderly houses).

The most common sequence associated with the name Euler angles is (3, 1, 3) as in Fig. 5. To disambiguate it from the other conventions that share the same name, it is also known as the x-convention. In the study of the gyroscopic motion of a spinning rigid body, the Euler angles, φ, θ, and ψ, are known respectively as spin, nutation, and precession. A commonplace example of gyroscopic motion is a spinning top. In this case, the body-fixed z-axis is aligned with the spin-axis of the top, and the body-fixed x- and y-axes point out the sides of the top. The tilt of the top away from the world z-axis is the nutation angle, and the moment arising from this tilt produces the familiar slow orbiting motion, called precession [9].

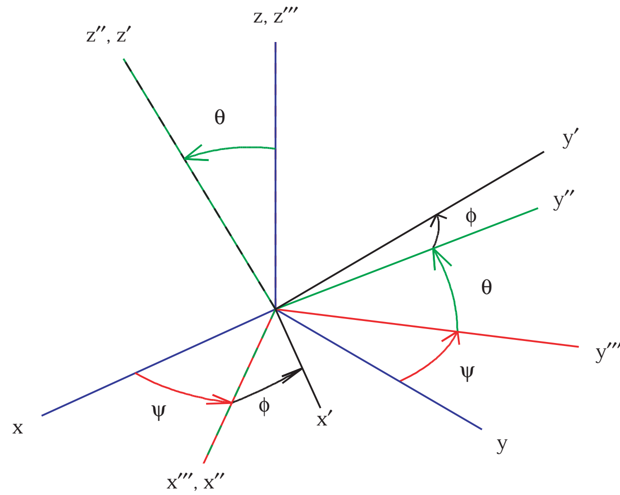


Fig. 5. Euler Angle Sequence (3,1,3) [9].

To simplify the idea of the smartphone, one can used the data of the 3D chart and be able to map an area with specific co-ordinates in accordance with that chart. As mentioned before with the accelerometer one can understand the way of movement (and also speed is possible to be calculated), but with the gyroscope it will be possible to exactly locate a person in mapped area with the use of Euler angles and a triangulation algorithm. Then it is possible to fully monitor someone's movement in that area. Moreover those types of sensors can be used in a dense area with the ability to exchange data easier, efficient and send them remotely not only to the BS, but also in other networks over Cloud or Satellites.

VI. Simulations and Discussions

After thorough testing we decided the function that gives the quicker and most reliable results, that is the light sensing. Firstly, Table 1 presents the value in csv form, exactly how are measured by the sensors.

Id	Time	voltage [V]	humid [%]	humtemp [C]	prtemp [C]	press [mbar]	lightc [lux]	accel_x [g]	accel_y [g]
5807	12:17	2.5506	85	29.95	29.126	1028.6	654.81	-0.02	0.04
5803	12:17	2.4799	44.6	24.22	-32.383	597.62	478.17	0.04	-0.06
5807	12:17	2.5454	84.3	29.96	29.148	1028.5	625.37	-0.02	0.04
5803	12:17	2.475	44.5	24.22	-30.134	610.94	456.09	0.04	-0.06
5807	12:17	2.5454	81.8	29.92	29.119	1028.5	566.49	-0.02	0.04
5803	12:18	2.4799	44.4	24.21	-18.562	605.85	478.17	0.04	-0.06
5807	12:18	2.5454	76.1	29.9	29.075	1028.6	595.93	-0.02	0.04
5803	12:18	2.475	44.4	24.22	-27.585	599.34	478.17	0.04	-0.06
5807	12:18	2.5454	70.6	29.85	29.053	1028.5	595.93	-0.02	0.04
5803	12:18	2.4799	44.3	24.21	-29.146	601.96	478.17	0.04	-0.06
5807	12:18	2.5454	66.3	29.8	29.045	1028.6	595.93	-0.02	0.04
5803	12:18	2.475	44.2	24.21	-49.551	569.79	456.09	0.04	-0.06
5807	12:18	2.5454	62.7	29.75	29.031	1028.5	566.49	-0.04	0.04
5803	12:18	2.4799	44.2	24.21	-23.828	611.11	456.09	0.04	-0.06

Table 1. Sensor readings.

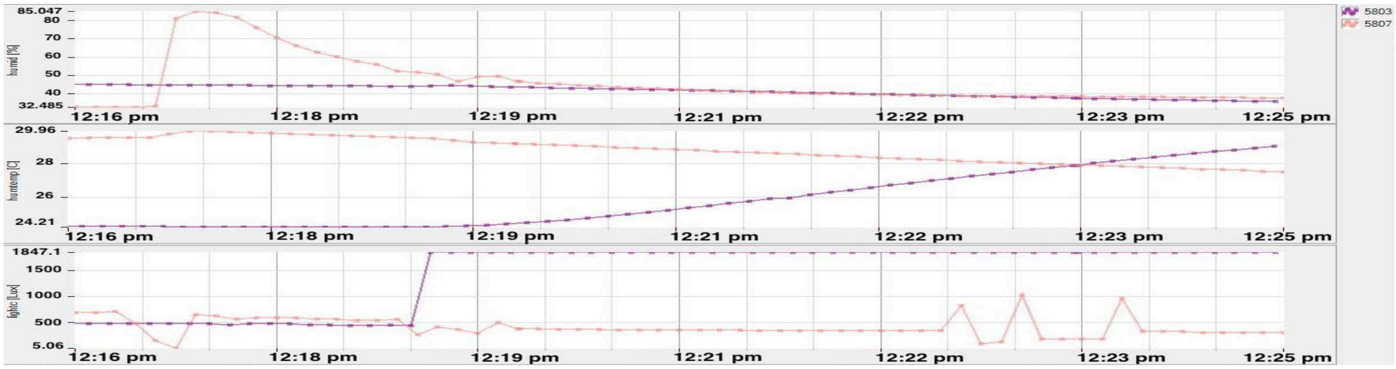


Fig. 6 Function readings graph.

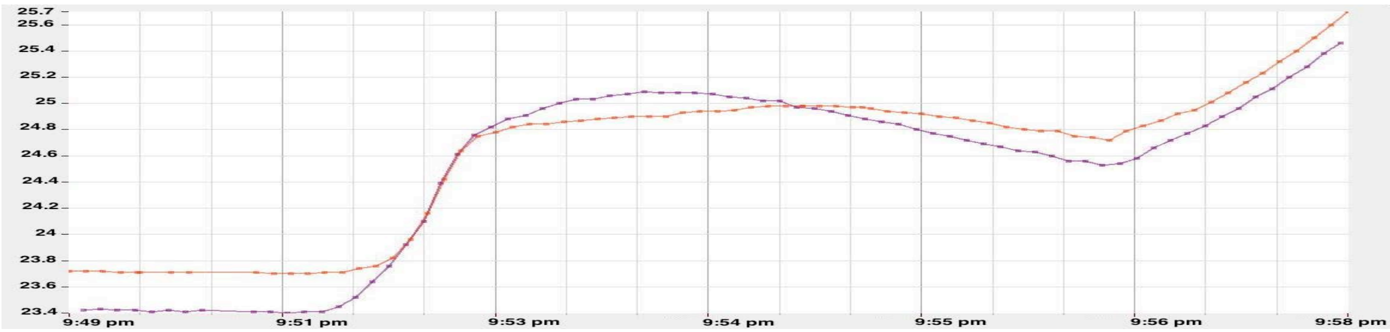


Fig. 7. Temperature values.

When designing a WSN, as mentioned before, there are some requirements needed to overcome the drawbacks such as QoS, energy consumption, etc. In this case the first thing that needs to be taken into consideration is the delay-latency, because the results have to be fast and efficient. After monitoring the delay for various functions then we will decide which of them is the most suitable (and why) for implementing the smart home service. Testing the speed of the humidity, temperatute and light readings (two different tests in each category), and by speed, meaning how fast the sensor understand the change around it, the graph in Fig. 6 is exctracted. The first one is the humidity readings, the second one is the temperature and the third the light readings. It has to be noted that we carried out several tests to reach the final conclusions and decisions. Additionally, we have plotted average results to efficienty present the results of this work. Figures 7,8 and 9 display into more depth each function. In the case of two sensors placed next to each to other to monitor the same function and to understand the timings and how long the motes take. This occurs by placing one of the sensors on the top of a radiator (for faster readings) and sensing for 10 minutes.

The temperature starts to increase but very slowly and eventually it takes almost one minute to obeserve change, as seen in Fig. 7.

In order to record the humidity, warm air was blown on the sensors (with warm breath) and it lasted 7 minutes. As seen in Fig. 8 it takes 4.50 seconds average for the value to change, however it takes a lot longer for the sensor to go back to its initial value, up to 30 seconds on an average (the seconds might not be possible to be displayed in the graph yet they have been monitored properly with an accurate watch to record the delay).

Moving to the next expirement, that is the testing of light readings, the sensors are placed underneath a source of light (just a simple lamp) and Fig. 9 presents the results in a detailed graph. Two sensors were used next to each other to also observe how sensitive they are and how equal the sensing for each mote is (in some cases there is a millisecond difference). As it seen, by just switching on and off the light,

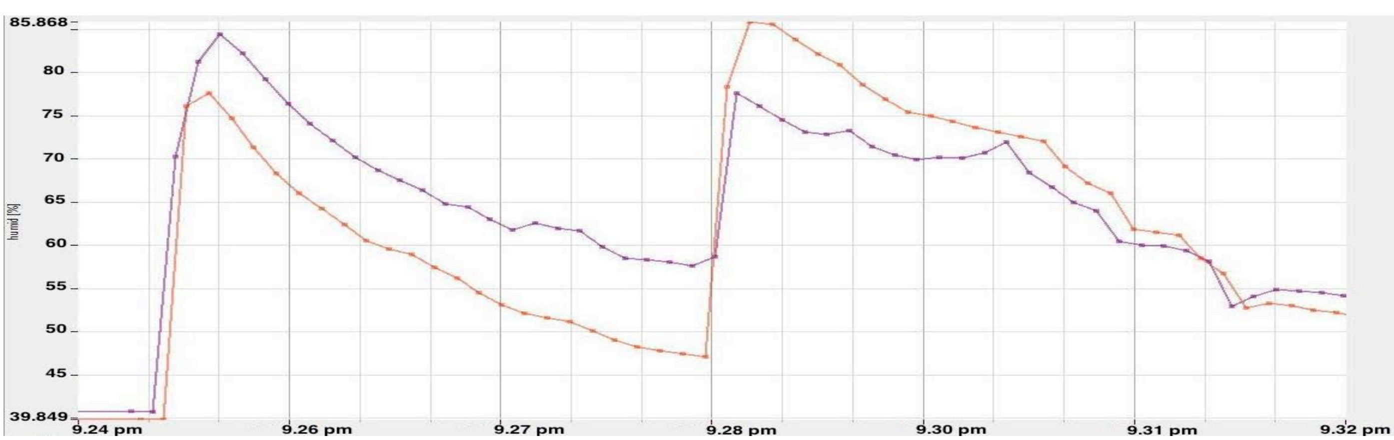


Fig. 8. Humidity readings graph

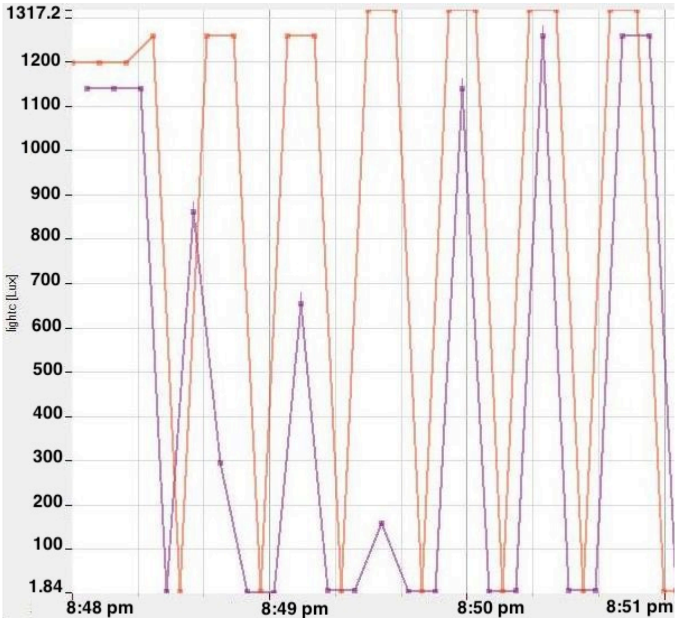


Fig. 9. Light readings graph.

the sensors only take 2.5 seconds on an average to understand the change (whether the light goes on or off), and the expirement lasts 3 minutes in which there are 7 times of switching on and off the light. It is pretty clear that out of all the readings, the light sensing function gives the best results thus making it the most appropriate choice. That latency (2.5 seconds) for the purposes of the implementation is acceptable as the person will spend a couple of seconds inside the room that he will switch on the light, giving enough time for the observervation to take place.

To sum up, each and every individual expirement was tested several times yet from all those information the most crucial are presented for clearer results and graphs. To be more precise for the purposes of this specific article the expirements for temperature lasted a couple of minutes (one was almost 10 minutes), and the change on temperature took more than 30 seconds to be sensed and almost a minute to go back to normal. The humidity expirements were a little bit better, as the expirement lasted 7 minutes, humidity was tested twice within that time frame and it took 4.5 secs for the mote to increase the value and less than 30 seconds to come back to normal (in both cases direct warm air was used on motes). The last one which is the light readings is the fastest and more efficient as it takes 2.50 seconds for the motes to sense the light and there are 12 times of shuffling with the light within 2 minutes of expirementation.

Another case that was monitored is the mobility of a mote and how the readings change against any kind of movement. In Fig. 10 the expirement is represented graphically, where the first graph shows the level of luminance and the second one the acceleration on x axis. There are two motes, in which mote with id 5768 (yellow line) is always steady and underneath the source of light and the node with id 5803 (purple line) is moving close to the source of light in a horizontal way (that is why only the x axis is displayed) with some speed. As it can also be seen from the graphs the mote that is on the move has a small delay in capturing the luminance from the source thus a delay sensing is observed in comparison with the steady one (as it was expected). Even though the sensors are both close to the source of light the movement of a mote is adding more delay in the sensing function of light.

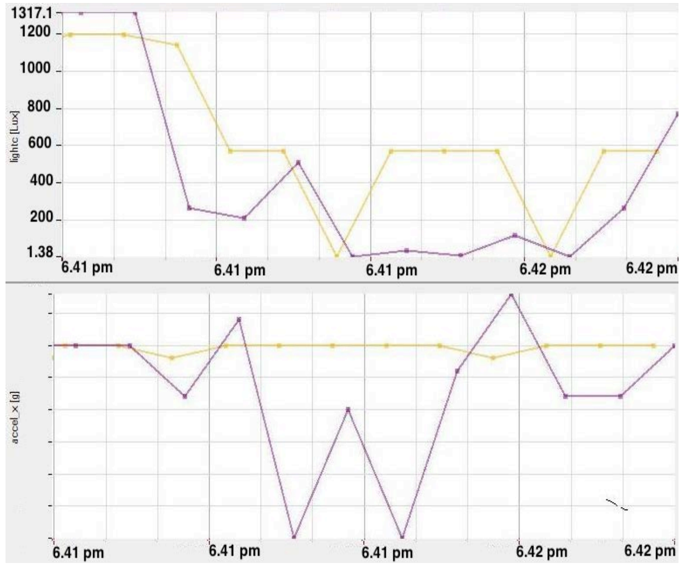


Fig. 10. Light readings whilst one mote is moving.

In regards to delay, another case is monitored, that is, the distance of the mote to the BS. To begin with, mote with id 5763 is under the source of light (up until 8.32pm in fig. 11) and the other one is moved away from the BS at around 50 meters, outside of the house that the service is being implemented. Firslty the luminance is low and after 30 seconds that the distant mote is underneath the source (outdoor one) the luminance is sensed. Then when the mote is hidden away the luminance goes to zero within 2 seconds. Again when the mote is revealed to the source it takes almost half a minute to understand the luminance. What that means is that the delay of sensing is increased along with the distance. Those issues can be added as extra reasons why a smartphone, or more sensitive, higlhy advanced sensors can be used to fullfill the mobility purposes in WSN scenarios.

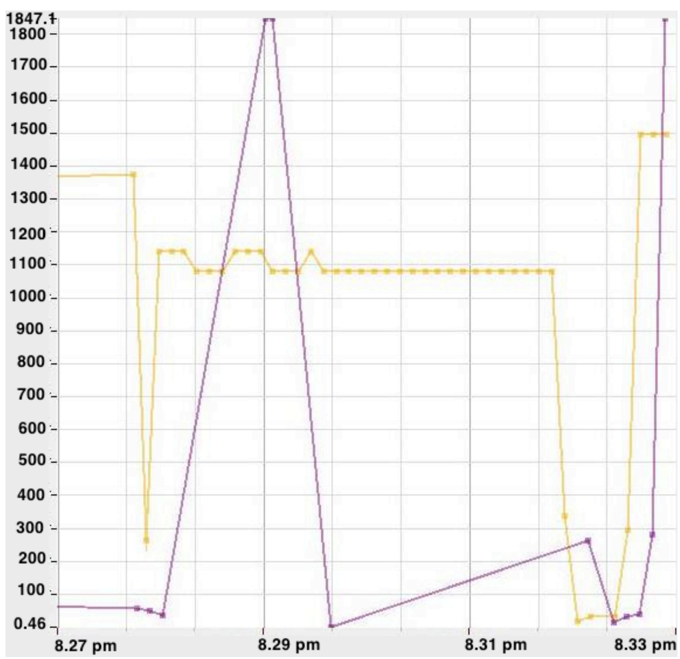
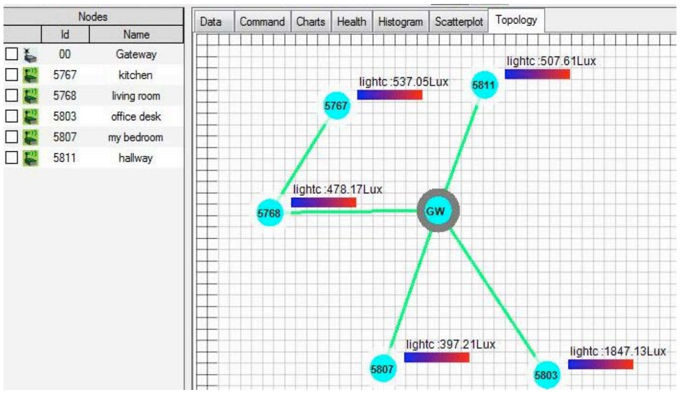
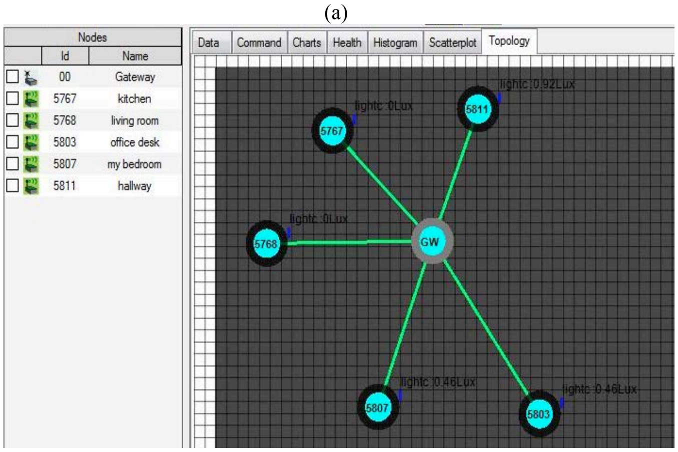


Fig. 11. Light readings when mote is away from the BS.

Under that concept and after the simulations above, the light sensing function was used for the scenario. After deploying the sensors in each room (as seen in figure 3), the shufling of the lights begin in order to monitor the movement of the individual. On the Fig. 12 (a) all the lights in the house are on and each sensor has a different luminance proofing the location in different places thus able to "map" an area just with the sensing of light. The higher the lux (luminance) the closer the sensor is to the source of light.



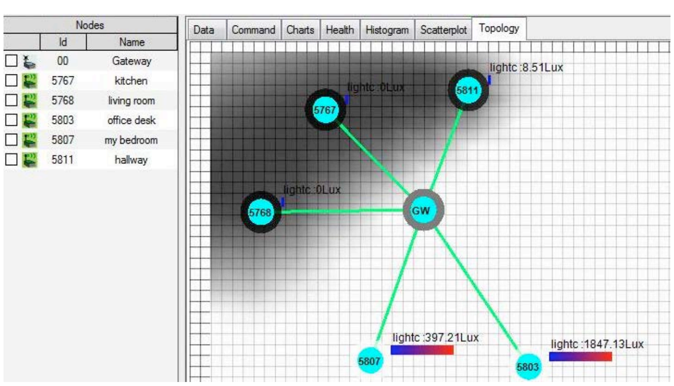
(a)



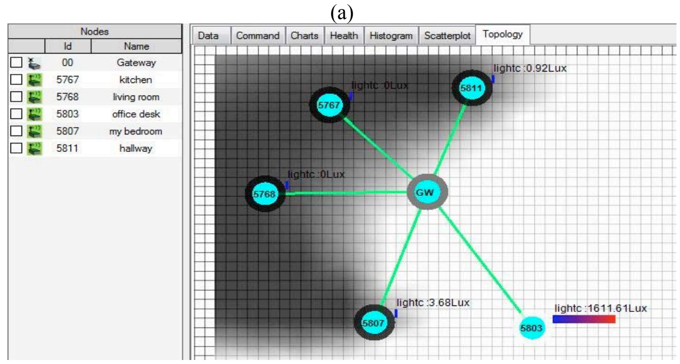
(b)

Fig. 12. All the lights are off.

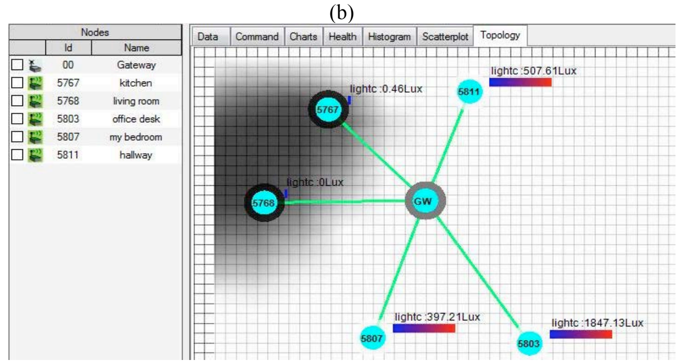
In Fig. 12 (b), all the lights are off, which someone can assume that either the person is away or asleep. Those two cases can be taken into consideration if someone want to build a web interface, so it can use the option that when the lights are off and it is evening the person is sleeping. The following figures, are just the different statues as someone switches on and off the lights in different rooms. By observing which room's light is on, it is possible to understand the location of a person.



(a)



(b)



(c)

Fig. 13. Light readings from different rooms.

As it can be seen, motes with zero value represent a dark room and high lux (luminance) means that the lights are on. The values of light as presented in the 8th column of Table 1 is how the light sensing functions measure the readings. High values of lux like 1847.13 in Fig. 12 (a) (compared to the rest of the values in the same figure) means that the mote is very close to the light. Values that are below 10 lux (in general very low values) like 8.51 and 0.92 as seen in Fig. 13 (a) and (b) respectively mean that the light in that room is off, but the sensor is getting some luminance from another room close to that one. So one can assume that the person is approaching a room, where the light is off, and on its way is switching on some lights. For example from the bedroom to the living room the individual has to switch on the hallway lights and then the one in the liviving room, but at the same time the mote in the kitchen will get some low level luminance as it is close to the hallway lights, and it can be used to double check that someone is present around.

All seem to be sufficient in order to observe a person's movement but when a person leaves a room and go to another where the light is still on, then it will not be easy to track its location, so that is why the use of the smartphone is implemented.

The use of a smartphone is slightly more complicated, even though there is an application that can manipulate the sensors they way the user requires. The application used is called Sensor Data and it allows the user to enable the 3D accelerometer and 3D gyro-meter in a way to record, collect data and transmit them wirelessly in a computer or store them on an online database (in the phone's operating system) in which someone can have access with a browser provided that is connected to the same network. There are two functions, the "capture" function, which stores the data on the web server and the streaming which will be presented thoroughly as it is the one required for the mobility purposes.

First the computer (the same that uses the Crossbow platform) needs to be connected to a wireless network. Then the programming language Python must be installed and run. Also the following program (which comes along with purchase of the application Sensor Data) must be written in a shell script.

```
import SocketServer
PORTNO = 10552
class handler(SocketServer.DatagramRequestHandler):
    def handle(self):
           newmsg = self.rfile.readline().rstrip()
           print "Client %s said '%s'" %
(self.client_address[0], newmsg)
           self.wfile.write(self.server.oldmsg)
           self.server.oldmsg = newmsg
s= SocketServer.UDPServer(('',PORTNO),handler)
print "Awaiting UDP messages on port %d" % PORTNO
s.oldmsg = "This is the starting message."
s.serve_forever()
```

Precisely the above means that whoever has access to the port with number 10552 can transmit and the device (in this case the computer that has the python script running) will receive the data as they come in a UDP form. Then running the module will switch the user to the Python Shell and wait for the data. The smartphone now has to be connected to the same wireless network and after opening the application in the configuration tab the mode has to be "Unicast" and in the address field the IP address of the server where the data are send must be entered. After everything is set up, the testing sesion which records the values of the iPhone that will be used to understand the mobility (thus the movement of the person), is started and the results are presented in Fig. 14.

The results can be divided into two parts; the Euler angles and the quaternions. The values on the 3D axis, are the Euler angles and they can be used to design an algorithm that will be able to triangulate someone's position (after mapping an area with the use of the 3D axis values). The quaternions on the other hand can be used within another algorithm for localisation.

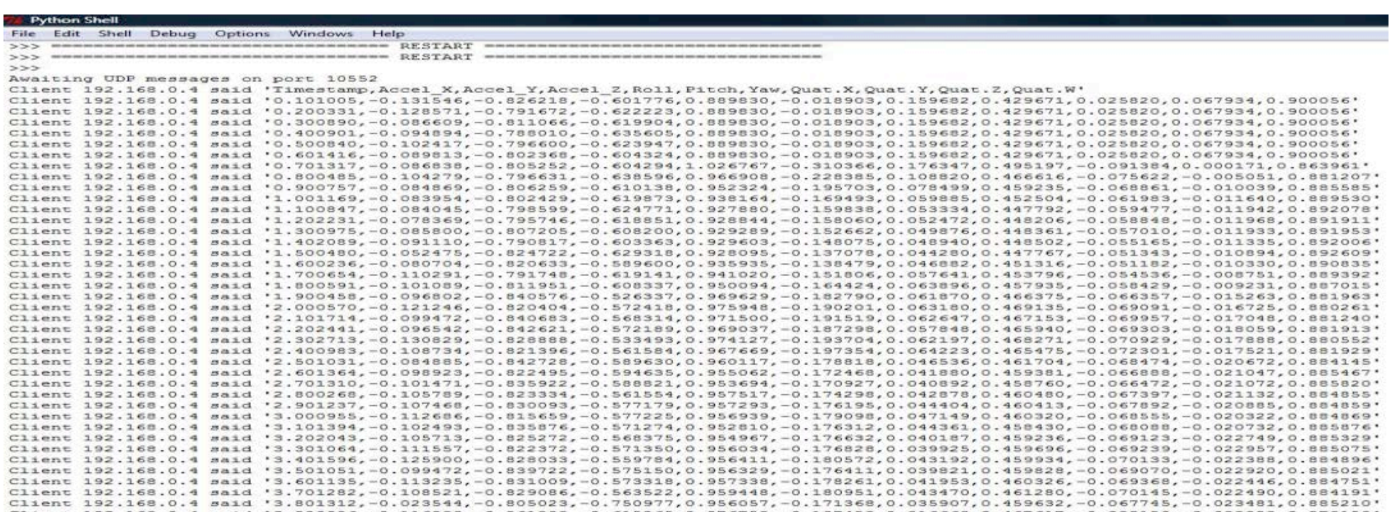
The client 192.168.0.4 is the IP address of the iPhone, the timestamp is with frequency 10 Hz and the 3D accelerometer collects the Accel_X, Accel_Y, Accel_Z. The gyro comes in and separates the Euler angles Roll, Pitch and Yaw and the last four values are quaternions. To make things clearer, an iPad with the same application (Sensor Data) was used along with the smartphone in order to explain and understand the results of each type of sensor individually. The reason using two mobile devices is that the iPad will remain steady as we want to have the same values as a comparison reference point. Then the iPhone will be used in order to monitor the movement around a steady spot and record the values of the accelerometer and the gyroscope.When both of the devices are on the same spot the values will be almost equal in the x-axis chart (as seen in Table 2) because the values that we get are on a 3D chart, so practically we can have the devices at the very same spot (the iPhone has to be inside the iPad). The IP address 192.168.0.8 belongs to the the iPad which is in a steady position as seen from Roll value and the client 192.168.0.11 is the IP address of the iPhone which is moving around and when it comes close to the iPad its values (as seen in Table 2 in the roll column 1.549107 and 1.542809) are almost equal which can be used to translate a movement towards the starting point.

Table 2. iPhone and iPad reading values.

Client id and Timestamp	Roll	Pitch	Yaw
Client 192.168.0.8 at 0.101417	1.549107	0.096999	-0.105656
Client 192.168.0.8 at 0.200644	1.549107	0.096999	-0.105656
Client 192.168.0.8 at 0.400381	1.549107	0.096999	-0.105656
Client 192.168.0.11 at 0.100405	1.516170	1.010550	-0.924614
Client 192.168.0.11 at 0.201097	1.516170	1.010550	-0.924614
Client 192.168.0.11 at 0.300888	1.516170	1.010550	-0.924614
Client 192.168.0.11 at 0.400474	1.516170	1.010550	-0.924614
Client 192.168.0.11 at 0.500861	1.516170	1.010550	-0.924614
Client 192.168.0.11 at 0.601099	1.516170	1.010550	-0.924614
Client 192.168.0.11 at 0.700301	1.537475	0.478332	-0.463228
Client 192.168.0.11 at 0.800659	1.542252	0.462291	-0.447805
Client 192.168.0.11 at 0.901799	1.542809	0.410149	-0.396409

In this way, one of those types of sensors can be placed in a steady spot, such as the threshold of each door. While the person who is being monitored carries the iPhone when their values are almost equal we can understand where the person is located.

Unfortunately the results from the Crossbow platform and the results from the iPhone sensing are different. We were anticipating this since the platform uses a sensing board and the iPhone uses accelerometer. However, as all of the results are collected into one computer, they can all be used to design a web interface to control a mobility application within a residential area. The data might be different, but all of them can be extracted or transformed to xml format so that they can be used for a web page development.



```
Python Shell
File  Edit  Shell  Debug  Options  Windows  Help
>>> ================================ RESTART ================================
>>> ================================ RESTART ================================
>>>
Awaiting UDP messages on port 10552
Client 192.168.0.4 said 'Timestamp,Accel_X,Accel_Y,Accel_Z,Roll,Pitch,Yaw,Quat.X,Quat.Y,Quat.Z,Quat.W'
Client 192.168.0.4 said '0.101005,-0.131546,-0.826218,-0.601776,0.889830,-0.018903,0.159682,0.429671,0.025820,0.067934,0.900056'
Client 192.168.0.4 said '0.200331,-0.128571,-0.791672,-0.622223,0.889830,-0.018903,0.159682,0.429671,0.025820,0.067934,0.900056'
Client 192.168.0.4 said '0.300890,-0.086609,-0.811066,-0.619904,0.889830,-0.018903,0.159682,0.429671,0.025820,0.067934,0.900056'
Client 192.168.0.4 said '0.400901,-0.094894,-0.788010,-0.635605,0.889830,-0.018903,0.159682,0.429671,0.025820,0.067934,0.900056'
Client 192.168.0.4 said '0.500840,-0.102417,-0.796600,-0.623947,0.889830,-0.018903,0.159682,0.429671,0.025820,0.067934,0.900056'
Client 192.168.0.4 said '0.601416,-0.089813,-0.802368,-0.604324,0.889830,-0.018903,0.159682,0.429671,0.025820,0.067934,0.900056'
Client 192.168.0.4 said '0.701317,-0.086838,-0.805252,-0.604294,1.026767,-0.310366,0.176347,0.495197,-0.091384,0.000171,0.863961'
Client 192.168.0.4 said '0.800485,-0.104279,-0.796631,-0.638596,0.966908,-0.228385,0.108820,0.466616,-0.075622,-0.005051,0.881207'
Client 192.168.0.4 said '0.900757,-0.084869,-0.806259,-0.610138,0.952324,-0.195703,0.078499,0.459235,-0.068861,-0.010039,0.885585'
Client 192.168.0.4 said '1.001169,-0.083954,-0.802429,-0.619873,0.938164,-0.169493,0.059885,0.452504,-0.061983,-0.011640,0.889530'
Client 192.168.0.4 said '1.100847,-0.084045,-0.798599,-0.624771,0.927880,-0.159838,0.053334,0.447792,-0.059477,-0.011942,0.892078'
Client 192.168.0.4 said '1.202231,-0.078369,-0.795746,-0.618851,0.928844,-0.158060,0.052472,0.448206,-0.058848,-0.011968,0.891911'
Client 192.168.0.4 said '1.300975,-0.085800,-0.807205,-0.608200,0.929289,-0.152662,0.049876,0.448361,-0.057010,-0.011933,0.891953'
Client 192.168.0.4 said '1.402089,-0.091110,-0.790817,-0.603363,0.929603,-0.148075,0.048940,0.448502,-0.055165,-0.011335,0.892006'
Client 192.168.0.4 said '1.500480,-0.052475,-0.824722,-0.629318,0.928095,-0.137078,0.044280,0.447767,-0.051343,-0.010894,0.892609'
Client 192.168.0.4 said '1.600236,-0.080704,-0.820633,-0.589600,0.935935,-0.138479,0.046882,0.451316,-0.051182,-0.010330,0.890835'
Client 192.168.0.4 said '1.700654,-0.110291,-0.791748,-0.619141,0.941020,-0.151806,0.057641,0.453796,-0.054536,-0.008751,0.889392'
Client 192.168.0.4 said '1.800591,-0.101089,-0.811951,-0.608337,0.950094,-0.164424,0.063896,0.457935,-0.058429,-0.009231,0.887015'
Client 192.168.0.4 said '1.900458,-0.096802,-0.840576,-0.526337,0.969629,-0.182790,0.061870,0.466375,-0.066357,-0.015263,0.881963'
Client 192.168.0.4 said '2.000570,-0.121246,-0.820404,-0.572418,0.975948,-0.190201,0.063180,0.469135,-0.069091,-0.016725,0.880261'
Client 192.168.0.4 said '2.101714,-0.099472,-0.840683,-0.568314,0.971500,-0.191519,0.062647,0.467153,-0.069957,-0.017048,0.881240'
Client 192.168.0.4 said '2.202441,-0.096542,-0.842621,-0.572189,0.969037,-0.187298,0.057848,0.465940,-0.069303,-0.018059,0.881913'
Client 192.168.0.4 said '2.302713,-0.130829,-0.828888,-0.533493,0.974127,-0.193704,0.062197,0.468271,-0.070929,-0.017888,0.880552'
Client 192.168.0.4 said '2.400983,-0.108734,-0.821396,-0.561584,0.967669,-0.197354,0.064223,0.465475,-0.072301,-0.017521,0.881929'
Client 192.168.0.4 said '2.501031,-0.084885,-0.842728,-0.589630,0.960117,-0.178818,0.046536,0.461704,-0.068474,-0.020672,0.884145'
Client 192.168.0.4 said '2.601364,-0.098923,-0.822495,-0.594635,0.955062,-0.172468,0.041880,0.459381,-0.066888,-0.021047,0.885467'
Client 192.168.0.4 said '2.701310,-0.101471,-0.835922,-0.588821,0.953694,-0.170927,0.040892,0.458760,-0.066472,-0.021072,0.885820'
Client 192.168.0.4 said '2.800268,-0.105789,-0.823334,-0.561554,0.957517,-0.174298,0.042878,0.460480,-0.067397,-0.021132,0.884855'
Client 192.168.0.4 said '2.901237,-0.107468,-0.830093,-0.577179,0.957293,-0.176195,0.044404,0.460413,-0.067892,-0.020885,0.884859'
Client 192.168.0.4 said '3.000955,-0.112686,-0.815659,-0.577225,0.956939,-0.179098,0.047149,0.460320,-0.068555,-0.020322,0.884869'
Client 192.168.0.4 said '3.101394,-0.102493,-0.835876,-0.571274,0.952810,-0.176312,0.044361,0.458430,-0.068088,-0.020732,0.885876'
Client 192.168.0.4 said '3.202043,-0.105713,-0.825272,-0.568375,0.954967,-0.176632,0.040187,0.459236,-0.069123,-0.022749,0.885329'
Client 192.168.0.4 said '3.301064,-0.111557,-0.822372,-0.571350,0.956034,-0.176828,0.039925,0.459696,-0.069239,-0.022957,0.885075'
Client 192.168.0.4 said '3.401596,-0.125900,-0.828033,-0.559784,0.956411,-0.180572,0.043192,0.459934,-0.070133,-0.022388,0.884896'
Client 192.168.0.4 said '3.501051,-0.099472,-0.839722,-0.575150,0.956329,-0.176411,0.039821,0.459828,-0.069070,-0.022920,0.885021'
Client 192.168.0.4 said '3.601135,-0.113235,-0.831009,-0.573318,0.957338,-0.178261,0.041953,0.460326,-0.069368,-0.022446,0.884751'
Client 192.168.0.4 said '3.701282,-0.108521,-0.829086,-0.563522,0.959448,-0.180951,0.043470,0.461280,-0.070145,-0.022490,0.884191'
Client 192.168.0.4 said '3.801312,-0.023544,-0.805023,-0.750977,0.956057,-0.171368,0.035907,0.459632,-0.067745,-0.023481,0.885210'
Client 192.168.0.4 said '3.900986,-0.116989,-0.861893,-0.615265,0.976753,-0.197453,0.016663,0.467617,-0.083150,-0.038923,0.879150'
```

Fig. 14 Data collected with Python through the Sensor Data application from the iPhone.

VII. Conclusion

Wireless Sensor Networks (WSNs) is an upcoming technology with so many issues and challenges, and it capable of creating advanced technological solutions for the residential, industrial and every day world. A lot more challenges will be raised, considering that the technology grows faster, the equipment and hardware is being minimised and the urge for ease and convenience inreases too. In the future fully co-operation of the WSNs and the Internet will be expected, achieving finally the Internet of Things, which will radically change the world and the daily life. In this paper we have used two different sensing technologies the environmental Crossbow platform and the iPhone's sensors to observe, record and come with results on how those two can work together to implement a smart home service within the realm of WSNs and IoT. After thorough testing and collection of several results the average values were plotted in this paper. As part of the case study, the latency of the sensing of motes was tested to understand and make sure that the best QoS can be achieved. Throughout the entire paper up to the final results, a more in depth understanding and knowledge aims to be attained and used as future reference to new projects.

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