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Independent Living for Persons with Disabilities and Elderly People Using Smart Home Technology

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Abstract

Smart Home Wireless Sensor Networks (SHWSN) are now capable of incorporating large amounts of computing power to monitor the activities of its occupants and anticipate their needs. They can provide elders and disabilities with complex customization options to allow them to tailor their environment to precise requirements. According to the latest government projections in South Korea that 38% of its population will be defined as elderly by 2050, due to life expectancy rising and birth-rates falling to record lows [1], [2], and since the U.S.A. population aged over 65 reached 14% of population in 2010 with about 16% of the U.S. adults have a disability, actually for all of these high percentages, many governments are beginning to see smart home technology as a viable option in reducing the financial burden of supporting elder people through their retirement as well as for disabled people. This paper will give a snapshot on the state of the art in the smart home technology for elders and disabilities people. Also it proposes a new Elders/Disabilities Wireless Smart Home for assistive independent living (E/D-WSH) with its approximate cost compared with the Indian home automation market.

Keywords: Wireless Sensor Networks, Smart Home, Elder, Disabilities.

1. INTRODUCTION

Wireless Sensor Networks (WSNs) can be considered as a revolution in the field of data gathering and management. A lot of very vital applications can benefit from these networks to improve its performance and reach decisions based on realistic gathered information. Thus, a lot of applications can benefit from WSNs as habitat monitoring for gathering information about a plant or animal without disturbing them to learn optimal environmental conditions favorable for the flora/fauna's growth, military applications where WSNs can provide real time information of the enemy activities to commando teams and thus making coordination and planning more effective, smart homes for networking various home appliances and managing them remotely [3], the WSNs can be also used in precision agriculture for monitoring environmental conditions in which farming is done to make it more profitable and sustainable [4], moreover, one important application is the traffic control and management approaches, it gathers the traffic information and controls the traffic flow according to the incoming traffic data [5].

A Smart Home (SH) is understood as an integration system, which takes advantage of a range of techniques such as computers, network communication as well as synthesized wireless technology to connect all indoor subsystems that attach to home appliances and household electrical devices. In this way, smart home technology enables households to effectively centralize the management and services in a home, provide them with all-round functions for internal information exchange and help to keep in instant contact with the outside world, figure (1) demonstrates different applications for smart home. In terms of convenience, they help people in optimizing their living style, rearranging the day-to-day schedule, securing a high quality of living condition and in turn enable people to reduce bills from a variety of energy consumptions in that home. Smart homes could provide them with cheap affordable home support with health care advice for elders and disabilities.

Figure 1 Smart home applications

Smart home applications employ microcontrollers to monitor ovens, washing machines, lighting, refrigerators, and HVAC facilities (Heating/Ventilation/Air-Conditioning) with respect to temperature or humidity and to adjust accordingly to meet the home owner's requirements. Figure (2) shows the development of smart home technologies along the past 13 years and the expected development in the next 6 years around the world. It shows how energy efficiency control is increasing rapidly in smart home techniques. It started in early 2000s by individual control until 2005 when centralized monitoring of all energy consumption applications started to have a centralized monitoring point to integrate all items. Starting 2010 tablets and other remote devices are used compute and control energy utilization in smart homes, and it is expected in the coming years that cloud computing technology will be used to connect home automation systems [6].

Therefore, it is obvious that smart home applications to some extent takes responsible for the indoor energy management and supervision with the instructions of household owners. Such facilities are of very great importance to individuals in the community with elders and disabilities to help them run their daily activities on their own safely. Many governments are beginning to see smart home technology as a viable option in reducing the financial burden of supporting this generation through their retirement.

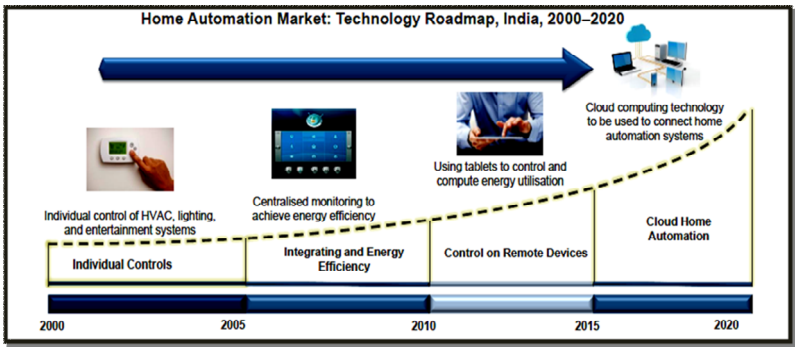

Figure 2 The development of wireless smart home technologies [6]

Figure (3) demonstrates the number of adults with and without disabilities, by age group in the United States [7]. According to the World Health Organization, disability has three dimensions: first, impairment in body function or structure, such as loss of a limb or loss of vision; second, limitation in activity, such as difficulty seeing, hearing, walking, or problem solving; and third, restriction in participating in normal daily activities, such as preparing a meal or driving a car. Any of these impairments, limitations, or restrictions is a disability if it is a result of a health condition in interaction with one's environment, and based on U.S. Department of Health and Human Services disability data standards released in 2011 that consider only serious limitation, about 16% of U.S. adults have a disability. The estimated proportion of adults with disabilities increases with age, and more than one third of all adults with disabilities are aged 45–64 years [8].

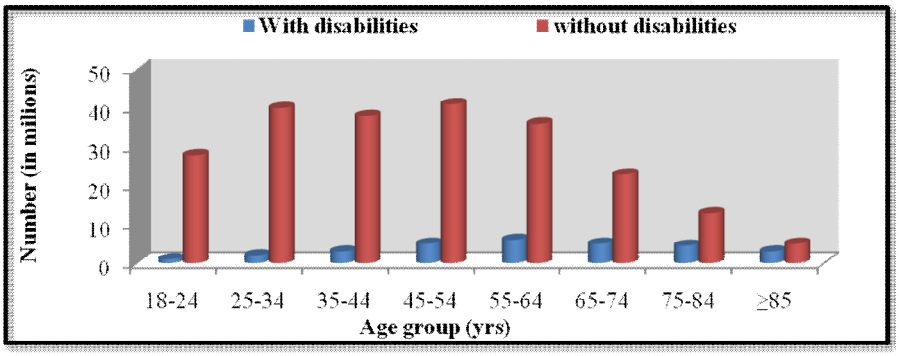

Figure 3 Number of adults with/without disabilities, by age group — National Health Interview Survey, United States

This paper demonstrates the benefits of the smart home, such as support for the elderly and disabilities and energy saving and it also describes different technologies used by it. This paper also proposed a smart home environment scenario that is able to deal with doors, windows, light, fire alarm and safety for elders and disabilities. The rest of this paper is organized as follows, Section 2, describes the state of art in wireless smart home revolution, section 3, defines the components of wireless sensor network smart home, section 4, proposes an Elder /Disabilities Wireless Smart Home for Assistive Independent Living (E/D-WSH). Finally Section 5 represents the conclusions and the future trends.

2. THE STATE OF ART IN WIRELESS SMART HOME REVOLUTION

Although the benefits of smart homes are numerous they can be divided into main four distinct categories, which are energy saving, support for elderly or disabled, safety and security and entertainment [[9]. Each of these categories is briefly discussed below.

2.1 Energy Saving

The need to significantly reduce carbon emissions is arguably todays greatest challenge. Energy efficient smart technology can be utilized within the home to offer the user a host of energy saving ideas. The installation of smart meters will allow a whole host of energy saving techniques to be implemented within the home. Smart meters will allow feedback of energy consumption to easily be delivered to the user. Many researches explore the idea of using energy feed-back displays to inform user of the amount of energy being used by the various devices currently active within the home. With these displays motivation techniques can be used to encourage a reduction in energy usage. TV, laptop, tablet and mobile could be used to deliver information back to the user showing them their historic consumption, daily costs and comparisons with other homes.

The proposed smart home in [3] allows central light control in which the light switches will be opened and closed electronically in addition to the ordinary way, the central unit command some selected lamps to open for the person who enters the home after he was authenticated. Also the authors in [3] targeted also the safety of the electrical equipments against different causes such as the sudden return of a cut electrical current and the long opening of the refrigerator door. In [10], a home energy management is presented based on a set of sensors to minimize the domestic energy waste according to human habits. A proposed scenario is suggested for daily routine to maximize the occupant's energy saving. The home power consumption is calculated and the rooms lighting are simulated using DIALUX software. The results are satisfactory and indicate that smart home based on a set of sensors could perform energy management which is not only an individual need but economical target. Thermal loads, such as air conditioning, electric space heating and water heating, can be controlled by "intelligent" thermostats. Contrary to traditional thermostats operating according to the hysteresis principle, an advanced thermostat such as the Nest thermostat; most people leave the house at one temperature and forget to change it, so the Nest Learning Thermostat learns your schedule, programs itself and can be controlled from your phone [11]. The thermostat adapts the room temperature efficiently, e.g., by auto-scheduling heating according to arrival and departure times and by detecting when the users are away [12]. These strategies can help in reducing energy consumption, especially when traditional or programmable thermostats are not configured properly, or cannot detect that users are away. The Nest Thermostat can lower your heating and cooling bills up to 20%. Detailed control of household loads would allow the inherent thermal inertia of smart housing stock to be used for energy storage. The controller could “learn” the thermal response of the home, including factors such as weather forecasts, weather observations, and load levels from monitored devices. The resulting model would better predict future loads, which could be used locally or aggregated for the utility to plan short-term control options. For example, a smart home controller could pre-cool a house in the morning, before the system peak load, reducing air conditioning loads when signaled from the utility [13] implementing the emergency demand response when the load becomes too heavy and must be reduced to maintain service. In [14], the authors introduce a peak shaving energy management system that reduces peak demand of the power usage, shifts usage to off-peak hours and lowers total energy consumption. Constraints such as due time of a process, limit of electrical energy consumption and use of preferable resources are taken into account. The proposed system takes into consideration the rated power and the usage time of the house applications and adapts them to the available power with the help of sensor networks using smart monitoring and controlling algorithms. The proposed system enables the use of the renewable energy and uses Yahoo weather forecast from the Internet to make tuning for the controlling algorithms. The used sensor network includes motion detection sensor to turn off the unnecessary devices when there is no need for it. It is proved that implementation of the proposed strategy would improve energy management by proper choice and timing of resource usage in smart houses. The smart house energy management affects the resident behavior, thus the resident could feel gradually that his daily life at the house is getting better. In [15], the authors have been designed smart home energy management descriptions and application environment. Because the current building control strategies are unable to incorporate occupant level comfort and meet the operation goals, the authors have been presented a building control strategy that optimizes the tradeoff between meeting user comfort and reduction in operation cost by reducing energy usage. They presented an implementation of the proposed approach as an intelligent lighting control strategy that significantly reduces energy cost. A novel architecture for a proposed system is implemented, using the communication technology ZigBee. Their prototype system achieved an energy savings of 6% - 10% by implementing a relatively simple control policy. The authors in [16] proposed a Smart Home Energy Management System (SHEMS) architecture based on hybrid sensor networks to make consumer devices more energy efficient and intelligent. They also presented a new routing protocol they named CPER (Cooperation between the PIMS and EIMS based Routing protocol) to increase the hybrid sensor networks lifetime, whose basic idea is in cooperation between the Power Information Monitoring Sensor (PIMS) and the Environment Information Monitoring Sensor (EIMS). They implemented their system in real test bed and conducted some experiments, and they proved that the reduction in service response time, the average number of packet

transmissions, and energy consumption is approximately 29.8%, 42.3% and 17-22%. The authors in [17], designed a wireless sensor network protocol for smart energy meter applications. The system consists of a digital energy meter, a ZigBee coordinator, and a management program. The designed system is capable of automatically read the unit then send a terminal and a cover alarm to the management program. The system can support up to 100 energy meters, 10-hop network depth and automatically detects a new energy meter. Their experimental results showed that the proposed system is feasible to implement in practical applications for automatic meter reading especially in indoor and outdoor conditions. The system can be divided into two parts: the ZigBee-based energy meter and the rear-end processing system. The ZigBee-based energy meter is composed of a digital energy meter model EMS12C 15(45A) from Energy Max International Co., Ltd and ZigBee device model MNZB-24-A2/B0 from Atmel Corporate Co., Ltd, which is composed of Atmel MCU and Atmel RF front end. The digital energy meter is responsible for accumulating a power consumption data and storing it in the internal memory. The duty of ZigBee device is to read out the power consumption form the digital energy meter via UART communication and to communicate with the ZigBee coordinator. The rear-end processing system is composed of a ZigBee coordinator and the software designed for the proposed automatic energy meter. The ZigBee coordinator is responsible for initiating and maintaining the ZigBee devices on the network. The software of the proposed rear-end processing system is responsible for configuring the ZigBee network, correcting data from the ZigBee network, and storing data in the database system.

2.2 Support for the Elderly and Disabled

Elders and disabled people are more likely to be exposed to daily life problems than other healthy people. Smart homes can be used to support elders and disabled people, providing safe, secure and empowering environments. The system can allow the user to control many features or automate them. The environment can also be monitored by the smart home system to ensure safety and alert people when there is some dangerous situation. For example, deaf people cannot hear the door bell and Alzheimer diseased people can forget the gas open in the kitchen. But with the help of smart home technology, they can overcome their difficulties. The author in [18] develops a smart home system for disabled people to make their life easier by using WSN. He developed three actuations for three kinds of disability: The first actuation is developed for disabled people who do not have arms or hands. Because of their disability, they cannot use the key to open and lock the door. Door control system is developed for these people in this project. The system recognizes the person who approaches to the door, then decides to open or not open the door according to identity of person. The second actuation is for deaf people, when deaf people are at home, they are not aware of any sound such as doorbell and gas leaking warning alarm. So, he tries to make aware of deaf person by vibrating the device that is carried by person when something happened to warn him or her. The last actuation is for Alzheimer diseased people. The main problem for Alzheimer diseased people is that they forget what they are doing. For example, when they cook, they can forget the gas open and leave the kitchen. If the gas starts leaking, smart home system detects that then warn person with sound, warning message and vibration. The work in [19], presents and discusses the Teleherence system that uses web and phone technology to optimize care plans. It uses text-to-speech and speech recognition along with landline, cell, smart, SMS (text messaging), and VOIP phone technology. Teleherence delivers surveys that can inform, remind, suggest, persuade, encourage/motivate, teaches, reward, query and branches, and query and alert. Teleherence system is most applicable for clients who are familiar with technology and do not have problems answering phone messages in a recorded or computer generated voice. It is most relevant for client whose care plans concern maximizing their independent living at home or in more structured environments. One obvious use of the Teleherence system concerns medication management. Clients could be called as needed with instructions for taking medications. These calls could be followed 10 minutes later asking if the person took the pill. These follow-up calls could continue until a yes response was received. If the care plan objective concerned safety, a video for checking on home safety could be provided. These videos could be replayed as often as needed and rescheduled to reinforce the education whenever necessary. An additional use is to involve a client's support system in their care. For example, someone who visits the elderly person could be called periodically and asked for their input on how well the client is doing. If the discrepancy between what the client is reporting and what the support system person is reporting becomes too great, an alert could be triggered to the care manager or a more extensive check up survey could be triggered that tries to determine what is happening in this particular situation. Teleherence is able to chart responses over time and these charts could be available online to family or support group members. The European research project Service-oriented Programmable Smart Environments for Older Europeans (SOPRANO) developed supportive environments for older people based on the concept of Ambient Assisted Living (AAL)[20]. The focus of the project was on providing services that would enable older persons to live independently by providing solutions that empower them and make them feel respected. Services were presented by use cases that do not merely reflect the development of a technical system and components, but include a strong reference to the social world within which the person lives. This is crucial as the key to creating useful and acceptable technology-based services is to understand how they are embedded in a person's everyday life. The use cases that were used in the SOPRANO are medication reminding, remembering, exercise facilitating, fall detecting, entertaining, activity monitoring, and safety monitoring. For the developed use cases, a common hardware setup was created. This common set-up supported both the

complete SOPRANO system shown in laboratories as well as the sub-set of the system installed in real homes. In[21], the authors developed an intelligent and versatile home safety environment that could help the elderly and individual with disability live independently in their own home. This paper presents the design and development of a telehealth system and how it is integrated with its monitoring system to monitor the elderly at home. An Android-based smart phone with 3-axial accelerometer is used as the telehealth device which could detect a fall of the carrier. The smart phone is then connected to the monitoring system by using the TCP/IP networking method via Wi-Fi. A Graphical User Interface (GUI) is developed as the monitoring system which exhibits the information gathered from the system. In addition, the concept of a remote panic button has been tested and implemented in this project by using the same android based smart phone. With the developed system, elderly and chronically ill patients could stay independently in their own home with care facilities and secure in the knowledge that they are being monitored.

2.3 Safety and Security

Safety and security are very important issues for many people not only for elders and disabled people. Nearly 43% of the elderly respondents were worried about the event of an accident involving gas and approximately 22% were anxious that outsiders would suddenly invade their home [9]. Smart home technology offers many benefits for preventing accidents and reducing security fears. IP bases security cameras are commonly used as a home security feature. These types of cameras can be controlled from remote locations by sending control commands allowing users to view their home from the office or on their mobile phone while out. Security aware smart systems are a more advanced security feature. This type of system can monitor occupants in the home, learn daily routines and use a whole host of sensing technology to analyze and flag potential security risks to the user. Far from the problems of fostering policy dogs and the problems of the ordinary keys and kallons from imitation, loss, breaking of keys in kallons, difficulty in opening to the extent that the door couldn't be opened, etc., the authors in [3], proposed an entering system in which the entering authentication done through pattern recognition. The home entering will be through a Two- Factor Authentication (TFA), but in this system the two authentication factors will be "Something the user is" for easy entering, the user of the system will only put his right thumb finger in a special place on the wall and then open the door by turning its knob with his right hand palm. This is a very easy way for entering, in the same time, it is very secure. This process is achieved by making the front door closed by electronic knob and bolt. The bolt is controlled by a fingerprint recognition sensor reading transferred to a central control unit (PC or laptop) where resides a data base of legal fingerprints for home owners. The electronic knob also controlled by palm vein recognition. If the central controller evaluates that the two patterns match the person, it sends an "open command" wirelessly for the electronic bolt then for the electronic knob. They proposed two systems in [3], one for burglar detection and the second for deception. Also they used Smoke detectors and gas detectors to measure the required type of gases concentration. The work in [22] gave an innovative idea for ARM-based embedded, video processing technology and 3G wireless networks Smart Home Security System, full use of embedded in the image processing, network communication on the advantages and the existing 3G network resources, not only achieve a rapid security alarm, record evidence and features such as remote monitoring, and high reliability, low False Alarm, cost-effective and less loss of advantage. The system uses the third generation communication for capturing the video and sends it to the mobile phones in the place of anti theft alarm, fire alarm, gas leak alarm systems images etc. It carefully analyses and studies video data compression of USB digital camera and the 3G network transmission. Thus, a design of a convenient and economical device on real-time video capture and transmission is realized. A tested showed that the stable operation of the system to achieve the design requirement. The system also can be used in banks, libraries and museums, such as required security and remote monitoring of the place. In [23], a Burglar Alarm Systems was designed, the LABVIEW software based home alarm system which act as a security guard of the home. The basic purpose of a home alarm system is to keep people and home safe from crime. When the alarm is triggered, it emits a loud sound design to frighten away intruders. To protect home from unauthorized entities, consider an entry from front door only where keypad is connected. The home alarm system is created in lab view by setting a suitable code for alarm to work. The code for actual alarm is fixed. It is assumed that a person can enter the home through front door, the person will enter the code through keypad; if the code is not matched with the fixed value of code then a written warning will be displayed, then buzzer alarm will ring. It is noted that after 3 seconds, this system automatically clears the code which entered earlier. The paper[24], focuses on the security of a home when the user is away from the place and suggests two methods for home security system. The first system uses web camera. Whenever there is a motion in front of the camera, it gives security alert in terms of sound and a mail is delivered to the owner. The second method sends SMS which uses GSM-GPS Module and Atmega644p microcontroller, sensors, relays and buzzer. In case of intruding, if the nearby police station email id is also configured in the system, then the intrusion mail can be received by police also and necessary action can be taken. The authors in [25] have been proposed an Intelligent Home Security Monitoring System (IHMS) using Received Signal Strength Indicator (RSSI). They presented a system using WSNs enabled smart home environments to create pervasive and ubiquitous applications, which give scalable services and context-aware to the end users. This system develops an application and reports its implementation on real WSN to provide remote home security. They used variations in RSSI value to find intrusion activity at home. Architecture of an application has been presented

consisting of Moteivs Tmote Sky motes and a base station. The application sends a piece of alarm as a short message (SMS) on cellular phone of the homeowner in case of any intrusion activity has been detected at home.

2.4 Entertainment

Smart home isn't only designed for the elderly and disabled; with an overall goal of creating assistive environments it demonstrates the type of convenience technologies which could be common place in the average home. Smart home boasts an impressive array of smart devices that are connected to the homes network and are designed to monitor all aspects of daily life. Example of these devices includes a smart mailbox, capable of sensing when the post arrives, and a smart front door complete with RFID tag for keyless entry. The smart bathroom is capable of detecting low toilet paper, toilet flushes, occupants cleanliness as well as regulating the shower water temperature. Along with a whole host of other devices, the home is capable of sensing itself and the resident so it can, for example, replenish stocks when necessary or automatically controlling the home entertainment system depending on your location.

The work in [26] is a smart home entertainment systems provide high quality audio and video distribution throughout your house. For example, the user can access his entire CD collection in every room via one music servers with the album cover art displayed on his touch panel. Centralized Sky+ hard drive recorders can allow to watch recordings anywhere in the home - also multiple recorders can be installed, one for adults and one for kids, with a dedicated home cinema room (big screen and surround sound system) as part of the home entertainment system. In the bathroom, there is a remote bath filling systems which means that with only one press on a button in the kitchen the bath could be filled to the desired temperature, with Waterproof Mirror TV's, with the saunas and steam cabins controlled remotely to get them up to temperature ready for the person arrival. Lighting control systems can create a relaxing ambience in the room whilst bathing before subtly changing for shaving or teeth cleaning. A standardized communication system between different AV devices allowing to control multiple compatible home entertainment devices from the TV to the Blu-ray player or home entertainment system – with just one remote. All you need to do is connect the devices together using HDMI cabling. Once connected, the devices will simply pair and recognize one another allowing your TV remote to control other compatible devices [27].

3. WIRELESS SENSOR NETWORK SMART HOME COMPONENTS

3.1 Wireless Sensor Node

The wireless sensor network is composed of a large number of sensor nodes consist of sensing, processing, transmission, mobilizer, position finding system, and power units (some of these components are optional like the mobilizer and position finding system). Figure (4) demonstrates different components of the wireless sensor node. Sensor nodes coordinate among themselves to produce high-quality information about the physical environment. Each of these scattered sensor nodes has the capability to collect and route data either to other sensors or back to an external base station(s), mobile or tablets. A base station may be capable of connecting the sensor network to an existing communications infrastructure or to the Internet where a user can have access to the reported data.

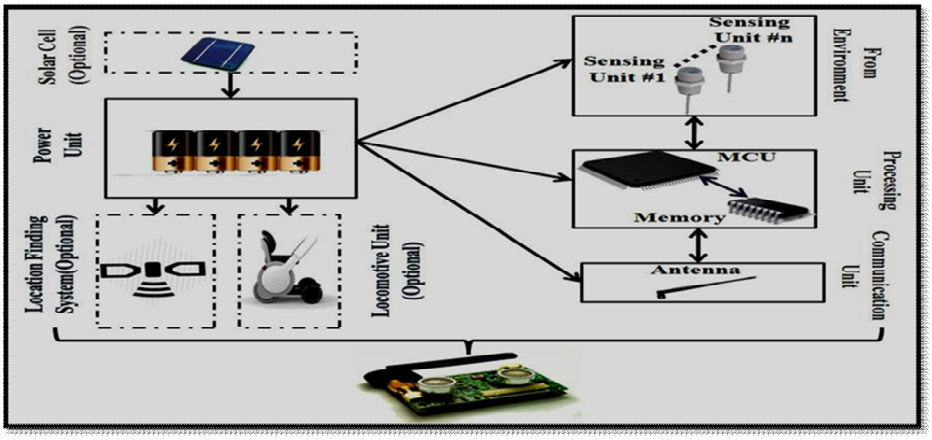

Figure 4 The components of a sensor node

Figure (5) presents different types of sensors such as medical body sensors, environmental sensors, location sensors, and time stamps that are used in wireless smart home monitoring system [28].

Body Sensors: body sensor devices play an important role in healthcare applications, to obtain information of an elderly person or a patient's body condition. Actually there are two types internal sensor devices and external sensor devices:

Internal Sensor Devices: For internal types of body sensors, ingestible capsule and implanted sensors can be used. For

instance, a core temperature sensor embedded in an ingestible capsule that is easy to swallow can measure a core body temperature. Also, some implants sensor can check medical information by using implant chip. These may diagnose conditions such as Parkinson's disease and paralysis. The VeriChip [29] is a small RFID chip sized grain of rice that is implanted under the skin. In addition, Endoscope sensor that is swallowed by patient measures internal body conditions by using various kinds of information.

External sensor device: External types of body sensors include wearable and detachable electrical signaling devices. For example, Pulse Oximeter sensor measures heart rate and blood oxygen saturation. For blood oxygen saturation, the sensor detects colors of beams based on hemoglobin molecules. The sensor uses two beams on finger or earlobe then calculates the amount of beam rejected by hemoglobin. Moreover, a heart rate is measured by contracting and expanding of blood vessels. Also, Electrocardiograph sensor checks the cardiac information. Sensors detect cardiac rhythm then electrocardiograph obtains the information signal from the contraction and extension of the cardiac muscle. In addition, skin temperatures are detected by dermal body temperature sensor.

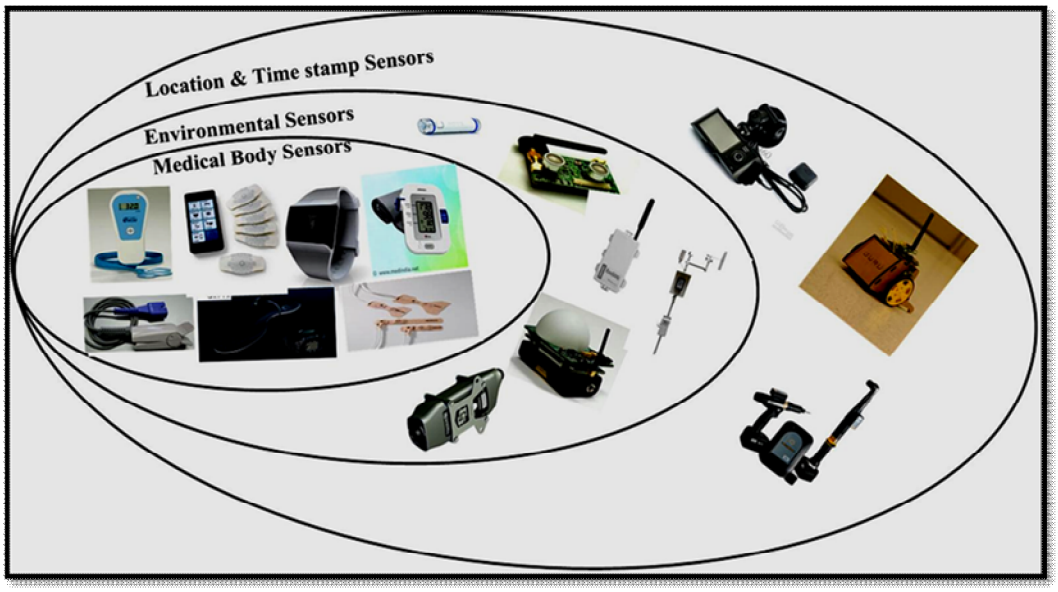

Figure 5 Different types of sensors

Environmental Sensors: Environmental variables such as temperature, humidity, air quality, illumination, and noise are also important factors in SHWSN. Sometimes environmental sensing data is combined with sensed body/location/time data to assist the analysis of personal situations. In addition, decision making is enhanced by operating smart actuators or providing feedback requests of a doctor. For instance, assume that elderly person enters the bathroom. His physiological condition using body sensors could be checked with his location by using location sensors. However, we cannot easily distinguish a cardiac episode from a period of staying in a hot tub unless location information is provided, since both situations can cause rapid heartbeat and degenerated ECG signal. In this case, temperature and humidity sensors can help to analyze the current situation and an acoustic sensor can trace the activity of the elderly person to make a context. In addition, a pre-installed actuator can reduce the CO2 level and can control the lighting level based on the air quality and illumination sensor readings to support better conditions. Therefore, it is important to include environmental types of sensors for determining a reliable context generation and a better quality of service. A dimmable lighting, fire alarm, flood alarm, heater, ventilate, and air conditioning are examples of systems that can be controlled by various types of actuators.

Location Sensors: In SH the system has to keep tracking the person's location, because depending on the location, a body condition of a body sensor worn person might be changed. For example, when the person exercises in a fitness room, his heart rate and body temperature can be increased and these changes of body condition are normal. Therefore accurate location information is a momentous factor to make a correct decision of the need for emergency aid. The most uncomplicated solution is that each healthcare needing person uses a Global Positioning System (GPS) receiver, and a home gateway system intercommunicates with the GPS receiver to track the person. However, the GPS is not a practical solution because GPS is limited in indoor circumstances and accuracy of this system is not stable due to the several sources of error such as ionospheric effects, ephemeris errors, and satellite clock errors. Therefore, relative localization in the indoor healthcare area is required among the sensor nodes in a pre-specified space, for example, home arrangement and furniture places. For high accuracy, the home gateway device has to pre-acquire localized sensors' precise location, and it maps the targeted person's spatial information based on the sensed data into the prespecified space. Types of On-

Board sensing equipment include Acoustic, Infrared, Pressure, and camera. With the use of sensed data, the location of a person can be processed by Triangulation, Trilateration, or Multilateration Approaches. Moreover, active RFID based localization schemes can be employed in the indoor health care system.

3.2 Wireless Communication Standards for Smart Home

The transmission of measured data in the overall context of WSN needs to be performed for two different purposes [30], [31] first, for communicating the collected physiological signals from the sensors to the system's central node; and second, for sending the aggregated measurements from the system to a remote station or to a physician's cell phone. The first type of communication can be handled either by wires or by multiple wireless links. In case of wire, the user's mobility and comfortableness can be severely hindered by the use of wires and moreover there is an increased risk of system failure. Alternatively, in the second case, data transmission to a remote station, which can be a PDA, a smart-phone, a pocket PC or a custom designed microcontroller-based device, can be done by one of the wide variety of available wireless technologies, Such as, WLAN, GSM, GPRS, UMTS, and WiMAX, which can offer wide coverage and ubiquitous network access. Furthermore, advances in the fourth generation (4G) mobile communication systems are expected to guarantee worldwide seamless access to the Internet at much higher data rates, and thus to facilitate more efficiently the need for gathering real-time measurements from a wearable health-monitoring system at a remote location. In this section, we will briefly discuss the features of the short-rang wireless communication technologies that have been utilized so far for smart home communications [22].

The Zigbee standard is the most commonly employed wireless communication standards in WSN [32] [33], it targets low-cost, low data-rate solutions with multimonth-to-multiyear battery life, and very low complexity. It operates in 16 channels in the 2.4 GHz industrial, scientific, and medical (ISM) band (250 kb/s, OQPSK modulation), in 10 channels in the 915 MHz band (40kbps, BPSK modulation) and in one channel in the 868 MHz band (20 kb/s, BPSK modulation). It utilizes Carrier Sense Multiple Access—Collision Detection (CSMA-CD) channel access or synchronized channel access based on a beaconing mechanism and Direct Sequence Spread Spectrum (DSSS) coding. Maximum transmission range is about 75 m and it supported network architectures include star, tree cluster, and mesh topologies. Finally, Zigbee uses an Advanced Encryption Standard (AES) algorithm with 128-bit keys to guarantee message integrity and privacy and to perform authentication. Table (1) provides a reference to the most important features of the most prevailing wireless communication technologies for SHWSN.

Table 1: Wireless communication standards for SHWSN.

	Max. Data Rate	Range	Frequency
ZigBee	20/40/250 Kbps	10 – 75 m	868/915 MHZ or 2.4 GHZ
Bluetooth	1 - 3 Mbps	10 – 100 m	2.4 GHZ
IrDA	16 Mbps	1 m	Infrared
MICS	500 Kbps	2 m	402 -405 MHZ
Z-wave	20 Kbp/s	30m indoor/ 100m outdoor	868M/869/920/908/919/921/950MHz
Dash7	200 kbp/s	10m-10km	433 MHz
INSTEON	37 Kbps	45m	869/921/915MHz
802.11g	54 Mbps	200 m	2.4 GHZ

Bluetooth (IEEE 802.15.1 standard) [34] is an industry specification for short-range RF based connectivity between portable and also fixed devices. It is a low-power and low-cost RF standard, operating in the unlicensed 2.4 GHz spectrum. It uses a frequency hopping technique over 79 channels in the ISM band to combat interference and fading and it may support up to 3Mb/s in the enhanced data rate mode and maximum transmission distance of 100 m (although 10 m is the most common mode). Its basic configuration is the piconet, a star topology network with one master and seven slaves. Encryption is optional and is provided by a 64 or 128-bit SAFER+ algorithm, however, the Bluetooth framework is often found to be vulnerable to possible attacks and risks. Finally, the Bluetooth SIG announced the addition of two alternative protocol stacks, e.g., the Bluetooth low energy, an ultralow power technology for devices with limited battery capacity and the Bluetooth 3.0 specification which adopts the Wi-Fi PHY/MAC layers for higher data throughput. The Bluetooth low-energy technology allows for consumption of only a small fraction of the power of the original Bluetooth products and amongst others is targeting sports and wellness, and healthcare devices.

Alternative technologies for short-range intra-BAN communication include InfraRed Data Association (IrDA), the

Medical Implant Communication Service (MICS) and Ultra WideBand (UWB). IrDA [35] is a low-cost communication protocol for short-range exchange of data over infrared light. Infrared remote controllers are widely exploited for the remote control of consumer electronics in home. Despite the fact that it is a low power technology that supports up to 16 Mb/s, it has the main disadvantage of requiring line-of-sight communication, thus making it impractical for WSN applications. MICS [36] is an ultralow power, unlicensed, mobile radio service for transmitting low-rate data in support of diagnostic or therapeutic functions associated with medical devices. It uses the 402–405 MHz frequency band, with 300 kHz channels. Effective Isotropic Rediated Power (EIRP) is limited to 25 μWand targets mostly devices such as pacemakers and defibrillators. Despite its favorable characteristics, MICS has not been utilized widely by researchers due to the lack of commercially available MICS solutions. Finally UWB (IEEE 802.15.3), operating in the frequency range of 3.1–10.6 GHz, is a standard that is inappropriate for BANs due to its high complexity and the unsuitable wide bandwidth modulation.

Z-wave offers a low bandwidth half-duplex protocol designed for wireless communication in a low cost control network. The design goal of the protocol has been to transfer small amounts of time critical data. Z-wave is a preparatory protocol with very similar features as in Zigbee. Z-wave supports less data rate and a considerably less robust communication as compared to Zigbee.

Dash7 the goal of the Dash7 standard was to expand the market for low power wireless technologies by leveraging ISO 18000-7. The protocol is intended for RFID and wireless sensor networks. Dash7 has been designed based on the BLAST Concept, BLAST is an acronym for Bursty, Light-Weight, Asynchronous and Transitive. Dash7 operates in the 433.92 MHz frequency (available worldwide) and achieves a maximum data rate of 200Kbps (its data rate is dynamically adjustable from 28 kbps to 200 kbps). Dash7 is relatively long range adjustable from 10 meters to 10 kilometers.

INSTEON [37] is a dual- band mesh proprietary network solution which was developed by the Smart Labs Technology lead by a consortium of companies. INSTEON solutions use power line communication, RF or both. The solutions provided by INSTEON communicate in a peer-to-peer fashion. The goal of INSTEON has been to intercommunicate devices such as light switches, door locks, thermostats, clocks, smoke detectors, security sensors and remote controls, which were far from talking to each other due to the both complexity and expensive installation costs. INSTEON RF operates on 915 MHz/ 869.85MHz/921.0MHZ frequencies in different countries and the power line uses 131.65.KHz. INSTEON embedded devices can be used in a wide range of applications, such as: embedded sensors, heating ventilation and air-conditioning systems, lighting, home appliances and security systems. Also it can be used in entertainment consumer electronics, energy management, voice recognition and response, as well as other smart devices.

Actually, the IEEE 802.11 protocol is a set of standards for implementing a Wireless Local Area Network (WLAN), which is suited for high-data-rate applications over large areas. The IEEE 802.11 standard, commonly referred to as WiFi, is the most accepted technology for indoor wireless communications, but the basic shortcoming of this standard is the high power requirement of devices it used.

3.3 Routing Protocols for Smart Home Wireless Sensor Networks

In [38], the authors proposed a novel Dynamical Hierarchical routing Protocol with prime numbers (D-HiPr) addressing that use prime numbers as the sensor nodes' 16-bit local address. The key advantages of this protocol meet the requirements of SHWSN well, where it is featured by; first, nontable-Driven; D-HiPr uses a single Location IDentifier (LID) for packet routing other than traditional routing table, this mechanism helps to save memory of the transmission nodes as well as reduce traffic delays. Second, Energy Saving; D-HiPr uses a very simple way to compute routing path and packets in smart home can arrive at the receiver faster and more computation saving to save energy of the relay nodes even it is battery powered. Third, mobility; D-HiPr needs no routing table, and the nature of the prime numbers makes the address allocation more flexible, therefore, D-HiPr can support the mobility of nodes better than traditional routing table. Fourth, End-to-end Communication; in smart home with D-HiPr, not all the packets need to be sent via the gateway. In real domain, most packets are directly passed between sensor nodes, and it improves the efficiency of smart home to reduce the traffic of the gateway. Finally, Medium Scalability; although the scalability of prime-numbered addressing is normally hundreds, however, it matches the scalability of smart home well as it is always composed of hundreds of sensors as well. Also the authors in this paper modified three typical WSN routing protocols, LEACH, SPIN, and DD to incorporate traditional WSN routing algorithms into their smart home architecture, and they made a comparable efficiencies between them.

In [39], a smart home gateway model is designed, in this model, a mobile is used to control the device and collect home information through home gateway with multi-hop routing mechanism to connect the gateway with the sensor network. Because the capability of the sensors is important for forming network, the authors took the factor of its energy and hops into account. They defined the capability from one sensor to the other as the measured value, and the measured value is calculated according to the following methods: if the hop between the sensor and gateway is h, and its energy is e, then $\text{measured value} = h \times (2^{E/e})$, where, e is the percent of it full energy E. When the energy on the sensor is dissipating gradually, the measured value will become infinite, and the node would not be chosen by the others to forward the data package. In order to save energy for each sensor, they use a protocol like Routing Information Protocol (RIP) to route data

for each other. Each sensor will broadcast its information to the nodes which it can connect, the information include the number of hops to the destination home gateway and its remaining energy. Each sensor will calculate the measured value and updates its mini-routing table based on the received information. When a sensor sends data of itself or from others, it will select the sensor whose measured value is the least as the next hop, and transfer the data to it. To avoid the question of loops, before each sensor send the data, it will add its ID in the head of the data. When a sensor found an ID in the head of the data, it will not forward the data package to the sensor.

In [40], three routing strategies were proposed in an AODV-based/ZigBee-based network to offer diverse routing alternatives to be exploited in the Wireless-Powerline combined network. The joint-path strategy takes advantage of route entries to establish joint routes that may traverse multiple networks to destination nodes. The backbone-based routing strategy is built upon the joint-path routing mechanism to forwarded packets firstly through the power line. Composed of a wireless path and a backbone-based path, the dual-path routing strategy allows nodes failing to receive packets along one route to receive packets through another route as the two built-in routes are established independently from each other within each node.

In [41], the authors compared the performance two protocols in a Home Automation scenario with heterogenous traffic patterns including a mix of multipoint-to-point and point-to-multipoint routes in realistic dense non-uniform network topologies; the two protocols are, RPL, the routing protocol proposed by IETF for IPv6/6LoWPAN Low Power and Lossy Networks which has significant complexity, and the LOADng protocol which is a lightweight variant of AODV, emerges as an alternative solution. They used Contiki OS and Cooja simulator to evaluate the behavior of the Contiki RPL implementation and a basic non-optimized implementation of LOADng. The performance comparison results showed that RPL is better in the overall performance for their home automation scenario while LOADng could serve better sparse Low Power and Lossy Network (LLN) deployments with low-priority traffic in which the route hold tme can attain a large value. For home automation applications in which the response time is important, the results suggest that LOADng is not the best candidate. RPL delay is small and its overhead strongly depends on the implementation and a careful choice of parameters. Moreover, RPL has shown better results and less memory requirements than LOADng, but at the price of a higher implementation complexity. However, it is important to recall that they have used a simple flooding scheme and a better mechanism may reduce the control overhead. Furthermore, an intelligent route storing algorithm may reduce memory requirements of LOADng and improve the efficiency and scalability, but at the cost of a higher implementation complexity.

New routing protocols called Two-Hop Low Delay routing protocol (THLD) and Binary Tree Routing Protocol (BTRP) have been proposed in [42] to evenly distributing energy dissipation and reducing delay.The authors applied the THLD routing protocols to the networks of smart home. Then general n-tree multi-hop routing schemes are analyzed theoretically. The simulation results showed that both BTRP and THLD outperform Direct in terms of delay by introducing more energy dissipation costs with 25% and 20% respectively. Also, the lifetime of BTRP is not better than THLD, and BTRP performs better than THLD in terms of delay with 5%. Also the lifetime/delay metric in BTRP is greater than both THLD and Direct routing protocols with 5 % and 12% respectively.

4. PROPOSED ELDERS/DISABILITIES WIRELESS SMART HOME FOR ASSISTIVE INDEPENDENT LIVING (E/D-WSH)

As the remote and automatic control of windows and doors for example can represent a luxury or convenience matter for healthy people it represents an important issues for people who are can't see these objects and have trouble to reach it, need repose or have to rest in beds, and forget always anything, who are blind, elder, and Alzheimer people. The system is considered as a smart home for ordinary persons but with enhancements to suite persons need special deal and care who are the blind and elder persons, offering facilities such as reminders, voice alarms and directives, and giving voice orders. Also, some nodes are equipped with rechargeable battery to take the heavy responsibilities of nodes that acquire its power from the main current in case of electric current cut for continuous proper work of the system in this case.

4.1 E/D-WSH System Scenario

The smart home system that presented in [3] offers the convenience and comfort needed for elders, but it can be enhanced to be more suitable for disabilities in general and for blind, sight impaired and Alzheimer people specially not only for elders. The assistive living for the people who lose the visual sense can be based on benefiting from blessings of hearing and speaking. The matter is how to make the home talks to blind people, guides them, and makes them to a high degree dispense with doing businesses by hands; also it is how to make blind people talk to their home. The E/D-WSH consists of the following systems:

Entering System: The Entering System (ES) is best to be through the two options finger print that is more convenient to elders and voice recognition that is more convenient for blind people.

Fall Detection System: For fall detection and improving home caregivers work a floor sensor mats can be used, also floor sensors can be placed in different places such as the bed sides and doorways; with this arrangement, if a person fall from the bed or in the bathroom or he is attempting to depart a place and needs a help, a signal can be sent to another node(s)

equipped with a buzzer to alert about this event.
RFID System: Identifying the place of the elders or blind people can be done by integrating RFID tags and readers with wireless sensor nodes.
Lighting System: The light switches will be opened and closed electronically in addition to the ordinary method. Also, all the lambs will be turned on/off through the home Remote Control (RC) or by voice commands. Generally, the user can choose the lambs he wants to open/close and determines a time schedule and/or an event from a set of available events to trigger the specified action; this set of events is based on the reported events by the sensors used in the system. The lighting system can be made more easier to more assist independent living for elders, such that it automatically sense the existence of people in a place and accordingly switches on/off the light using occupancy sensors.
Windows Control System: The windows will be turned on/off electronically by the remote control or by voice command if a certain situation happened. Also, the user of the system can choose the windows he wants to open/close and determines an event from a set of available events to trigger the specified action.
Microphone/ Speech Recognition System: A sensor node in each place will be equipped with a microphone and a speech recognition circuit programmed to identify some commands such as “open window1 in room1”, upon these commands these nodes send the appropriate commands to the appropriate nodes.
Proximity Sensor/ Sound Synthesizer System: Proximity sensor embedded in a sensor node can detect the approaching of a person and according to its place and what the sound synthesizer was configured by, it alerts and guides the blind and Alzheimer person, such as “you are approaching the wall of the kitchen don’t forget to take your medication now, its five o’clock”, “at the end of the wall turn right to enter the bathroom”, “you are at the corridor and you can go ahead to enter room1 or turn right to enter room2”, “take care you are approaching a two stairs”, etc. A detailed sound confirmation of what the system already have done acquiescently to the person order usually is issued after its related tasks completion and directed to the node that originated the order, for example, when a blind person (or an ordinary person) orders through a node in the bedroom the windows to be closed, the system sends a confirmation voice message to that node after it closes the windows to assure the person that the windows are actually closed.
Reminder system: simply the central controller which is a PC with suitable application can be fed in any time with a timing schedule relates important times through the day such as the time of taking the medicine, to program the system nodes by broadcasting commands to it to issue voice alarms at these times reminding and directing these times’ events, these alarms repeat after its events due time in some cases such as the passing of the person beside a node contain a proximity sensor.
Gas Leakage Detection System: smoke detectors and gas detectors will be used in the kitchen and in the bathroom to measure the required type of gases concentration, and warns about that following the same behavior of the windows motion sensors, in addition they will aid to home ventilation as a quick countermeasure through running the electric air hood. Also, a water leak sensor is used in the bathroom and the kitchen to alarm if the water leaks from its sources by mistake or forgetting and it is going to swamp the place.
Electrical Devices Monitoring: two cases are considered in our solution as in [3]; first, the sudden return of a cut electrical current and the second, is the long opening of the refrigerator door. Against cut of electricity and its sudden return problems, a current sensor will detect the cut of electricity and then isolate the electrical equipments from the electric current wire until it detects the return of the current and its stabilization, it supplies equipments with the electric current. This is different from the system in [3] in that it is a centralized action where one current sensor at the main power switch in the home open and close it complying to the just mentioned required action no need to broadcast a signal commands the electronic switches at the electrical outlets of the electrical equipments to do this separately each one for its relative device as done in [3]. Against long opening of the refrigerator door, a light intensity sensor will be put inside the refrigerator besides its lamp, if it detects that the lamp light is open for a specified period it runs the kitchen buzzer and sends a notification message to the central control.
Home Structure Health System: a 3-axis accelerometer will be attached to each wall to detect the motion and vibration of the structure due to exposing to dynamic loads originating from a variety of sources such as earthquakes, aftershocks, wind loads, working machines, ground failure, blasts, fatigue, etc.; these sensors send periodically their readings to the central controller to be recorded and graphed. Measuring and recording how a structure responds to these dynamic loads is critical for assessing the safety and viability of a structure, detecting and alarming about a damage before reaching critical state saving money and lives, and enabling engineers to better diagnose and solve any damage if occurred.
In the proposed E/D-WSH system, the base station which is an ordinary radio/processor module is attached to PC or laptop acting as a server provides protocol bridging between the sensor network and the Internet. The sensor nodes collect information and send it to the base station using their dedicated protocols; the base station then forwards this information to the connected server which takes the responsibility to prepare it and send it to the remote user over the Internet and also receive commands and queries from him to be delivered to the WSN through the attached base station. With this system, the user can monitor and control the state of different things, doors, windows, lamps, etc. and control them, detect serious events such as an attempt to breaking into the home, gas leakage occurrence, or damage in the home structure that require quick procedure, and also the user can open the front door from a remote place for a trusted person. Figure (6),

represents a one level home of area 210 m2 consists of a hall partitioned into a large part and a smaller part, large and small balconies, kitchen, large and small bathrooms, and three closed rooms, the walls of the home is made transparent in the figure to show its contents. The distribution of some sensor nodes in the home is explained in the figure, and the numbers in indicated in the figure are explained in table (2), where the proximity sensors, which are not presented in the figure, they will be in each node contain the 3-axis accelerometer and 6 nodes additional in other places.

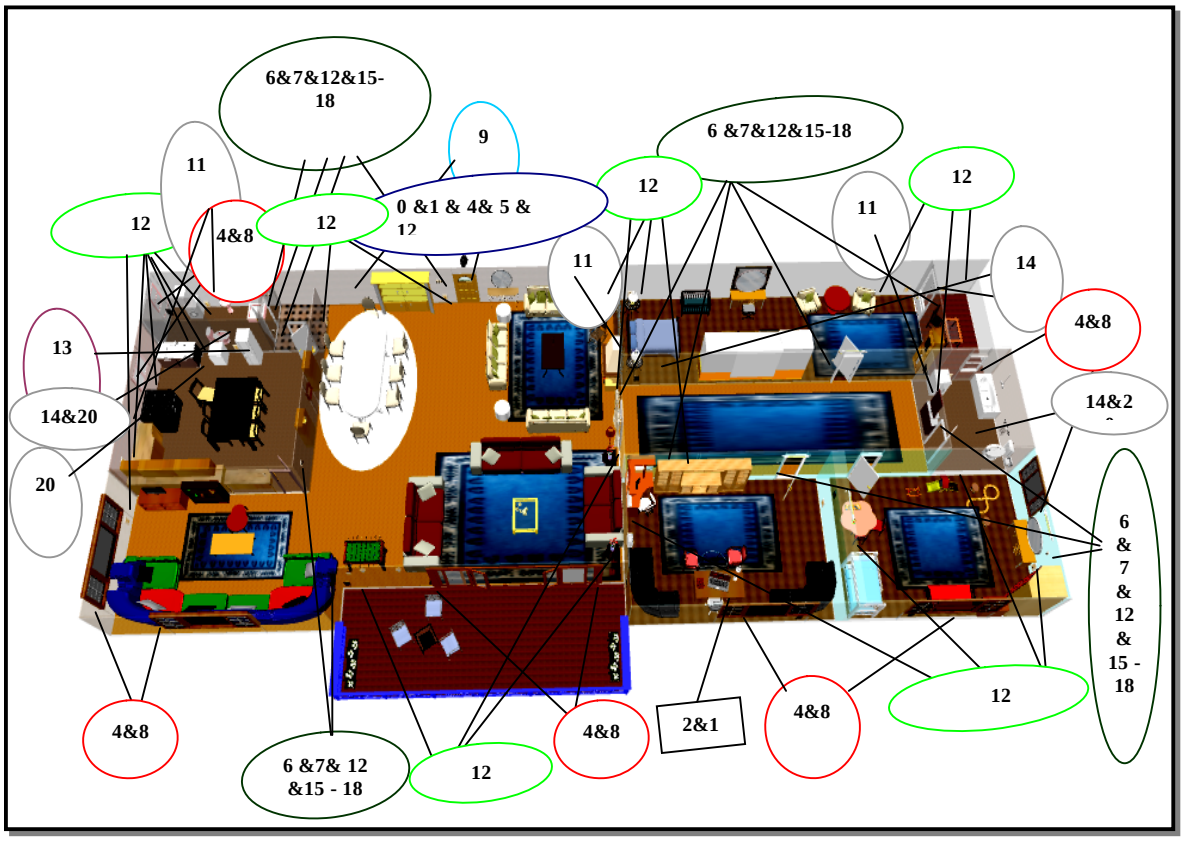

Figure 6 The distribution of sensor nodes in proposed E/D-WSH system

4.2 Communication Paradigm for the E/D-WSH System

The communication paradigm for E/D-WSH system is based on a fixed Base Station (BS) that takes an ID equal to zero, numbering of each room or a specified place by the ID of the node responsible for its light switching, the wireless nodes in each room which responsible for some operation like windows opening/closing form a Group with ID (GID) equals the room number and each one of them has its own ID starting from one and incremented by one, the remote control and node responsible for entering system take specific predefined IDs (e.g., IDRC= 100 and IDES= 200).

For initial setup, there are two types of announcement message the wireless and wired nodes use to inform about their existence. The announcement message which broadcasted by the wireless nodes will be approximately in the range that covers one room and it will contain the node ID, GID and type of node from the power point of view. The announcement message which broadcasted by the wired nodes in its maximum transmission range and if needed forwarded through multi-hops (nearest neighbor is the next hop) until it reaches the BS contains its ID, its type from the power point of view, and the IDs and GIDs of the wireless nodes it heard from. Upon these messages the nodes construct a table for neighbor nodes contains the ID, GID, node type regarding power, RSSI, and identifies special nodes such as the remote control or the BS. This communication paradigm also constitutes the basis for the previous work of [3].

The BS constructs a sleeping schedule [43] for wireless nodes, in which each node or group of nodes has a specific time to awake constituting a repeating round composed of all nodes awaking periods. At any time, a node can awake and transmit using CSMA/CA with optional acknowledgement. The remote control and the node responsible for the entering system are given a higher schedule rate. This schedule is passed to the wired nodes one after another according to their distance from the BS as indicated by the BS itself in the sent message. Each wired node stores awaking periods of the remote control and of any neighbor wireless node or group and sends them the start time to begin to compute the beginning of their slots and the length of the whole schedule. The time of reception of this schedule by the first wireless nodes or groups will be taken as the start time for all nodes to compute the start of the awaking periods, so as the message containing the schedule is propagated, a suitable time offset is embedded in this message by its sender to aid its receiver

compute the correct reference time as shown in figure (7).

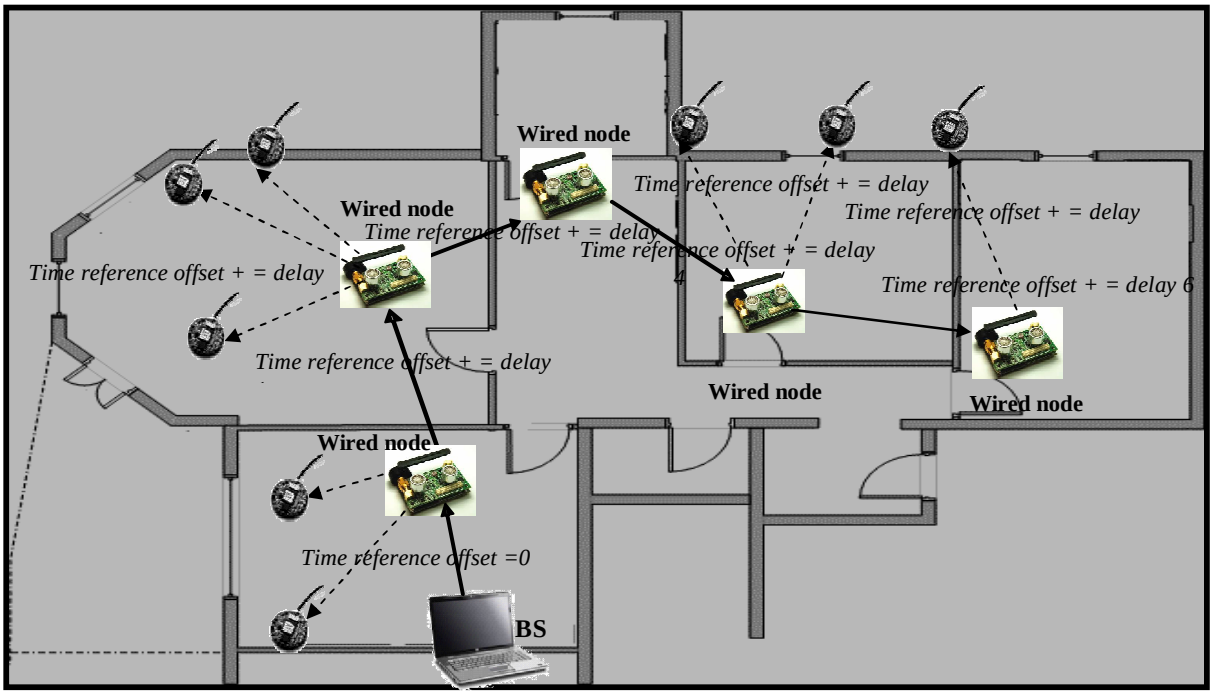

Figure 7 A plan view for the proposed E/D-WSH system with the propagation of the time offset

According to these schedules, the maximum delay time of a response to a command sent to wireless nodes (N_{wrn}) or wireless nodes groups (N_{wrg}) is computed from equation (1), where the maximum delay time of a response to a command sent to special nodes like front node or RC is computed also from equation (1)

$$nd_{response\_Max} = (m \times (N_{wrn} + N_{wrg}) - 1 + |(m-1)| \times 2) \times S_m \qquad (1)$$

Where,

$nd_{response\_Max}$: Maximum response delay of a wireless node or a wireless nodes group

m: is a variable equals 1 for wireless nodes and groups schedule, and equals 0 for special nodes schedule

N_{wr} : Number of wireless nodes

N_{wrg} : Number of wireless nodes groups

S_1 : Slot time for wireless nodes and groups schedule

S_0 : Slot time for special nodes schedule

Reference time = current time – time refernce offset (2)

First slot start time = Reference time + (Sno × S) (3)

Where:

Sno: slot number

S: slot time

After that, each wireless node knows when it should be awake to receive and each wired node knows when its neighbor wireless nodes or groups are awake. The transmissions of commands and data, and how the rest of the network setup is done by learning paths to destinations are illustrated in the following figures. Figure (8) will demonstrate different

transmissions flows from the wired nodes to the BS, whereas figure (9) presents different cases of transmissions flows in case of the destination is a wireless node or group of nodes.

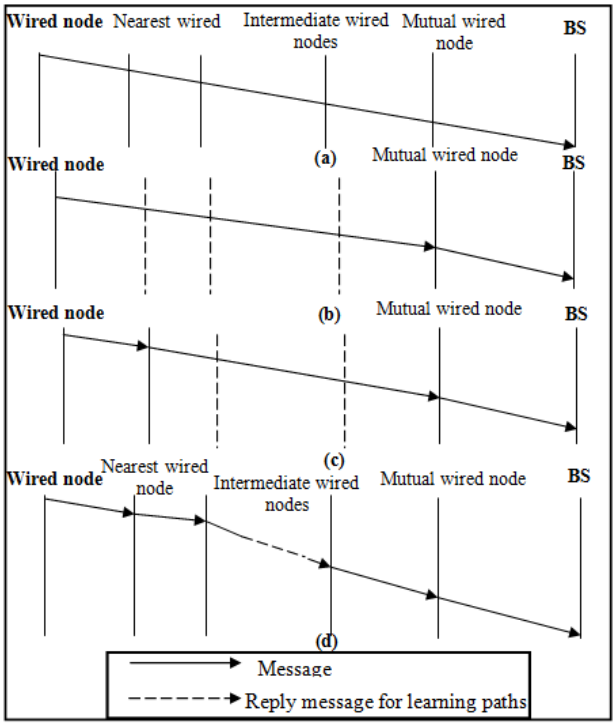

Figure 8 Different cases of transmissions flows from wired node to the BS

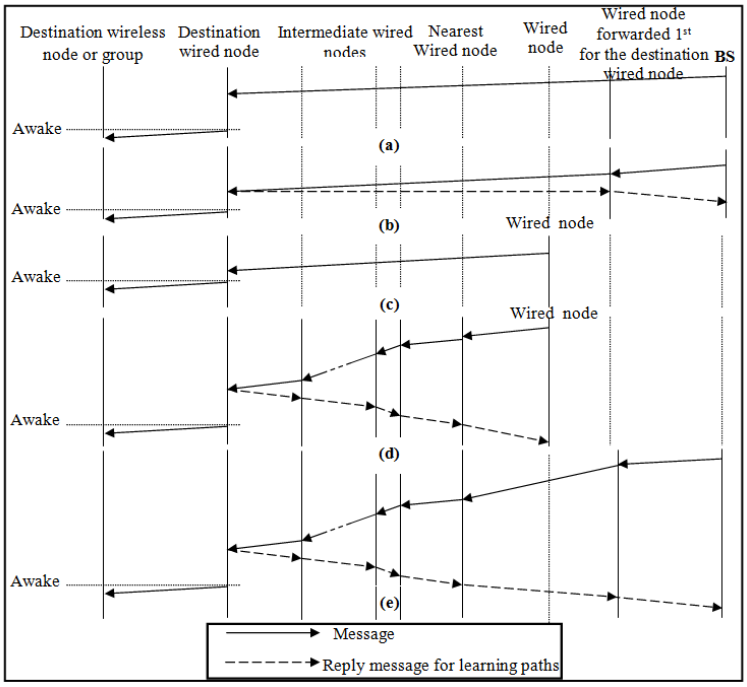

Figure 9 Different cases of transmissions flows from different sources to wireless node or group of nodes.

4.3 E/D-WSH System Cost

To apply the proposed E/D-WSH system on a home of an area 210 m2 as the system in [3], this will require a minimum number of sensors with a certain types, the approximate number and prices of the components required by this enhanced system are depicted in table (2).

From this table and after adding an approximate value for the cost of the system fabrication, other secondary components required for fabrication, system software, and system installation. Where the H.W. fabrication process requires specific materials such as soldering, and some secondary components such as wires, covers, etc., which they all and the workmanship fees add additional costs, and the system software includes the framework which will run on the nodes which represents the whole network stack comprising the appropriate application to each node type and the programming interface which will be used to program nodes with the appropriate settings; also the software represents the user application which will run on the central controller and represents the user interface to the system through which he can monitor and control locally or remotely, also the system installation includes the inspection of the home identifying its places or contiguous parts which will be considered as one place, identifying what each place represents, a room, a salon, a kitchen, etc., identifying each place with a number, determining the appropriate places of nodes and accordingly the required number of nodes and the system cost, , delivering the system, setup of the programming interface on a PC, programming the nodes with appropriate IDs, installing the various wireless and wired nodes in the appropriate locations, setup the user application, powering the nodes and finally explaining the usage of the whole system, all the additional components are represented in table (2) by the shaded rows, so it could be said that the whole system will cost approximately $8100.

Table 2 Approximate Cost for E/D-WSH System

Components	Representative number	Approximate price (US $)	Quantity
voice recognition device	0	40	1
Fingerprint reader	0	20	1
Electronic knob	1	55	1
A motion sensor	4	6	12
Front door alarm buzzer	5	3	1
Home part alarm buzzer	6	2	13
Electronic light switch	7	5	13
Electronic door/window lock actuator	8	11	11
Current sensor	9	10	1
Smoke and gas leakage sensors	11	7 + 2	4
3-axis accelerometer	12	0.6	37
Light intensity sensor	13	3	1
Floor sensor mat	14	132	3
Occupancy Sensors	15	28	13
Microphone sensor	16	2	13
Speech recognition circuit	17	35	13
Sound synthesizer chip	18	34	13
RFID reader	19	30	1
Water leak sensor	20	35	3
Proximity sensor		5	43
LCD display	-	8	1
Rechargeable battery for RC and some wired nodes	-	5	13
Battery charger	-	5	1
AA battery	-	0.43	63
AA battery holder case	-	0.26	102
Extension interface connector	-	1.24	102
ADC	-	15	100
DAC	-	15	91
Antenna	-	14	59
CC2420	-	6.68	59
ATMEGA128L	-	12.9	59
Keypad	-	3	1
RFID tag	-	15	1
Central control unit	2	-	-
Mobile remote control unit	3	-	-

By Comparing the obtained E/D-WSH system cost by the cost of WB-SH system in [3] which is suitable for ordinary/elders people only without any assist for disabilities which is approximately 6000$, actually E/D-WSH system wouldn't increase greatly the whole system cost.
According to the "The Indian Home Automation Market"[6], Smart home solutions will cost, on average, about INR 250 to 300 per square foot, i.e., for our 210 m2 home example, the average cost is from 9140.130025068$ to 10968.1560300816$. Also they remarked that:
Home automation installed with lighting, HVAC, and security for a luxury apartment with 5,000 square feet will cost up to 15.0 lakhs (24261.3 $).
Lighting control, by itself, will cost about up to 3 lakhs (4852.26 $), with limited ballast relays and without a Web server.
If a Web server is to be connected through an iPad or iPhone, then the cost would be approximately 6 lakhs (9665 $).
If the solution is smartphone controlled, investments could be in the range of INR 4 to 6 lakhs (6469.68$ to 9704.52$).
According to these findings, our proposed system cost which is approximately $8100, represents a convenient cost especially that it incorporates a lot of features and this cost includes adding an approximate value for the cost of the system fabrication, other secondary components, and system software.

5. CONCLUSION AND FUTURE WORKS

This paper reviewed the state of the art in wireless smart home revolution, as presented in the paper smart home wireless sensor networks have the potential to revolutionize the assistive independent living for persons with disabilities and elderly people. This paper also proposed a new smart home wireless sensor networks suitable for elders, blind, sight impaired and Alzheimer people specially and for disabled people in general, which called E/D-WSH system. E/D-WSH system offers a complete solution for the whole home environment for elders and disabilities by designing entering system, fall detection system, RFID system, lighting system, microphone/ speech recognition system, proximity sensor/ sound synthesizer system, gas leakage detection system, electrical devices monitoring and home structure health system. The proposed system is extendable and easy in installation and maintenance it costs about $8100, with this system the home can be controlled locally using a remote control or an application on a PC or laptop, or remotely through the Internet.
Actually, E/D-WSH system still has some limitation that should be taken in consideration in our future research, the most important enhancement to be taking into account is the verbalizing of the energy saving benefit of smart home technology by, first, using other resources for supplying power especially the solar power, second, continuous measuring of power consumption loads of different devices in such a way that gives the home owner guidance to control their use of electrical devices to reach a specific level of consumption or certain electricity bill, also the usage control can be done automatically through special program.

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