HELPERT: A Home assisted and cost Effective Living system for People with disabilities and homebound Elderly

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Abstract — Although there has been significant research and development on automation devices for assisted living, there has always been trade-offs in terms of the cost, complexity, design and efficiency. In this paper, a state-of-the-art simple and efficient yet cost effective reconfigurable assisted living system is proposed and implemented which will cater for the needs of bed-ridden patients, people with disability and senior citizens. The distinct feature which makes this implementation unique is its low cost, low power consuming hardware and user-friendly control, hence the user can operate the system without any external assistance. Additionally, the proposed work is a good head-start towards Internet of Things (IoT) concept and provides multitude of input options to the user by integrating cellular communication and Zigbee protocol based wireless devices with internet.

Index Terms — Assisted Living; Automation; Zigbee; IEEE 802.15.4; Labview

I. INTRODUCTION

The concept of connecting & integrating the everyday physical entities in the world with the internet has been a topic of noteworthy and challenging research which is commonly known by the term Internet of Things (IoT) [2]. The primary aim behind such astute integration is to simplify the people’s lives by having a technology that can deliver incessantly assuming ubiquitous presence of internet. Moreover, in the world of consumer electronics, persistent efforts are being made to ensure safe and smart life by incorporating the home automation systems (HAS) [3], which are extensively based on the wireless sensor systems where the true potentials of wireless standards are exploited. However, in spite of technological advances in IoT and HAS over the past decade, there are millions of humans who are devoid of such technological gestures, and for them apart from the cost their inability to use it is also an issue. Such technological advancements and smart systems are immaterial if they cannot be afforded and utilized by the people who need them the most.

According to the World Health Organization (WHO) statistics [1, 4, 5, 6] as shown in Figure 1, out of the world’s total population of approximately 7 billion, about 18.9% people are disabled and about 11% people are above 60 years of age. About 400 million people i.e. 67% of the population of the disabled and about 450 million i.e. 58% of the total population of the elderly, live in developing countries and majority of them belong to the continents such as Africa and Asia. Hence, it is quite apparent that significant proportion of the world population is dependent on someone or need some sort of external assistance to carry out their day to day activities. In order to assist these people solutions in the form of assisted living [7] have been proposed. Assisted living addresses the needs of elderly and disabled in their home environment by the use of remote services and home automation thereby assisting them in carrying out their daily living activities. It not only reduces their dependency on others but also simplifies and revolutionizes their life.

However, the currently available systems are expensive and cannot be afforded by people living in developing countries. As per International Labor Organization (ILO) [6], the average monthly income of an individual in Asia and Africa is less than $500 however, a HAS, from basic lighting to full-fledge feature-laden configurations, price ranges from $300 to $10000 [8]. So, a full-fledge automation system is out of...
bound of most people living in developing countries, moreover so for the elderly and disabled who are already dependent on others for their basic day to day activities. Apart from above, most of these systems are very complex to operate and are largely ineffective in solving the diversified needs of such people. For example, a system serving the needs of bed ridden patient may be futile for a blind person or a person with no limbs/legs, etc. Thus, there is an acute shortage of cost-effective assisted living systems with numerous input options that will reduce the dependency of elderly and disabled on others.

Motivated by the above, in this work we designed and developed a full fledged automation system which is cheap, affordable and has low energy requirement so that it can be readily used by the elderly and the disabled user. Furthermore, the proposed system has highly robust and flexible architecture incorporated with multitude of input options that can cater for diversified needs of such people.

Before going into depth of the architecture, it is very important to discuss the significant research and advancement that has taken place in this field. Different types of wireless standards such as Wireless Fidelity (Wi-Fi), Bluetooth, IPv6 Low Power Personal Area Network (6LoWPAN), Zigbee, RF, X10, Z-wave, etc. have been used in form or the other for HAS depending on the needs of the consumer and/or the application. X10 [9] is the oldest industry standard which was developed in the 1975 establishing a communication between the electronic devices using power lines. Java [10] based systems have also been developed where the electronic devices are controlled via a web server based PC however it requires extensive wired installations which is certainly not a cost effective solution. Bluetooth [11] based home automation systems provides good amount of data rate and security but incurs latency issues and one-to-one pairing which make them less efficient to be utilized in automation scenarios. Telephone line [12] based systems are heavily dependent on separate telephone cable architectures which again requires heavy cable installation with no graphical user interface and furthermore it also involves the pain of remembering numerous access codes. A hand gesture [13] based automation and control system give rise to user fatigue and inaccuracy problems. Home gateway [14] systems are also used in various homes and industrial applications to interconnect the private area network along with the public network or internet but they consist of very complex architectures. Wi-Fi based [15] systems are efficient and interoperable but they suffer from higher cost and comparatively high power consumption. Table I summarizes the advantages and disadvantages of various technologies that have been predominantly used to implement a HAS. In this work, IEEE 802.15.4 based Zigbee protocol has been chosen which can be re-configured to support different applications like automation, smart energy, health care, remote control, etc. according to the need of the user. Moreover, the unique feature of the proposed and implemented system is that a user only needs a phone and a desktop/Laptop to control and monitor the devices.

Most of the assisted living based works [15, 16] use sensor based devices to shift the dependency of the elderly and disabled to the machines, however excessive use [7] of assisted devices might adversely affect the well-being of the user. Figure 2 shows the possible side-effects of excessive use, with lots of devices, wires and sensors, a user might feel uncomfortable. In the proposed work, depending on the user requirement, input can be configured. For instance, if a person is blind then a remote with braille keypad and speech recognition is provided to control the home devices. If internet is unavailable, then all the devices can be controlled and monitored via cellular call. If a user is handicapped or armless then in-voice response system can be activated and

**Table 1. COMPARISON OF THE ALREADY EXISTING AUTOMATION TECHNOLOGIES**

<table>
<thead>
<tr>
<th>Technology Type</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Java Based [10]</td>
<td>User Interface, Secured, Reliable</td>
<td>Complex, Costly, Extensive Wired Installation</td>
</tr>
<tr>
<td>Wi-Fi Based [15]</td>
<td>Accurate, Fast, Supports Multimedia, Interoperable</td>
<td>High power consumption, complex, costly</td>
</tr>
<tr>
<td>Phone line based [12]</td>
<td>Easy access, simple, Remote access</td>
<td>No GUI, user has to remember access codes, Wired Architecture.</td>
</tr>
<tr>
<td>Bluetooth based [11]</td>
<td>Secured, Supports Multimedia</td>
<td>Medium power consumption, Paring, supports up to 7 nodes only.</td>
</tr>
<tr>
<td>Zigbee Based</td>
<td>User Interface, interoperable, easy, Cost effective simple implementation</td>
<td>Link Breakage problems, Interference issues No multimedia support, Low data rate</td>
</tr>
</tbody>
</table>

**Figure 2 Side-Effects from the Excessive use of the Assisted Devices**

intended devices can be controlled using speech recognition. Similarly there are other ways like direct DTMF (dual tone multiple frequency) tones[12, 17], type mode and cloud instruction mode which not only let the users to control the devices from inside the house but remotely as well as per their comfort.
The project consists of software front end which prepares and transmits instructions to a set of portable end devices to perform a given task. It also includes a monitoring device which is specifically designed to display the status message and monitor the network by getting a feedback from other end devices. The software for the project is developed using NI Labview [18]. This provides flexibility to update & build custom interface

This paper is organized as follows: Section II discusses the system architecture with the implementation of the proposed assisted living home automation system. It also contains the description of the software, hardware and flow charts of the inputs to enlighten their instruction processing. Section III discusses the evaluation and analysis of the system which includes the delay analysis, packet loss characteristics and cost analysis. Section IV wraps up the paper contents by throwing some light on future work.

II. IMPLEMENTATION AND SYSTEM ARCHITECTURE

Figure 3 shows the implementation of the prototype with the complete setup, which includes the master control system and the end devices. The original version of the IEEE 802.15.4[19] standard specifies two physical layers based on direct sequence spread spectrum (DSSS), one of them works on the frequency band of 868/915 MHz and baud rate of 20 to 40 Kb/s, other in frequency band of 2450 MHz with a baud rate of 250 Kb/s [19]. The latter is the choice for this work.

The multiple input availability is the highlighting feature of the work presented in this paper which brings out the flexibility of the system efficiently. The input ways are incorporated in the implementation with an option to activate or deactivate any device except the display. Hardware and software description is as follows:

1. Hardware Description

For the DTMF feature to function properly there is no need for any external DTMF module as employed in the past work [20], however the phone being deployed must have DTMF tones enabled. There is a need for at least a Microphone or a double headed Tip-Ring-Sleeve connector for higher accuracy. Figure 4 illustrates the system block diagram where the receiver and the transmitter blocks consist of Zigbee modules.

The Labview decodes the user input and then sends the corresponding instruction through Universal Serial Bus (USB) ports to the transmitter module. The baud rate can vary in between 2400 – 115200 b/s [19]. The instruction is then received by IEEE 802.15.4 receiver, thereby enabling the end device to perform the intended function (as shown in Figure 4). The Atmega2560 and Atmera328 microcontrollers are used in this work.

2. Software Description

As seen from Figure 5, the software once it gets the input from the user, it will traverse through a look-up table to find whether it’s one of the controlling inputs or not. If yes, then it will parse it in form of a standard instruction and transmit, otherwise it will send that input as a text which will be displayed in the form of a text message on the monitoring device.

The end devices are dynamically programmed to gather all the transmitted data in the channel, however to act only when they are instructed to do so, thus making them smart. The software has an astute design that is capable of accommodating various inputs from the users and can be reconfigured whenever
required. The algorithm incorporated in the software for different input methods is graphically represented in the form of a flow chart depicted by Figure 7. The system architecture shown in Figure 6 depicts all the input options that have been incorporated till now. A brief explanation of some input methods is also given below:

a. Control Through a GSM/CDMA call
This feature will help the user to control the devices off-line (through GSM/CDMA calls). As long as the user is connected to the mobile network he can control and get status about each and every device connected to the network. This control, which can be inferred from the flowchart in Figure 7 (a), works as follows: the designed central gateway will sense the Dual Tone Multi-Frequency (DTMF) [12, 17] tones and will convert them to an instruction set for the network devices. Then the intended device will perform the desired function. The significant feature of this method is that any phone or landline capable of generating DTMF mobile keypad tone can be used.

b. Control Through Voice Command
As shown by the flowchart in Figure 7 (b) this feature will be an on-demand feature where the user will have to record his voice command samples so that the devices will be switched only when he intends to do it. This can act as a boon to the handicapped and bed ridden patient, so that just by their voice they can activate or deactivate any appliance.

c. Control through Internet and cloud instruction mode
The master gateway can be connected to the internet for the users who want to use the internet (through an app/email/voIP) as the mode of network instruction input.

A user has to activate the internet mode and then he can access the software via remote desktop connection. It is also possible that one can simply control and get status of each device through an email by typing the instruction in the internet cloud mode.

Apart from the various input option, the proposed implementation has numerous additional features which can certainly fulfill the day to day needs of elderly and disabled but the most important feature is Power on Self-Test and Security. Unlike the previous implementations [13, 14, 15, 16], we have included a Power On Self-Test (POST) feature where each node when powered up, (or turned on) will try to complete a switching cycle with all the nodes connected to it. It will once switch On and then switch Off each device. If this cycle doesn’t get completed, then it will send a feedback to the central gateway and the user will be notified about this. Also, any unauthorized user will not be able to access the network. Only the wireless device with a particular Personal Area Network (PAN) [19] id can get an access to it. Moreover, any user who intends to get an access to the network has to provide a password. In the cloud based control, the user need to login to edit the command file saved in storage box whereas the voice instruction control is based on user’s accent and tone. For the cellular call based control, one needs to remember the access code and the user will have the option to allow only a specific cellular calls to access the system, using the block-call and auto-reply feature.

III. SYSTEM EVALUATION AND INFERENCES

To demonstrate a qualitative proof of assessment of the implemented system, series of experiments were conducted via a Zigbee test bench as shown in Figure 8 which was created in the communications lab at IIIT Delhi. The end devices used for testing purpose were: 15 watt bulbs, dc motor, fan, Light Emitting Diodes (LEDs) and buzzer alarms. Liquid Crystal Display panel was used as a display device.
The focus was more to extract the observations that define the quality of service by creating the reference benchmarks, in terms of the System Response Time (SRT) and packet loss rate. In order to get a more realistic data, the system performance was deliberately tested under more chaotic and heavily cluttered environment to replicate a worst case scenario. A time stamp module was encoded at the transmitter and received at the receiver module to calculate the system response. It takes an average 614 milliseconds which is an average of the values observed from 15 trials carried out on 3 different days in cluttered condition which the past work [3, 11] have not taken into account. Since the serial interface is the bottleneck for the data rate so optimum selection had to be made which will allow minimum error occurrence and give least number of packet drop.

![Packet Drop vs Baud Rate](image)

**Figure 9 Number of packets dropped out of 1000 for different baud rates.**

To select the optimum rate, 1000 packets were transmitted with each baud rate using the Zigbee test bench and it was observed that with lower baud rate lower number of packets are dropped which is evident from Figure 9. Extremely low baud rate may result in zero packet drops but data transfer rate is adversely affected. So, keeping the text messaging feature in view, baud rate of 19200 bps was chosen which provides good data transfer along with almost negligible packet drop.

- **Cost Analysis**

We have done cost analysis through leading electronics import channels (Alibaba & DealeXtreme) for our work & came out with the following average pricing formula: (650 × a + 60 × b + 400 × c) INR, where a=Number of controlling nodes, b=number of devices intended to be controlled, c=Number of Display device required. While concluding this formula we have assumed that we have ordered the components in bulk. The pricing analysis is done in Indian National Rupee (INR), which is also subjected to current currency valuation as compared to USD. Our National Rupee (INR), which is also subjected to currency valuation as compared to USD. Our National Rupee (INR), which is also subjected to current commercial availability solutions of HAS, from the same good import channel.

**IV. CONCLUSION**

In this paper, we proposed a Zigbee test-bench in communications lab of IIIT Delhi. The reference benchmarks such as system response time and packet loss rate showed that the proposed system performed satisfactorily even in a worst case scenario. Future work is focused on developing a mobile app to replace the master computer with a smart-phone, which will control the end devices directly, thus eliminating the need of a dedicated computer.

**V. REFERENCES**


