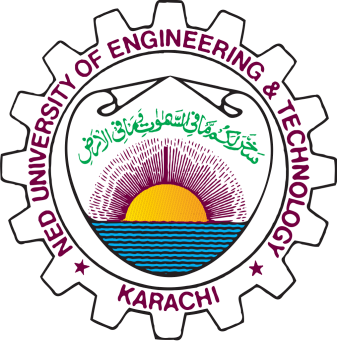
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**Proposal / Application**

**for**

**ICT-Related Development**

**and Research Grant**

****

**A Cost Effective Solution for Smart Homes in Pakistan**

**Submitted by**

**Dr. Muhammad Khurram**

**Read carefully before filling the form.**

1. Please do not alter the layout of the application form. Information must be filled in the spaces provided, under set format.
2. Guidance notes in various fields should not be deleted.
3. Required information should be duly filled in the specified fields.
4. Required heads/fields which are not relevant to the project should be marked **N/A** (Not Applicable) or left blank and should not be deleted.
5. Specifications, justifications, purposes must be provided against each item in the Budget file.
6. Please do not change the formulas in the budget sheets.
7. We have prepared financial guidelines to evaluate the remuneration for human resource associated with the proposed project. The guidelines are available on our website (click application forms>Financial Guidelines for Preparation of R&D and HRD Proposals>.

**List of Abbreviations and Acronyms**

|  |  |
| --- | --- |
| EE | External Evaluators |
| ICT | Information and Communication Technologies |
| IPR | Intellectual Property Rights |
| CPI | Co-Principal Investigator |
| PI | Principal Investigator |
| PIO | Principal Investigator’s Organization  *"Principal Investigator’s Organization" means the person, company, partnership, undertaking, concern, association of persons, body of individuals, consortium or joint venture which receives funding from the Company to execute a research and development project.”* |
| R&D | Research and Development |

**List of Abbreviations and Acronyms Used by PI in the Proposal**

(Please add abbreviations and acronyms in the table below, if any.)

|  |  |
| --- | --- |
| SB | Smart Board |
| SIT | Smart Interactive Terminal |
| PLC | Power line communication |
| GIO | General Input Output Pins |
| MCU | Micro-controller Unit |
| SS | Smart Switch/socket |
| UART | Universal Asynchronous Receiver/Transmitter |
| SPI | Serial peripheral Interface |
| IR | Infrared |
|  |  |
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**Application for ICT-Related Development and Research Grant**

**Guidelines and Forms**

**Introduction**

National ICT R&D Fund was created in January 2007 by Ministry of IT with the vision to transform Pakistan's economy into a knowledge-based economy by promoting efficient, sustainable, and effective ICT (IT and Telecommunications) initiatives through synergic development of industrial and academic resources. Collaborative efforts between academia, research institutions, and industry are greatly encouraged to ensure that local economy can reap the monetary benefits of investment in research. This organization has significant funds available for proposals that are geared towards creating ICT related technologies.

Research grants will be awarded for high-level and promising ICT-related development and research projects by individuals or groups from academia and/or industry actively involved in the research and development individually or collaboratively. These projects should be based on either a universally known technology or a new technology developed by the applicant and should be aimed at achieving economically viable systems, products, or processes beneficial to the nation.

The grant will cover the honoraria of the principal investigator and co- principal investigators, salaries of professional researchers and developers at market rate, stipends for student research assistants, and supporting staff. It will also cover travel(s) within and outside the country for project-related activities and for scientific conferences where project team’s research paper, an outcome of the project, has been selected for presentation. The grant may be used to purchase very specific unavoidable equipment kept to the bare minimum, consumable materials, and other items needed for the project.

**Submission Procedure**

Duly filled application forms complete in all respects along with any documents should be submitted online through Fund’s website www.ictrdf.org.pk. A hard copy should also be submitted by registered post or by fax at our mailing address given below. On receipt of the applications the proposals will be evaluated internally as well as externally as laid down in our policy documents. The PI may need to revise the proposal in light of the evaluator’s recommendations.

There is no deadline for submission of the application forms for Unsolicited Projects. The deadline for Solicited Projects will be given in the RFPs whenever floated.

**Joint Funding**

The project proposal may be jointly funded by ICT R&D Fund and other funding agencies/industry. The efforts to obtain joint funding will be at the discretion of the Principal Investigator Organization (PIO) to which Principal Investigator belongs. However any such information must be provided to ICT R&D Fund. The funds released will be provided to the PI.

**Agreement**

A written agreement will be made between National ICT R&D Fund and PI. The PI will undertake to administer the grant according to the agreement and to provide laboratory space, and other facilities necessary for the project. The equipment purchased with ICT R&D Fund for the approved project will remain the property of ICT R&D Fund. The laptops will be returned to ICT R&D Fund after completion of the project. The grantee is required to submit a final narrative and financial report within one month of the completion of the project. The IPR issues will be sorted according to the policy in vogue.

**For further information, please contact:**

Manager Administration,

National ICT R&D Fund,

6th Floor, HBL Towers,

Jinnah Avenue, Blue Area, Islamabad

Tel.: (+92-51) 921 5360 - 65

Fax: (+92-51) 921 5366

Website: [www.ictrdf.org.pk](http://www.ictrdf.org.pk)

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**Application for ICT-Related Development and Research Grant**

# 1. Project Identification

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Reference Number: | | | | | | | | | | |
| (for office use only) | | | | | | | | | | |
| Project Title: | | | | | | | | | | |
| Design of a Cost Effective Solution for Smart Homes in Pakistan. | | | | | | | | | | |
| Principal Investigator (PI): | | | | | | | | | | |
| Name: | | | **Dr. Muhammad Khurram** | | | | | | | |
| Designation: | | | Associate Professor | | | | | | | |
| Organization: | | | Department of Computer & Information Systems Engineering, NED University of Engineering and Technology, Karachi, Pakistan | | | | | | | |
| Mobile # : | | | 0335-3046110 | | | | Tel. # : | |  | |
| Email: | | | Khurram.ned@gmail.com | | | | | | | |
| *(A letter from the competent authority regarding PI’s time commitment for the proposed research project must be provided.)* | | | | | | | | | | |
| **C1. Co-Principal Investigator (CPI):** | | | | | | | | | | |
| Name: | | | Dr. Syed Raheel Hassan | | | | | | | |
| Designation: | | | Assistant Professor | | | | | | | |
| Organization: | | | Department of Computer Systems Engineering, Quaid-e-Awam University of Engineering Science & Technology (QUEST), Nawabshah, Pakistan | | | | | | | |
| Mobile # : | | | 0336-2292402 | | | | Tel. # : | | 0244-9370544 | |
| Email: | | | Raheel.hassan@quest.edu.pk | | | | | | | |
| **C2. Contact Person:** (If different from PI.) | | | | | | | | | | |
| Name: | | |  | | | | | | | |
| Designation: | | |  | | | | | | | |
| Organization: | | |  | | | | | | | |
| Mobile # : | | |  | | | | Tel. # : | |  | |
| Email: | | |  | | | | | | | |
| Principal Investigator’s Organization (PIO): *(Please indicate the name, address, telephone and fax of the Principal Investigator’s Organization. The Principal Investigator should belong to this organization.)* | | | | | | | | | | |
| Name: | |  | | | | | | | | |
| Address: | |  | | | | | | | | |
| Registration #: | |  | | | | | | | | *(Please attach certified copy)* |
| National Tax #: | |  | | | | | | | | *(Please attach certified copy)* |
| Tel. # : | |  | | | | Fax # : | |  | | |
| Website: | |  | | | | | | | | |
|  | | | | | | | | | | |
| Other Organizations Involved in the Project: *(Please identify all affiliated organizations collaborating in the project, and describe their role/contribution to the project.)* | | | | | | | | | | | |
| **E1. Industrial Organizations:** | | | | | | | | | | | |
| *#* | *Organization Name* | | | | | *Role / Contribution* | | | | | |
|  |  | | | | |  | | | | | |
|  |  | | | | |  | | | | | |
| **E2. Academic Organizations:** | | | | | | | | | | | |
| *#* | *Organization Name* | | | | *Role / Contribution* | | | | | | |
|  | Quaid-e-Awam University of Engineering Science & Technology (QUEST), Nawabshah, Pakistan. | | | | To collaborate in the development of the project. | | | | | | |
|  |  | | | |  | | | | | | |
| **E3. Funding Organizations:** | | | | | | | | | | | |
| *#* | *Organization Name* | | | | | *Role / Contribution* | | | | | |
|  |  | | | | |  | | | | | |
|  |  | | | | |  | | | | | |
| **E4. Other Organizations:** | | | | | | | | | | | |
| *#* | *Organization Name* | | | | | *Role / Contribution* | | | | | |
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|  |  | | | | |  | | | | | |
| Key Words: *(Please provide a maximum of 5 key words that describe the project. The key words will be incorporated in our database.)* | | | | | | | | | | |
| Smart Home, Assisted living, Smart sockets, Energy Management, Safety & Security. | | | | | | | | | | |
| Research and Development Theme: *(If the proposal belongs to a theme specified by NICT R&D Fund, please identify the Research Theme.)* | | | | | | | | | | | |
| <type here> | | | | | | | | | | |
| Project Status: (Please mark 🗹)   * New  Modification to previous Project    Extension of existing project | | | | | | | | | | | |
| **H1. Project URL:** *(The project URL should be provided. This URL should be hosted by the project executing agency. Sufficient details such as executive summary, objectives are expected on the website. Once the proposal is approved, the website should also provide final copy of the proposal and deliverables/progress.)* | | | | | | | | | | | |
| NA | | | | | | | | | | | |
| Project Duration: | | | | | | | | | | | |
| Expected Starting Date: | | | | 1st -July-2015 | | | | | | | |
| Planned Duration in months: | | | | 24 - Months | | | | | | | |
| Executive Summary: | | | | | | | | | | |
| This project presents a prototype solution for energy efficiency at residential level, home safety & security, and assisted living for elderly people by using smart home technology. Lack of electricity is one of the major issues in Pakistan resulting in 12-16 hours load shedding throughout the country. Since residential sector accounts for one of the highest energy consumer in Pakistan. Therefore efficient energy management at this level has become essential and smart home concept is an appealing way to promote the efficient energy management systems. According to customers the home safety & security are their top most concerns. Especially in Pakistan where home theft events occur more often due to which home owners are not mentally relax when they are away. Safe home also play an important role in giving peace of mind to home owners. With safety system implemented unpredictable events can be avoided. Assisted living for elderly people has become an important aspect of life because nowadays female members of the family are also involved in professional life. Therefore it becomes difficult for them to monitor and give time to home and its members. It has become essential to develop solutions in which elderly people could live independent life without depending on other family members much. Assisted living for people through smart home will result in better home environment. With the help of this technology, it becomes easier to control and monitor the home therefore resulting in better time management for home owners. Over all secure, safe, well managed, independent, and good home environment can be created with the help of smart home technology. The main hurdle in the growth of this technology is its cost, complexity, maintenance and an infrastructure that is not compatible with existing homes.  Therefore this project aims at providing a cost effective solution for smart homes in Pakistan which must be compatible with existing infrastructures and fulfills the basic & main needs of customers. This project proposes the design of smart switches, sockets, interactive terminal, remote control for elderly people, security & safety system, mobile application and finally connecting all modules to smart interactive terminal through power line communication. Another module for infrared (IR) based device control i.e., IR hotspot has also been included. Through this module the user will be able to control TV, Split or other IR based appliances. For each module low cost and efficient solutions will be obtained. The complete prototype system will be implemented and tested in any voluntarily available home near NED University or near Quaid-e-Awam University. | | | | | | | | | | |

# 2. Scope, Introduction and Background of the Project

|  |
| --- |
| Scope of the Project: |
| IoT is an emerging technology and probably will rule in near future. Smart home as one of its effective applications which can bring lots of changes in the lifestyle of common people. Through this technology things will become automated, easy to monitor and operate. The customers love to have cost effective, efficient, reliable and easy to use solutions/ products through which their life become safer, secure, easier and they can easily manage their work load and time as well. Through this project an attempt has been made to provide cost effective solutions for smart home so that people in Pakistan can afford the latest technology and make use of it for better living and having safe & secure environment. |
| Introduction:Smart homes are gaining vast popularity as one of the most promising application of the emerging IoT. With the help of this technology various issues can be resolved but the focus of this project is on its three main sub-categories i.e., efficient energy management, safety & security, and assisted living. The reason behind working on the mentioned applications are to overcome some of the major issues faced by people in Pakistan i.e., lack of electricity, home theft events, short circuits which results in Fire, electricity wastage or misuse and others. Lots of advancements have been made in technology but it is equally important that the market also make growth at the same rate. If technology is getting advanced rapidly but people are unable to make use of it then there should not be any need of further enhancement. Technology is there just for people to utilize it efficiently for their comfort and benefits but due to its cost and complexity people are not willing to adopt it especially in Pakistan where poverty and low employment rate are also some of the major issues.Therefore the prime aim of this project is to introduce the cost effective solutions for smart homes in Pakistan so that people here can easily afford it and also try to replace existing homes with smart ones. In the proposed solution we will be designing smart switches/sockets through which the customers can easily operate and monitor the energy consumed by each appliance and hence can estimate the overall monthly bill. Through smart sockets/switches the customers can more efficiently utilize the energy. Smart appliances have also been introduced in the market but due to cost involved in it, this option is neglected and preference has been given to design of smart switches/sockets for providing cost effective solution. The data from these smart boards will be transferred to a smart interactive terminal (SIT) through PLC communication so that it will not affect the existing infrastructure of the home and customers do not find it difficult to install new system. Few simple sensors i.e., obstacle, smoke, sound and others will be designed for safety & security purpose and a camera will also be located at the main gate for capturing any unauthorized access to home. The complete safety & security system will be implemented and interfaced with the main SIT in an intelligent way. A smart remote control for elderly people will be designed so that they can control their room remotely and can also generate some alarms in case of any need or emergency. Another IR hotspot module will be designed for controlling the IR based appliances remotely through mobile app. Each individual module will be interfaced with SIT. SIT will be the main terminal which will be interfaced with Wi-Fi and GSM module for providing remote access to users. |
| B1. Literature Review: *(Detailed summary of what all has been done internationally in the proposed area quoting references and bibliography. Please note that this section demonstrates the depth of knowledge of the project team and builds the confidence of the evaluators about capability of the team in achieving the stated objectives.)* |
| **B1.1 Internet-of-Things (IoT)**  Nowadays, nearly two billion people around the world use Internet for browsing the Web, sending and receiving emails, playing games, using social networks and many other tasks. Since more and more people will gain access to such a global information and communication infrastructure. Therefore another big leap forward is coming, related to the use of the Internet as a global platform for letting machines and smart objects communicate, dialogue, compute and coordinate. It is predictable that, within the next decade the Internet will exist as a seamless fabric of classic networks and networked objects. Content and services will be all around us, always available, paving the way to new applications, enabling new ways of interacting, entertainment, and living. The Internet-of-Things is emerging as one of the major trends shaping the development of technologies in the ICT sector at large. From a conceptual point of view the IoT builds on three pillars, related to the ability of smart objects to: (i) be identifiable, (ii) to communicate, and (iii) to interact, either among themselves or with end users or with other entities in the network. At the single component level, the IoT will be based on the notion of “smart objects” which will complement the existing entities in the Internet domain. Smart object in **[1]** is defined as an entity that:   * Have a physical embodiment and a set of associated physical features. * Have a minimal set of communication functionalities such as the ability to be discovered and to accept incoming messages and reply to them. * Possess a unique identifier. * Are associated to at least one name and one address. * Possess some basic computing capabilities. * May posses’ means to sense physical phenomena or to trigger actions having an effect on the physical reality (actuators).     Fig. 01 Internet-of-Things a new dimension [47]  The Internet of Things vision (refer to Fig. 01) provides a large set of opportunities to users, manufacturers and companies. In fact, IoT technologies will find wide applicability in many productive sector including e.g., environmental monitoring, health care, inventory and product management, workplace and home support, security and surveillance. From a system level perspective, the Internet-of-Things can be looked at as a highly dynamic and radically distributed networked system composed of a very large number of smart objects producing and consuming information. The ability to interface with the physical realm is achieved through smart objects and through suitable actuators some actions are triggered based on the sensed data. As scalability is expected to become a major issue due to the extremely large scale of the resulting system, and considering also the high level of dynamism in the network, the quest for inclusion of self-management and automatic capabilities is expected to become a major driver in the development of a set of enabling solutions. From a service level perspective the main issue relate to how to integrate the functionalities and resources provided by smart objects into services. This requires the definition of (i) architectures and methods for “virtualizing” objects by creating a standardized representation of smart objects in the digital domain, able to hinder the heterogeneity and composing the services of smart objects into value added services for end users. From a user point of view, the IoT will enable a large amount of new always responsive services, which shall answer to users’ needs and support them in everyday activities. When a user has a specific need, he will make a request and an ad hoc application, automatically composed and deployed at run time and tailored to the specific context the user is in, will satisfy them **[1].**    Fig. 02 IoT a system for more connected world [48]  A number of large scale initiatives on IoT are active in the US, Europe, Japan, China, Korea and other countries. In US, the American National Science Foundation (NSF) launched in 2008 a program on **Cyber Physical Systems [2]**, aimed at introducing systems able to merge computational and physical resources. The program was meant to cover a wide array of application scenarios, ranging from smart electric grid to smart transportation, from smart medical technologies to smart manufacturing. The 2010 report of the president’s Council of Advisors on Science and Technology, **Designing a digital future: federally funded research and development in networking and information technology [3]**, encourages further investments in Cyber-Physical system, due to their high potential impact on a number of critical industrial sectors. The European Commission has been publishing initiatives related to IoT since 2005 **[2]** and has recently launched an initiative on “Internet Connected Objects”. Within the initiatives which have taken place at the European level, four large scale projects are worth mentioning. The **HYDRA project initiated in 2009 [4]** developed a middleware based on service oriented architecture, transparent to the underlying communication, supporting distributed as well as centralized architectures, security, and trust models. This project was meant to provide a middleware solution allowing the developers to incorporate heterogeneous physical devices into their applications by offering easy to use web service interfaces for controlling the physical devices. The **RUNES project initiated in 2002 [5]** was meant to create a large scale, widely distributed, heterogeneous networked embedded systems which provide a flexible and adaptable ICT tool to leverage environmental data. In RUNES, one of the target challenges was to achieve the required level of self organization to suit a dynamic environment, while ensuring that proper interfaces were provided to programmers in order to ease the development of applications and services. This was meant to allow for a significant cut in the cost of new application development and a much faster time to market. The **IoT-A project initiated in 2006 [6]** aims at introducing an architectural reference model for the interoperability of Internet of things into service layer of the future Internet. The **iCORE project initiated in 1984 [7]** aims at empowering the IoT with cognitive technologies and is focused around the concept of virtual objects (VOs), intended as semantically enriched virtual representation of the capabilities/resources provided by real world objects fostering their re-usability and supporting their aggregation into more composite services. One key element in the iCORE project is the use of advanced cognitive techniques for managing and composing VOs to improve IoT applications and better match user/stakeholder requirements. Four use cases are put forward for validation purposes: ambient assisted living, smart office, smart transportation and supply chain management. IoT centric projects are active also in Japan, under the umbrella of the **UNS initiative** (Ubiquitous Networked Society, part of the wider “e-Japan” strategy) started in **2009[8],** which focuses on ubiquitous presence of sensors and RFIDs in order to enable pervasive services, with target applications ranging from smart home to supply chain management. However the widespread diffusion of research initiatives denotes the vitality of the field and IoT applications potential, it brings alongside a risk of fragmentation and lack of adoption to adequate standards. As the technology gets mature and makes its way into the real world, IoT would require a careful standardization process, in order to ensure interoperability among devices and applications coming from different countries, building the foundations the real arising of an Internet of things.    Fig. 03 IoT in future [49]  Six major applications of IoT are defined by D. Miorandi et al., in **[1].** According to authors the following applications can play a leading role in the adaptation of IoT technologies.   * Smart Homes/Smart buildings Management * Smart cities * Health care * Security and Surveillance * Environmental Monitoring * Smart business and product management   **B1.2 Smart Home**  A Smart home can be defined as, “an electronic networking technology to integrate devices and appliances so that the entire home can be monitored and controlled centrally as a single machine”. Instrumentation of buildings with advanced IoT technologies may help in both reducing the consumption of resources associated to buildings (electricity, water) as well as in improving the satisfaction level of humans populating it which impacts both economic and social sectors. In this application, a key role is played by sensors, which are used to both monitor resource consumptions and to proactively detect current users’ needs. Smart home concept has been developed rapidly since the early 1990’s. After almost two decades, the widespread deployment of smart homes is still limited and has not taken off on a large scale, although, many people consider it as the “Future Living”. Smart home concept encloses multiple applications belonging to the different areas, interacting with each others.   * Lighting control * Appliance control * Entertainment * Safety system * Climate control * Assisted living     Fig. 04 Smart home infrastructure [50]  One of the important applications field since the introduction of smart home technology has been safety and security. Starting off from protection against burglars sensors are increasingly used to monitor behavior and use that information to prevent accidents from happening, e.g., detection of harmful gasses, fall detection, and reminders for open windows, appliances left running. Assisted living is also considered as one of the major applications of smart home. Through this one can assist and monitor the elder people, with the ultimate goal of permitting them to live longer in their homes. These different application areas do not exist in isolation, they can benefit from progress made in one area and should be considered as being one integrated system for the home environment.    Fig. 05 American customer survey by Lowe’s [9]  Fig. 05 shows recent survey about smart homes by home improvement retailer **Lowe’s in 2014 [9]** found that, in general, Americans have a favorable attitude toward smart homes, with security ranking as the top benefit of home automation. In the survey conducted online for **Lowe’s by HarrisPoll**, **52%** of respondents said that having a smart home is at least important to them. The top reason was **security for 62%** of survey participants. **Energy efficiency and cutting utility costs was cited by 40%** as the most important reason to own smart home products. More than 2000 U.S. adults participated in the study. Respondent indicated that the top three things they would like to be able to control while not at home are the lights (18%), thermostat (16%), and door locks (5%). When it comes to a smart home solution, half of the survey respondents said they prefer a do it yourself solution, and 21% said that they would prefer a professionally installed system with a monthly service fee. More than half (56%) said that cost was the most important factor when considering a purchase of smart home products. In a recent report on connected home [10], **BI intelligence** takes a closer look at this market, and forecasts shipments and revenue growth for connected home devices over the next five years. According to report connected home device shipments will grow at a compound annual rate of 67% (refer to Fig. 06) over the next five years, much faster than smart phone or tablet device growth, and will hit 1.8 billion units shipped in 2019. Connected home devices include all smart appliances, safety & security, and energy equipments (refer to Fig. 07).    Fig. 06 Global Connected Home devices annual shipments [10]  **iControl** has discovered the real drivers behind smart adoption in its **“2014 state of the smart home” report [11]**. From the survey results they found that, no matter what the age, gender, or income level of respondent is, the key factor here is their enthusiasm for technology. According to **90%** of the respondents’ **family security and safety** is the most important reason for using smart home, with 67% ranked it as the top most reason overall. After personal and family security, **86%** of the respondent mentioned **property loss protection** as an important feature of the smart home over any other feature. According to **Paul Dawes, Executive vice president, General Manager of iControl networks**, “Security has always been the workhorse of the smart home system. As this industry grows, the definition of security will only expand to include even more features that help consumers keep themselves and their families safe and healthy.” **78%** of respondents ranked **energy management** as one of the top features that matter most in the smart home. According to respondents the smart home technology that will be common place in next decade is voice controlled light and appliances (39%), Automated lighting and HVAC based on home occupancy (34%), and Sensors that track food inventory and automatically orders grocery accordingly (20%).    Fig. 07 Global connected home devices shipment [10]  According to a market report published by **MarketsandMarkets** in 2013 **[12],** the global smart homes market is expected to grow at a compound annual growth rate **(CAGR) of 17%** between 2015 and 2020, and reach **$58.68 billion by 2020.** The smart home market revolves around green home solutions, which include smart energy management systems and monitoring of the home’s HVAC system and appliances. Many homeowners are attached to smart concept not only because it offers energy management and efficiency, but also for security, convenience, and comfort. North America is expected to retain its position as the largest smart homes market. The revival of construction activities in new residential buildings and renovations is expected to support the growth of the North American smart homes market. The U.S. will remain the major market for smart homes throughout the forecast period, due to its high adoption rate and continuous development. High investments in building infrastructure and the need to lower power consumption are expected to drive demand for smart homes systems in Asia-Pacific and Europe. According to another market research report by **MarketsandMarkets** in 2013 **[13],** the total market for European smart homes will be worth **$13.81 billion by 2020** at an estimated **CAGR of 18.17%.** The European smart homes market covers the whole industry on the basis of products, services, and country. All the major products, the security systems are expected to have higher adoption rates with respect to the mass market. The services section covers the installation & maintenance, renovation and customization. The country analysis consists of top countries in Europe, namely the U.K., France, Spain, Italy, and Rest of Europe. According to report the major drivers for the European smart homes are energy and cost saving, reduced carbon emissions, helping ageing population, security, convenience and government initiatives. Assistance of power line communication and smart grids are key opportunities for the global smart homes market.  Smart home research from **Parks Associates [14]** shows over 50% of all smart homes device owners consider interoperability as “very important”. According to them, with interoperability implemented the value increases with each device purchased, reaching 60% among households that have three devices. *"*Interactive and smart home services extend the value of security while creating new revenue opportunities for dealers", said [**Tom Kerber**](http://www.parksassociates.com/staff/tom-kerber)**, Director, Research, Home Controls & Energy, Parks Associates.** Device interoperability is crucial to realizing the new value equation for the smart home, and the security channel, because of its consultative selling approach, is leading the market. [**Parks Associates research**](http://www.parksassociates.com/whitepapers/smart-home-service-providers)**shows that over 60% of U.S.** broadband households are unfamiliar with smart products and services. Therefore, a consultative selling approach that educates consumers on product and service options is necessary in the early stages of the smart home market.  **B1.3 Overview of Smart Home projects round the globe**  Many projects on Smart home are under progress around the globe. Few of them have emphasized on particular applications based according to their country needs and constraints. Others are working by keeping in view the demands of customers and growth of smart home market. Some of the projects working on smart home technologies are discusses as under.  **SmartBo[15]** – A smart house for people with disabilities built in 2000. A project by Gerhard Elger which has been financed by the Swedish Inheritance Fund, the Swedish Handicap Institute and also other private companies. The main objectives of this project were to monitor and employ new technologies for the benefit of people with disabilities and to support independent living for them. The work on smart living is being continued at the Swedish handicap institute in a new activity called **SmartLab** involving all departments of the institute. Knowledge, experience and equipment from SmartBo have been utilized in this project. **Aware Home Research Initiative (AHRI) at Georgia Institute of Technology [16]** is another smart home based ongoing project aimed at addressing fundamental technical, design, and social challenges for people in a home setting. Researchers are trying to invent the future tools for applying new off-the-shelf technologies in innovative ways to improve the lives of people at home. Central to this research are the **Institute for People and Technology (IPaT) Living Labs** of, **The Aware Home**, a 3-story, 5040 square foot facility designed to facilitate research, while providing an authentic home environment. **The Wesley Woods Towers Senior Living apartment (Suite 609) at Emory University** designed to extend the reach of the Aware Home into a senior living environment. [**HomeLab**](http://homelab.gtri.gatech.edu/), a GTRI managed resource, including a population of individuals 50 and older willing to participate in research studies and evaluate products in their homes over time. **The Child Study Lab**, located in the Health Systems Institute space, provides a controlled and monitored environment for studies involving child behavior, such as Autism. **ZUMA a project initiated in 2006 [17],** funded by Gigascale Systems Research is a smart Home based project at the University of California, Berkeley, USA.The project circles around four tenets of smart-home environment namely **Zero-configuration, Universality, Multi-user optimality, and Adaptability (ZUMA),** and describes a platform based on a set of clean abstractions for users, content, and devices. ZUMA presents a set of abstractions, specifically for those elements affecting people, content, and system capabilities. It is a platform to enable configuration and organization of content and networked heterogeneous devices in a smart-home environment. it is a platform to enable configuration and organization of content and networked heterogeneous devices in a smart-home environment. The **Adaptive house [18]** is a smart home project, owned by university of crux, built in Boulder, Colorado around 2004 and is still under work. The aim of this project is to develop a home that essentially programs itself by observing the lifestyle and desires of the inhabitants, and learning to comfort systems-HVAC (heating, ventilation, and air conditioning), water heater, and interior lighting. A secondary consideration of the system is to conserve energy resources, when possible. **ENABLE [19-21]** is a **European project** started in 2011 and still in progress. It is operating with the support of the Lifelong Learning program of the European Union which started on the 1st November, 2011; it holds a network of 16 European Partners and four third country partners. They have planned to use electronic networking tools to gather information and investigate the ICT support Lifelong Learning by disabled adults. Specific outcomes of their project relate to the organization, categorization and evaluation of knowledge and include overview of current state of the art on ICT. The ENABLE project has developed a suite of training modules for tutors of disabled adult learners as well. **CENELEC Smart House Roadmap is another European ongoing project started in 2010 [22**]. It has been funded by the European Commission and the European Free Trade Association. The objectives of this project are twofold; firstly to identify all existing initiatives or standardization works in the area of smart home. Secondly to co-ordinate actions so that existing and future work should deliver interoperable solutions for any Smart Home service or application. The CENELEC Smart House Roadmap Project was carried out by a Project Team which latter supported by a steering group.  The **Center for Advanced Studies in Adaptive Systems (CASAS) Smart Home project at Washington State University is an ongoing project established in 2007 [23].** It is focused on the creation of an intelligent home environment. The CASAS views the smart home as an intelligent agent that perceives its environment through the use of sensors, and can act upon the environment through the use of actuators. The goals of this project include minimizing the cost and maximizing the comfort. CASAS team has been testing the technology in sheltered accommodation for the elderly to help them get up, prepare food, make hands-free phone calls and remember to take their medication making life easier for everyone. The team has managed to create “fairly robust models” for houses. The vision is to detect changes in occupant behavior that indicate cognitive or physical deterioration. If the house could adjust to such impairments and provide warnings to family members, elderly with physical and mental disabilities can look after themselves at home for longer. CASAS is funded by the National Institutes of Health, the National Science Foundation and Washington State’s Life Sciences Discovery Fund. The **Duke Smart Home is an ongoing project initiated in 2003 [24]** Program is a research-based approach to smart living sponsored by the Pratt School of Engineering. Primarily focused on undergraduates, the program encourages students from different academic disciplines to form teams and explore smart ways to use technology in the home. More than 100 students, mostly undergrads from a variety of academic disciplines, are carrying out research on what it means to live smartly. The goal of the Duke Smart Home Program is to offer a research and educational program that emphasizes energy efficient, sustainable and ‘smarter’ living. In addition, the program provides a budget, oversight and mentoring guidance for the student-run Smart Home Club. An **Intelligent Sweet Home** for Assisting the Elderly and the Disabled is funded by **Human-friendly Welfare Robot System Engineering Research Center (HWRS-ERC), KAIST, KOREA [25].** It is an ongoing research project. This intelligent house for physically impaired people integrates devices for movement assistance of the resident and devices for continuously monitoring of his/her health status. The approach will reduce significantly the medical care costs per person. The goal of this research is to design human-friendly and effective man-machine interaction systems for the human being. The work is focused on the development of three detailed research parts: intelligent bed robot, soft remocon and network. The disabled and the elderly can have independent livelihoods by extending functionalities of and adding conveniences to conventional houses in an intelligent home.  **B1.4 Need of Smart Home in Pakistan**  The extent of some issues in Pakistan makes it essential to adopt smart home technology based solutions. The major issues which cannot be easily ignored and have great impact on the life of common people in Pakistan are;   * Efficient Energy Management * Security and Safety * Assisted living   **B1.4.1 Efficient Energy Management**  Pakistan’s Power Sector is, and has been for many years, plagued by significant challenges. These include limited availability of reliable and affordable electric power, aging infrastructure, increasing cost of fossil based generation, outdated policies and with practices that lag behind those of modern utilities elsewhere in the world. Moreover, extremely low levels of investment in utility infrastructure is a huge barrier standing in the way of improving operating performance and facilitating improved outcomes to the end consumer. Everything in the world is going global and energy theft is following the trend. It is a known fact that electricity theft is a growing problem that continues to get worse. According to **World Bank report in 2009 [26]**, there is an annual worldwide electricity loss worth 220 billion USD due to electricity theft or technical problems with the grid.    Fig. 08 Electricity consumption by different sectors in Pakistan [27]  Due to inadequate infrastructure in Pakistan high system losses take place resulting power cuts in the form of load shedding and price hiking of electricity which are the main factors hampering the economy. During 1972-2012, high economic and population growth led to a sharp rise in electricity consumption. The percentage share of residential electricity consumption in total electricity consumption has been increased from **11.9% in 1972 to 46.5% in 2012** (refer to Fig. 08 and 09). The number of electricity consumers in residential sectors has been increased over the years due to the rapid expansion in the supply of electricity to villages between 1996 and 2010, as a 112%growth was observed in residential consumers of electricity according to **Pakistan Economic Survey in [27].**    Fig. 09 Change in electricity consumption from 1994 to 2012 [28]  In a country with low-income, consumers are unwilling to replace relatively expensive items, such as refrigerators, computers and air conditioners, in response to the high cost of electricity. On the other hand the country experiences extreme shortages, both in winter due to low hydroelectricity availability and in summer due to higher air conditioning demand (5000 + MW) **[28].** Since residential sector is consuming largest amount of electricity and has the largest growth rate as well when compared to others. Therefore it is necessary to make efficient utilization of electricity in this sector. One way to deal with it is the use of home automation technology. Using this technology the consumer has full control on each and every part of his/her home no matter that he/she is at home or away. Besides controlling, the consumer can also monitor the energy consumed by each appliance/device and accordingly he/she can manage the overall energy consumption of his/her home.  **B1.4.2 Security and Safety**  Different types of crimes in Pakistan are serious problems for society, especially in multi-cultural locations, Metropolitan cities such as Karachi. Burglaries can occur at any time which results in psychological burden on daily life of common people. Due to fear of intruders, home owners often don’t open their doors until they’re certain of the person’s identity. People are afraid to leave the safety of their homes and when they do, they’re afraid of burglars getting into their houses during their absence. In Pakistan, the day by day increasing theft crimes are pushing people to search for upgrades in protection of their houses. This strong security device demand has urged to produce some gadgets one can install in order to make home resistant to burglary. The country must overcome the multi-dimensional problems to apparent wellbeing of its residents and their patience. Some important steps should be taken for the security issues the whole nation is having today. Safety and security issues of the state need to be addressed through brining some upgraded technology, innovations, and advancement related to home security, fire fighting, workplace safety, emergency, rescue and mobility. Nowadays thieves are using military strategies and high-tech gadgets in breaking down the poorly guarded homes making it very difficult to protect ones house by obsolete security systems. Therefore the security systems need to be upgraded to get protected from burglars. The introduction of smart home can be used to enhance security using various assortments of sensors and cameras. During the absence of the owners, these sensors will be able to detect intruders on the property and be able to alert the users as well as to the concerned authorities.  **B1.4.3 Assisted Living**  According to the **2014 estimate of the CIA World Fact book, 4.3%** of the population of Pakistan (male 3,951,190/female 4,490,045) are 65 years or over. Almost all of these elderly people live with their children owing to the joint family culture that is dominant in Pakistan. According to **the Persons with Disabilities (PWDs)** Statistics in Pakistan of 2012 **[29], 2.54%** of the population has a disability. This amount equals to 5,035,951 people with disabilities in Pakistan.  Fig. 10 PWDs population by disability in Pakistan 2012 **[29]**  Smart Home solution can be used to enhance the quality of life for such individuals without them having to rely on others for help. Bedridden patients can control their room conditions such as lighting, air-conditioners, fans etc. or call nurses/family members in case of emergencies. Smart home technology is foreseen as a way to help the elderly, particularly those suffering from forgetfulness and dementia. It could, for instance, locate misplaced eyeglasses or keys, and remind residents about taking medication. Smart homes can contribute to the support of the elderly, people with chronic illness and disabled people living alone at home. The main goal is to provide a real home environment for real elders, capable of continuous functioning with minimum of maintenance. In a **research study conducted in [30] by Lee et al.,**  it has been found out that “busy households, that is a family with children and both parents working could themselves become adopter of smart home services”. Dual Income families often live with a very structured life with almost no un-scheduled time. Since rate of Dual-Income families in Pakistan has also been increased therefore the potential time-saving features that a smart home can provide will help to maintain a sense of control and relieve some of the stress associated with running the household.  **B1.5 Problems encountered in the area of smart home**  Some of the problems in the area of smart homes have been found when conducting the literature review. They are summarized in Table 01.  Table 01 Problem encountered in smart home technology [33]   |  |  | | --- | --- | | **Problems** | **Explanation** | | **Privacy and confidentiality** | Access to data (who will see).  Transfer to third party.  Invasion into private life and discrete space. | | **Standardization** | Interoperability of devices is complicated by the disparity at several levels: different wireless technologies, device communication protocols, and presentation standards.  Agreement on a common set of standards is doubtful. | | **Cost** | Smart home has image of being costly and luxurious.  Need to install equipment and change home.  Cost includes product cost and process (training + administrative cost) over time.  Perception of limited market. | | **Users’ needs** | Most past smart home focus on technical and physical aspects.  Most smart home projects focus on elderly and disabled needs.  Cultural diversity.  No clear definition of user. | | **Effect on life style** | Changes in the position of home master.  Difference in dominance.  Reducing need for self decision. | | **Psychological barriers** | Fear for reduction of social interaction.  Dependency on automation.  Smart home will substitute personal care and contact. |   From customer’s point of view the privacy and confidentiality is one of the major concern and can lead to less adoption of smart home technology. For providing better privacy it is required to avoid frequent use of cameras. Strong encryption along with user accessing techniques must be defined for confidentiality of data. Interoperability is another major concern which can affect the market of smart home technology. The interoperability gives customers’ variety of options while purchasing the smart home products. It means customer would not be limited to buy a complete suite of smart home products from same company. With interoperability implemented, customer would not also be worried about the compatibility of new products with old ones. Therefore standardization for a common set of protocols is needed and it will play a major role for advancement of smart home technology. Smart home has image of being costly and luxurious because the products and infrastructure needed for smart home completely differs from existing ones. Not everyone can afford to replace the old infrastructure with new one. Therefore it is required to design compatible smart home infrastructure so that one does not need to invest much amount of money.  In the area of research and technology it is quite common to only refer to the success of projects and to not so much focus on the failures within projects. Smart homes that can learn and adapt to changing behavior are not state-of-the-art when looking at real homes. In [33] the level of intelligence in the most advanced homes is at level four of the stages mentioned below.   1. Homes which contain intelligent objects. 2. Homes which contain intelligent, communicating objects. 3. Connected homes. 4. Learning homes. 5. Attentive homes.   Nevertheless aspects of trust and reliability are important for users even without the system being capable of adapting according to the behavior of the user. Even though the technology is invisible, it can have a huge impact on the lives of people. Knowledge about user abilities, needs, requirements, preferences and the way technology is used by them in different contexts is a fundamental support to the design of accessible interactions, useful services and applications. In the area of smart home technology the focus is mainly on the intuitiveness of an interface. Some organizations do focus on the requirements for people with limitations but in the entire area of the smart home technology this is a very limited group. By involving users’ in early stage of the research, usability, utility applications, and devices would be addresses early in the design phase. Planners would take into consideration people’s needs, limitations, and expectations **[31].** It has been found that when users’ are involved early in the scientific research process, they can challenge the research direction and assist scientists in demonstrating, communicating and exploring potential future applications as well as supporting technology commercialization **[32].**    Fig. 11 Interoperability required at different layers of smart home network  One of the major concerns in smart home technology is the standardization and interoperability as already mentioned. Since smart homes are equipped with variety of devices and services manufactured by different companies therefore interoperability of devices is complicated by the disparity at several levels: different wireless technologies, device communication protocols, and presentation standards. The ideal scenario is to provide access to all services by means of a single interface (well adapted to the user). To overcome this issue some work has been carried out by CENELEC. The objective of the CENELEC Workshop Agreement (CWA) for an Interoperability Framework Requirements Specification (IFRS) is to provide a methodology that will give consumers the confidence to install home and building automation products from different companies, both now and in the future, knowing that they will operate together and interact effectively with each other. Achieving this requires several phases of standardisation to ensure integration from the physical connectors to the way systems function. There are three phases of integration, see Fig. 11.  Table 02 Seven levels of Interoperability **[33]**   |  |  | | --- | --- | | **Level 0** | A single system of supplier-defined structure built from devices using a single home and building electronics system (HBES) specification and locally defined interoperability verified by the supplier one or more application domains. No assurance of coexistence is provided. | | **Level 1** | A level 0 system operating across one or more application domains. Verified coexistence is required. | | **Level 2** | Multiple Level 1 systems that interwork to exchange information and interoperate across specification and application domains verified by the suppliers using conformance specifications agreed by each HBES specification used. | | **Level 3** | As Level 2, and the interoperability is verified with respect to international standards applicable to the HBES specifications used in the system | | **Level 4** | As Level 3, but conforming to IFRS so that the applications and devices can be installed, managed and changed during the operation of the system by a qualified installer. | | **Level 5** | As Level 4, and changes of application and devices will be done automatically. | | **Level 6** | As Level 5, and with remote management, diagnostics and maintenance. (Automatic installation, operation and support). |   The Interoperability Framework Requirements Specification, IFRS, addresses the third of these terms. It provides a common set of rules to enable products that use different standards to interoperate when they are present in an installation. A further classification is done by identifying 7 levels of interoperability (see Table 02). The purpose of the classification by level of interoperability reflects the choice available to installers, service providers and users and the dynamic nature of the systems at the respective levels. Level 0 offers no choice: a standalone system from one supplier with a fixed set of functions that cannot be guaranteed to run alongside other systems. As we move up the levels, the degree of choice expands: systems can coexist; they can be interconnected; their applications can be joined together; and eventually they can be operated and managed by their users, locally and remotely using products from a wide range of suppliers and interconnect technologies [33].  **B1.6 Smart Home Case study**  In a smart home case study done by CARDIAC project **[33],** the research related to smart home has been clustered into 5 main themes. The themes are user centred design, service development, human environment interaction, technical requirements and testing, and business strategy.   1. **User centred design**   Following points come under User centred design theme,   * Human factors, * End user participation and needs analysis, * how people can understand and use full potential of the technology   From literature in [33] it has been concluded that exploring users interaction and cooperation with intelligent systems is the most significant research action regarding smart home. Technology and services should be shaped together with clients and other relevant stakeholders. It is vital that the needs and desires of the various users are taken into account. Technology and services are supporting, not leading. In the area of smart home technology there is a need for innovative methods which allows an equal and creative interaction between users and experts. Tools are needed to facilitate the communication between persons who approach the design process from a usage point of view and persons who approach it from a technical point of view. By using methods like co-design, user-centred-design and participatory design it is made possible to work together on a conceptual level but when implementing ideas it became clear that on a detailed level still misunderstandings occur. In addition more emphasis needs to be placed on showing the effect of the user-centred-design process on the developed products and services to clearly show the added value of this intensive process.   1. **Service development**   Following points are clustered in service development theme,   * Privacy, safety and trust * Holistic approach to HCI * Social networking and applications * Social context and impact   The research should give a holistic approach, looking at smart homes as “Home” and not residency, keeping privacy, and connecting to social networking. Developing technological solutions for monitoring while preserving privacy such as developing algorithms to identify a moving person in the image and extracting a silhouette **[34];** sensors instead of cameras (floor and pressure sensors, IF); thermal imaging and pattern recognition, infrared monitoring’ Doppler monitoring, indirect imaging; avoiding the collection of visual information in every room and replacing it with auditory monitoring (e.g., using auditory recording or pressure sensors in the bathroom instead of visual data); using non identified data; virtual reality techniques; activity density maps **[35];** developing indirect measurement methods by using the homes’ infrastructure (e.g., plumbing, electricity); options for controlling the system operation so that it can be turned off (a vision-based off/on system) **[36],** and more. Given that participants varied in their desire to view the data and whether their family should see the data, privacy concerns may be mitigated by allowing participants to customize the system operation, determining if they want to view the images, and which of their family, friends or health care providers may access the data **[36].** Storing data as no identified data; develop strategies for avoiding the transfer of personal information to third parties, without proper consent (e.g., for pharmaceutical companies, insurance, commercial, Government). A smart home is much more than a house equipped with advanced technology. It needs a holistic approach dealing with images of privacy, control, warmth, comfort, stability, security, the creation, family and feeling familiar, independence, identity, social status and esteem and more.   1. **Human Environment Interaction**   Following points are clustered in to Human Environment Interaction theme,   * User modeling and adaptive user interfaces * Innovative user interfaces * Access to advanced ubiquitous computing environment   Context awareness can greatly help to build new adaptive user interfaces that can provide more simple and useful functionality to people. This is therefore an interesting area of research also in the area of smart homes. Within the smart home area specific attention is paid to emotion detection. When taken a service oriented approach a lot research is done in the area of services to reduce levels of stress for informal carers. But that is more targeted at the outcome of the use of a service and not on measuring stress while performing tasks and adapting the interface to the level of stress. When this would be possible it could provide an additional possibility for personalization of services [33].   1. **Technical Requirements and Testing**   Following points come under the technical requirement and testing theme,   * Interoperability and standardization * Advanced design and development methodologies and tools * Test and evaluation methodologies and tools   Interoperability is one of the key research themes within the area of smart homes. There are differences in terms of the focus of the work on interoperability and the different problems encountered. Within the area of smart homes a research area is developing methods that allow the connection of any set of devices to any other set of devices. Within the home environment a large variety of products is present so first thing is to make sure that the data from these devices can be combined as they will utilize different formats. Next challenge is to integrate these devices that are heterogeneous and therefore not always interoperable. Assuming that people will have a large set of devices in their home that could be used, an approach is needed to select the proper devices for a specific impairment or intervention. Finally, all this needs to be scalable towards a wide range of new devices that will emerge in the future. On addition, it is important to not only test for interoperability in lab environments but also in ‘real life’ [33].   1. **Business Strategy**   Following points are clustered under Business and Strategy theme,   * Formal methods to validate e-Inclusion services * Collaborative research and knowledge sharing * Market, service delivery and public procurement   The most important issue regarding business strategies for smart homes is the lack of empirical evidence to support or refute the use of smart home technologies. There is a great need for establishing a good quality scientific experimental platform to conduct research on issues related to smart homes. This also calls for developing an objective quantitative outcome measures for assessment of success or failure that will be based on economical, technological, social and cultural criteria. There is a great need to sponsor grants that will promote collaboration between academia, industry and users. Grants, funding agencies and consortia should insist on having partners both from academia and industry (private sector) as pre-requirements for receiving financial support (especially, national or international granting agencies such as the EU commission), thus stimulating collaboration. Branding is very important. Smart home should be presented as home for “full life” and not “end of life”, to abolish the stigma of elderly as “future living for everyone”. In the area of smart homes new entry points are taken into consideration. For example by focussing on energy saving when installing smart home technology [33].  **REFERENCES**  [1] D. Miorandi, S. Sicari, F. D. Pellegrini, and I. Chlamtac (2012), “Internet of things: Vision, applications and research challenges”, Published in journal of Ad Hoc Networks ELSEVIER, pp. 1497-1516.  [2] J. 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| B2. Current State of the Art: *(Please describe the current state of the art specific to this research topic.)* |
| The Internet of Things (IoT) market is projected to grow rapidly. Cisco Systems Inc., a global communications and information technology company, puts the value of the Internet of Everything (IoE) at $14.4 trillion over the next decade **[37].** This growth is driven by connectivity. According to **Gartner research** this number will reach upwards to **26 billion by 2020 [38; 39],** some even estimate this number will be closer to **100 billion [40].** Analyzing the energy market a bit further, Navigant Research predicts that global revenue from HEM system will grow from **$512 million in 2013 to $2.8 billion in 2020.** It also pointed out that the market will develop along a continuum, from paper bills to web portals to standalone HEM to in-home displays to networked HEM [41]. According to **statesShreyas Naidu** in a recent research report by **Big Market**, “Smart home Market is expected to evidence significant growth due to growing security concerns and enhanced safety features that smartautomations can currently offer. With an increase in the working population, safety concern with respect to aged parents and children is the biggest challenge. Smart home address these issues with highly sophisticated remote monitoring technologies.” The report forecast the market to attain a value of **$35.3 billion by 2020**, registering a healthy **CAGR of 29.5% during 2012-2020** [42]. Rising environmental concerns, increasing cost of energy and stringent government regulations are propelling the market growth. However factors such as interoperability, high upfront cost and lack of standardization would impede the market growth. Due to steep rise in the cost of energy and increase in the greenhouse effect, the demand for energy efficiency has been increased. This demand for efficient energy has been accepted by numerous construction businesses across the globe and hence, they are adopting automated system for their smart home and buildings [42].  In January 2014, **Samsung**, the global electronics giant, unveiled its Smart Home platform. This platform lets user connect and control their home using their Samsung devices through one app via their Samsung smart TV or their smart phones [43]. According to Computerworld, “the company claimed that it will collaborate with third party partners to make the Smart Home service extensible to their products and services, but it will doubtfully support its competitors’ products [44].” This building project is set for completion in 2017. As of October 2014, Google did not yet have a completing platform, but with the acquisition of Nest, it has position itself as a key contender. Nest has partnered with Airbnb, providing users with free access to MyEnergy, its energy monitoring service in 2013. According to Greentechmedia’s Stephen Lacey [45], this strategy brings “thousand more customers onto the platform, a great way for Nest to gather more information on how people are using the devices and saving energy, while potentially pitching more services like residential demand response as the company expands utility partnership.” In its 2014 report [46], visionmobile said it best: “the evolution in mobile phones in the past 6 years holds a clear lesson for the Internet of Thing.” |
| Challenges: *(Please describe the challenges, specific to this research topic, currently being faced internationally.)* |
| Following are the main challenges that will be faced during the implementation of this project:   * Reliable and efficient transmission of data from different smart boards to smart interactive terminal through power line communication. * Obtain an optimal low cost solution for each module. * Fully utilization of Microcontroller modules by creating logics in an intelligent and efficient way. * Efficient way of integrating different modules with smart interactive terminal. * Implementation of complete designed smart home system without much disturbing the existing infra structure. |
| Motivation and Need: *(Please describe the motivation and need for this work.)* |
| People here in Pakistan are suffering from various issues; few of the main issues are pointed out as under.  **Lack of electricity:** Since long Pakistan is suffering from this problem. For years the matter of balancing Pakistan’s supply against demand for electricity has remained a largely unresolved matter. The supply demand gap has continuously grown over the past 5 years until reaching the existing levels. Such an enormous gap has led to load-shedding of 12-16 hours across the country. The electricity has become more expensive because expensive fuel sources have forced Pakistan to create electricity at rates that are not affordable to the nation and its populace. The aforementioned inefficiencies, theft, and high cost of generation are resulting in debilitating levels of subsidies. Reducing these losses would lead to significant improvement in the bankability and profitability of the sector and could be used to improve the efficiency of the power system as a whole.  **Safety & Security:** Homes in Pakistan have always been a good target for intruders because they contain items that are easy to sell and difficult to trace. A large number of break-ins take place during day when no one is at home or mostly at night when all the family members are sleeping. They do not occur to just lower socio-economic areas; such events can happen with anyone at anywhere. People who are unfortunate enough to become a victim of break-in usually suffer from depression and feelings of insecurity. Break-ins can be major trauma, making secure design important for peace of mind. On the other hand home safety is also important for avoiding minor injuries and sudden events like falls, poisoning, Fire and others. Home owners can have more peace of mind when home safety features have been incorporated.  **Assisted Living:** Nowadays in Pakistan, it has become a common practice that female members of families are also involved in professional activities. Therefore it becomes difficult for them to manage their home and professional activities efficiently. They do not have much time to pay attention to elderly people or even to their kids since they do not spend much part of time at home. Through assisted living for elderly people things will become easier for elderly and home owners as well because some how they will be living independent life. They don’t need to have someone continuously to take care for them.  The mentioned issues are mostly common here but people are unable to deal with them. Although the technology has advanced rapidly but due to its cost, complexity, and lack of awareness people are unable to efficiently make use of it for their comfort and satisfaction. Customers are always interested in cost effective and reliable solutions/products especially in Pakistan where poverty and low employment are also some of the major concerns. Therefore, the prime motivation behind working on this project is to resolve some of the above mentioned issues faced by people in Pakistan by producing cost effective, simple and easy to use smart home based solutions. In the proposed solution the highest priority is given to customers’ needs and existing home infrastructure so that people won’t feel it hectic/difficult to replace existing homes with smart ones |

# 3. Objectives of the Project

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| Specific Objectives Being Addressed by the Project: *(Please describe the measurable objectives of the project and define the expected results. Use results-oriented wording with verbs such as ‘to develop..’, ‘to implement..’, ‘to research..’, ‘to determine..‘, ‘to identify..’* ***The objectives should not be statements and should not include explanations and benefits. The objective should actually specify in simple words what the project team intends to achieve (something concrete and measurable/ deliverable). Fill only those objectives that are applicable to the proposed project****.)*  To achieve cost effective solution for smart homes in Pakistan is the specific objective of this project. It will produce a benchmark and take care of the existing infrastructure thus meeting the consumer’s expectation by providing them efficient and cost effective solution. |
| **A1. Research Objectives:** *(if any)* |
| * To obtain a low cost optimal design for smart switches/sockets compatible with existing infrastructure. * To explore high processing capabilities of the microcontrollers for scheduling and multitasking purposes. * To explore the possibility of achieving suitable data rates using existing transmission lines by keeping in view higher value of line losses i.e., explore the feasibility of power line communication using the existing infrastructure. * To integrate different modules in home network by developing an efficient design for smart interactive terminal. * To develop a real time smart home solution by scheduling the tasks intelligently. * To efficiently control different designed modules through Wi-Fi and an interactive application. |
| **A2. Academic Objectives:** *(if any)* |
| * To create and enhance the research and development environment in the academia by involving different students i.e., Graduate and Post Graduate students in hierarchical fashion. * To introduce new and latest graduate courses after development of IoT based Lab. * To improve the ranking of our academia in international research community by producing quality based research publications from this project. * To flourish the quality of R & D culture in Academia. * To create opportunity for students to conduct applied research in contrast to theoretical research usually part of our academia. * To enhance the academic activities and participation of students by successful implementation of this project. * To build a new era of bondage between industry and academia so that academia will become part of their R & D and use their facilities to enhance their product efficiency and quality. * To open a new door for academia to conduct similar research projects in future |
| **A3. Industrial Objectives:** *(if any)* |
| * To enable service providers to offer better services with less hassle by the designed home network infrastructure. * To present the successful designed prototype to different vendors in Pakistan and if approved the designed system will become the part of most of the homes in Pakistan. * To increase the industrial growth. Since proper energy management will result in reduction of electricity theft and also other waste usage of electricity. This in turn will improve the electricity in terms of regulated voltages, less load shedding and cost efficiency, thus attracting local industry to purchase it and introduce new industries in the locality. |
| **A4. Human Resource Development Objectives:** *(if any)* |
| * To provide internees/ students an exposure to practical research and development activity. * To help in creating product design & development experience and improve project management skills for the people from academia. * To develop the skills in high-tech software, hardware, and firmware. * To provide opportunity for industry professionals to work on latest trends in smart home energy management system, safety & security, and assisted living. * To fund the interested undergraduate students for their final year projects on emerging research topic. * To train the technical staff, this will be a valuable asset for interested beneficiaries/ customers. |
| **A5. Other Objectives:** *(if any)* |
| NA |

# 4. Research Approach

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Development / Research Methodology: *(Please describe the technical details and justification of your development and research plan. Identify specialized equipment, facilities and infrastructure which are required for the project and their utilization plan. The block diagrams, system flow charts, high level algorithm details etc. have to be provided in this section.)* | | | | | | | | |
| Since the focus of this project is on three main applications of smart home namely Efficient Energy Management, Security & Safety, and Assisted living. Therefore each part will be designed and tested separately but the overall affects of the project on the life of people will be observed as a whole. The complete system will be implemented and tested in any voluntarily available home near NED university or at QUEST.  **Efficient Energy Management**  The importance and need of efficient energy management systems has already been discussed in literature review part section B1.4. By keeping in view the customers need and constraints this part of the project aims at developing a cost effective and efficient prototype solution for home energy management system in Pakistan. With the help of this prototype the customer will be able to monitor the electricity usage by each appliance/ device and therefore can control the overall energy use and hence the utility bill. The main objectives of this part of the project are;   * To design Smart Switches/smart sockets with energy measuring capabilities * To use PLC communication for transferring data to server * To design a Smart Interactive Terminal * To design a Mobile Application for remotely controlling smart home network.   Sensors for automatic light/ appliance control have not been considered in our prototype design because of the overall cost and the complexity involved in it. Since the main aim of this project is to provide simple and cost effective solution for smart homes in Pakistan. Actually the role of automatic light/appliance control in efficient management is negligible as compared to smart switch/socket design. That is why in this project design the main factors affecting the energy management has been considered.   * **Smart switches/sockets**   Smart switch/socket is the basic and very important component of smart home. The smart socket is mainly used to control large power appliances, and the smart switch is mainly used to control home lighting line. At present due to intellectualization of appliances is still unable to meet the requirement for building smart indoor network therefore smart socket/switch is seen as a transition device. The main functions that will be performed by our designed smart socket/smart switch are listed as under,   * To receive control commands from customers through remote application/ smart interactive terminal and perform tasks accordingly. * To measures power consumption of appliances. * To transfer the related information to main server or remote application. * To monitor and provide protection for appliances abnormality.   Since number of sockets/switches need to be installed therefore economic practicality need to be taken under consideration. The general block diagram for smart socket design has been given in Fig. 12. The function of power module is to provide required power supply for different modules of the smart socket and electromagnetic compatibility will also be considered. Switch module controls the midget relay opening or closing, thus to control home appliances. Communication module exchanges data with main server, this module will be discussed later in detail. The main function here is performed by the metering module and control module. As the name suggests the function of metering module is to simply measure the power consumption of appliance and send data to control module. The control module is the core unit which performs the necessary processing on measured data, receives commands from consumers through communication module and performs the required task.  Fig.12 Block diagram for smart socket design  **Communication Module**  **Load**  **Switch Module**  **Metering Module**  **Power Module**  **Control Module**  **220 Vac**   * **Metering Module**   This module design requires an energy measuring IC, current sensor and voltage sensor, please refer to Fig. 13. We will be using ADE7753 IC (latest version) as a low power energy measuring device. This energy IC has two fully differential voltage input channels. The maximum differential input voltage for input pair is V1P/V1N and V2P/V2N is 0.5 V. The IC is highly accurate with a 0.1% error in active power measurement. It can be used to measure a variety of electrical characteristics such as active, reactive and apparent energy, root mean square (rms) current and voltage plus it has a built in temperature sensor. It can also be used to detect voltage drops or surges by comparison to programmable threshold levels. ADE7753 costs around $2 on the Digikey website [51].  Fig.13 Block diagram for metering module  **Current Sensor**  **Voltage Sensor**  **Energy Metering IC**  **MCU**  According to a survey on current sensing techniques by Zeigler et al., in [52], four most common sensor technologies for current measurement are: low resistance current shunt, Current Transformer (CT), the Hall effect sensor, and Rogowski coil. All four technologies are compatible with selected energy meter IC (ADE7753). The design requirements we need to consider are: (i) the current technology should be as small as possible; (ii) the ADE maximum differential voltage input channels are 0.5V; (iii) Current measurement capability up to 16A. The Rogowski coil, combined with digital integrator, offers a cost competitive current sensing technology and could be the best option among the four technologies, but the main drawback is its size. Resistance current shunt is really cheap solution but it has a problem of high heat generation. Current transformer is a feasible option but it suffers from saturation problem. Hall effect sensor is also cost effective but it provides much lower measuring accuracy and drift significantly, requires compensation. We have chosen CT and Hall effect sensor method for further exploration. In our final design we will be using one of these two technologies for current measurement based on our design requirements. Voltage measurement is very simple when compared to current measurement. Resistive voltage divider will be used to drop the line voltage to threshold level of the energy measuring IC.   * **Control Module**   Control module is the core unit of smart socket as already mentioned. This module performs all the necessary processing and actions in response to any command issued by consumer. This module is the center/meeting point of all other sub modules i.e., metering, communication and others. The proper hardware selection and logic design of this module is really important for an efficient design of a smart switch/socket. For the control module, Atmel’s AVR microcontrollers will be used. There are a variety of different microcontrollers available based on size, power consumption, clock speed, processor word length, flash memory etc. These microcontrollers provide UART and SPI interfaces to be used with other ICs or for programming. Arduino provides development boards for working with these microcontrollers. These boards provide a serial interface for programming through USB port and the pins of the microcontroller routed to headers. This makes Arduino boards easy to use and quicker to set up working prototypes. The selection of board will depend upon the complexity of the implemented algorithm and hardware requirements.  It has been planned to use just one micro controller unit (MCU) for one switch board consisting of multiple switches and single socket. The reason behind using single MCU is design simplicity, size, and cost. Multi tasking will play a key role and therefore different real time operating systems (like FreeRTOS and others) are available for tasks scheduling and multitasking but at the cost of MCU memory. It has been decided that in our prototype design we will try to avoid the use of any operating system. The tasks will be scheduled intelligently by using interrupts of MCU with different priorities assigned. Based on the customers’ needs, respective priority will be assigned to particular task. Besides on/off switching the functionality of light dimming and fan speed control will also be a part of the design.   * **Communication Module**   Communication Module is one of the most important part which affects the overall infrastructure of the smart home. For any communication to take place there are basically two primary options available i.e., wired or wireless. Various advantages can be achieved by the use of wireless technology i.e., support of user and device mobility, no cable installation. It also entails few disadvantages i.e., loss of physical barrier, easier to eavesdrop the transmitted data, interference due to multiple wireless devices. Few of the main wireless technologies i.e., WLAN, Cellular Communication, Bluetooth, Zigbee suitable for HAN are further explained.   * **Wireless LAN (WLAN):** it is a very common and well known technology. In terms of smart appliance design and application. Up till now the WLAN technology plays a supporting role for protection and monitoring. The advantages of WLAN are the higher data rates with larger coverage. In contrast, the fact that more than one technology like Zigbee, Bluetooth and others are sharing the same frequency band is adversely and thus, leads to interferences and degradation of quality. * **Cellular Communication Techniques:** A big advantage of using this communication technique is, it does not require building up a new setup. Hence, this solution is widespread, cost efficient, and very secure. * **Bluetooth:** The main advantage offered by this technology is that, it is easily available, in reach of common people, and much cheaper compare to aforementioned. It consumes very less battery power during a single transfer but if it is kept running whole day then the battery loss is significant, affecting the battery life considerably. * **Zigbee:** It is one of the important communication standard for smart appliances based on IEEE 802.15.4 standard. The U.S. National Institute for Standards and Technology defines Zigbee and the Zigbee Smart Energy Profile (SEP) as the most suitable communication standard for smart grid technologies. Zigbee is a low cost, low power low data rate wireless mesh standard. It suffers from the lack of Internet Protocol support, extra internet gateway infrastructure, and low data transmission rates. It also suffers from potential interference since shared license free industrial, scientific and medical (ISM) frequency band is used by many other communication techniques like IEEE 802.11, Wi-Fi and Bluetooth.   Besides wireless communication, wired communication can also play its part for different smart home applications. The major agent of this type is Power Line Communication (PLC).   * **Power Line Communication (PLC):** PLC has a big advantage that it can use existing power lines for communication and is also suitable for urban areas. There are no interference issues with other devices in PLC. The main drawback of this technology is related with the electrical noise generated by home appliances and/or by nearby electrical cabinets.   Table 03 Comparison between different communication technologies   |  |  |  |  | | --- | --- | --- | --- | | **Technology** | **Data rate** | **Range** | **Frequency Band** | | **WLAN** | 54Mbps | 100m | 2.4, 5.8 GHz | | **GSM/GPRS** | 240kbps | 10km | 894/1900 GHz | | **Zigbee** | 250kbps | 50m | 2.4 GHz | | **PLC** | 3Mbps | 3km | 30MHz | | **BlueTooth** | 2.1Mbps | 100m | 2.4 GHz |   For our prototype design, PLC has been chosen for local communication. The reason behind the selection are manifold;   1. No extra infrastructure needed. 2. No interference with other wireless devices usually part of the home i.e., Wi-Fi and Bluetooth. 3. Cost effective solution. 4. More secure as compared to wireless protocol. 5. Provision of Internetworking support (IPv6).   Today, there are several PLC protocols in market. These protocols break down into one of two basic modulation schemes i.e., Frequency shift keying (FSK) and orthogonal frequency division multiplexing (OFDM). FSK is an older modulation scheme and suffers from a significant drawback because receiver loses reception when an interferer coincides with one of the transmitted frequencies. FSK provides low data rate since it switches between two possible frequencies only and hence the bandwidth is not utilized efficiently. For real time application purposes this low data rate is a severe problem. The OFDM is another option for PLC, which has been used in many modern communication systems such as digital radio, TV, Wi-Fi, and WiMAX, as well as in some early generation narrowband PLC protocols i.e., PRIME. Among the most significant benefits, it gives the bandwidth needed to build real time intelligent power grid solutions while eating aggressive cost targets.  By observing the eclectic line conditions of homes in Pakistan and demands of our prototype design we will be choosing a particular PLC protocol. In our prototype design locally all smart sockets/switches will be connected to smart interactive terminal through PLC. For accessing the smart interactive terminal (SIT) remotely, this will be connected to Wi-Fi. Since Wi-Fi nowadays is the part of most of the homes in Pakistan. In a situation where the user is out of home, at a place where internet is not available, then the Wi-Fi solution will not work. For handling such situations, it has been decided to connect the SIT with a GSM module. Usually the GSM module will not be used but in case of urgent situations the SIT need to make use of GSM module for transferring data/ specific alarm to remote user.  Fig. 14 Different communication protocols involved in prototype design  **Smart Switch Board**  **SS1; SS2; SS**  **Smart Switch Board**  **SS1; SS2; SS**  **Smart Interactive Terminal**  **(SIT)**  **Wi-Fi**  **GSM Module**  **PLC**  **PLC**  In short, three different communication protocols will be part of our smart home prototype design as shown in Fig. 14. PLC will be used for communication between SIT and smart switches/sockets. When user is at home Wi-Fi will be used as a WLAN accessing point for issuing commands to smart interactive terminal through mobile application. In case of remotely accessing the SIT the same Wi-Fi device will provide the internet connectivity. For emergency situations the cellular communication has also been included as a backup.   * **Smart Interactive Terminal**   The smart interactive terminal is the core of friendly smart home energy system, equivalent to the brain of smart home network. The smart interactive terminal will be designed by keeping in view the users’ need for smart home energy management, security & safety, and other value added services. The main functions that will be performed by our designed smart interactive terminal are,   1. It will receive large amounts of data which is sent by the smart switches/sockets. 2. It will store the data on SD card/ cloud network for providing remote access to data. 3. Send user’s control commands to smart switches/sockets. 4. Provide friendly human machine interface to achieve real time view of consumed energy by each appliance individually and as a whole. Task setting, help users to analyze energy consumed, and for other operations. 5. In case of urgent situations transfer necessary data/alarms to remote location through internet or GSM module. 6. Home safety and security module will also be controlled by this terminal. 7. Other value added services for assisted living will also be a part of SIT.   Fig. 15 Block diagram for smart interactive terminal design  **Control Module**  **Display Module**  **Data Storage Module**  **Power Module**  **Communication Modules**  **Keypad**  Since this is the main terminal therefore the best selection of hardware component will be required. It has been decided to use suitable version of Raspberry Pi for this module design. A very interactive desktop application will be designed with variety of functions for accessing, controlling, and monitoring of different modules. A database will also be created that will maintain the record of each module for user convenience. This module will be interfaced with a GSM module as a backup plan. In case of any emergency the SIT can send particular message to remote user.   * **IR Hotspot Design**   A module for controlling IR based devices/ appliances will be designed. The function of this module will be to receive the commands from user through mobile app using combination of Wi-Fi and PLC communication and to perform required task of switching TV channels or controlling Electric appliances i.e., air conditioner. This module design will include the IR sensor interfaced with Microcontroller. For communication through mobile app either Wi-Fi / PLC module will be used. Since PLC communication is one of the main parts of our smart home design therefore we can exploit it for controlling IR based appliances as well but it can pose the problem of delay. On the other hand Wi-Fi is the better option but the design will become costly. Therefore in this module design we will be selecting suitable communication module by keeping in view both performance and cost factor.   * **Mobile Application Design**   Mobile application will be designed for providing wireless control of the different modules designed. Since smart phones are very common and Wi-Fi is an integrated part of it. Therefore through Wi-Fi mobile app will communicate with SIT, when a signal will be generated for particular switches/sockets or other modules based on users’ command. The designed Mobile App will be very interactive and user friendly. Besides providing local control the Mobile app will also have functionality to control home when away. The designed mobile app will be versatile in a way that the single app will be performing different tasks from controlling switches/sockets to IR based appliances and others.  **Safety and Security**  Safety and Security is one of the major concerns for home owners since ever. Everyone wants to make their home a better place by avoiding unpredictable accidents/events. This part of the project contains sensors to detect obstacles, heat, smoke, and sound. Since position of each sensor will be different based on the data they need to process for certain actions to take place. Therefore, it is not an efficient and reliable solution to use a dedicated MCU for controlling all sensors within a home. There will be number of smart boards consisting of MCU therefore each sensor will be connected to its nearest smart boards’ MCU i.e., smoke sensor will be interfaced with MCU of kitchen’s smart board, obstacle sensor will be connected to MCU of smart board near to main gate. Any signal generated from sensors will be transferred to SIT through MCU and then from SIT particular alarm will be transferred to remote user through Wi-Fi or GSM module.  A camera interfaced with an MCU will also be placed at the main gate. It will not be working all the time 24 hours saving lots of energy, its full control will be given to SIT. In case of any signal generated by sensors the camera will be switched on by SIT and will capture a photo and send it back to SIT. From where it will then be further transferred to remote user through Wi-Fi or GSM module. This module provides assurance with more satisfaction to users’ and also have a great impact on false alarm rate. In case of any false alarm generated by the sensors the photo captured by camera will make it clear that the home is safe and secure. It is required to switch on the complete security and safety system only when there is no one at home or at night when everyone is sleeping. Otherwise it will be the wastage of resources and also false alarms will be generated due to presence of family members.    Fig. 16 Safety and Security system with different sensors embedded   * **Obstacle detector**   An infrared (IR) based obstacle detection sensor will be designed consisting of an IR transmitter and a receiver unit, mounted face to face on opposite walls of the main gate such that the IR beam gets interrupted when someone is standing at the gate or passing through it. The transmitter unit will be designed around a timer IC which will be wired as an astable multiviberator. The infrared beam will be transmitted through IR LED connected to timer IC. As long as IR beam will fall on sensor, the output will remain low (off state). When anyone will interrupt the IR beam falling on the sensor, output will go high (on state). As a result a signal will be generated to GIO pin of the MCU.   * **Smoke detector**   This sensor design will also be based on IR transmitter and receiver. When the smoke is present the IR signal will get attenuated. The receiver conductivity will be converted into voltage which will be compared with a threshold voltage. If the conductivity falls below the threshold a certain signal will be generated on one of the GIO pins of MCU.   * **Sound detector**   In this sensor design, the sound received by a microphone will be amplified by an operational amplifier circuit and compared with a fixed DC voltage. If threshold value exceeded a signal will be transferred to one of the GIO pins of MCU. The sensitivity of the circuit can be controlled by proper selection of passive components.   * **Heat detector**   The PIR sensor will be used to detect unauthorized intruders. It will detect the heat generated from the human body and sends a signal to MCU.  **Assisted Living**  Assisted living is also one of the major applications of smart home. Around the globe projects have been carried out on smart home by considering this particular application. Learning capabilities has been deployed in most of the projects for the smart home. In which the sensors learn from the human behavior and set their parameters accordingly. Such system can be a good choice for elderly people but we did not consider it in our prototype design due to the reasons discussed as;   1. Human behavior is very dynamic. It is really difficult for machines to understand. 2. For deploying learning based systems the cost will be higher. 3. Overall design will be bulky due to installments of different sensors. It will affect the overall infrastructure of the home causing trouble for elderly people.   **MCU**  Keypad  Rechargeable battery  Wi-Fi shield  Fig. 17 Block diagram for smart remote control  Since we will be developing the smart sockets and switches which mean elderly people can at least control their room remotely. The problem is that elderly people cannot operate smart phone and it is not reasonable to purchase a smart phone for them to control their room remotely. Therefore the aim is to design a simple and easy to use Wi-Fi based remote control through which elderly people can control their room, they can generate some alarms reporting to home owners in case of any emergency, they can inform home owners about their daily medication update. The design of remote will be simple but it will be very functional. This developed remote, one doesn’t need to be with elderly people all the time since they can themselves generate the particular alarm in case of any emergency or need. The developed remote control will be at least cheaper than a smart phone and also easy to use. It will be consisting of a keypad, MCU, rechargeable battery, and a Wi-Fi shield.  **Project Plan**  This project is mainly consists of two parts   * Design of hardware module, implementation, installation and software development/ database design. * Communication network infrastructure and data scheduling.   Both of these parts need extensive work to achieve the job within stipulated amount of time. We have devised the following mechanism in the form of various phases to tackle the job and make sure we deliver the desired products well within time.  **Phase 1: Survey and Startup**  **Objectives:**   * To acquire the required Human Resource and Equipment * To review in detail the of existing solutions * To provide the system design specifications and guidelines * To conduct survey for analyzing customer’s needs and priorities   **Overview:**  In order to achieve the objectives outlined above, the work will be started with the appointment process for prescribed positions in the initial phase of the project. Emphasis will be laid on acquisition of only those who can contribute positively towards meeting the end goals and objectives of the project but also adhering strictly to the deadlines. The job descriptions will therefore be carefully prepared so that only people with relevant experience and knowledge base are hired. The required equipment for the project will be purchased. After the successful acquisition of the required human resource and the equipment, and delegation of responsibilities and tasks, a detailed literature review related to smart home technology, efficient way of designing smart energy efficient systems, Pakistan’s customers needs and priorities for having smart home, need and support for assisted living, the available solutions, their impact, advantages and disadvantaged will be carried out. During this phase, a good theoretical base on different techniques related to our design and customer’s needs will be developed. This phase will help us to identify the major hurdles in the path of adoption of new technology. Desired hardware, software, and database platform will be identified. The major emphasis of the literature review will be on the feasibility and cost effectiveness of the available solutions.  **Phase 2: Design and implementation of energy management system**  **Objectives:**   * To design metering module with proper selection and design of current sensor and other components for smart socket. * To design smart switch with built in simple logic for estimation of energy consumption. * To design reliable light dimming and fan speed control system. * To efficiently utilize single MCU for controlling multiple switches and sockets at the same time. * To design efficient logic for multitasking and real time processing of the MCU.   **Overview:**  During this phase of the project the emphasis will be on efficient design of the smart boards consisting of multiple switches and at least one socket. For smart socket metering module will also be designed for measuring the amount of energy consumed by the appliance/device connected to the socket. The energy consumed by the lights and fans will be estimated through implementing simple logic by monitoring the duration of time for which the switch is on. This will produce overall cost effective smart board design. Each part of this module will be designed and tested individually and combined as a whole. Troubleshooting will be part of each step. Single MCU will be configured and coded intelligently so that it can perform multitasking in real time without using of any real time operating system. All observations, measurements, and conclusions made throughout the design process will be compiled in the form of a report.  **Phase 3:** **Design and implementation of Safety & Security system.**  **Objectives:**   * To efficiently design different sensors i.e., smoke, heat, obstacle, and sound detector. * To interface the sensors with their respective smart boards. * To design simple and efficient main gate security system through camera. * To design IR hotspot for controlling IR based appliances.   **Overview:**  This phase of the project will cover the design and implementation of IR hotspot, home safety and security system. A further detailed study will be carried out about safety sensors and with its design then based on our requirement a particular solution will be devised. Different sensors will be designed and tested under different conditions. The aim will be to come up with efficient sensor design with minimum false alarm rates. All the observations and measurements made through this part will be compiled in the form of a report. After successful design of sensors, each will be interfaced with the MCU of its nearest smart board. A main gate security system will be designed by interfacing a camera with nearest MCU of the smart board.  **Phase 4: Design of Smart interactive terminal (SIT)**  **Objectives:**   * To properly configure the hardware of SIT. * To develop an interactive application for SIT. * To develop an efficient integrated database.   **Overview:**  In this phase of the project the main terminal of our smart home network will be designed. First of all the raspberry pi module will be configured based on our requirements and other modules design. An interactive application for user interface will be designed. A database will also be created for storage of information so that user can access it at any time. The database design needs to be versatile, since it will need to store the data related to three different sub systems i.e., energy management, safety & security, and assisted living. All the work carried out during this phase will be compiled in the form of report consisting of flow chart and diagrams for better understanding.  **Phase 5: Smart remote control and mobile application design**  **Objectives:**   * To design an interactive mobile application for users. * To design a simple cost effective smart remote control.   **Overview:**  During this phase of the project a versatile and interactive mobile application will be designed through which customers can control switches, sockets, safety & security system in the home. Besides controlling the customer would also be able to access the data from SIT and can monitor the energy usage or any other update needed. A smart remote control will be designed for elderly people through which they can control the switches in their room and can generate particular alarms in case of any emergency. The emphasis will be on keeping the design of remote very simple so that elderly people will not find it difficult to use and understand. At the end all the designed parameters and specifications will be documented in the form of a report.  **Phase 6: Integration of different modules**  **Objectives:**   * To investigate and select proper PLC protocol for smart home network. * To reliably transfer data from different modules to SIT through PLC communication. * To interface SIT with GSM and Wi-Fi module. * To install and test the complete prototype of the system.   **Overview:**  This phase of the project will deal with the efficient and reliable communication between different modules. More specific and best suitable PLC communication protocol will be selected after analyzing the electric line conditions at homes in Pakistan. The data from each module will be transferred to main terminal efficiently through PLC communication. All the observations made through this phase will be compiled in the form of report. Other two communication technologies involved in our project i.e., GSM and Wi-Fi, their modules will also be explored and interfaced with the main terminal. At the end complete system will be installed in a voluntarily available home near NED or QUEST university. All the observations, measurements, and conclusions will be summarized in the form of report.  **Phase 7: Finalization of the Prototype, Benchmarking and Publications**  **Objectives:**   * To provide easily readable manuals, user guides and step by step tutorials relevant to the proposed solution in general as well as the individual modules. * To publish the results in reputed conferences and journals. * Arrange a seminars and workshops. * Develop and launch project website.   **Overview:**  In the final phase of the project, the results and the experiences gained will be documented thoroughly in the form of user manuals, user guides and step by step tutorials related to individual modules as well as the complete working prototype. The research done, with the contribution to knowledge and the results obtained will be published in reputed international conferences and journals. At the end of this phase, workshops/seminarswill also be conducted to bring awareness in the society to attract common people. A website will also be prepared for the whole project and will be marketed on social websites i.e., Facebook. To continue the research in the field and provide new and innovative solutions to other problems of similar nature, a research lab will be setup at the end of this phase using the resources acquired and the experiences gained. It will provide an opportunity not only to the undergraduate students but also to the graduate students (M. E and PhD) to have hands on experience with the testbed equipment and conduct their research to increase their theoretical as well as practical knowledge. New and better devices with cost, reliability and performance are the main design objectives that can be developed to provide low cost solutions to the local market and the industry. Workshop/Seminar will be conducted to present newly developed products and solutions that can attract the industry and hence a platform for better collaboration between the industry and the academia. | | | | | | | | |
| Project Team: *(Please attach the curriculum vitae (CV) of PI and CPI(s). Also attach the CVs of key research/ development personnel if available. Please follow the format included in Annexure A.*  ***The numbers in the table below must tally with the HR Cost sheet in the Budget file.****)* | | | | | | | |
| ***Title / Position*** | | | | | | | ***Number*** |
| Team Leads (PI) | | | | | | | 02 |
| Researchers / Developers | | | | | | | 04 |
| Researcher / Development Assistants | | | | | | | 06 (UG) |
| Support Staff | | | | | | | 01 |
| Technical staff | | | | | | | 02 |
| Others (please specify) | | | | | | |  |
| Add more rows if required | | | | | | |  |
| Team Structure: *(Please define the team structure (organogram) and role/key responsibilities of each member. If in collaboration with another partner, the division of manpower at various locations of partners be provided.)* | | | | | | | | |
| **Principal Investigator**  **(PI)**  **Researcher 3, 4**  **Software Design**  **Researcher 1, 2**  **Hardware Design**  **Researcher Assistant 1, 2, 3, 4**  **Researcher Assistant 5, 6**  **Technician 1, 2**  **Co Principal Investigator (Co-PI)**   |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | **Title/Position**  **(of each member)** | **Role/Key Responsibilities** | **Minimum Qualification Required** | **Expertise / Background Required** | **Minimum Experience Required (years)** | **Title/Position**  **(of each member)** | **Role/Key Responsibilities** | **Minimum Qualification Required** | **Expertise / Background Required** | **Minimum Experience Required (years)** | | Researcher 1, 2 | Embedded system design, digital system design, Transceiver based system design, integration of different modules i.e., communication modules with MCU | M. E (in progress) Electronics/ Communication/ Computer systems | C/C++, Assembly Language, Microcontrollers, Embedded System Design, Communication Modules. | 1. Year |  |  |  |  |  | | Researcher 3, 4 | Relational database design, implementation of software and connecting it with database, graphical user interface for real time monitoring and connectivity, communication network and protocol design, data scheduling algorithms. | M. E (in progress) Software/ Communication/ Computer systems | C/C++, Object Oriented Programming, Database Design, | 1 year |  |  |  |  |  | | Researcher Assistants 1,2,3,4 – (UG) | Assist team leads and researchers in hardware design. | B.E (in progress)  Electronics/ Electrical/ Communication/ Computer system | C/C++, Assembly Language, Documentation Skills using MS-Office, Understanding of LATEX. | 0 |  |  |  |  |  | | Research Assistants 5,6 – (UG) | Assist team leads and Researchers in software design. | B. E (in progress)  Software/ Computer systems. | C/C++, Object Oriented Programming, Documentation Skills using MS-Office, Understanding of LATEX. | 0 |  |  |  |  |  | | Technical Staff 1 | Electronic Technician | Diploma in Electronic Engineering | PCB design, Soldering, Electronic Component troubleshooting. | 2 years |  |  |  |  |  | | Technical Staff 2 | Electrical technician | Diploma in Electrical Engineering | Capability to handle electric lines, Experience of installation and maintenance. | 2 years |  |  |  |  |  | | Accountant | Support overall team in administrative matters, record keeping of funds consumed | Bachelors in Administration | Administrative tasks and record keeping. | 1 year |  |  |  |  |  | | | | | | | | | |
| Project Activities: *(Please list and describe the main project activities, including those associated with the transfer of the research results to customers/beneficiaries. The timing and duration of research activities are to be shown in the Gantt chart in Section 8.)* | | | | | | | | |
| The complete project span is 24 months and is divided into 7 phases. The main project tasks associated with each phase are given below. To check the timing allocated to individual tasks, please refer to the Gantt charts in section 8.  **Phase 1: Survey and Startup (3 - Months).**  **Tasks:**  T1.1: Human Resource and Equipment Acquisition  T1.2: Literature Review  T1.3: Design Specifications  T1.4 Planning and Management  **Phase 2: Design and Implementation of Energy Management System (3 - Months).**  **Tasks:**  T2.1: Design of smart switch (Hardware + Software).  T2.2: Design of Smart Socket with energy measuring capability (Hardware + Software).  T2.3: Design and implementation of a smart board consisting of multiple switches and one socket.  **Phase 3: Design and Implementation of Safety & Security system (3 - Months).**  **Tasks:**  T3.1: Design of different sensors i.e., smoke, sound, obstacle,  T3.2: Interfacing of designed sensors with MCU.  T3.3: Design of main gate camera system.  T3.4: Design of IR hotspot.  **Phase 4: Design of Smart Interactive Terminal (4 - Months).**  **Tasks:**  T4.1: Hardware configuration of Smart Interactive Terminal.  T4.2: A graphical user interface application design for Smart Interactive terminal.  T4.3: Design and integration of database.  **Phase 5: Mobile Application and Smart Remote Control Design (4 - Months).**  **Tasks:**  T5.1: Interactive Mobile application design for remote user.  T5.2: Remote control design for elderly people.  T5.3: An application for elderly people to monitor their daily medication.  **Phase 6: Communication between Different Modules (4- Months)**  T6.1: Interfacing of smart boards with Smart Interactive Terminal  T6.2: Interfacing of safety and Security system with Smart Interactive terminal  T6.3: Interfacing of Smart Interactive terminal with Wi-Fi and GSM Module  **Phase 7: Finalization of the Prototype, Benchmarking and Publications (3 - Months).**  **Tasks:**  T7.1: Project Documentation  T7.2: Dissemination of Results | | | | | | | | |
| Key Milestones and Deliverables: *(Please list and describe the principal milestones and associated deliverables of the project. A key milestone is reached when a significant phase in the project is concluded, e.g. selection and simulation of algorithms, completion of architectural design and design documents, commissioning of equipment, completion of test, etc.) The timing of milestones is also to be shown in the Gantt chart in Section 8.* ***Quarterly deliverables are preferred****.* | | | | | | | | |
| The information given in this table will be the basis of monitoring and release of funds by the National ICT R&D Fund. | | | | | | | | |
| *No.* | | *Elapsed time from start (in months) of the project* | | *Milestone* | | *Deliverables* | | |
|  | 3 months | | (Phase-1)  M1.2: Completion of Literature Review.  M1.3: Formulate general design specifications. | | D1.1: Detailed literature review of all the problems and solutions in process, proposed and abandoned for cost effective smart home network design.  D1.2: More detailed overview of design guidelines and specifications for the proposed system. A report describing in details various structural elements with the desired specification for the proposed system. | | |
|  | 6 months | | (Phase-2)  M2.1: Successful design of smart switch.  M2.2: Successful design of smart sockets.  M2.3: Successful design of smart board, consisting of multiple switches and a socket. | | D2.1: Fully tested hardware parts of the smart board and its PCB design.  D2.2: Fully tested real time multitasking software for smart boards.  D2.3: A report explaining the design procedure, flow charts, and observations made during testing. | | |
|  | 9 months | | (Phase-3)  M3.1: Successful design of different sensors.  M3.2: Interfacing of designed sensors with nearby MCU.  M3.3: Successful implementation of main gate camera system.  M3.4 Design of IR hotspot | | D3.1: Tested designed sensors and their PCB design modules.  D3.2: Complete implemented safety and security system.  D3.4: Tested PCB design of IR hotspot.  D3.3: A report describing the design of sensors, their working, logic flow charts and the observations made during testing phase. | | |
|  | 13 months | | (Phase 4)  M4.1: Proper configuration of hardware part of the SIT.  M4.2: Interactive GUI based application design for SIT.  M4.3: development and integration of database with SIT. | | D4.1: Design specifications of SIT required, along with its successful configuration, implementation of SIT application, with integrated database.  D4.2: Testing of the designed SIT terminal.  D4.3: Report describing the working and design of the SIT. Flow charts block diagrams for further explanation. | | |
|  | 17 months | | (Phase 5)  M5.1: Successful design of Mobile Application for remote user.  M5.2: Successful design of Remote control design  M5.3: Successful design of application for elderly people | | D5.1: An interactive mobile app for remote accessing and control of home appliances, security and with some other value added services.  D5.2: Implementation, testing, and PCB design of a remote control for elderly people.  D5.3: Submission of a report describing the details, flow charts, block diagrams, and all the observations made during testing phase. | | |
|  | 21 months | | (Phase 6)  M6.1: Interactive Mobile application design for user.  M6.2: Successful interfacing of safety & security modules with SIT using PLC communication.  M6.3: Successful interfacing of SIT with GSM and Wi-Fi using serial communication. | | D6.1: Interactive mobile application designed for users.  D6.2: Installation of complete prototype system. Its measurements, analysis, observations and drawn conclusions.  D6.3: All the observations, measurements, and conclusions drawn during this phase will be submitted in the form of a report. | | |
|  | 24 months | | (Phase 7)  M7.1: Implementation of complete prototype.  M7.2: Finalizing the documentation. | | D7.1: A comprehensive manual and project report with example configurations and testing scenarios.  D7.2: Final version of the optimized software with documentation, implemented hardware, design documents, research papers, will be submitted.  D7.3: the final integrated system along with User’s Manual and system requirements will be delivered to ICT R & D Fund.  D7.4: Results of the implemented system will also be delivered in the form of field testing results. | | |
|  |  | |  | |  | | |
| (Please add more rows if required.) | | | | | | | | |

# 5. Benefits of the Project

|  |
| --- |
| Direct Customers / Beneficiaries of the Project: *(Please identify clearly the potential customers/beneficiaries of the research results and provide details of their relevance, e.g. size, economic contribution, etc.)* |
| * Industries: Since most of the part electricity is consumed at residential level. Therefore, better electricity management at this level will definitely enhance the efficiency of the WAPDA and hence the income. * Consumers: The most important beneficiary of this project is consumer. If electric energy will be managed efficiently, the WAPDA will also be in profit and ultimately enhance the production and reduce the cost of electric power, benefiting the end user. Customers will be mentally more relaxed about their home security when not at home. * Government: WAPDA being governmental industry will ultimately improve the economy. * Academia: Indigenous research activity will be triggered based on the setup lab, trained faculty and students. Undergraduate students will be financed for their thesis/project on an emerging research topic. |
| Outputs Expected from the Project: |
| Following are the expected outcomes of the project:   * Smart switches, Smart sockets, and smart board design along with its PCB. * Smart Interactive Terminal Design. * Mobile application for remote user. * Wi-Fi based remote control for elderly people. * Monitoring of Appliances and their energy consumption. * Controlling appliances and switches while not at home. * Estimation of monthly bill based on energy consumption Analysis. * Capturing unauthorized person access to Home. |
| Organizational / HRD Outcomes Expected: |
| Among the main objectives of this project is an intention to fund interested undergraduate students for their thesis/project on this emerging research topic. It has also been expected to get one or two ME thesis out of it. A lab would be set with the purchased equipment for research on this and other active topics in the relevant fields. International level research will be triggered leading to International publications and recognition. Following outcomes are therefore expected:   * Trained personnel for modern industry in the form of undergraduate students involved in the project. * Undergraduate thesis of various students on various modules developments during the process. * A research lab and experimental setup for future projects of similar nature. |
| Technology Transfer / Diffusion Approach: *(Please describe how the outputs of the project will be transferred to the direct beneficiaries/customers. Please also state if the project outputs are sustainable, i.e. if they can be utilized without further external assistance.)* |
| A number of Postgraduate and Undergraduate students along with fresh faculty members will be involved in the project. This will cause the development of a mechanism for technology sharing and continuity of academic research. All the members will participate in the project as a whole thus building a whole community in fact a research group at the department. Seminar/Workshop will be arranged at the end of this project where number of speakers will be invited to present their work in the relevant field. The project outcomes will also be presented during the workshop. The guest from industry will also be invited to attend the workshop. |

# 6. Risk Analysis

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Risks of the Project: *(Please describe the factors that may cause delays in, or prevent implementation of, the project as proposed above; estimate the degree of risk.)*   |  |  |  |  | | --- | --- | --- | --- | | (Please mark 🗹 where applicable) | Low | Medium | High | | * Technical risk |  |  |  | | * Timing risk |  |  |  | | * Budget risk |  |  |  | |
| A1. Comments: |
| * Technical risk is medium since the hardware components required for this project are easily available in the market. * Timing risk is medium as proof-of-concept prototype is committed; since the major part of project is to develop a smart home system focused on three major applications i.e., energy management, safety & security, and assisted living therefore the time claimed might be risky. * HR and equipment prices may deviate from the one claimed depending on the market. |

# 7. Contractual Matters

|  |
| --- |
| Contractual Obligations under this Project: *(Please indicate any contractual obligations with third parties that will be entered into for this project.)* |
| NIL |
| Ownership of Intellectual Property Rights: |
| All newly developed intellectual property rights arising out of or capable of legal recognition with respect to the projects implemented by the National ICT R&D Fund (The “Company”) shall vest with the Company.    The Company may assign or license its rights in the said intellectual property to any person on such terms as it may deem appropriate. |
| Competent Authority of the Principal Investigator’s Organization: *(Documentary proof of the Competent Authority (VC/Rector/CEO..) as being the authorized signatory for the PIO is mandatory for approval of the Project Proposal.* ***Please attach copy of the proof.****)*   |  |  |  |  | | --- | --- | --- | --- | | Name: |  | | | | Designation: |  | | | | Email: |  | | | |  |  | | | | Date: |  |  | Signature  & stamp: | |

# 8. Project Schedule / Milestone Chart

***(Project schedule using MS-Project (or similar tools) with all tasks, deliverables, milestones, cost estimates, payment schedules clearly indicated are preferred.)***





# 9. Proposed Budget

Double click the icon to open the worksheet.



# Annexure A – Curriculum Vitae

|  |  |
| --- | --- |
| Please provide relevant information and also attach CVs of key research / development personnel (if available) and PI, CPI. | |
| 1. **Professional Information** | |
| 1. Name : | **Dr. Muhammad Khurram** |
| 1. Title or Position Held : | Associate Professor |
| 1. Experience : (yrs) | 12 |
| 1. Email Address : | mkhurram.ned@gmail.com |
|  |  |
| 1. **Research Papers in Relevant Area** | |
| 1. Zainab Fatima, Muhammad Inshal Uddin, **Muhammad Khurram** “Design of On-Cloud Laboratory Platform to Bring Internet of Things to Laboratories”, 30th IEEEP Multi-Topic International Symposium, March 25-26, 2015, Karachi Pakistan. 2. H Ahmed, **MuhammadKhurram**, "Performance Analysis of MAC Layer Protocols in Wireless Sensor Network" I.J. Information Engineering and Electronic Business, 44-52, 2014. | |
| 1. **Courses Taught in Relevant Area** | |
| Embedded Systems | |
| 1. **Thesis / Projects Supervised in Relevant Area** | |
| NIL | |
| 1. **Grants Received in Relevant Area** | |
| Leading a research group working on different IoT based project. International grants are received. | |
| 1. **Industrial Work Done in Relevant Area** | |
| NIL | |
|  | |

Please find attached the C.V of Dr. Muhammad Khurram for further details.



|  |  |
| --- | --- |
| Please provide relevant information and also attach CVs of key research / development personnel (if available) and PI, CPI. | |
| 1. **Professional Information** | |
| 1. Name : | **Dr. Syed Raheel Hassan** |
| 1. Title or Position Held : | Assistant Professor |
| 1. Experience : (yrs) | 12 |
| 1. Email Address : | raheel.hassan@quest.edu.pk |
|  |  |
| 1. **Research Papers in Relevant Area** | |
| [1] **Raheel Hassan Syed**, Maxime Syrame , and Julien Bourgeois. Protecting Grids from Cross-Domain Attacks Using Security Alert Sharing Mechanism. Journal of Future Generation Computer System (Elsevier), 29(2):536--547, 2013. Impact Factor: 1.978  [2] **Raheel Hassan Syed**, Jasmina Pazardzievska, and Julien Bourgeois. Fast Attack Detection using Correlation and Summarizing of Security Alerts in Grid Computing Networks. Journal of Supercomputing (Springer), 62(2):804--827, 2012. Impact Factor: 0.917  [3] **Raheel Hassan Syed**, Julien Bourgeois,Vaidy Sunderam and Li Xiong . Detection of Distributed Attacks in Hybrid & Public Cloud Networks . In SKG2012 , Int. Conference on Semantics, Knowledge and Grids (SKG), IEEE, ISBN: 978-1-4673-2561- 5, pages 9-15 , Beijing, China, 22-24th October 2012.  [4] **Raheel Hassan Syed**, Jasmina Pazardzievska, and Julien Bourgeois. Minimization of Security Alerts Under Denial of Service Attacks in Grid Computing Networks. In GCA 2011, Int. Conf. on Grid Computing and Applications, Las Vegas, United States, pages 1--7, July 2011.  [5] Julien Bourgeois and **Raheel Hassan Syed**. Managing Security of Grid Architecture with a Grid Security Operation Center. In SECRYPT'09, Int. Conf. on Security and Cryptography, Milan, Italy, pages 403--408, July 2009. INSTICC Press. | |
| 1. **Courses Taught in Relevant Area** | |
| Modern Research Testbeds in Phd program  Advance Data Communication & Networks in Masters program | |
| 1. **Thesis / Projects Supervised in Relevant Area** | |
| **Past Projects:**  Undergraduate project:   1. “The telephonic and web based system which controls electric appliances and locks of the offices and the residences at Mehran University of Engineering & Technology” in 2007.   Postgraduate Projects:   1. “The Security Alerts Correlation in Grid Computing Networks” 2. “The Security Evaluation in Grid Computing Networks” in 2010 at Laboratoire d'Informatique Université de Franche-Comté (LIFC).   **Ongoing project:**  PhD Project   1. Management of Security in Wireless Sensor Networks. | |
| 1. **Grants Received in Relevant Area** | |
| NIL | |
| 1. **Industrial Work Done in Relevant Area** | |
| NIL | |
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# Find Attached the CV of Dr. Syed Raheel Hassan.

