**Building a Responsive Smart-Home**

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**Introduction**

Smart home design and implementation has become a trend in our society today. In as much as smart phones are considered a must have tool for everyday living, the trend towards establishing smart homes as the recommended housing system has also led to the rise of a global societal phenomenon. A lot of homes in today’s world already implement aspects of what would be termed a smart home, such as Bluetooth powered light bulbs, security cameras, wireless doorbells, smart TVs, and Amazon Alexa, which is a cloud-based voice service that offers customers the capability to build natural voices for a more intuitive way to interact with their technology.

Over the past couple of years, studies have been conducted towards connecting several appliances and everyday objects. This revolution led to the development of the term Internet of Things (IoT). Internet of things is a system of devices or machines with the ability to transfer data over a network. The IoT ecosystem consists of web-enabled smart devices that use embedded systems, such as sensors and processors to collect and send data acquired. IoT is the basic system of communication between devices in a smart home. The uniqueness of a smart home is in the ability of the devices to be able to gather information from one another and act based on said information. This is done with the help of an IoT based system.

Smart home automation is the process of automatically controlling different home appliances and programming them to replace several human interactions for handling essential home functions. These devices are operated via IoT supported platforms­ providing connectivity and control to them from anywhere. Smart homes are equipped with sensors, actuators, and/or biomedical monitors. The devices operate in a network connected to a remote center for data collection and processing. The remote center diagnoses the ongoing situation and initiates assistance procedures as required. The technology can be extended to wearable or implantable devices to always monitor residents.

Many organizations have developed smart home systems, but majority are costly and do not allow for easy integration of sensors and actuators. There are many areas in a smart home to which different kinds of devices can be applied such as security, automation, and energy management. A lot of the developed systems are usually aimed towards a single area and do not provide a solution to manage all the smart home needs within a single framework hence, many of the devices usually work alone rather than with each other. The rapid growth of IoT however makes it more possible for devices to collaborate with each other.

The following are the objectives of this paper: Discuss the different layers to be considered in building a smart home and the advantages and disadvantages of a smart home system with integrated and connected appliances.

**Method**

When designing a smart home, there are four architectural layers to consider – the physical layer, the communication layer, the data processing layer, and the interface layer. The physical layer refers to the sensors in the environment and physiologic sensors. The communication layer is responsible for networks. The data processing layer is responsible for data storage and machine learning, and the interface layer is responsible for information display.

In the physical layer, smart home sensors collect data from the environment and transfer the data to the communications layer for activity analysis. Within the physical layer, there are two important categories of sensors. These include discrete state sensors and continuous state sensors. Discrete state sensors have only two kinds of output – on and off. They are used to collect data from appliances that usually only have two states. Continuous state sensors which have outputs in form of images, numbers, or sounds. Data from these sensors are generally more complex. An example of this is a temperature sensor or a camera.

In the communication layer, components are in constant contact with each other over a network. The network is an important part of smart objects connectivity. Smart objects include controllers, sensors, actuators, and different processors, which are used to control, monitor, and communicate with each other in the network. Smart homes usually take advantage of cloud computing, but there are significant deficiencies in cloud computing including latency and response time. Because of this, several researchers have proposed a technique known as fog computing to overcome the limitations of cloud computing. Fog computing is an architecture that uses edge devices – devices that provide entry point to a service provider, usually routers – to carry out a considerable amount of computation. Fog computing, also called edge computing, is intended for distributed computing where numerous devices are connected to a cloud. In fog computing, IoT devices will generate voluminous raw data (e.g., from sensors), and rather than forward all this data to cloud-based servers to be processed, a lot of the processing is completed using computing units located in places same as the data-generating devices, so that processed rather than raw data is forwarded, and bandwidth requirements are reduced. This enables real time interactions between smart objects overcoming latency and data volume issues.

The data processing layer refers to the action layer. It is the part of a smart home that inherently makes it smart. Basically, it uses the data collected by the physical layer. Possible implementations of the data processing layer are as follows. The thermostat sensor measures the room’s temperature to control the heating and air condition system. If the temperature of the room is higher than a specified threshold degree and motion is also true, the AC turns on automatically; otherwise, the AC will turn off. Photoresistor sensors are used to measure sunlight intensity. If the sunlight is lower than a specific threshold, this will automatically turn on the outdoor lighting system of the house and vice-versa. Water measurement sensors are used to find the water level in the water tank. If the water level is less than the specified threshold, it will automatically start the water motor, and when the water tank is full, the water motor will be turned off automatically. Besides this, gas and smoke detection sensors could detect smoke leakage in rooms and the kitchen. In contrast, flame sensors are used to detect fire in the room. If gas, smoke, or fire is detected, the siren will automatically turn on, and an SMS alert is sent to the authorized person. This brings us to the interface layer.

The interface layer, which is the final layer, reports data and actions back to the smart home user or authorized personnel. Visual sensors are used to provide live streaming to the homeowner on smartphones/PC to enhance home security, and the live data will be protected from unauthorized access using a proper authentication mechanism to ensure system privacy. A large section of smart home users are patients, elderly, or disabled residents. If an accident is ever faced within the home, details of the accident could be automatically reported to their primary care givers or the assigned health centers. The design of the interface should be as user friendly as possible considering the consumer might not be tech savvy. The interface also allows for human control of the smart objects incase the user is unsatisfied with the automation.

**Discussion**

Smart homes are a relatively new product of technology so there is a lot of skepticism surrounding them. This is of course normal for any new product. Smart homes however have several advantages that argue in their favor. Firstly, smart homes contribute to the support of people in the elderly and disabled community. It serves as a method for improving the basic quality of life of patient while also serving as a data collection point for clinics. Behavioral patterns and measured quantities about the patient’s physiology could be translated into accurate predictions of health risks and allow action to be taken at earlier stages.

The University of Colorado, Boulder in one of the earliest smart home projects, explored the concept of a self-automated home. The researchers developed a prototype that can monitor and control several different aspects of the home such as ventilation and lighting. This automation allows for proper subsidization of energy consumption. It also eases the residents as the role for completion of these routine tasks becomes redundant. The researchers also collected data from the neural network of the residents to learn and predict the lifestyle of the occupants and to accommodate their needs accordingly.

Higher levels of safety and security of residents is also another essential advantage of smart homes. Because these homes can report discrepancies to physical quantities, things like gas leaks could easily be spotted and resolved as soon as possible. Visual sensors like cameras and motion detectors could feed information to the interface, and temperature spikes could be counteracted by air conditioning automation systems. Gas leaks could also trigger alarm systems on the interface, such that even when there is no one in the home, dangers like this could still easily be resolved.

Smart homes allow continuous monitoring of health and activities of residents as well as monitoring of the environment, safety, and security of the home. While there is indeed a lot of research going into the development of a fully functional smart home, there are some challenges that need further research and development to improve the overall performance and increase the market penetration of the smart home systems.

 The lack of studies related to user needs is a major barrier to the implementation of health care technology in smart homes. Inadequate comprehension of user needs and poor demands for products and services to be used in smart homes are partly explained by the fact that the industry tends to be dominated by suppliers hence there is more of a supply than a demand, causing user disappointment.

Another one of the concerns for the smart home technologies is the privacy and security of the transmitted data. The data may contain sensitive, protected, or confidential information that can endanger residents’ privacy and safety, if breached. Therefore, ensuring strong data encryption, database security as well as secured communication channels is critical for smart homes.

Also, smart homes use a wide range of sensors, actuators, and other wireless devices, thus generating a large volume of data. Therefore, the communication protocols, hardware, and computation resources for the central node of the body area network and wireless sensor network

could impose bottlenecks for the seamless and delay-less connectivity as well as data handling

capability. The gateway node in wireless sensor network performs extensive data processing as well as communicates with all the components of the system along with the remote server. Robust and efficient algorithms along with effective data compression techniques are the key to optimize the performance of the smart home system.

Fourth, smart home is a complex system with many discrete devices and systems connected in a common platform. However, the system needs to be carefully designed to deal with integration issues among different devices and have an optimum number of sensors to avoid redundant data, minimize infrastructure and maintenance cost as well as energy consumption without losing key information.

Fifth, the sensing systems of the smart homes, particularly the portable and wearable physiological parameter measurement systems, are aimed for long-term monitoring purposes. Therefore, these systems need to be energy efficient, which can be achieved by using low power

components and efficient batteries. Researchers may also exploit energy harvesting techniques to fulfill the energy requirements of the devices.

Finally, although many researchers have been working towards smart homes, they mostly

addressed some specific aspects of smart homes. A fully functional and comprehensive smart home that addresses all aspects such as home automation, monitoring of residents’ health, safety and security, and home environment is still to be realized.

**Conclusion**

This paper discusses the different layers necessary for smart home development and the functions of each layer in the home. It also discusses the challenges faced by researchers in this field. The primary objectives of a smart home are automation, safety, and security and each layer should have devices or tools that perform at least one of the objectives. When designing a smart home, each layer must be considered and satisfied to allow for a seamless design and a truly automated system.

As technology advances and data collection methods mature, it is inevitable that the current healthcare system will undergo a paradigm shift to keep up with the changing needs of the population. There are both benefits and challenges in the use of Smart Homes, with the main benefit being an increased awareness of one’s health status, and the main challenge being privacy issues. As mentioned earlier, the biggest groups that benefit from Smart Homes are – but not limited to – seniors, disabled patients, and dementia patients who are not able to be accompanied by caregivers daily. Smart Homes can assist them to live more independently and comfortably by reducing the amount of travel to see physician offices. However, the residents must be aware of where the sensors are located, and which information will be collected about them so that the issue of privacy can be fully addressed as well as understand their interactions with these technologies.

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