A Literature Review of IoT Technologies for Home Automation

Submitted by,
Names and IDS

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talk briefly about different IoT applications and in more detail about home automation in particular.

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mention briefly about each domain and what we aim to explore

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4 Security systems for smart homes

With the advent of smart homes, due to increased connectivity between a home system and many other large-scale systems, it is important that no malicious softwares enters the system and causes any kind of corruption. Let us consider this with the example of smart homes and smart grids. An energy aware household is expected to optimize the power budget used whilst also not slacking on comfort of the residents. This requires communication not only with the smart grid and the house, but also within all entities in the smart house. With all the communication depending on Information Technology, the system becomes vulnerable, which if exploited could not only damage the infrastructure of the home system but also the Smart Grid, which will have a large-scale impact. This also means that with the rise in Smart Grids, the role of Smart Homes and their residents becomes increasingly important.

4.1 6 Aspects of System Security

The following are the 6 aspects which are used while considering security of a system:

1. Confidentiality: only authorized personnel should have access to the data
2. Integrity: assurance that the accuracy and consistency of the data is maintained. Any and all changes in the data are detected.
3. Availability: Any network resource should be available to authorized entity.
4. Authenticity: of the communicating parties involved i.e., all communicating parties must be validated and the information sent by them must indeed be sent by them
5. Authorization: access control of each entity must be defined in the network.
6. Non repudiation: undeniable proof should exist for any claim of any entity

Any security attack can be divided into categories based on whether the attack affects the system:

- Passive: Here the threat is only attempting to take information from the system network, without affect its resources. This information could be valuable and be used in different ways to plan a more disastrous attack. In dealing with such attacks, one focuses on prevention rather than detection, as that can be very tough.
- Active: Here the attack actively attempts to damage/affect the system network resources or operation. The most common amongst these attacks are masquerading, replay, message modification, denial of service and malicious software.

4.2 Impact Evaluation

Now based on the impact of the attack to the system, the FIPS 199 standards can be used categorizing the attacks as Low level, Moderate level and High level, which in themselves fairly explain their damage extents.

The architecture of the Smart home system is divided into internal and external systems, where, in this case, the Energy Service Interface (ESI) is in contact with the smart grid, and manages communication with the external system. And the Energy Management System (EMS) manages the internal system.

4.3 Smart Home Attacks

4.4 Security countermeasures

5 Energy management solutions

Using energy efficiently in smart homes saves money, enhances sustainability and reduces carbon footprint at large. Consequently, the need for smart energy management is on the rise for smart homes and for smart cities in general. However, the lack of low cost, easy to deploy, and low maintenance technology has somewhat limited a large-scale deployment of such systems. The sheer quantity of data collected throughout different cities of a country presents multiple challenges in data storage, organization, and analysis. Internet of Things (IoT) technology and Big Data are natural candidates to address these challenges. IoT technologies can provide a ubiquitous computing platform to sense, monitor and control the household appliances energy consumption on a large scale. This data is collected using many different wireless sensors installed in residential units. Similarly, Big Data technology can be utilized to collect and analyze large amounts of data [3]. Data analytics on this data using business intelligence (BI) platform plays an essential role in energy management decisions for homeowners and the utility alike. The data can be monitored, collected and analyzed using predictive analysis and advanced methods to actionable information in the form of reports, graphs and charts. Thus, this analyzed data in real-time can aid home owners, utilities and utility eco-systems providers to gain significant insights on energy consumption of smart homes. The energy service providers can use the power consumption data available with analytics engine to provide flexible and on-demand supply with appropriate energy marketing strategies. The consumers, being aware of their consumption behavior and having a close interaction with the electricity utilities, can adjust and optimize their power consumption and reduce their electricity bills.

5.1 Energy Harvesting and Management

In order to have an effective cost saving system, it is important to monitor and control the operation of residential loads depending on the aggregate power consumption over desired period, the peak power consumption, the effect of weather/atmospheric conditions and consumption slab rates. This is where the combination of IoT technology, Big Data analytics and BI comes into play for implementing energy management solutions on a local and national scale. Finally, as an additional advantage, the use of IoT also enables seamless remote access control of home devices where the customers get online access to the ON/OFF usage pattern of in home appliances via a personal computer or a mobile phone.

Bharat et. al.[4] focused on the advantages of home automation such as - reduced installation cost, system stability, easy extension, aesthetically benefited and integration of mobile devices.

Farzana et. al. [16] in their research proposes an implementation of smart home automation system by dividing our regular household appliances into two categories, low load and some scheduled high load appliances. After automation and scheduling, a solar system power supply has also been incorporated that can supply power to some appliances and reduce power consumption from national grid. This system also provides a detail analysis on energy management which has been developed by measuring power consumption throughout a year in different seasons.

Another interesting approach by for implementing energy efficient automation is presented by Michael C. Mozer in [12], where they have developed a home system that essentially programs itself by observing the lifestyle and desires of the inhabitants, and learning to anticipate and accommodate their needs.The system controls basic residential comfort systems-air heating, lighting, ventilation, and water heating. They call the system ACHE. ACHE has two objectives.

- One is anticipation of inhabitants needs. Lighting, air temperature, and ventilation should be maintained to the inhabitants comfort; hot water should be available on demand. When inhabitants manually adjust environmental setpoints, it is an indication that their needs have not been satisfied and will serve as a training signal for ACHE. If ACHE can learn to anticipate needs, manual control of the environment will be avoided.

- The second objective of ACHE is energy conservation. Lights should be set to the minimum intensity required; hot water should be maintained at the minimum temperature needed to satisfy the demand; only rooms that are likely to be occupied in the near future should be heated; when several options exist to heat a room , the alternative minimizing expected energy consumption should be selected.

They archive the optimal control by defining an average energy cost function as

$$J\left(t_0\right) = \mathrm{E}\left[\lim_{\kappa \to \infty} \frac{1}{\kappa} \sum_{t=t_0+1}^{t_0+\kappa} d\left(x_t\right) + e\left(u_t\right)\right]$$

Where $J\left(t_0\right)$, is The expected average cost, starting at time t_0 , $d\left(x_t\right)$ is the discomfort cost associated with the environmental state x at time t, and $e\left(u_t\right)$ is the energy cost associated with the control decision u at time t

The goal is to find an optimal control policy (a mapping from x_t to decisions u_t) that minimises the expected average cost.

Il-Young Joo et. al. [10] proposes a distributed optimization algorithm for scheduling the energy consumption of multiple smart homes with distributed energy resources. In the proposed approach, the centralized optimization problem for home energy management is decomposed into a two-level optimization problem, corresponding to the local home energy management system (LHEMS) at the first level and the global home energy management system (GHEMS) at the second level. The controllable household appliances (e.g., air conditioner, washing machine) are scheduled in the LHEMS within consumer's preferred appliance scheduling and comfort level while the energy storage system (ESS) and power trading between households are scheduled in the GHEMS. In the simulation study, the proposed distributed algorithm shows almost equivalent performance to the centralized algorithm in terms of the electricity cost and the consumer's comfort level. The impact of different network topologies on the proposed algorithm is also analyzed, and the result provides insight into the selection of the optimal network configuration in view of the consumer's electricity cost saving.

Junyon Kim et. al. [1] proposed a very simple and appropriate idea on smart home which includes internal home appliances and their internal connectivity. They called this model HEMS(Home Energy Management System) model using Internet of Things (IoT).

Zhao et al. [19] in their paper propose a smarter model on scheduling system that can be useful on our home automation system design assignment.

Haque et al. presented an optimized stand-alone green hybrid system to supply electricity in an island of Bangladesh called Saint Martin[8].

F Shabnam [15] talked about eco-friendly cellular network where base stations of cellular network will harvest energy and trade the excess harvested energy to electricity grids.

Various studies have been steered in the application of IoT environment for HVAC control and scheduling methods to optimize HVAC energy consumption [[14], [7], [17]]

5.2 Node energy management

Apart from papers that talk about using IoT to optimise power consumption and financial aspects of a house as a whole, techniques to minimise the IoT device power are discussed in the following paper.

The authors of [6] discuss a fuzzy logic based mechanism that determine the sleeping time of an IoT devices in a home automation environment based on BLE. The proposed FLC determines the sleeping time of field devices according to the battery level and to the ratio of Throughput to Workload (Th/Wl). Simulation results reveal that using the proposed approach the device lifetime is increased by 30% with respect to the use of fixed sleeping time.

5.3 Communication

A HEMS requires a reliable communication network using WSN that can transport the consumption details and consumer load behavior periodically. In [[2], [13], [5]], an implementation of a HEMS Unit in a Wireless Sensor Network using a ZigBee Module to communicate with sensor nodes, is presented. The system monitors the device consumption data and sends control signals to end nodes during peak load hours. However, the lifetime of a WSN network deteriorates with time due to the deployment of new sensors in the network. Additionally, Han et al. in [9] introduced a system for monitoring power consumption using ZigBee as the communication protocol in a WSN. However, in this system the data was collected and aggregated solely by the home server which could lead to data loss in case of a system failure. Moreover, a bridge between ZigBee and TCP/IP stack would be required to connect this system to a community of homes. The above mentioned WSN networks have been extended to wider ranges in the IoT paradigm utilizing the GSM/GPRS networks to remotely control the end-devices in [[18], [11]].

6 Challenges of Home automation systems

7 Conclusion

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