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# A Survey on Novel Services in Smart Home (Optimized for Smart Electricity Grid)

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## *(Optimized for Smart Electricity Grid)*

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# Abstract

Advancement in technology has not only transformed our life but also extended in every sphere of our way of living. Till now in most of the cases we are adapting our lifestyle with the way that is directed by the functions of the modern devices. But scientists are researching on more modern smart devices that should rather adapt with our lifestyle seamlessly. That is the core concept of pervasive computing - a collection of invisible and visible sensors and computing devices to ease our daily life. Recently there has been an increasing interest in smart devices containing endpoints like sensors and actuators also known as the things. They can connect to the internet to cooperate and create new services at homes and industries. The typical application scenarios include smart home, e-health, smart grid and so on.

Development of Smart Grid and Smart Meter encourages the consumer to use smart appliances in their home. There is an increased trend in adoption of smart appliances in general, as witnessed by the many new IoT enabled systems and services. A well designed smart appliance can take the full advantage of smart meter to optimize the electricity usage. There are many household products and devices in the market that provides smart control to manage home system. Our goal in this thesis is to investigate the products, what are the services they provide and which services can be developed in future by using these devices. We called the services here as Novel Services. Additionally, we propose a framework based on the novel services provided by the smart home devices and appliances to evaluate their services. Smart Electricity Grid consists of a wide range of solutions for the electricity grids of the future. If we can utilize and integrate information communication technology with the contemporary electric grid system into smart grid that will make the production, storage, distribution and management of energy highly efficient which will eventually benefit our people, community, nation and country.

# Preface

This thesis is submitted to the Norwegian University of Science and Technology (NTNU) in fulfilment of the requirements for an MSc degree in Information Systems at the Department of Computer and Information Science under the Faculty of Information Technology, Mathematics and Electrical Engineering.

The work has been conducted at the IoTSec project coordinated by University Graduate Centre at Kjeller (UNIK). The IoTSec - Security in IoT for Smart Grids initiative was established in 2015 to promote the development of a safe and secure Internet-of-Things (IoT)-enabled smart power grid infrastructure. The Research Project received funding from the Research Council of Norway (RCN) to contribute to a safe information society.

Professor Trond Aalberg has been the dissertation supervisor at NTNU. Professor Josef Noll and Christian Johansen from the IoTSec project were the supervisors.

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# Abbreviations

AAL	Ambient Assisted Living
ADSL	Asymmetric Digital Subscriber Line
AMI	Advanced Metering Infrastructure
AMR	Automated Meter Reading
API	Application Programming Interfaces
AS	Application Services
A/C	Air Conditioner
BAN	Body Area Network
BACnet	Building Automation and Control Network
BSN	Body Sensor Network
CDH	Cognitive Digital Home
CMU	Central Home Management Unit
DoE	Department of Energy
DRS	Dash Replenishment Service
DSM	Demand Side Management
DVR	Digital Video Recorders
EISA	Energy Independence and Security Act
GPS	Global Positioning System
HAN	Home Area Network
HI	Home Intelligence
HVAC	Heating, Ventilation, and Air Conditioning
IFTTT	IF This Then That
IoT	Internet of Things
IR	InfraRed
kWh	Kilo Watt hour
MAN	Metropolitan Area Network
MFi	Made for iPhone/iPod/iPad
NIST	National Institute of Standards and Technology
OSGP	Open Smart Grid Protocol
PAN	Personal Area Network
PLC	Power Line Carrier
REST	Representational State Transfer
RF	Radio Frequency
RFID	Radio Frequency Identification
SG	Smart Grid
SHE	Smart Home Environment
SHEMS	Smart Home Energy Management System

SHOS	Smart Home Operating System
SM	Smart Meter
ToU	Time of Use
UPnP	Universal Plug and Play
WBAN	Wireless Body Area Network

# Chapter 1

## Introduction

### 1.1 Assignment

The thesis is done in cooperation with the IoTSec project [IoTSec, 2015]. The ‘IoTSec - Security in IoT for Smart Grids’ initiative was established in 2015 to promote the development of a safe and secure Internet-of-Things (IoT)-enabled smart power grid infrastructure. IoTSec addresses the basic needs for a reliable and efficient, uninterrupted power network with dynamic configuration and security properties. It addresses in addition the needs of businesses and end users of additional IoT services by exploring use cases for value-added services with the intent to design the building blocks for future services that consider the necessary security and privacy preconditions of successfully deployed large-scale services. The project is coordinated by University Graduate Centre at Kjeller (UNIK) along with other industrial and academic partners.

The research question of this thesis was to investigate the state of the art IoT devices available and developed in the industry and their novel services in Smart Homes. Moreover, this literature review focused on the following criteria: efficiency, usability, security and privacy aspects. The goal of this thesis that relates it to the IoTSec research efforts is to focus on the Smart Home as part of the Smart Grid, and thus on how these smart devices can be used to enhance the energy efficiency and to control energy load in a smart electricity grid. The connection between the Smart Home and the Smart Grid is mainly through the Smart Meter, which itself can be seen as an IoT device. More discussions of all these concepts are included in this thesis.

### 1.2 Motivation

The current trend of the Smart Grid implementation assumes a sustainable and environment friendly energy solutions. Norway is already on the way of developing its own Smart Grid



strategy. The Norwegian Smartgrid Centre works with research and development, education, demonstration projects and commercialization of smart grid. Traditional power engineering is being incorporated with the advanced information communication technology that requires major upgrade and enhancement aimed to support energy services and functionalities for utilities and end users. In the vast landscape of smart grid research area, different researchers envision the smart grid in many different perspectives. Power consumption measuring in fine granularities is the most important part of smart grid. To achieve the full potential of the smart grid, implementation of Smart Meter is necessary. It provides the benefits of smart grid to customer by empowering them to optimize electricity usage. It plays a role of gateway to increase efficiency and integrate renewable resources, while supporting a new generation of smart appliances and plug-in electric vehicles that will provide enormous benefit for customers. This drives us to find out the existing and potential novel services related to smart home appliances that eventually connect to smart meters and grids.

There is an increased demand to develop services in home appliances to make use of the benefits of smart meters. Smart home appliances can interact with each other and with the sensor driven Internet of Things that makes a home smarter. Internet of things opens up the window for making many useful services in home. It can make automated home that will work for not only making life easier but also beneficial in terms of economy and society. Though in the IoTSec project the main focus was the security and privacy issues related to Smart Grid and Smart Meter along with big data analysis collected by smart meter, we were also interested to see the impact of introducing smart grid inside the consumer's premise. In this regard we focused on the smart home appliances and their ability to interact with smart grid.

In this thesis one of our motivations is to find out the practical significance of using IoT at home. Thus to encourage the consumer, prosumer (a new term used in Smart Grids to denote users that are also producing their own energy and also delivering it back to the grid when in surplus), manufacturers and researchers with an overview of the current trend apparent in the IoT world of Smart Home.

The analysis of pros and cons, technology, frameworks, platforms, etc. of smart grid and home automation are an ongoing research field, but we did not find any study on the smart appliances and related services those are able to meet the smart grid requirement, and in

which context we tell the smart devices smart enough to operate in our home to serve the best. That is an important part to achieve the full benefits of smart grid. Therefore, here we are interested to find out the services that are applicable to home automation related to smart electricity grid and derive a general framework to analyze them.

## 1.3 Research Objectives

Let us fix a few hypotheses first. A service can contain several products. A novel service can make use of an existing IoT device or product, in a way that was not previously thought about. A service from one provider can use products from other providers. A product should always come with a service on top.

The concept of service is a very important part for both consumer and business perspective. In this thesis ‘Novel Services’ delineates more than general services that we have ever known. In fact, we can see that in IoT a company no longer sells just a device, but also a service corresponding to it; e.g. most of the appliances we have discussed in chapter six come with a subscribed online services to control and access those through the Internet. Often the service allows the respective device to be integrated into a larger IoT ecosystem, and interact with other IoT devices and services. Since the assumption in IoT is that everything is connected with the Internet technology, all the things around a person could potentially be connected. As a result, people have multitude of sensors in their surroundings like temperature sensors, motion sensors, light sensors, etc. In consequence, people need to control a lot of devices and applications surrounding them in a smart environment.

All smart things can be connected with smart phones or smart controller that is easily available and will keep the consumer and producer always interconnected. The IoT services has opened up the real opportunity for manufacturers to leverage the technology to create new business models by merging the technology and business. Sometimes services are difficult to identify because they are closely associated with a product.

Novel services in home automation and smart usage of energy can achieve the real benefit by connecting residential electric devices with Smart Meter. As by 2020, most of the countries will implement Smart Grid technology as well as every house will have a smart meter

integrated. Therefore, we evaluate those appliances which are coming into the consumer market and which are already available to the consumers.

In this research we will address the following research objectives:

- Collect and survey existing Smart Home Applications and Services
- Analyze the relevance of these services for the Smart Grid and Smart Metering
- Evaluate and compare these services with respect to these four criteria:
  - Efficiency,
  - Security,
  - Privacy and
  - Usability.

Products with the capability of working with the smart meter and responsive to smart grid are able to satisfy end user by providing energy efficiency, reliability, security, privacy and comfortability and this is one of the important requirement of future smart home. Lots of intelligent devices and products are already in market to address home automation. Some of them exist from earlier and many are serving as smart devices, applications and services that we are not actually noticing in everyday life e.g. smartphone, thermostat, garage door opener, smoke detector etc. Therefore, we find out the existing devices and applications and analyze them in relation to the four criteria mentioned above. As a result, future products could be designed to utilize them as per choice of requirement. Smart devices have gained appreciation from the consumers. In a connected home all smart devices are not only connected among themselves but also with smart meter and smart grid for real time pricing facility. This leads to the question of energy efficiency, security, privacy and usability.

## 1.4 Methodologies

We explore smart grid, smart energy, and smart home related literature as well as commercial offerings related to the IoT enabled devices. To study on the contemporary research on the above topics, we look for the following keywords such as, smart meter, AMI, smart energy management, distributed energy, Internet of Things, smart home and appliances, smart home protocols, sensors, connectivity, etc. Hence we expanded our search criteria by reviewing literature from a wide set of research areas and sources to include articles which dealt with

devices that could both monitor and track their environment through sensors and had the capability to transmit data - common elements of the IoT.

We surveyed literature and scholarly articles on smart grid and also studied on the framework of the smart grid and potential applications of it. We found that the framework of smart grid is not a single one that is related with only energy generation, distribution and transmission rather it also includes the residence and its appliances. Measuring energy consumption at fine granularities in real time is main part of the next generation grid. Therefore, the system requires more than a conventional meter and as a result smart meter is evolved. This meter will be deployed to all type of consumers, but our concern is only for residential consumers. So we studied to gather knowledge about smart meters in details. Since we are focusing on the services of home appliances, we include smart meter and smart grid chapter respectively, presented with the basic information and sketched out the relation between the smart appliances and smart meter with respect to smart grid. We have noticed the importance of the development of smart devices and their services those are available and are in development. This research will be beneficial for consumers, who like to be ensured to get the advantages and would be encouraged to deal with smart appliances.

When we studied more details on IoT devices and their implementation, we sought to answer several questions such as, why do we need to identify their services, how can we achieve these and in which particular areas deserve these services more. Given the fact that the IoT is still a relatively new research domain, we have limited access to real home appliances that support full extent of IoT services. We found that very few research articles evaluate IoT appliances explicitly. We mainly surveyed a number of products based on their information available online. We limited our searches to primarily everyday products as opposed to industrial solutions. We have looked for the household products that are designed to provide IoT services and currently available in the market. We also looked for home appliances that can be integrated with smart grid to utilize the scheduling and power saving features of future smart meters. At the end of the thesis, we narrowed our research into mainly four criteria that is able to measure the competency of smart devices and appliances. Later we evaluated the products on the novel services based on the proposed Evaluation Framework.

## 1.5 Report outline

The next chapters in this report are organized as follows:

From **chapter Two** through **chapter Five**, we present the literature review and background knowledge of the thesis.

Chapter **Two** briefly gives a description of Internet of Things (IoT) and **chapter Three** presents the idea of a smart home, its requirements and advantages.

**Chapter Four** presents the development of smart meter, its usage and its interfaces with pervasive computing devices. **Chapter Five** presents the smart grid infrastructure and how it influences the future energy market.

**In chapter Six** we have presented several smart home appliances under discussion, their features and ability to communicate with provided services. In this chapter we have developed the framework to evaluate a smart appliance in terms of efficiency, usability, security and privacy.

**Chapter Seven** describe some standard services that can be utilized by the smart devices. The chapter also discussed how a standard service can be designed to protect user privacy at the same time leverage the use of smart meter in the smart grid.

**Chapter Eight** presents the conclusion of the thesis and in **chapter Nine** we have discussed what can be done as a further step beyond this thesis.

# Chapter 2

## Internet of Things (IoT)

### 2.1 Introduction

Internet of Things, briefly known as IoT is not now a futuristic term, we are already on the wave of computing that are the outside realm of traditional desktop. This term was first coined by Kevin Ashton in 1999 in the context of supply chain management [Ashton, 2009]. Albeit the definition of ‘Things’ has changed as technology evolved, the main goal of making computer sense information in the absence of human intervention remains unchanged.

Following definition about Internet of Things has taken from [Vermesan et al., 2014].

**Definition:** “Internet of Things (IoT) is a concept and a paradigm that considers pervasive presence in the environment of a variety of things/objects that through wireless and wired connections and unique addressing schemes are able to interact with each other and cooperate with other things/objects to create new applications/services and reach common goals.”

### 2.2 IoT Devices

The Internet of things (IoT) refers to a broad vision whereby ‘things’ such as everyday objects, places and environments are interconnected with one another via Internet. It is predicted that by 2020, Internet-connected devices are expected to number between 26 billion to 50 billion. For every Internet-connected PC or handset there will be 5–10 other types of devices sold with native Internet connectivity [James, 2014].

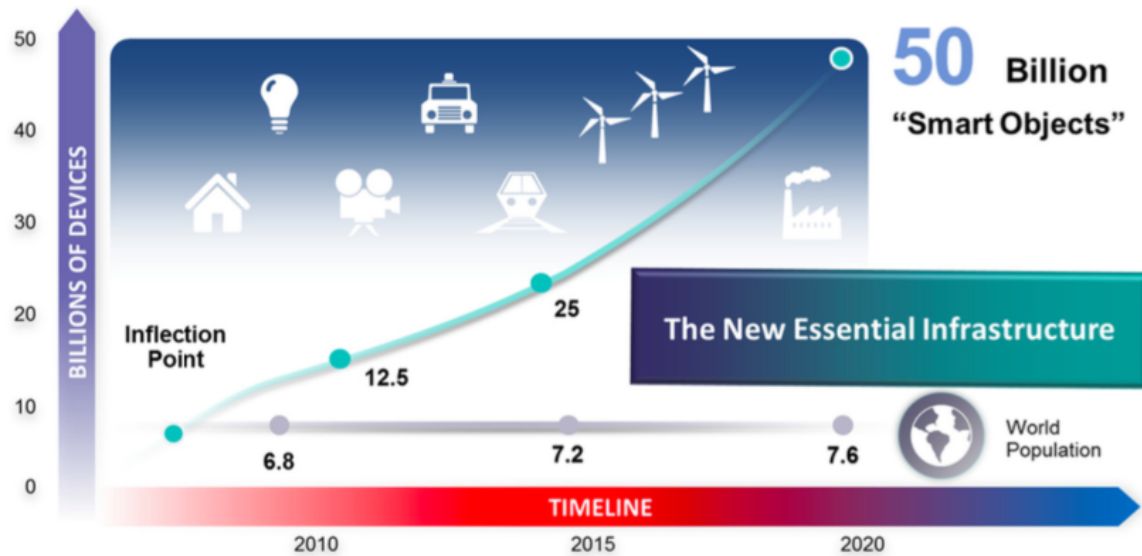


Figure 2.1: Internet-connected devices and the future evolution [Vermesan et al., 2014]

According to industry analyst firm International Data Corporation (IDC), the installed base for the Internet of Things will grow to approximately 212 billion devices by 2020, of which almost 30 billion will be connected devices. IDC sees this growth driven largely by intelligent systems that will be installed and collect data across both consumer and enterprise applications [IDC, 2013]. These types of applications can involve the electric vehicle and the smart house, in which appliances and services that provide notifications, security, energy-saving, automation, telecommunication, computers and entertainment will be integrated into a single ecosystem with a shared user interface.

IoT is not a single technology, it is a concept where many heterogeneous devices are connected and networked, embedded with electronics, software, sensors, and network connectivity that enable these objects to collect and exchange data.

## 2.3 IoT Applications and Services

IoT applications are changing our way of life by saving time and resources and opening new opportunities for growth, innovation and knowledge creation. The term IoT has been more inclusive covering the wide range of applications like healthcare, utilities, transport, etc. through the past decade [Sundmaeker et. al., 2010]. Potential applications of the IoT are numerous and diverse. It covers a huge scope of industries and applications including all

areas of every-day life of individuals, enterprises, and society as a whole. Internet of Things applications, which span numerous applications domains such as, smart energy, smart health, smart buildings, smart transport, smart industry and smart city are some of them.

The majority of the governments in Europe, Asia and in the America consider the internet of things as an area of innovation and growth. The Internet of Things (IoT) allows us to use technology to enhance our comfort level, improve energy efficiency, simplify routine work life and personal tasks providing better management for the tasks that consume our home and work life and give us greater control over our lives.



Figure 2.2: Elements of an IoT Application [Oleksiy & Passi, 2014]

Several application domains can be classified based on the type of network availability, coverage, scale, heterogeneity, repeatability, user development which will be impacted by the emerging Internet of Things. In [Gubbi et. al., 2013], they categorize the applications into four application domains: (1) Personal and Home; (2) Enterprise; (3) Utilities; and (4) Mobile.

Considering the above domains, we are interested in the domains ‘Personal and Home’ and its relation with the ‘Utilities’.

### 2.3.1 Personal and Home

Smart Home applications has two categories such as person centric and home centric [Koreshoff et al., 2013]. In the home perspective, applications are developed to control home equipment such as air conditioners, refrigerators, washing machines, etc. On the other hand,



person centric approach includes security alarm, webcam, lighting etc. Both of them altogether allow better home and energy management. More details about Smart Home can be found in Chapter 3 and Smart Home applications in Chapter 6.

### 2.3.2 Utilities

The information from the networks in this application domain is usually developed for service optimization rather than consumption. Utility companies are already adding IoT applications to obtain better resource management in order to optimize cost vs. profit. They get access to the in-home resources through smart grid. More details on Smart Grid are discussed in chapter 5. These are made up of very extensive networks for monitoring and controlling critical utilities. Large organization on a regional and national scale need to focus on efficient resource management.

Smart grid and smart metering are potential IoT applications which are being implemented around the world. Efficient energy consumption can be achieved by continuously monitoring every electricity point within a house and using this information to modify the way electricity is consumed. This information at the city scale is used for maintaining the load balance within the grid ensuring high quality of service.

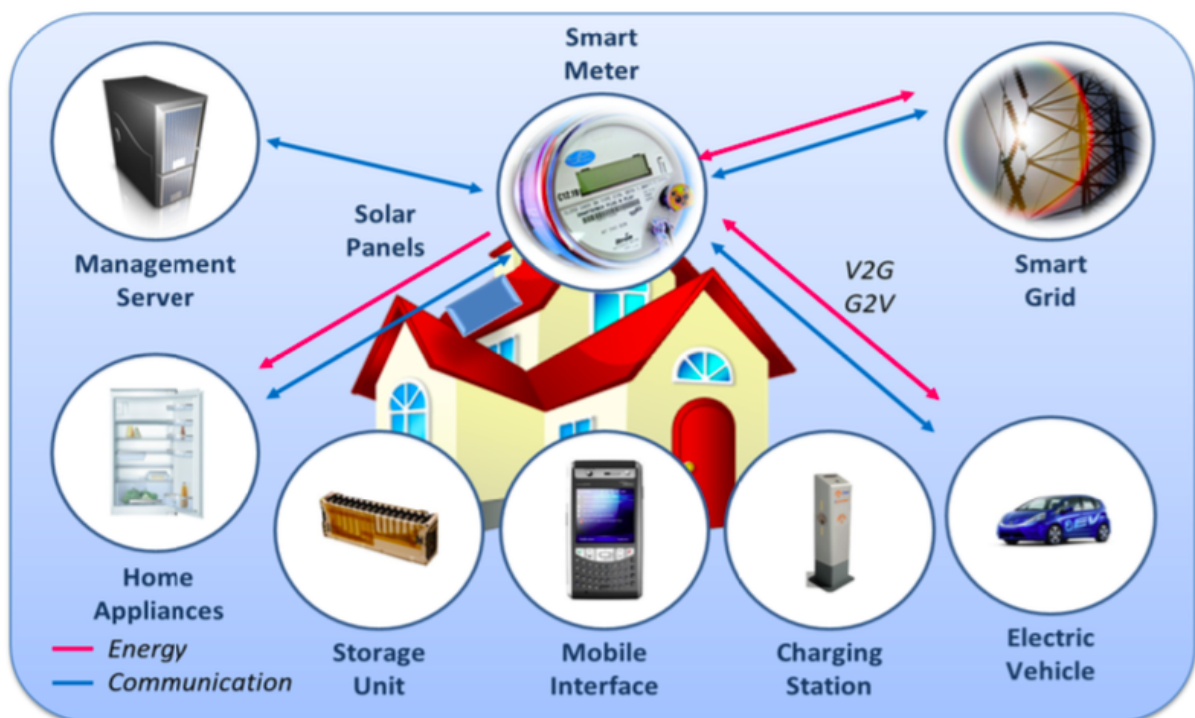


Figure 2.3: Internet of Energy - residential building ecosystem [Vermesan et al., 2011].

## 2.4 The Internet of Things of Tomorrow

The Internet revolution led to the interconnection between people at a novel scale and pace. The next revolution denotes the interconnection between objects to create a smart environment [Gubbi et al., 2013].

Smart Environment is the one that is able to acquire and apply knowledge about an environment and also able to adapt to its inhabitants in order to improve their experience in that environment. IoT can be considered as the foundation of Smart Environment that is a small world where all kind of smart devices are continuously working to make inhabitants' lives more comfortable.



Figure 2.4: Schematic view of Smart Environments [Das & Cook, 2005]

[Das & Cook, 2005] listed the feature of Smart Environments:

- Remote control of devices
- Device communication

- Information acquisition from intelligent sensor network
- Enhanced services by intelligent devices
- Predictive and decision making capabilities
- Networking Standards and regulations

Smart homes, Smart Transportation Systems, Smart Healthcare Services, Smart livestock farming, Smart Cities, Smart grids etc. are the element of making the environment smart. IoT applications have the main role to achieve those in reality.

## 2.5 Importance of IoT for a Consumer

There are numerous ways in human life that is improved by the realization of IoT. Researchers from SINTEF, Norway described this in their book [Vermesan et al., 2014]. Some related topics are pointed out here:

- To increase consumers' safety or the safety of their family members - for example remotely controlled alarm systems or activity detection for elderly people;
- To make it possible to execute certain activities in a more convenient manner - for example: a personal inventory reminder;
- To generally improve lifestyle - for example monitoring health parameters during a workout and obtaining expert's advice based on the findings, or getting support during shopping;
- To decrease the cost of living - for example building automation that will reduce energy consumption and thus the overall cost.

End-users in the private and business domain have nowadays acquired a significant competence in dealing with smart devices and networked applications.

## 2.6 Conclusion

Now we have already entered in the new era of Internet of Things leading to Smart Systems. These changes affect the overall ecosystem of business environments as well as people's lifestyle, work cultures etc. Smart environments contain a lot of IoT applications and each and every part of smart environment consists of many heterogeneous devices that varies with the individual and the type of environment. For Smart home we see that, researchers and producers are continuously working on the development of their findings and products.

Before deploying IoT in a smart home, we must consider the pros and cons during the transition period. The benefits and services inevitably have to be meaningful so that users and consumers can be interested to adopt this technology.

# Chapter 3

## Smart Home

### 3.1 Introduction

The concept of Smart Home emerges with the introduction of network enabled devices and ultra-modern electronic equipment usable at home. The Internet of things is changing simple homes into smart homes. IoT is changing our traditional approach regarding building devices, systems and services. Thus entering to the era of Internet of Things (IoT) is affecting the overall ecosystem of national and international industries and transforming people's living style. Smart home technologies delineate a broad picture in our environment. Now this approach is not only focused on for fancy of life and elderly person's helping environment, but also ensure efficient, comfortable and secure life for all homes.

In this chapter, we will describe the basic idea about smart home and its features, technology, benefit and application areas. We will elaborate the smart home devices, products, appliances and how those are related with smart grid.

### 3.2 The Concept of Smart Home

There exist numerous alternative names for “Smart Home” in the literature and on the web, including: Automated homes, Intelligent buildings, Integrated home systems or Domotics, Adaptive home, Aware house, Smart House, eHome etc. Smart homes incorporate intelligent devices that control the features of the home. Sometimes we use the term “Connected home”. A Connected Home may represent different things to different people, but it is essentially a home with one or more devices connected together in a way that allows the homeowner to control, customize and monitor one's environment [Silicon Lab, 2016]. It is an Internet of Things application of ubiquitous or pervasive environment. Smart home should be proactively change its environment depending upon user behaviors and needs. Eventually it will promote convenient, highly efficient, comfortable and independent life style. The concept of smart home is becoming a reality because of the unprecedented advancement of information technology and development in Internet of Things.

Many researchers have drawn a picture of Smart Home in the context of their individual research. Those are mostly similar. Here we present several notable definitions of smart home that we have found in different literatures.

The Smart Home energy webpage [Smart Home Energy, 2016] mentioned,

“A smart home, or smart house, is a home that incorporates advanced automation systems to provide the inhabitants with sophisticated monitoring and control over the building’s functions. For example, a smart home may control lighting, temperature, multimedia, security, window and door operations, as well as many other functions”.

From a technical perspective, [Vincent et al., 2006] defined Smart Home as,

“A smart home can be described by a house which is equipped with smart objects, a home network makes it possible to transport information between objects and a residential gateway to connect the smart home to the outside Internet world. Smart objects make it possible to interact with inhabitants or to observe them”.

And the definition from [Rosslin & Kim, 2010] is,

“A smart home or building is a home or building, usually a new one that is equipped with special structured wiring to enable occupants to remotely control or program an array of automated home electronic devices by entering a single command. For example, a homeowner on vacation can use a Touchtone phone to arm a home security system, control temperature gauges, switch appliances on or off, control lighting, program a home theater or entertainment system, and perform many other tasks.”



Figure 3.1: Smart Home Devices [Smart Home Energy, 2016]

### 3.3 Present Smart Home

A smart home has highly advanced automatic systems for controlling lighting, temperature and remote switches, programmable multimedia equipment, monitoring and activating security apparatus and arming and disarming remote facilities and many more. These qualities provide intelligence to the environment that makes the home ‘smart’. For example, the washing machine can be set on and off remotely, even schedulable, and may be able to measure energy spent to optimize cost. This way, every standalone machine can be connected in smart home to operate their task seamlessly without user intervention.

Anything that uses electricity can be connected in a smart home system. In a Smart Home, all heterogeneous connected devices and appliances such as lighting, heating, air conditioning, TVs, computers, entertainment devices, security and camera systems should be able to communicate with each other, are proactive and controllable remotely, and schedulable by home owners. The command can be by voice, remote controller or computer. Remote control and scheduling of system is possible from anywhere regardless of anyone presented in the

home. Different types of home appliances are described in chapter six and there it is elaborated how they work and contribute in the home.

Smart home consists of various type of devices and applications which should be multifunctional with intelligent control system, easily synchronizable, energy efficient and secured. In [Bregman & Korman, 2009], a universal implementation model for Smart Home is proposed.

The Smart Home Model Architecture comprises of four modules:

- Central Management Unit (CMU)
- User Interface (UI)
- Home Equipment and Appliances Interface (HEAI)
- External Communication Interface (ECI)



Figure 3.2: The Smart Home Model Architecture

The Central Home Management Unit (CMU) components are:

- Operating System (SHOS - Smart Home Operating System)
- The Smart-Home Database (SHDB)
- AI (Artificial Intelligence) Engine - Home Intelligence (HI)
- Application Services (AS)



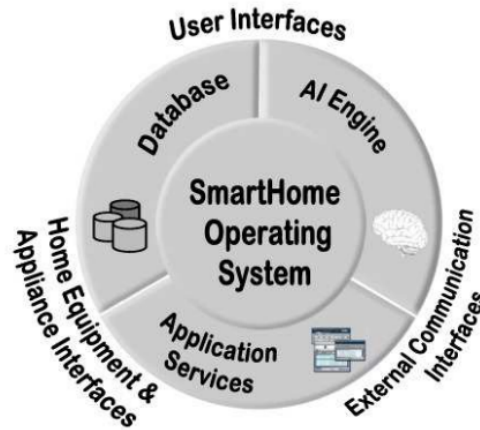


Figure 3.3: CMU components

## 3.4 Technology

The technology of smart home is not a single one. The collaboration of technology and services through a network provide ease and convenience to everyday activities in the home. The smart home technology is used to make all electronic devices to act “smart” since automation is one of the main part of it.

From the definitions above, we get three elements of a smart home:

- Internal network
- Intelligent control and
- Home automation

Internal network is the basis of a smart home, and it can be wired or wireless. Intelligent control means gateways to manage the systems. Home automation represents products within the home and links to services and systems outside the home [Jiang et al., 2004]. Home automation also encompasses different kinds of sensors and actuators inside the smart home.

Communication technology is one of the challenging aspects, as it affects both security, privacy, battery consumption and connectivity. Communication technology in smart home covers two aspects - internal network and home automation that links the services and systems to the outside Internet world. The different kind of area networks involved in this communication are: WAN, MAN, LAN, PAN and BAN.

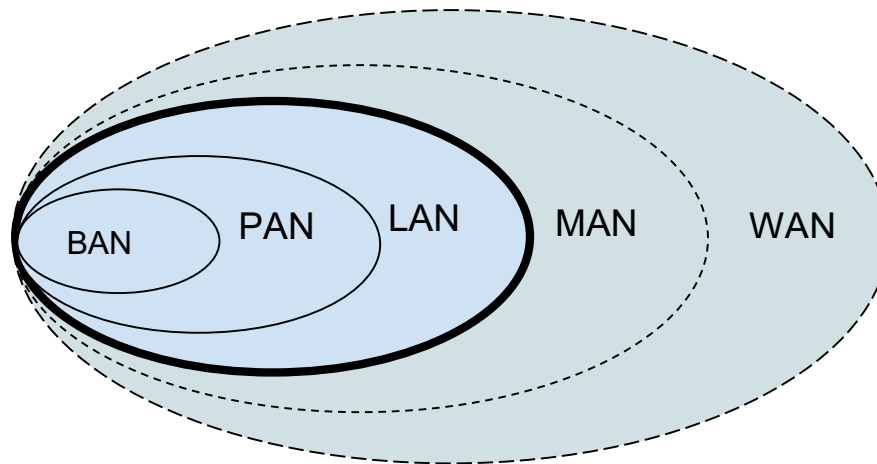


Figure 3.4: Different kind of area networks

WAN (Wide Area Network), generally consists of satellites, antennas, ADSL or fiber optic cable covering a large geographical area spanning from regions, countries and even the world.

MAN (Metropolitan Area Network) serves a restricted area, for example customers of a district.

LAN (Local Area Network) interconnects computers and devices within a limited area such as a residence, school, university campus or office building and has its network equipment and interconnections locally managed. HAN (Home Area Network) can be referred to as a subtype of LAN that facilitates communication among devices within the close vicinity of a home.

PAN (Personal Area Network) serves the personal needs for a user with close objects such as a computer, telephone, tablet etc.

BAN (Body Area Network), also refers to WBAN (Wireless Body Area Network) or BSN (Body Sensor Network) is a wireless network of wearable computing devices.

Smart Home devices usually communicates within the range of LAN and often form a PAN. For LANs, WiFi and HyperLan are main wireless solutions and Ethernet is the main wired solution. In case of PAN, several popular wireless standards exist. Bluetooth, RFID, Z-Wave and ZigBee are the most supported communication protocol supported by most of the smart home devices. Wireless USB is the wireless version of the USB and make it possible to communicate at short distance through USB without a wire. Insteon is the home automation technology that solve the interference problem of electrical lines as well as radio frequency communication or both. It makes dual mesh network to communicate over electrical wires

and radio waves. It has been associated with the Internet of Things like other home automation systems.

Z-Wave and ZigBee also use mesh network to communicate within a HAN and to extend the range of their communicating devices. Powerful home devices such as, white goods prefer Wi-Fi as the communication medium. But many IoT devices such as small sensors with limited computing power, memory and battery life prefers low power protocol like Z-Wave or ZigBee.

Above technologies are based on existing computer technologies. Nevertheless, there are standard that can use the existing cables installed in the home. Smart home technology available in these areas are [Vincent et al., 2006]:

- Powerline: A technology known as Powerline Carrier Systems (PCS) is used to send coded signals along a home's existing electric wiring to programmable switches, or outlets. One common protocol for PCS is known as X10, a signaling technique for remotely controlling any device plugged into an electrical power line.
- Busline: Busline technology involves the use of a cable which are present into the home. The data is transferred through the cable to the devices enabling the devices to communicate with each other. The well-known protocols for this are EIB (European Installation Bus), CEBus, Lonworks, Batibus and EHS.
- BACnet is a data communication protocol for Building Automation and Control Networks. LonWorks devices communicate with each other using the protocol LonTalk.

A major challenge in smart home communication technology is the variety of interfaces, with the lack of gateways integrating them.

### 3.5 Smart Home Application Areas

A wide variety of applications have branched out since researchers have been working on smart home. Smart devices and appliances in home are able to manage and control different areas of an individual smart home. This is about comfort, well-being, energy efficient and security of the residence. Smart home environment's applications are myriad. Based on our

literature survey, four distinctive general functional areas of services are classified in [Mendes et al., 2015] and [Costin et al., 2013] are:

- Energy Efficiency and Management
- Health Care
- Entertainment and
- Security

### 3.5.1 Energy Efficiency and Management

The major part of the world's energy is consumed in the household. As the growth of population is increasing, the demand of electricity is raising up with high pace. With the inception of IoT, a lot of smart appliances and connecting devices are used at home now. To ensure a sustainable energy system, we should emphasize on the efficient use of energy.

The main part of energy management is to reduce cost of energy of the households and residential building facilities without compromising the user's well-being and comfort. The functions of the home energy management are [Mendes et al., 2015]:

- controlling (activation/deactivation) of home appliances
- collecting real-time energy consumption from smart meter and power consumption data from various household appliances
- generating and monitoring a dashboard to provide feedback about power usage
- providing control menus to control appliances and providing a universal link to the broadband Internet.

Autonomous lifestyle demands a lot of energy consumption but automatic energy saving is the most useful and demanding feature to meet that challenge.

There are several proposals to achieve such energy management in a smart home, such as:

- Energy saving that aims at using sensors and actuators from Smart Home Environment (SHE) for controlling energy savings by switching off or to low-power mode the consumer appliances currently not in use or according to the user preference settings [Costin et al., 2013].
- Smart Grid integration that addresses the integration of energy-aware SHE into the Smart Grid [Costin et al., 2013].
- Energy efficiency driven Smart Home system, where remote control and monitoring facilities are possible in smart devices and appliances. Using battery supplied nodes,

which work with limited amount of energy and decision support tools designed to assist users in making smarter decision by using energy saving services [Mendes et al., 2015].

- Smart Home Energy Management System (SHEMS) works for reducing electricity bill of consumers and flatten demand peaks [Hu et al., 2013].
- Designing a power security system based on stream data mining to ensure the household electricity appliances [Peruzzini et al., 2013].
- Renewable Energy Management Driven Smart Home: This include the use of solar and wind power including other renewable sources with an intelligent power consumption mechanism to ensure the communication between smart home appliances and smart grid. [Mendes et al., 2015]
- Smart Meter: Smart meter opens up the opportunity to lower energy consumption in cooperation with Smart Grid. The details about smart meter is discussed in chapter 4 “Smart Meter”.

### 3.5.2 Health Care

The use of advanced technologies in our homes lead us to various opportunities in case of health care. This application area was the primary interest of researchers for addressing the problems of the elders related to health, loneliness, disability, cognitive limitation etc. Elder care is an area of critical needs as a result of increasing aging population growth. The simple devices with sensors that can be used as smart healthcare technologies are blood glucometers, oximeters, blood pressure monitors, etc. The devices deliver standardized output for specific physiological conditions to smart application and software for further processing. Moreover, continuous monitoring of such parameters as diabetes, hypertension, and cardiac diseases could allow for constant control of elderly people’s physical conditions and provide valuable information since these chronic diseases are more common among this age group [Dawadi et al., 2013].

### 3.5.3 Entertainment

Today, our personal and social life is reflecting our images and sounds. We deal with these elements from any place in any time and store in any device digitally. Home theater and multimedia room, smart remote, distributed audio/video systems are the parts of this

application area. Lighting, background music, advanced user interface such as voice command, gestures, face recognition, scheduling task etc. are the content that are increasing the level of automation and comfort.

Some notable Advanced Multimedia Services are:

- A main promoter for the evolution of future Home Area Media Networks (HAMNs) is the emergence of beyond High Definition (HD) media formats. These formats oblige far greater demands on networks for low latency, high-capacity and rigorous Quality-of-Service (QoS) in comparison to other existing formats. Furthermore, their data-intensiveness will require real-time interconnection of multiple, probably distributed, high performance media processing and storage resources [Mendes et al., 2015].
- A framework for resource allocation in a Cognitive Digital Home (CDH) with a multiplicity of radio access technologies (RAT) such as cognitive radios and legacy radio devices supporting heterogeneous applications is developed by [Li et al., 2013].

Feel@Home project envisions an environment where people can access his own multimedia contents from any place because having the facilities of local and remote access to multimedia home library and also sharing content with relatives and friends. Linking our digital personal life with the capabilities of a smart, digital home is the main objective of this project [Rodrigo et al., 2012].

### 3.5.4 Security and Surveillance

Introduction of smart home technologies contribute a lot to the safety and security for its inhabitants. Safety refers to the detection of abnormal situations inside smart home, for example, fires, floods, accidents (e.g. falls of disabled or elderly), whereas security refers to the detection of malicious behaviors with respect to smart home, for example, burglary, unauthorized access etc. For the detection, signaling and response to such safety or security violation situations, Smart home are equipped with sub-systems for movement sensors, video surveillance, remote monitoring, alarming, and emergency response [Costin et al., 2013].

## 3.6 Advantages of Smart Home

Every advancement in technology enhances their impressive capabilities and makes our life easier. Smart home is now one of the most significant new trends in digital innovation after smartphone. Transition to a smart home has eminent benefits. Some of those are listed below.

### 3.6.1 Safety

Advance security system in smart home consist of surveillance cameras, motion detectors, alarms, automated door lock, and a link to the local police station or a private security company. Products developed with similar functionalities are: Nest Cam (chapter 6.4.2), Canary (chapter 6.4.13), Honeywell Tuxedo Touch (chapter 6.4.14). Smart homes also use key cards, fobs or fingerprint identification in place of conventional locks to provide stronger security. Kevo kwikset (chapter 6.4.11) is one of the similar products. List of safety features are:

1. Owners can monitor the comings and goings of guest, home delivery and can be alert when suspicious activity is detected (for example, see the Nest Cam in Chapter 6.4.2).
2. Doors can be locked and unlocked, security systems armed and disarmed, cameras monitored from phone or remote devices, provide a safer and more secure environment to the user. Instant notification can be send to user's phone by text message, telephone or e-mail if intruders break or fire alarm starts.
3. Alerts can be sent to one's phone when members of his/her family leave their house, and it is possible to keep track of them where they go after they leave. This is a very convenient system for children and elderly persons who need more care and attention.
4. Home automation systems has facility to view live video and also store IP camera images on a secure server, which may be used as evidence for the police - if required.
5. Trigger lights when the smoke alarm goes off. The best home automation systems allow to turn all the lights on around the house when smoke is detected.
6. Keyfob remotes and lots of smartphone Apps are available to activate lights as user approaches near home. For example, Kevo kwikset (chapter 6.4.11).
7. Flood sensor with home automation controller will enable notifications on smartphone of flooding events as they start to occur. Water leakage detector on the floor works as the same to avoid overflow. SmartThings from Samsung (described in chapter 6.4.6) developed Water Leak Sensor along with their other smart products.

### 3.6.2 Accessibility

1. Smart home technology can greatly increase the quality of life of elderly or disabled residents. Voice-command systems can do things like control lights, lock doors, operate a telephone, multimedia or use a computer. Homes security products from Canary (in 6.4.13) and Honeywell Tuxedo Touch (in 6.4.14) also provide this extended accessibility services.
2. Setting up automated systems or a schedule for activities like lawn care removes unnecessary stress from the lives of individuals.

### 3.6.3 Convenience

Convenience is one of the biggest reasons that people are interested to build and purchase smart homes.

1. Remote access to systems including heating and cooling systems (Nest thermostat describe in chapter 6.4.1), intercoms, music and multimedia devices throughout the home give the peace of mind for living in a home.
2. Homeowners can enjoy video and music from any place in home.
3. Video intercoms make it easy to communicate with others in the home or visitors at the door whether user in home or not. Having the convenience of accessing other persons in home remotely can be a real time saver.
4. Remote control of lighting with mood enhancing settings make the user feeling better. Philips Hue Product (described in chapter 6.4.5) and Belkin WeMo (described in chapter 6.4.4) have the options to control lights other household products.
5. Control appliances remotely is a great advantage for busy people.
6. Remote security arm and disarm system reduce the extra caution for home.

### 3.6.4 Energy Efficiency

The prominent advantage of smart home is energy efficiency.

1. Smart home technology allows appliances to work with the least amount of energy needed. LG Smart ThinQ appliance (chapter 6.6.8) can detect when power consumption in area is lowest.



2. Automated thermostat can recognize the presence of person and can be set to let the indoor temperature drop during day before returning of the residents in home. All of these automated tasks, along with modern, energy-efficient appliances, can save huge amount of electricity and money (See Nest Thermostat in chapter 6.4.1).
3. Smart devices can be synced up to household appliances with real-time energy information. This helps the appliances to operate in the most cost-effective way. For example, dishwasher may run at 2 am because this is the best time for the lowest price. Whirlpool 6th Sense Live washing machine works like that (described in in chapter 6.4.3).
4. Certain faucet technology reshapes the water droplets giving a better and more fulfilling shower experience while using less water.
5. Lights can shut off automatically when no one is in a room.
6. Remote system to switching on and off lights provides the facility to stop standby consumption and save energy. ‘Smart things’ collection of smart devices can do those operations (in chapter 6.4.6), others are, Skylink Home Control Receiver (in chapter 6.4.7),

### 3.6.5 Cost Effectiveness

1. Smart home can also be a prosumer by using solar power, that can save cost as well as becomes more self-sufficient with energy production.
2. It was reported in a study done by the US Environmental Protection Agency that users of smart home technology for thermostat control alone saved anywhere from 10%-30% on their energy bill [Malinick et al., 2012].

### 3.6.6 Resale

Smart Home has the potential to sell for much more than comparable homes with conventional technologies. Automating a home can be a worthwhile investment in increasing its market value and attracting possible buyers in the future.

# Chapter 4

## Smart Meter

### 4.1 Introduction

The Smart Meter that we focus on here is a next generation electricity meter. There exist also smart meters for gas or for water, which have many functionalities in common with the Smart Electricity Meter, like two-way communication with the provider, Internet enabled and control capabilities. Smart Electricity Meter (which we will just call Smart Meter in the rest of this thesis) is one of the system components of the smart grid which has an important use in the new services and functionalities of the smart grid. This electronic device consists of a stand-alone embedded system that enables two-way communication between the meter and the central system. It is responsible for recording consumption of utilities such as home appliances, office building heating, factory equipment, etc.

We focus on Smart Meters installed in Smart Homes, and thus look at appliances usually found in private homes (but some of these can also be found in buildings or shops, like refrigerators, or heaters). Electricity consumption is recorded in intervals of one hour or less, and the data is sent back to the utility provider for monitoring and billing purposes, at least on a daily basis. Currently, in the beginning phase of the smart grid, the stated purpose of the smart meter that one usually finds advertised, e.g., in Norway by the elhub.no project or by the electricity companies, is for more precise, and thus better and cheaper billing of customers. Another purpose, sometimes uttered as a desired future use of the smart meter is to control peaks of electricity; but this would require the smart meter to also be a control device, which is far from current industrial endeavors, or at least to communicate desired commands to a home gateway control, maybe through an API that shows the current electricity price. But what is less discussed publicly is the amount of private data the smart meter would produce, and how this data could be used by the electricity company in a “big-brother” business model that we nowadays see on the Internet adopted by companies like Google or Facebook.

This advanced energy meter obtains information from the end users' load devices and measures their energy consumption which is then provided to the utility company or to the system operator. Smart meters may have the built-in ability to disconnect-reconnect certain loads remotely. In the different setting of the “smart-buildings”, smart meter can be used to monitor and control the users' devices and appliances to manage demands and loads [Zheng et al. 2013].

Electricity demand is increasing with the growth of population. Governments around the world and researchers are concerned about environmental consequences and focus on the reduction of carbon emissions by increasing the utilization of renewable energy sources in the power chain. The existing grids are under pressure to match the increasing demand of power and are more and more unable to make a stable and sustainable supply of electricity. The drive towards Smart Grid is intended to meet the increasing global demand of electricity.

Smart Meter is a common form of Smart Grid Technology. It is an integral part of the Smart Grid infrastructure in data collection and communication. A Smart Grid monitors electricity delivery and tracks power consumption with Smart Meters that transmits energy usage information to utilities via communication networks [Edison, 2011].

## 4.2 Scheduling

Smart meter is developed to give precise billing of electricity depending upon the time of use and in a smart grid the unit price of electricity will be less during off peak hours. In such case, users need to know everyday pricing profile of electricity in advance in the same day to find out the suitable time to use electricity in cheaper rate i.e. “scheduling” the use of electricity. Otherwise smart meter will be a burden for the user and be a one sided profit making business for utility provider.

Presently we can see the day-ahead electricity price at Nord Pool [Nord Pool, 2016]. But this is not utilized in consumer level. Household user provides the meter reading (consumption in kilowatt hour) on a monthly basis. And the price of electricity is adjusted per month. But with the introduction of smart grid and smart meter when providers are going to make the price list

as per 30-minute window or less and the price will be variable, the user obviously need to take a closer look for his usage.

For the consumers, manually scheduling everyday use of electricity in various purpose is not practical. To gain full spectrum of benefit from smart meter, one need to do schedule the electricity usage as much as possible in high precision. Therefore, the scheduling responsibility can be rendered to the smart meter or to a smart device,

1. Smart meter gets the power profile of all the household devices and their preferred usage patterns. Smart meter can get price information from smart grid and schedule electricity usage.
2. Consumer can take the responsibility for scheduling the electricity usage by using intelligent devices that can learn from users' behavior and that is programmable and can be scheduled on user's choice.

## 4.3 Evolution

The commercial use of electricity spread around 1880s and necessitated the measurement of consumption of electricity to bill the consumers. With a short span of testing different types of electric meters, the traditional induction meter for alternating current we use now with a moving disc was introduced in 1890s [Electricity Meter, 2016]. Since then there is hardly any changes in the way we measure the power. For about a century the conventional metering technology persisted. But with the advent of information communication technology and its quick integration in our daily life along with various environmental needs we need to think of a new way for metering our usage of power. This results in further improvements of traditional meters. Researchers are introducing innovative features and technology over the traditional meter transforming it into a smart meter.

### 4.3.1 Traditional Meter

Traditional utility measurement devices are placed into user's premises. These can be analog or digital. A traditional electric meter shows the user's household overall electric consumption in kilowatt hour (kWh) using analog rotating numbers or on a digital screen. A meter reader person comes at regular intervals, e.g. monthly, to register the current consumption to prepare the bill. In some modern systems the user can register the usage in the provider's web page or by using a mobile app.



Figure 4.1: Traditional Electric Meter

### 4.3.2 Automated Meter Reading (AMR)

Automated Meter Reading (AMR) is the technology of automatically collecting data from energy metering devices, and transferring those data to a central database for billing, troubleshooting and analyzing. AMR was established in 1990s, that saved utility providers the expense of gathering data manually from each physical location by reading the meters [Edison, 2011]. Additionally, billing became based on real-time consumption rather than on estimates based on past consumption. This timely information coupled with analysis helped both utility providers and customers better control the use and production of electric energy. These techniques are similarly applied to gas usage or water consumption.

An AMR meter can be read remotely, but reading the meter is the only remote function supported. The benefits of AMR metering are restricted to reducing meter reading costs to the supplier and the ability to bill the customer based on actual meter readings.

The first generation of AMRs transmitted information back to the utility company on monthly basis. The second-generation of smart meters could transmit daily and some even hourly.

### 4.3.3 Advanced Metering Infrastructure (AMI)

Recent smart meter technology known as Advanced Metering Infrastructure (AMI) is the third-generation of smart meter, which has run over two generations of AMRs. *Arc innovations* was the first company to introduce Smart meters in New Zealand in 2005 [Arc, 2016]. Now, the third-generation of smart meters allow two-way communication, on demand. AMI is the combination of electric meters with two-way communication technology for information, monitor and control.

Therefore, AMI extends AMR providing utility providers with the ability to extract detailed information on power usage of individual homes, including “time-of-use”, pricing information, demand-response actions, and remote monitoring and services control. On the other hand, consumers can control their usage of energy as well.



Figure 4.2: Example of a smart meter based on Open Smart Grid Protocol (OSGP) [ETSI, 2012] in use in Europe that has the ability to reduce load, disconnect-reconnect remotely, and interface to gas and water meters. Picture is taken from [Smart Meter, 2016].

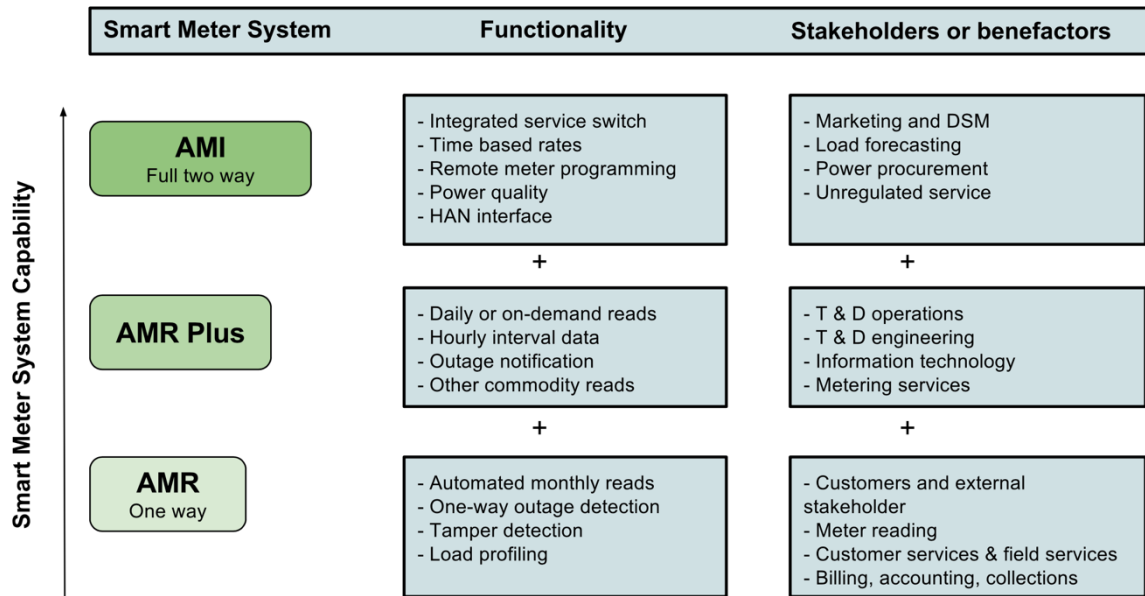


Figure 4.3: Smart meter technology evolution [Edison, 2011]

AMI creates a two-way communication network between smart meters and utility systems. It integrates advanced sensors, smart meters, monitoring systems, computer hardware, software, and data management systems, to enable the collection and distribution of information between meters and utilities. This also allows and encourages consumer participation in managing energy consumption [Gungor et al., 2012], [Paudyal et al., 2011].

The choice of the communication technology for AMI depends on the coverage and the number of customers per area, the availability of the Internet connection, the expected energy efficiency, scalability, the required data rate, and the expected communication delay. Figure 4.4 shows some possible communication patterns from residences to data collector units and from data collector units to meter data management systems in the AMI [Gungor et al., 2013].

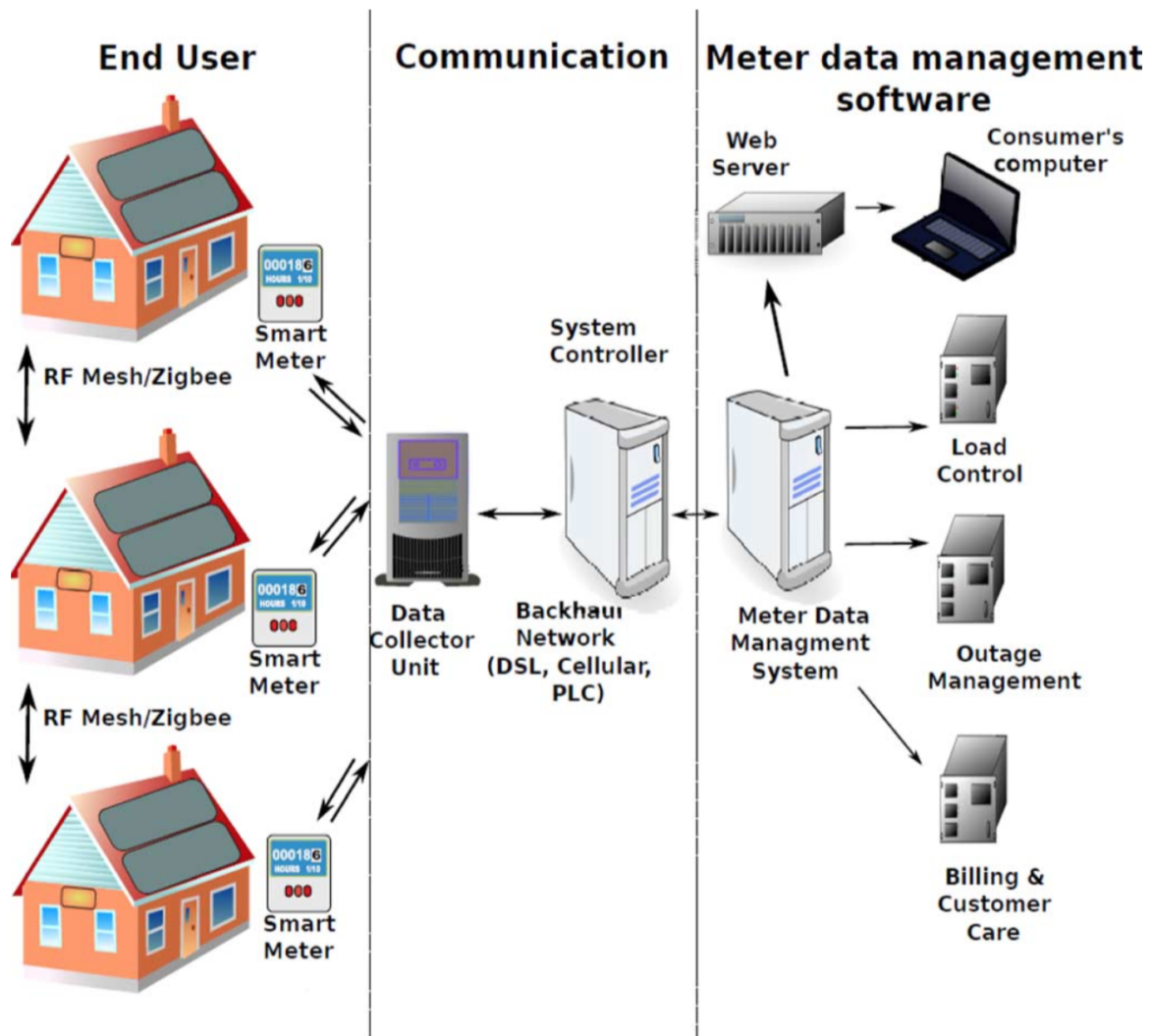


Figure 4.4. Detailed communication architecture of an AMI [Gungor et al., 2013]

AMI does not only mean the physical deployment of smart meters in a smart grid, it also incorporates a complicated communication network and IT infrastructure, including many systems, such as a meter data management system, that handles the huge amount of data and manages the raw data to create meaningful information and messages for customers, assisting them in using energy intelligently. Hence, consumer awareness, interactive services for regulation of energy demand, avoidance of electricity-related frauds, and more timely and precise billing services are the advantages of AMI systems [Benzi et al., 2011].

AMI technology was introduced while finding out the challenges of Smart Grid deployment and is considered as the foundation of Smart Grid [Molina et al., 2010]. Here we concentrate our discussion on Smart Meter which is one of the important component of AMI.



## 4.4 Smart Meter Technology

Smart Metering technologies consist of several different technical components which may vary according to the specific market conditions in different countries. But most of them include the following common essential features [ESMIG, 2016]:

1. Accurate measurement and transmission of electricity (gas, water, or heat) consumption data.
2. Provision of a two-way information gateway and communication infrastructure between the meters and relevant parties and their systems, for:
  - raising awareness and empowering the consumer through delivery of actual consumption data;
  - improving Customer Relationship Management (CRM) and services, including automated billing/invoicing based on detailed metering data;
  - managing energy networks/grids better by shifting or reducing energy consumption, e.g. through Demand Side Management (DSM). DSM is the modification of consumer demand for energy through various methods such as financial incentives and behavioral change through education.
  - enabling new energy services for improving energy-efficiency;
  - encouraging decentralized, micro-generation of energy, thus transforming the consumer into an energy producer (“Prosumer”).

While Smart meter addresses some of the initial challenges of smart grid, it also brings in the new question of to what extent the meter will be involved with home applications and household devices. The survey and analysis in this thesis investigate several services for the homeowner and customers in relation to the Smart Meter.

Smart meter systems operate through a simple overall process albeit varied in technology and design. Smart meters collect data locally and transmit it via a local area network (LAN). The data transmission interval can be as often as 15 minutes or as infrequently as daily, according to the intended use of the data. The collector retrieves the data and utilize it for analytic and billing purposes. Not all data is useful at a time. Data is transmitted via a Wide Area Network (WAN) to the utility central collection point for processing and can used by business applications. The communications path is two-way, hence signals or commands can be sent

directly to the meters, customer premise or distribution device. Figure 4.5 below shows the basic architecture of Smart Meter System operations.

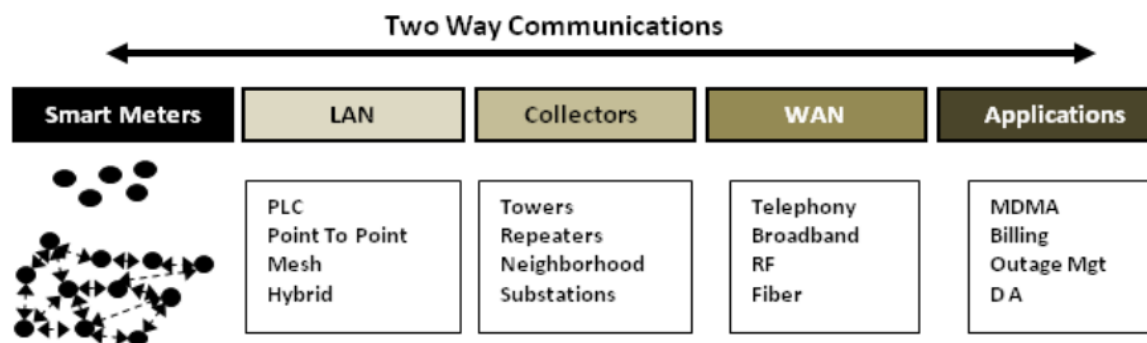


Figure 4.5: Smart Meter System basic architecture

#### 4.4.1 Network Communication Technologies for Smart Meters

There are two basic categories of Smart Meter Systems technologies, depending on their network communication topologies. They are Radio Frequency (RF) and Power Line Carrier (PLC). Utility companies select between these two based on their advantages and disadvantages with respect to their demographic and business requirements [Edison, 2011].

**i) Radio Frequency (RF):** RF Smart Meter measurements and other data are transmitted by wireless radio from the meter to a collection point. The data is then delivered by various methods to the utility data systems for processing at a central location. The utility billing, outage management, and other systems use the data for operational purposes.

RF technologies are usually of two different types:

- **Mesh Technology:** The smart meters talk to each other (hop) to form a LAN cloud to a collector. The collector transmits the data using various WAN methods to the utility at a central location.
- **Point to Point Technology:** The smart meters talk directly to a collector, usually a tower. The tower collector transmits the data using various methods to the utility central location for processing.

**ii) Power Line Carrier (PLC):** Smart Meter measurements and other data can be transmitted across the utility power lines from the meter to a collection point, usually in the distribution substation feeding the meter. Some solutions have the collection point located on the secondary side of a distribution transformer. Advantage with PLC is that it uses the existing

wiring structure to transmit data, thus saving money and being able to work on a longer distance than RF range. The challenge with PLC is to interface with distribution automation devices. Moreover, PLC has also low bandwidth and throughput.

## 4.5 Types of Smart Meters

On the basis of market demand, many companies have produced smart meters following different standards [IEC, 2016]. According to the different purposes, these meters are categorized into two applications: (i) residential smart meters and (ii) commercial and industrial smart meters. [Zheng et al., 2013]

## 4.6 Features of Smart Meters

We have already briefly discussed about what are the main changes in smart meter compared to the traditional meter and how they have evolved. Here is a list of widely accepted characteristics of the evolving meter that make it smarter than its predecessor [Conserve Energy, 2016].

### 4.6.1 Two Way Communication

A main feature of smart meters in AMI is that it can be remotely reconfigured and instructed, as it is remotely read. Some actions can be performed remotely in near real time, for example:

- On demand meter readings: Reading a meter in near-real time in response to a customer phoning the call center, for example.
- Change of tariff: Changing tariff rates and tariff structures in response to a supplier-instigated price change or a customer electing to move to a new, innovative smart tariff, for example.
- Change of payment method: Switching between credit and prepayment modes.
- Change in read frequency: Changing the consumption read interval from, say, monthly to daily, or even half-hourly.
- Load limiting/shedding: Remotely controlling an agreed portion of a customer's consumption in order to help balance generation and demand or as a means for preventing customers from running up massive debts while still having access to energy.

- Tamper alerts: Automatically detecting, notifying, and responding to attempts to tamper with the meter.
- Disablement/enablement: Turning supply on and off in response to, say, a tamper alert.
- Messaging: Communicating directly with the customer via the smart meter and Home Display Unit (HDU).
- Firmware updates: Remotely updating the software embedded within the smart meter in order to fix bugs or add new functionality.

## 4.6.2 Details About the Consumption

Smart meters are capable of recording user consumption in far more detail compared to conventional meters. Consumers get easily their time of energy usage and quantity. Moreover, the suppliers are able to give suggestions to their customers on how to optimize their usage of electricity, thus contributing to a greener environment too.

Time of Use (ToU) is a term that refers the ability to record when consumption takes place rather than just how much is consumed. So, Time of used consumption can be recorded down to hourly, half hourly and lower. ToU based lifecycle tariffs may encourage the consumer to schedule consumption in a slot when cheaper rates are available due to observation facilities during the day.

By installing smart meter in home one can use the new features of smart meter to improve the way of consumption and obtain more control and efficiency to manage energy usage behavior.

Since smart meter provides accurate and near real time information about consumption of energy, it is easy for the users to observe their consumption habit. In consequence, a user can control energy consumption to save energy expenses.

## 4.7 Smart Meter System Benefits

Household smart meters that measure power consumption in real time at fine granularities are the foundation of a future smart electricity grid. Recently, there has been an increasing focus

on “greening the home” using a combination of fine-grained power consumption monitoring, smart appliances, and renewable energy sources, e.g., rooftop solar panels. A home with such renewable energy sources is called a “prosumer” because it both consumes energy from the grid in the standard way, but it can also produce energy and when surplus is available it can provide it back to the grid. The trends have led to the design of smart electric grids that provide support for various technologies, including net metering, demand response, distributed generation, and microgrids. An important component of a future smart grid is the installation of smart (or net) meters in homes that support both dynamic pricing and a two-way flow of electricity and information between homes (or microgrids) and the larger grid [Molina et al. 2010].

Smart meters are a key component in the smart grid system that can help utilities balance electricity demand, reduce expensive peak power use and provide better deals for consumers by allowing them to see and respond to real-time pricing information through in-home displays, smart thermostats and appliances [EESI, 2009].

The benefits of Smart Metering installations are numerous for many different stakeholders of the systems. The table 3.1 below mentions some of the major benefits for utility stakeholders.

Table 4.1: Benefits of smart meter for the stakeholders [Edison, 2011]

<b>Stakeholder</b>	<b>Benefits</b>
Utility Customers	<ul style="list-style-type: none"> <li>● Better access and data to manage energy use</li> <li>● More accurate and timely billing</li> <li>● Improved and increased rate options</li> <li>● Improved outage restoration</li> <li>● Power quality data</li> </ul>
Customer Service & Field Operations	<ul style="list-style-type: none"> <li>● Reduced cost of Metering reading</li> <li>● Reduced trips for off-cycle reads</li> <li>● Eliminates handheld meter reading equipment</li> <li>● Reduced call center transactions</li> <li>● Reduced collections and connects/disconnects</li> </ul>
Revenue Cycle Services - Billing, Accounting, Revenue Protection	<ul style="list-style-type: none"> <li>● Reduced back office rebilling</li> <li>● Early detection of meter tampering and</li> </ul>

	<ul style="list-style-type: none"> <li>theft</li> <li>● Reduced estimated billing and billing errors</li> </ul>
Transmission and Distribution	<ul style="list-style-type: none"> <li>● Improved transformer load management</li> <li>● Improved capacitor bank switching</li> <li>● Data for improved efficiency, reliability of service, losses, and loading</li> <li>● Improved data for efficient grid system design</li> <li>● Power quality data for the service areas</li> </ul>
Marketing & Load Forecasting	<ul style="list-style-type: none"> <li>● Reduced costs for collecting load research data</li> </ul>
Utility General	<ul style="list-style-type: none"> <li>● Reduced regulatory complaints</li> <li>● Improved customer premise safety &amp; risk profile</li> <li>● Reduced employee safety incidents</li> </ul>
External Stakeholders	<ul style="list-style-type: none"> <li>● Improved environmental benefits</li> <li>● Support for the Smart Grid initiatives</li> </ul>

## 4.8 Security and Privacy

Since smart meter process huge amounts of consumer data, security issues with smart meters grow substantially. It is important to keep the integrity of the data in both ways, e.g. from the user to the central infrastructure for correct billing. By analyzing smart meter reading it is possible to get a consumer profile with high accuracy. Examples range from how many people are living in the house, their daily routine, type of appliances they are using, when leaving home, security and alarming systems, and to interfere special condition such as medical emergencies and new born baby etc. [Molina et al. 2010], [Murrill et al. 2012].

In the smart grid, smart meter can act as a hub to connect and control the internal smart home appliances. In that case it is very critical to have proper security measures built into the smart meter to protect the smart home devices from improper control by an attacker.

## 4.9 Conclusion

Smart meter is the next generation energy measurement device that meets the future environmental and technical challenges. Most of the countries in Europe, America and Oceania are going to adopt smart meters by 2020s. European Union, for example, has in recent legislation decided on such dates for all EU countries adopting Smart Metering technologies. Smart Meter usage will entice consumers to manage their consumption better and reduce usage leading the way to improved service level through richer billing information. Moreover, collaborating with the smart grid, Smart Metering can be a key weapon in the fight to reduce the effect of climate change. Beside the technical challenges it will help governments to implement liberalization of energy markets. However, Smart Metering has challenges, mainly related to security and privacy which is now the focus point of the researchers and many solutions are proposed to meet such challenges.

# Chapter 5

## Smart Grid

### 5.1 Introduction

Technology today is not just a part of our life but in many ways it has transformed our way of life. In case of energy supply infrastructure, the combination of information technology and power transmission can be a source of great benefit in our daily life as well as for the whole power industry. Therefore, we are looking for a more sustainable and environment friendly energy solutions for the future.

The Grid refers to the transmission systems for electricity, also called the nation's electric power infrastructure. The grid includes transmission wires, substations, transformers, switches and much more. An electricity grid consists of an interconnected network of synchronized electrical power providers and consumers. They are connected by transmission and distribution lines and operated by one or more control centers. The transmission lines consist of generating stations that produce electrical power and high-voltage transmission lines that carry power from distance sources to demand centers. Distribution lines connect individual customers to the transmission grid.

The present electric grid infrastructure was built around 1890s [Edison, 2016]. This century old technology becomes exhausted to cope up with our ever growing need and high requirement of electricity. As population growth is faster hence the demand for electricity but current one directional flow of electricity is unable to make up the demand. Now we use a lot more electric appliances in every home than we have used a few decades ago. And alternative to meet the power demand can be to add more power stations in order to handle the blackouts, sabotage etc. But most of the people do not want to get power station nearby they are living. The major causes of redesign of the traditional grid are global warming, an increase of carbon emission, and growing world population with power demand. Governments and energy utility companies have taken steps towards renewable energy usage



and their integration within the existing power transmission and distribution systems to reduce greenhouse emission, increase reliability and reduce energy in the delivery process of electricity [Gungor et al. 2013].

In future, we need a new kind of electric grid with intelligence that is able to handle digital and computerized equipment and technology dependent on it as well as automate and manage the increasing complexity and needs of electricity. Increasing reliability and security, reduce energy in the delivering process and reduce greenhouse emission are some significant required features. Therefore, smart grid evolved from traditional electricity grid to satisfy the power supply in optimal and efficient way as demand increases.

## 5.2 Evolution

Smart Grid (SG) is a recent concept that combines information technology and traditional electric grid. The application of intelligent and advanced digital technology into the existing electrical power network results the innovation of Smart Grid. Smart Grid includes a variety of operational and energy measures. The components and definitions of Smart Grid varies in different implementation concepts. The next definition is taken from [Fang et al. 2012], slightly changed.

**Definition:** The Smart grid can be regarded as the electricity distribution system that uses information, two-way, cyber-secure communication technologies, and computational intelligence in an integrated fashion across electricity generation, transmission, substations, distribution and consumption to achieve a system that is clean, safe, secure, reliable, resilient, efficient, and sustainable. This description covers the entire spectrum of the energy system from the generation to the end points of consumption of the electricity.

Smart grid is an application of information technology, a variety of operational and energy measures, tools and techniques including smart meters, smart appliances, sensors, real time communication, software, remote control equipment, renewable energy resources and energy efficiency techniques to improve grid reliability and efficiency as well as optimize the power distribution.

Smart grid adds four capabilities to the national electricity distribution system. These are monitoring, analysis, control, and communication, and are meant to maximize the throughput of the system while reducing the energy consumption [NEMA, 2016]. This modern infrastructure and technology together with the above new capabilities makes the electricity grid “smart”.

The development of smart grid is not intended to replace the present electricity grid, but it is a modern enhancement of the existing grid with new infrastructure and technology that implement self-monitoring, self-healing, two-way exchange of energy and information, variable pricing, adaptive and islanding, distributed generation, sensors throughout, pervasive control, etc. Table 5.1 gives a brief comparison between existing grid and smart grid.

Table 5.1: A brief comparison between the existing grid and the smart grid [Fang et al., 2012]

<b>Existing Grid</b>	<b>Smart Grid</b>
Electromechanical	Digital
One-way communication	Two-way communication
Centralized generation	Distributed generation
Few sensors	Sensors throughout
Manual monitoring	Self-monitoring
Manual restoration	Self-healing
Failures and blackouts	Adaptive and islanding
Limited control	Pervasive control
Few customer choices	Many customer choices
One rate at all times	Variable pricing

## 5.3 Characteristics of Smart Grids

Smart grids have different implementations depending on the requirements which may vary from region to region. Still there are some basic characteristics that are common to most smart grid architectures, according to [NIST, 2014].

- Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid
- Dynamic optimization of grid operations and resources, with full cyber security
- Deployment and integration of distributed resources and generation, including renewable resources
- Development and incorporation of demand response, demand-side resources, and energy efficiency resources
- Deployment of “smart” technologies for metering, communications concerning grid operations and status, and distribution automation
- Integration of “smart” appliances and consumer devices, which is the focus of this thesis
- Deployment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air conditioning
- Provision to consumers of timely information and control options
- Development of standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid
- Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services.

The above characteristics ensure the delivery of electricity from producers to consumers, control two-way flows of energy and information that creates an automated and distributed advanced energy delivery network which make the performance of the electric network more reliable and controllable. The next two figures are meant to illustrate the main characteristics of the Smart grid and how they differ from the traditional grid [Texas Tech, 2012].

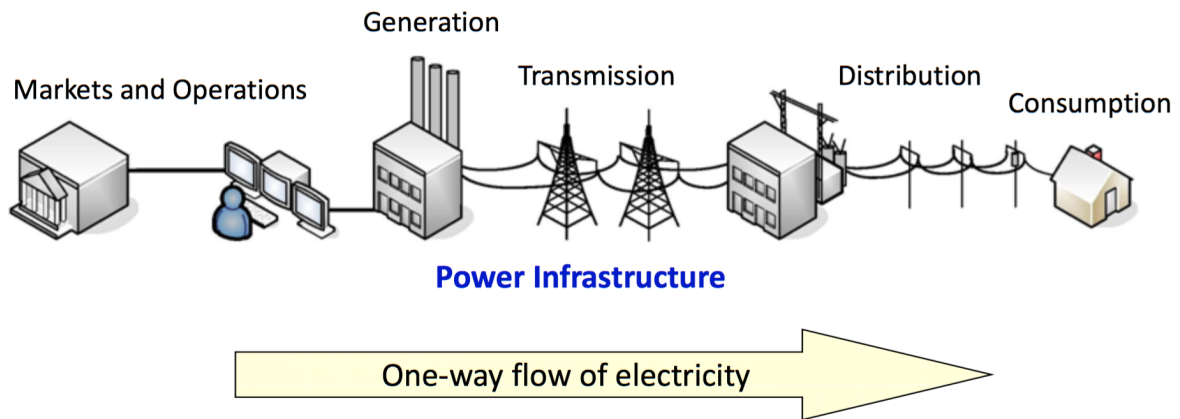


Figure 5.1: Traditional Power Grid.

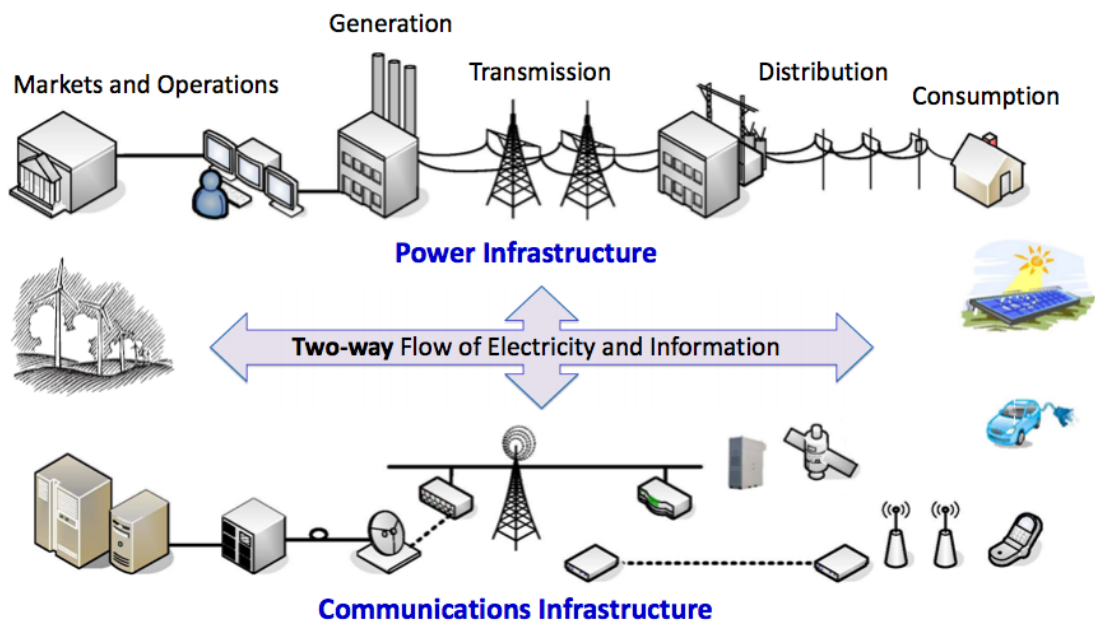


Figure 5.2: Concept of Smart Grid.

## 5.4 Technology

According to [Fang et al., 2012], Smart Grid is a loose integration of complementary components, sub-systems, functions, and services under the pervasive control of highly intelligent management-and-control systems. From a technical perspective, one can identify three major systems in Smart Grid:

1. **Smart infrastructure system** includes the energy, information and communication infrastructure underlying of the smart grid. It supports:

- advanced electricity generation, delivery, and consumption;
  - advanced information metering, monitoring, and management; and
  - advanced communication technologies with the purpose to allow real-time control, information and data exchange to optimize system reliability, asset utilization and security and privacy.
2. **Smart management system** is the subsystem of smart grid that provides advanced management, control services and functionalities. Smart grid is based on smart infrastructure which requires the development of new management applications and services. The management system works with demand profile shaping, energy loss minimization by using advanced management methods and tools, machine learning, game theory, auction schemes, etc.
  3. **Smart protection system** is the subsystem of smart grid that provides grid reliability analysis, failure protection including prediction, prevention, identification, diagnosis and recovery and security and privacy protection services. For information transmission, metering and measurement, the crucial point of implementing smart grid are security and privacy. The protection systems is composed of two parts: (1) system reliability and failure protection and (2) security and privacy.

Department of Energy (DoE) of the United States lists five fundamental technologies that will drive the Smart Grid [Fang et al., 2012].

1. Integrated communications, connecting electronic components to get information and control of every part of the grid in real time. Metaphorically, we could say that we want to make every part of the Smart Grid both ‘listen’ and ‘talk’.
2. Sensing and measurement technologies, to provide faster and more accurate response information of each important part of Smart Grid, such as remote monitoring, real time thermal rating, electromagnetic signature analysis, real-time pricing and demand-side management.
3. Advanced components, to apply the latest research in superconductivity, storage, power electronics and diagnostics. Here we could mention: flexible alternating current transmission system devices, high voltage direct current, first and second generation superconducting wire, high temperature superconducting cable, distributed energy generation and storage devices, composite conductors, and “intelligent” appliances.
4. Advanced control methods, to monitor essential components, enabling rapid diagnosis and precise solutions appropriate to any event. There are three categories for

advanced control methods: distributed intelligent agents, analytical tools, and operational application.

5. Improved interfaces and decision support information systems reduce the complexity of Smart Grid to make the work of both operator and manager more efficient and easy, thus focusing on human decision-making.

## 5.5 Smart Grid Framework

The power grid infrastructure contains a large number of interconnected components: generators, power transformers, distribution feeders that makes the infrastructure very critical [Morante et al., 2006]. Smart grid refers to the next generation power grid. This new approach of electricity distribution and management is upgraded by incorporating advanced two-way communications infrastructure and pervasive computing capabilities for improved control, efficiency, reliability and safety. A smart grid delivers electricity between suppliers and consumers using two-way digital technologies that requires sustaining power flows between components, sophisticated computing and information technologies as well as business applications. It controls intelligent appliances at consumers' home or building to save energy, reduce cost and increase reliability, efficiency and transparency [Yan et al., 2013].

In a smart grid framework there are four kinds of infrastructures that comprise the framework. Figure 5.3 depicts the hierarchical structure of the infrastructure. The energy infrastructure represents the physical infrastructure for energy generation, transmission, and distribution; the communication infrastructure is responsible for transferring the critical information through the network; Information Technology provides modeling, analysis, web visualization, and commercial transactions; potential applications are responsible for distinguishing the use cases of infrastructure usage. The communication infrastructure performs a critical role in the overall smart grid framework [Gungor et al., 2013].

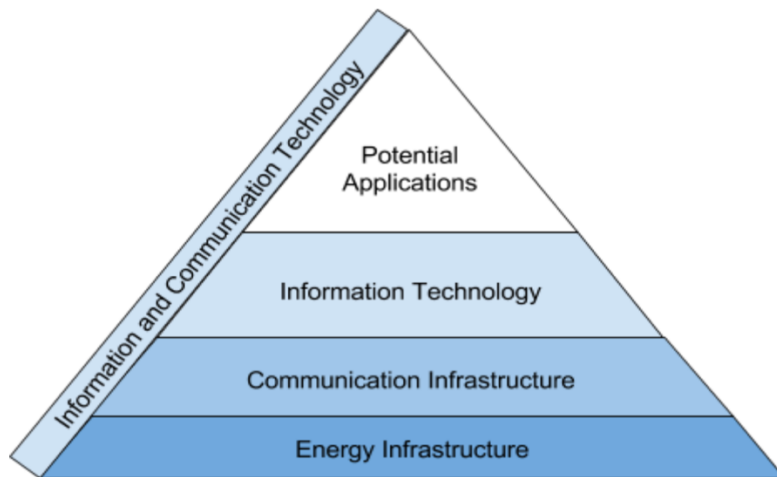


Figure 5.3: Hierarchical structure of the smart grid infrastructure.

Figure 5.4 illustrates all the different components in a smart grid infrastructure from energy infrastructure to potential application.

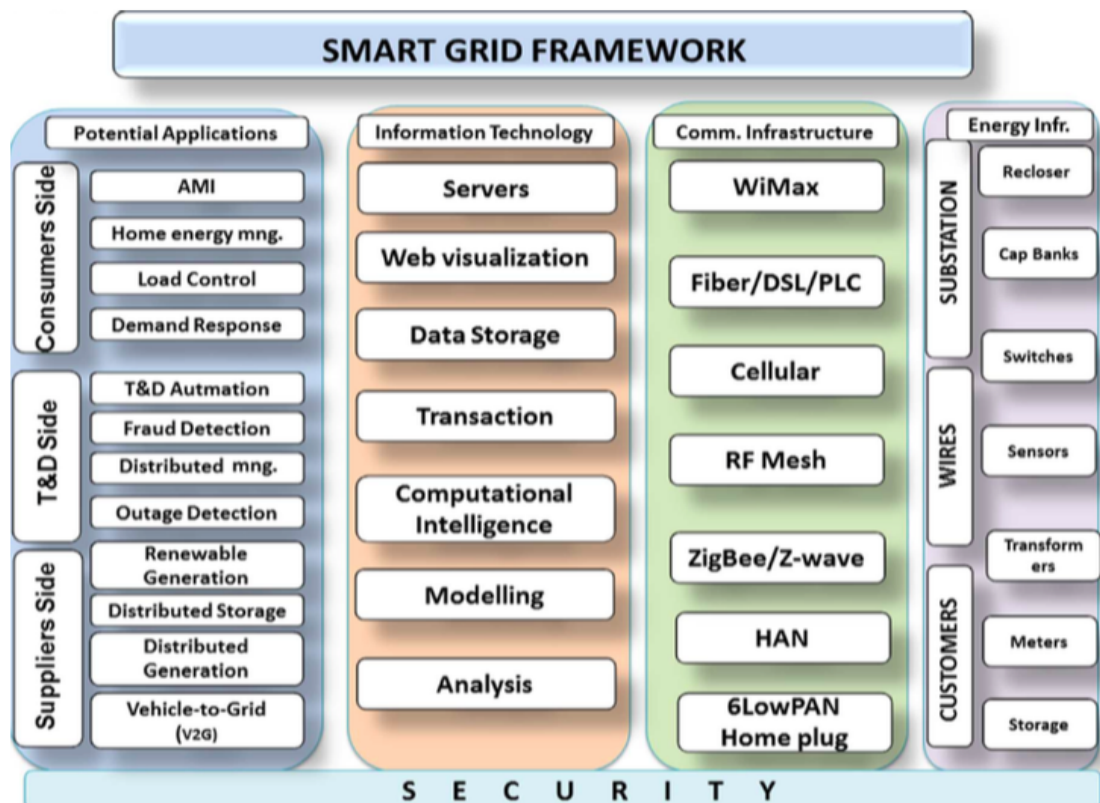


Figure 5.4: SG framework depicting the potential applications, information technology, communication, and energy infrastructure of the overall system [Gungor et al., 2013].

The Smart Grid concept aims to achieve a sophisticated system by integrating information and communication technology infrastructure to the existing power system infrastructure. A Smart Grid can be considered as a data communication network that achieves flexible, seamless inter-operation abilities among different advanced components of the system for efficient utilization of the energy with the support of specific power management hardware devices. On the other hand, smart grid end to end architecture is comprised of three main layers: the SG application layer, the power layer and the communication layer [Gungor et al., 2013].

- 1) **Application Layer:** It includes advanced applications providing interoperability among them. Demand response management, outage management, advanced metering infrastructure (AMI), asset management, and fraud detection are among the most considered.
- 2) **Power Layer:** The fundamental novelty in smart grid comes with: 1) the integration of renewable energy sources that disrupt the balance of the prediction of energy sources and the replacement of the one-way communication system and 2) two-way communication between the customer and the utility that will enable the possibility to balance between demand and supply of the energy. Therefore, the power generation, transmission and distribution system, and customer premises are all included in the power layer part of the system.
- 3) **Communication Layer:** It represents the core of the system by providing interconnections between all of the systems and devices. The telecommunication technology is used at the communication layer to enable the data digitization, intelligent self-awareness, and increased reliability. The unified architecture in the communication layer will enable two-way communication among the system component and big data support to handle the increasing amount of data from smart devices.

## 5.6 Smart Grids for a Smarter Energy World

Electricity has a major role in responding to the climate change. Optimization of consumption and innovative new technologies in different operating situation can help to increase the consumer awareness. As information technology makes its way into the power grid, it is opening up amazing opportunities for system optimization, which in turn would contribute to



cleaner and more secure, reliable, accessible and affordable electricity to tackle climate change.

To play an ever-larger role in economies worldwide, electricity must be cleaner, safer, affordable, secure and continuously reliable as well as efficiently generated, delivered and used. Smart grids, homes and cities will empower customers to be part of this change together with electricity providers. These, as well as global interconnected energy systems, will support the integration of decentralized and renewable sources, along with traditional centralized ones, into the generation, transmission and distribution systems [GSEP, 2015]. Figure 5.5 illustrates the characteristics and relationships among the different stakeholders in a smarter energy world.

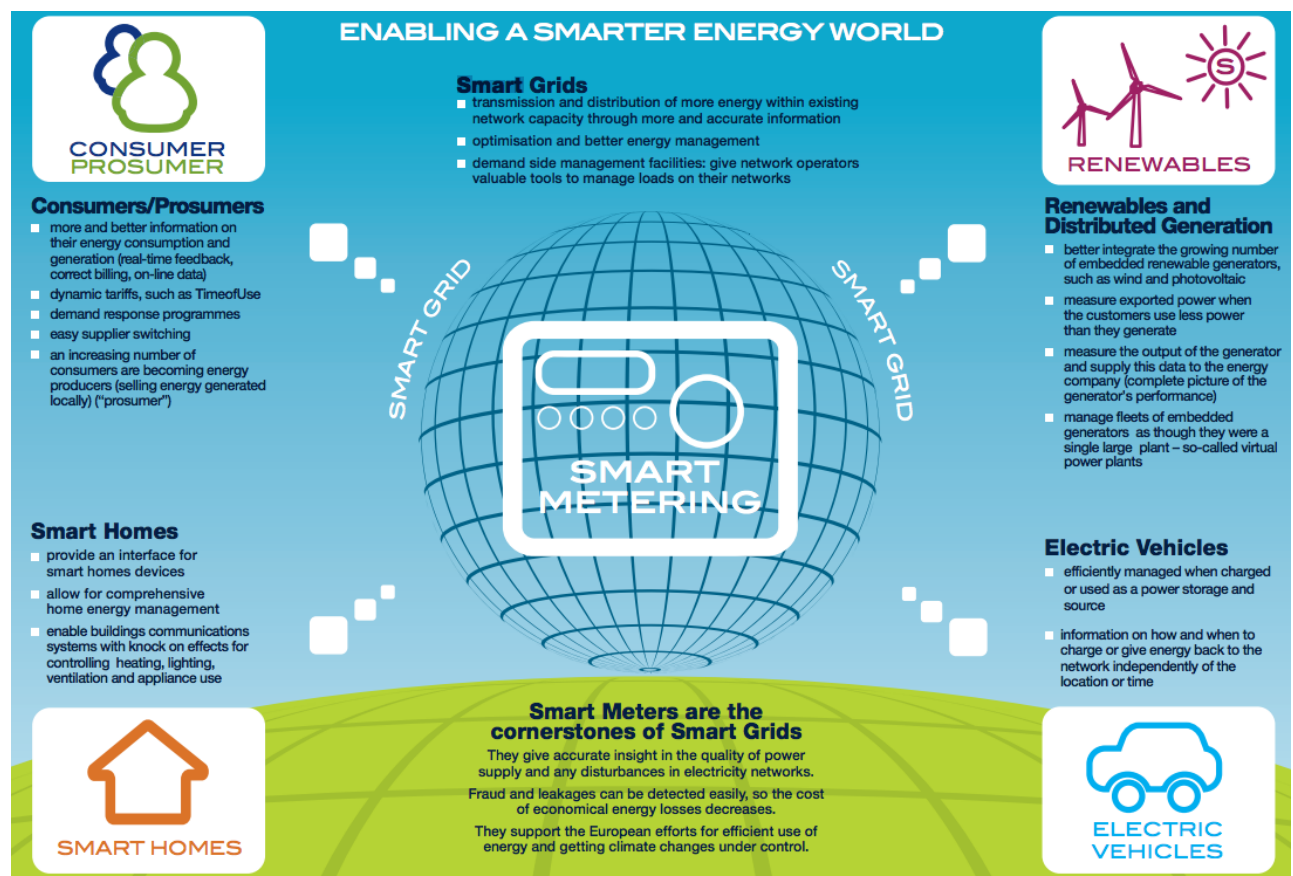


Figure 5.5: Smart metering towards a smarter energy world [ESMIG, 2016]

## 5.7 Advantages

The smart grid offers novel opportunities to move the existing energy industry into a new era of reliability, availability, and efficiency that will contribute to our economic and environmental health. During the transition period we can picturize the benefits envisioning that smart grid becomes a reality.

The smart grid will bring a wide variety of benefits to both producer and consumer, as well as prosumer, i.e., those households or communities that both produce electricity (and provide it to the larger grid when surplus exists) and consume energy from the larger grid, when demand surpasses the local production capabilities. The anticipated benefits and requirements are summarized below [NIST, 2014].

A modernized smart grid will have the following benefits:

- Improving power reliability and quality;
- Optimizing facility utilization and averting construction of back-up (peak load) power plants;
- Enhancing capacity and efficiency of existing electric power networks;
- Improving resilience to disruption;
- Enabling predictive maintenance and self-healing responses to system disturbances;
- Accommodating distributed power sources;
- Automating maintenance and operation;
- Presenting opportunities to improve grid security;
- Enabling transition to plug-in electric vehicles and new energy storage options;

The benefits associated with consumers are [SGCC, 2016],

- Smart Grid decreases brownouts, blackouts and surges saving sensitive electrical equipment.
- Consumers have control over their electricity bill. Users can schedule the most energy-intensive tasks for low-demand periods and pay less.
- Smart Grid facilitate real time troubleshooting.
- Smart Grid facilitates broad-scale electric vehicle charging.
- Smart Grid will enable and encourage new products, services, and markets to grow and make business.

- With increasing consumer choice, it encourages consumer participation in grid operations.
- Customer have the opportunity of load handling. The total of the power grid load is not stable and it varies over time. In case of heavy load, a smart grid system can advise consumers to temporarily minimize energy consumption.

The appreciable advantages in the environmental sector are:

- Facilitating expanded deployment of renewable energy sources.
- Reducing greenhouse gas emissions by enabling electric vehicles and new power sources.
- Reducing oil consumption by reducing the need for inefficient generation during peak usage periods.

## 5.8 Potential Applications in Smart Grid

In the smart grid framework, the infrastructure that deals with the customer is the potential applications that contributes to the smarter management of energy consumption. The applications can reside in three different places namely the consumers, transmission and distribution, and the suppliers. The consumer side is one of the important places where a large number of connected devices, home appliances etc. consume a lot of electricity. AMI, Home Energy Management, Load Control and Demand Response are those areas that give us the opportunity to find out where the novel services in home can influence the optimal usage of home appliances to be interconnected and incorporated with the smart grid.

Smart Grid concept is not only developed to improve the utility system but also to improve the usability, efficiency as well as security and privacy of its stakeholders in all levels. Our thesis focuses on the role of consumers and their smart appliances in potential applications along with the role of customers in the energy infrastructure.

# Chapter 6

## Smart Appliances

The emergence of smart appliances is the result of the rapid development in sensor, sensor driven object, Internet of Things and communication network technology. Smart products are enriched with hardware, software, sensors, data storage, microprocessors, and connectivity in myriad ways. These are the foundation of designing interfaces of a smart home.

### 6.1 Smart Home Appliances

Smart appliances include heating, ventilation and air conditioning systems, lighting, safety and fire alarms, TVs, sensors for motion, humidity, or heat, water heater, kitchen appliances such as refrigerators, coffee machine, oven, etc. All these could be thought as containing various forms of “smartness” like communication with the user or with the Internet for obtaining various services usually meant to automate human tasks and make the living simpler.



Figure 6.1: Smart Home appliances [Smart Appliances, 2016]

## 6.2 Smart Grid Promotes Smart Appliances

Development of smart grid and smart meter encourages the households to use smart appliances. The cost effective and efficient use of energy will be possible if we can schedule the execution of smart appliances through the smart meter or from the smart grid control center. According to [ETSI, 2016], recently household appliances are responsible for about two thirds of the energy consumed by buildings. By communicating among themselves with energy control systems, the impact of these devices on the environment can be managed and optimized.

One of the research question is how much control will be rendered to the smart meter to access all our smart appliances in a smart house. Accessing smart appliances through smart meter has a huge security and privacy impact.

We can think of several ways to control the scheduling of the smart home:

- Controlled by the smart meter: Smart meter is seen as the IoT smart home gateway. Selected smart home devices can be controlled from the central controlling system of smart grid. Ultimately that is the main essence of smart grid having the control of the electricity usage by the provider in off peak or peak hour to provide the highly demanded service higher priority during low production of electricity. The disadvantage with this approach is that the users may not be interested to give access to their internal housing appliances to the utility companies. So there can be a way to configure the access and incentive can be given to the users to encourage the use of the utility companies' smart control center.
- Controlled by the user over the internet using smart meter.
- Controlled by the user using a control station or hub inside the user's premise.

## 6.3 Service Evaluation Framework

There are many household devices in the market that provide smart control interface to schedule, save energy, delay start, and universal control through smartphone or smart gateway and many of them learn the user's behaviour and schedule themselves accordingly. While we were investigating their usage as a pervasive computing device, we discover that they provide several different and attractive features in terms of efficiency, security, privacy, usability that we are interested in. Therefore, we have proposed a service evaluation framework of the appliances in terms of the following features.

- Efficiency: We consider the efficiency of the device on the way how it or its smart features contribute to save energy and cost for its users. Ability to interface with Smart Meter is considered as an efficiency property too. In this way a device can be scheduled to save energy and electricity bills by running in off peak hours. Several others features can contribute to save energy such as,
  - Remote monitoring and controlling of devices so that when user forgets to switch off during leaving home can do that from remote place
  - Ability to schedule by self-learning from user behaviour e.g. turn off devices when user is not at home
  - Providing full statistics of energy usage to encourage and speculate the user how to save energy

- Interaction with another energy saving device e.g. Kevo kwikset is an electronic deadbolt, but able to communicate with Nest thermostat when the user is away and configuration in the Nest can save energy by setting the home in low energy mode.
- Usability: One of the most favourable feature in Internet of Things or pervasive computing is to have the device very much unobtrusive. Some of the investigated devices automatically learn the user's behaviour and can schedule the necessary action without user's direct intervention. We consider this to be the ultimate usability feature with regards to IoT [Weiser and Brown, 1996]. Alongside, we also consider how easily the user can use the device, the end user's learning curve or the accessibility features of the devices. The degree of usability is enhanced if the device capable of learning from user's lifestyle. Having smart phone app, web control panel, voice command support, auto scheduling, built-in touch panel display are also desired usability features in a smart home appliance.
- Security: Since many devices offer control over the internet and connection through Wi-Fi, Bluetooth, ZigBee or NFC, it is important that how the devices communicate with the control center in a secure way. Things to be considered here are how the device is transmitting data, is it in a secure way or encrypted, how the data is stored, is it in a cloud or locally; if it is in the cloud is it encrypted and protected.
- Privacy: In the list of devices we have investigated, we did not find any standard forms of communication to establish a control center in the home. Most of them need to have an account in the producer's server to control the device over the Internet which we termed as remote control. When we delegate the control data to an external server, we consider that there is a possibility of breach of privacy unless the end user do not read the terms and condition which very few private users really bothers to read. It is also important for privacy issues that if the user can control how, when and where the information and sensor data is shared.

Our main focus here is to investigate the selected criteria to find the novel services in a home automation and focus on smart usage of energy achieving the real benefit by connecting with smart meter. Later in this chapter we have summarized a selection of the devices and investigated their features in terms of aforementioned properties as listed by their producers.

## 6.4 Available Smart Products

Here we have investigated the available intelligent features of a number of smart appliances available in the market from their product brochure and corresponding websites. Some of the products mentioned here are planned to be released to the market in near future and are yet not in mass production. We will analyze the quality of the products with following criteria in mind: efficiency, privacy, usability, and security.

### 6.4.1 Nest Thermostat

Nest Labs is a home automation producer of programmable, self-learning, sensor-driven, Wi-Fi-enabled thermostats, smoke detectors, and security systems. They introduced the Nest Learning Thermostat in 2011 as their first product. Co-founded by former Apple engineers Tony Fadell and Matt Rogers in 2010, Google acquired Nest Labs in January 2014 [Nest Labs, 2015].

Nest produces thermostat that automatically learns user's lifestyle and seasons and adapt the temperature automatically learning by itself [NestWeb, 2016]. Nest is compatible with most standard HVAC systems that uses central heating and cooling and uses industry standard connections to facilitate the control of these appliances. Nest thermostat is able to conglomerate with other devices in terms of providing services such as Whirlpool washing machine. Nest devices interconnect with each other using a protocol called Weave, which is based on IEEE 802.15.4 and Wi-Fi 802.11 b/g/n. It also supports openHAB to interoperate with other home automation devices [openHAB, 2016].



Figure 6.2: Nest Thermostat



Table 6.1: Novel services in Nest Thermostat

Usability	<ul style="list-style-type: none"> <li>● Well-designed big touch sensitive display</li> <li>● Learn itself when to shut down and switch on</li> <li>● Easy to install and operate</li> <li>● Shows energy usage amount at the end of the day and month</li> <li>● Remotely controllable from anywhere</li> <li>● Can be controlled by Smartphone app and web interface</li> </ul>
Efficiency	<ul style="list-style-type: none"> <li>● Found in independent studies that Nest Thermostat saves an average of 20% energy consumption.</li> <li>● It can control to switch on and off other Nest compatible devices to save energy when it detects the user is away from home.</li> </ul>
Security	<ul style="list-style-type: none"> <li>● Need to communicate over Internet using WiFi and uses RESTful API to communicate with the Nest server.</li> </ul>
Privacy	<ul style="list-style-type: none"> <li>● It can be controlled through the Internet with Nest account. <ul style="list-style-type: none"> <li>○ Data are routed through Nest, so privacy question arises.</li> <li>○ Automatically adaptable with lifestyle may cause infringement of privacy.</li> </ul> </li> <li>● It knows when user is away, and sends this information to other Nest compatible devices.</li> </ul>

## 6.4.2 Nest Cam

It is a webcam that works with the nest thermostat, when user will be out of home, nest cam will switch on itself. It is synchronized with the thermostat’s “going away” status. Nest webcam gives the opportunity to see your home away from your home.

The Nest Cam security camera is designed to help you look after your home and family – even when you’re away. With 24/7 live streaming, advanced Night Vision, activity alerts, one app for all your Nest products, and a versatile magnetic stand, Nest Cam helps you keep an eye on what matters from anywhere.

User cannot always watch a video feed continuously looking at any screen. So the Nest Cam looks for motion and sends an alert to the phone if it sees something interesting. Nest Cam ignores background noise, like the sound of traffic. But it will send alert if it hears something that stands out, like a boom, crash or voice of an intruder. Advanced algorithms in the cloud

using depth sensing and face detection kick in to give more accurate alerts is available as a subscribed feature of Nest Aware [NestCam, 2016].



Figure 6.3: Nest Cam

Table 6.2: Novel services in Nest Cam

Usability	<ul style="list-style-type: none"> <li>● Switch on itself.</li> <li>● It helps user to keep an eye on what matters from anywhere, user feel always in home.</li> <li>● Ignoring background noise makes user comfortable from unnecessary caution.</li> <li>● Advanced usability features available on subscription.</li> <li>● Easy to install and setup.</li> </ul>
Efficiency	<ul style="list-style-type: none"> <li>● Switch on when Nest Thermostat sends ‘away’ signal.</li> </ul>
Security	<ul style="list-style-type: none"> <li>● Uses WiFi and Internet to transmit video and images.</li> </ul>
Privacy	<ul style="list-style-type: none"> <li>● Videos are streamed through cloud and depend on the clouds privacy.</li> </ul>

### 6.4.3 Whirlpool 6th Sense Live

Whirlpool produces a smart washing machine named ‘6th Sense Live Technology’. These smart appliances explore the next generation of connection, accessibility and efficiency.

These machines reduce energy usage and help protect the planet with Whirlpool® 6th Sense Live™ technology. By connecting to the Smart Grid used by utility companies, these models optimize energy use and track how much energy the appliance is using. Smart Energy features include Energy Advisor, Rate Revealer and Smart Delay [Whirlpool, 2016]. The machine offers Smart Stats to make sure you always have the product information you need. With this collection of features, one will never be left wondering about the status of the appliance. Smart Stat features allow people to access appliance's start date, days online and cycle progress from the smart phone, tablet or computer. Using the app one can see what the machine is doing, details usage history including power consumption and it supports many other features.



Figure 6.4: Whirlpool Smart Front Load Washer with 6th Sense Live Technology

Whirlpool have several devices that can work in collaboration seamlessly with Nest Learning Thermostat that has introduced the home and away modes. By leveraging these modes, washer and dryer can make better choice for fabric care and energy efficiency. It saves energy with longer, more efficient dryer cycles and auto-delay laundry cycles during energy rush hours. Using Amazon dash replenishment, the dishwasher and washing machine can order online necessary washing materials [Amazon Dash, 2016].

The Interactive Kitchen is another 6th Sense Live device from whirlpool that have option for warming coffee cup, infant milk bottle at desired temperature that is learned from everyday

usage for each individual user. It will also suggest lunch menu depending on the age, calorie requirement, everyday activity, daily schedule etc.

Table 6.3: Novel services in Whirlpool sixth sense live

Usability	<ul style="list-style-type: none"> <li>● Always have the product information, status of the appliance available on screen.</li> <li>● Features and controls are easily accessible using mobile apps or PC.</li> <li>● The detergent dispenser send notifications to smartphone app when it needs to be refilled and also can order online itself.</li> <li>● It has touch controls with memory program and speaking facilities.</li> </ul>
Efficiency	<ul style="list-style-type: none"> <li>● It help to save energy usage with smart energy features - Energy Advisor, Rate Revealer and Smart Delay etc.</li> <li>● Use “home and away” mode and save energy.</li> <li>● It saves energy with longer, more efficient dryer cycles and auto-delay laundry cycles during energy rush hours.</li> </ul>
Security	Communication is performed through Wi-Fi and need to subscribe to the vendor’s system.
Privacy	<ul style="list-style-type: none"> <li>● User have to communicate with the device through vendor’s system so user’s data is routed through their system.</li> <li>● Interactive Kitchen can remember each individual’s requirements.</li> </ul>

#### 6.4.4 Belkin WeMo

Belkin has several products that matches with smart home automation. WeMo is a family of simple, ingenious products that make life easier, simpler and better. Smart devices from WeMo includes light sensor, slow cooker, coffee maker, room heater, video camera etc. These are accessible remotely and in the home Wi-Fi through smartphone app running Android or iOS. It is possible to schedule them to perform their work and when finished they send notification to the app. The smart slow cooker has scheduling feature, possible to monitor cooking and adjust time through remote access. It is easy to schedule, monitor, and modify your brew from anywhere with coffeemaker. In addition to above features, smart heater has Eco-Smart energy saving technology with intelligent cycle between high and low settings to help save energy and reduce energy costs. The Auto Frost protect feature helps to keep home protected against frost [Belkin, 2016]. The WeMo App controls the WeMo devices from anywhere in the world as long as the WeMo devices’ wireless network is connected to the Internet. WeMo devices can also be controlled using IFTTT technology.



Figure 6.5: Belkin WeMo product series

WEMO Insight Switch contribute to get the most out of appliances and electronics like lights, TVs, fans, washers, dryers, wall A/C units. With the WEMO app, it is possible to turn any plugged-in device on or off. For example, if one forgets to turn off the iron and out of that place, it is very easy to switch off the iron plug by using WEMO app on mobile.

Table 6.4: Novel services in Belkin WeMo

Usability	<ul style="list-style-type: none"> <li>● Scheduling devices and appliances to perform their work and easy to monitor and control.</li> <li>● Remote access and notification to the app or through Internet.</li> <li>● With WEMO app, it is easy to create automating lighting schedule, raise or dim individual lights to create the perfect ambiance.</li> </ul>
Efficiency	<ul style="list-style-type: none"> <li>● Remote scheduling can be incorporated with proper smart grid control.</li> <li>● Remote control of switches to turn on and off from anywhere reduces energy consumption.</li> </ul>
Security	<ul style="list-style-type: none"> <li>● WeMo switches are controlled via IP networks; thus, for a switch to be controllable from a remote location, it must be open to receive connections from the Internet. In January 2013, it was revealed that the WeMo had a security flaw in its UPnP implementation that allowed an unauthorized user to take control of a switch. This could allow malicious attacks, such as flipping the switch at a very fast rate, which could damage certain devices and even cause electrical fires.</li> <li>● WeMo support WiFi and ZigBee protocols</li> </ul>

Privacy	Possible to control in user premise or through Internet. When using Internet to remotely control the devices, the data goes through WeMo server.
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### 6.4.5 Philips Hue Product

Philips Hue is a smart home personal wireless lighting product which combines three connected LED lighting bulbs capable of displaying a full spectrum of color using just a smartphone app. An accompanying mobile app connects to the Wi-Fi and allows to control multiple bulbs and lighting systems, changing color sets depending on mood or can be customized based on the spectrum of colors one enjoy, selected from images saved on the smartphone or tablet. Controlling facility draws from bedroom to backyard. Lights can be switched on when user enter into home and can switch off automatically when leave home with geofencing technology.

The Philips Hue Connected Bulb includes three LED light bulbs and the Hue Bridge. The Bridge is a hub that plugs directly into the wireless router and translates signals between Wi-Fi-connected smartphone and the ZigBee-based bulbs. Philips Hue utilizes the open ZigBee Light Link standard. This also means other products can integrate with them, but it isn't limited to just lighting products. Its interoperability allows users to control LED fixtures, light bulbs, timers, remotes and switches, so if you have existing ZigBee-connected products, you might be able to automate your home further.



Figure 6.6: Philips Hue bulbs and bridge

Hue claim that they are able to keep home safe and secure in smart and useful ways. Turning the lights on in the evenings can make illusion of presence when user is absent in home. User

can program the lights to be automatically switch on. If user forget to program the lights before leaving home, then simply control them remotely via portal. Setting the rooms to light up at different times remotely is an opportunity to secure home by making fake presence.

At its full intensity of 600 lumen and a color temperature of 3000 K, the bulbs consume 5W. However, the bulbs also draw a constant 0.4W when they are turned off by the app (as opposed to being turned off at the physical switch). This is so they can maintain their ZigBee connection to the bridge, in order to be able to respond to the smartphone app (alarms, remote on/off requests, geofencing, etc.). And the bridge itself consumes a constant 1.6W, so the three bulbs, plus the bridge, have a baseline consumption of 2.8W. When we compare the 2.8W to 60W from a conventional incandescent bulb, it doesn't appear to be a huge draw, but over 24 hours it does add up (it is the equivalent of leaving a 60W bulb on for a little over an hour and seven minutes per day) [GreenMonk, 2014].

To avoid burning the constant 2.8W, we can of course turn the bulbs off completely with the switch. Then they are no longer in 'listening mode' and consume 0W, instead of the constant 0.4W. The advantage of this approach is lower electricity consumption, the disadvantage is that the Hue bulbs are no longer connected to the Internet of Things.

This constant nibbling of power by the Hue devices is by no means unique to these bulbs only. By definition any devices constantly connected to the Internet are also constantly consuming power – which raises interesting questions around the costs and benefits of Internet of Things connected devices.

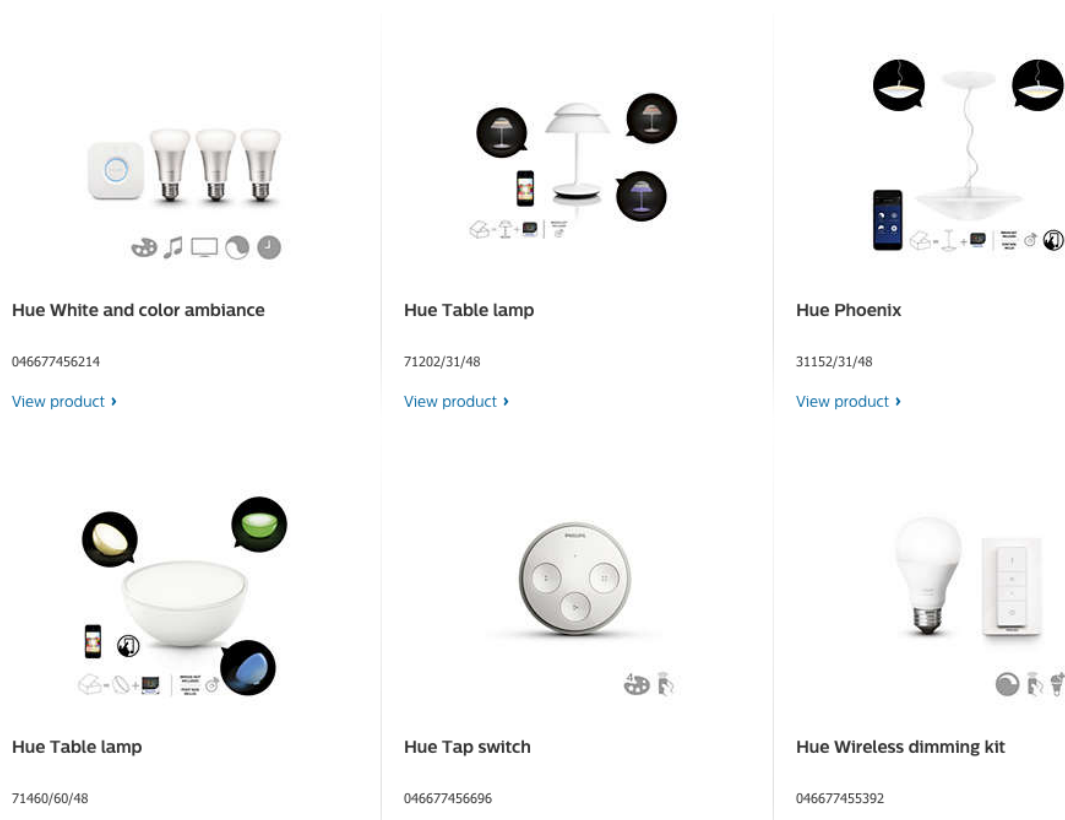


Figure 6.7: Philips Hue based devices

Table 6.5: Novel services in Philips Hue

Usability	<ul style="list-style-type: none"> <li>● Light can sync with music, TV and games for immersive effect.</li> <li>● By using geofencing technology lights can be on and off when user home and leave home.</li> <li>● Easy to automate home further by having ZigBee-connected products.</li> <li>● Programmable and can automatically switch on and off.</li> <li>● It also supports Apple’s HomeKit which enables it to be controlled using Siri and iOS devices.</li> <li>● The app contains four pre-programmed lighting settings based on Philips’ research around the biological effects that lighting has on the human body. These scenarios adjust bulbs to the optimum shade and brightness of white light to relax, read, concentrate or energize.</li> <li>● User can set color as per their choice even from saved image on phone.</li> </ul>
Efficiency	<ul style="list-style-type: none"> <li>● Has energy saving options as discussed earlier. Listening mode can be switched on or off as per choice of user. So that user can save energy.</li> <li>● Possible to schedule which save energy.</li> </ul>
Security	Philips hue communicates using ZigBee. Hue bridge needs Internet access to be controlled remotely.



### 6.4.6 SmartThings from Samsung

With a collection of smart devices in a smart home, we need a smart hub to control the operation of the appliances. SmartThings is one such a device equipped with Wi-Fi and Bluetooth connectivity provided by Samsung. SmartThings is building an open platform for smart homes and the consumer of Internet of Things. SmartThings obtains its objective through the use of a hub, that is sometimes called "gateway" or "home controller", cloud platform, and client applications. The hub works with many third-party IoT appliances from companies including Netgear, Philips, Honeywell and August. It can integrate the products such as, Philips Hue, Belkin WeMo etc. to form a connected house. With SmartThings app it is possible to control all smart devices in a smart home. The hub connects directly to a home's internet router and is compatible with communication protocols such as ZigBee, Z-Wave, and with IP-accessible devices. SmartThings also launched an online shop called SmartThings Shop that features a curated selection of home-automation devices. Products listed on the shop include those made by SmartThings as well as third-party products, all of which are compatible with the SmartThings platform [SmartThings, 2016]. SmartThings let user to monitor, control and secure home from anywhere.

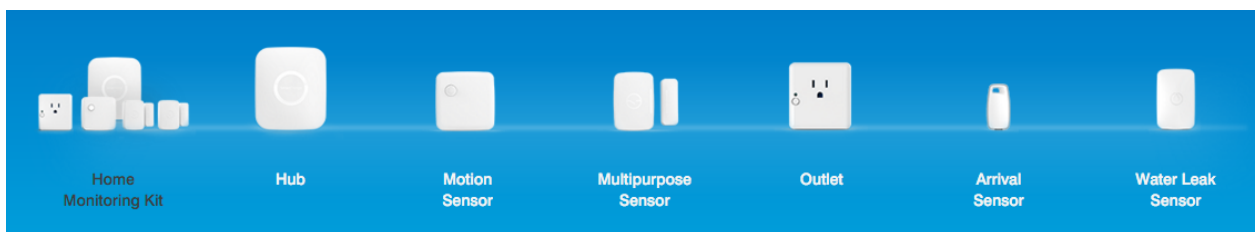


Figure 6.8: SmartThings product bundles

Having the motto that “Any home can be a smart home”, SmartThings has a wide range of products to create and monitor user's smart home in no time because of easy installation. It allows user to add hundreds of compatible smart devices for limitless possibilities to enhance home convenience.

Several SmartThings supported devices have many smart home features:

- SmartThings Arrival sensor send notification when family members arrive and leave home by placing in a purse or a keychain in child's backpack. It can even fit to pet's collar.
- SmartThings Water Leak Sensor makes alarm from leaking prone place if there is water where it does not belong. This way major damage can be prevented by sending alert to user's app.
- Connected camera give the whole picture when one is out of home.
- SmartThings can record video footage when unexpected entity, motion or sound is detected when one is in sleep or away and send immediate alert with video clip.
- User can get instant alerts if there is unexpected entry or movement. This can be happened by two ways. One is by placing a SmartThings multi purpose sensors on door or windows and second one is by placing SmartThings motion sensors in home. Smart phone will receive immediate alert, if someone is trying to enter.
- SmartThings compatible lock allows user to lock or unlock door from anywhere.
- SmartThings compatible alarm emits a loud, flashing siren or noise of loud barking dogs if there is unwanted entry or movement in home.
- Control and automation of lights facility help user to imitate their presence while they are out of home that is a secure manipulation.
- Turning on or off a switch from anywhere make it possible to secure home, for example, going out without releasing iron plug.

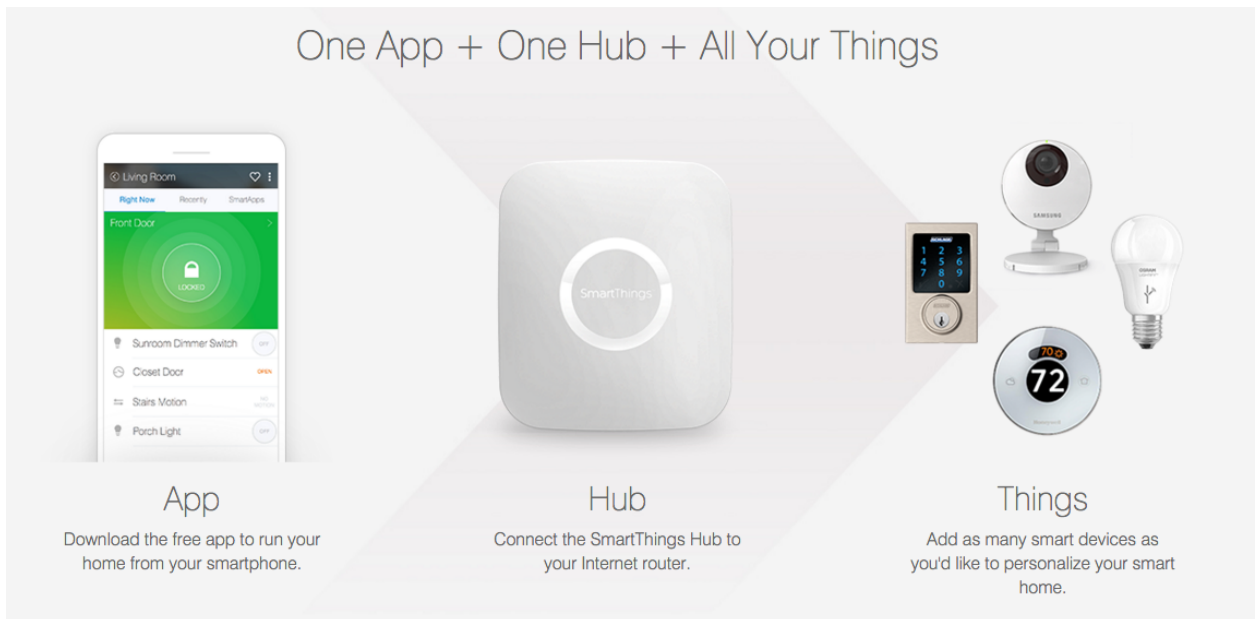


Figure 6.9: SmartThings product interaction

Table 6.6: Novel services in SmartThings

<p>Usability</p>	<ul style="list-style-type: none"> <li>• It allows user to add hundreds of compatible smart devices for limitless possibilities to enhance home convenience.</li> <li>• Monitoring and controlling temperature throughout home from anywhere.</li> <li>• It is possible to set up different notifications and alerts so users can keep an eye on what is important to them.</li> <li>• It can trigger action automatically when user is asleep, awake, or leave or come back home. The home will remember them.</li> <li>• User can reprogram a routine or pattern change to make it adaptable with circumstances.</li> <li>• More ways to control light and energy enhance the usability of it. Temperature control to individual room, control multiple lights by one button and auto on and off by sensing entering room or out are worthy criteria.</li> <li>• By plugging electronics and small appliances like a coffee maker, Crock-Pot, toaster, or blender into a SmartThings Power Outlet, is possible to control or automate them from anywhere.</li> <li>• To customize home some features like automate light color based on the weather outside, hear traffic report and weather forecast at coffee time in morning, start heating or cooking as schedule have enriched usability.</li> </ul>
<p>Efficiency</p>	<ul style="list-style-type: none"> <li>• Monitor and control home temperature from anywhere provide the facility to save energy consumption.</li> <li>• Automating lights to turn on and off depending upon different occurrence and monitoring where to need control on lights affect a lot of energy saving.</li> <li>• User can also save energy and money by setting SmartThings-</li> </ul>

	<p>compatible thermostats, A/C units, or portable heaters to automatically turn off when people leave.</p> <ul style="list-style-type: none"> <li>• SmartThings can also limit the amount of energy that electronics and small appliances consume.</li> </ul>
Security	The SmartThings hub communicates using protocols such as ZigBee, Z-Wave, and with IP-accessible devices.
Privacy	SmartThings provide smart home facility within the user's premise. But it is also possible to access the hub from the Internet.

### 6.4.7 SkylinkNet Home Security System

The SkylinkNet alarm system is one of several options on the market claiming to be a ‘smarter’ home security system [SkyLink, 2016]. As part of the system, window and door fixtures contain motion sensors which alert you when there is a trigger through an accompanying application. SkyLink's product is easy to set up and connect with the smartphone, and also comes with a keychain hob which allows users to remotely alarm and disarm a system - as well as a ‘panic’ button, which if pressed, alerts the connected smartphone to the call for help. This feature alone could be useful for those with elderly parents or for the disabled. The product can be connected up to multiple sensors and up to 10 wireless cameras. To be provide services over the Internet, it uses cloud technology.

Table 6.7: Novel services in SkylinkNet Home Security System

Usability	<ul style="list-style-type: none"> <li>• Easy set up.</li> <li>• Overview of what is happening in home, live view of various location of home, notification, event log and monitor various location using multiple hubs from different apps make the monitoring process easy for user.</li> <li>• By integrating Skylink HomeControl Receiver, home automation is possible in terms of lights and appliances switching on and off, control them remotely and make schedule with the Skylink app.</li> <li>• It can also use a back-up battery in the Internet hub that ensure security even during electricity grid failure.</li> </ul>
Efficiency	<ul style="list-style-type: none"> <li>• From above products, we have observed that when appliances, switches and lights are possible to switch on and off remotely with scheduling, it becomes energy efficient.</li> </ul>
Security	SkyLinkNet hub uses Wi-Fi to communicate with the sensors and the hub is connected to the Internet.

### 6.4.8 LG Smart ThinQ

LG Smart ThinQ appliances are a series of smart appliances that can interoperate among themselves specially using LG HomeChat hub. HomeChat hub is also compatible with other devices including the Nest Thermostat. LG calls communication between the hub and the devices a '*chat*' as it sends messages through an accompanying app which can then control the devices remotely - such as turning on washer, updating washing cycles, checking refrigerator's inventory and commanding robot vacuum to clean living room carpet and kitchen floor. In addition, the hub keeps an eye on appliances and is able to diagnose issues with compatible products such as LG Smart ThinQ ovens and fridges [Smart ThinQ, 2016].

LG Smart Appliances are built around Smart ThinQ Technology which features smart grid, access, diagnosis, adapt, and food management capabilities. The main concept of ThinQ is an intelligent WiFi grid built around a smart meter enabling homeowners to schedule the oven cooking time, washing machine cycle, and refrigerator defrosting at the most cost-effective or convenient times. Smart access allows users to control and monitor appliances from outside of home and better yet. LG refrigerator can count and display the number of times the door opening and send alert to home owner when the door is ajar. The display shows each of the appliances energy consumption as daily, weekly or monthly basis and obviously also accessible from smartphone or tablet. LG also produces a Smart ThinQ Sensor that is designed to work with traditional, low-tech home appliances such as refrigerators, washing machines and others, turning them into smart appliances and making them "smart-aware".



Figure 6.10: Smart ThinQ and LG HomeChat communicating with Nest

Table 6.8: Novel services in LG Smart ThinQ

Usability	<ul style="list-style-type: none"> <li>• ThinQ works as a hub all the smart appliances in a home.</li> <li>• User can observe energy consumption as daily, weekly or monthly basis.</li> <li>• LG diagnosis can diagnose and troubleshoot issues quickly and efficiently. Appliances can call LG center over phone or send message through WiFi to user's phone for a quick fix.</li> <li>• With Smart ThinQ Sensor, traditional dumb devices can be smarter.</li> </ul>
Efficiency	<ul style="list-style-type: none"> <li>• Smart Grid technology in every LG Smart ThinQ appliance is designed to detect when power consumption in its area is at its lowest, so the appliances can operate at lower energy rates.</li> <li>• Nest can communicate with LG HomeChat to activate Smart Savings mode on your appliances when users are away from home - helping them to save energy and operate their appliances more efficiently.</li> </ul>
Security	Uses WiFi or mobile internet.
Privacy	Users and products must be registered in ThinQ website to get the services.

## 6.4.9 Aros Smart Air Conditioner

The Aros Smart Air Conditioner is a smart air-conditioning system which learns from user's budget, location, schedule, and usage to automatically maintain the perfect temperature and maximize savings for the home. This IoT product, controllable via an app, can also be customized based on the budget and location [Aros, 2016].



Figure 6.11: Aros Smart Air Conditioner

Table 6.9: Novel services in Aros Smart Air Conditioner

Usability	It learns intuitively from the usage pattern. It uses smart phone's GPS to turn off when user leave and set perfect temperature at home and when user come back home. Apart from the mobile app it is not compatible with any kind of smart home gateway standard protocols. Aros features flat, touch-capacitive sensors, a sleek LED display, and retractable fabric wings that ensure the right fit in the window.
Efficiency	It can save unwanted use of energy since it is controllable remotely as well as it is possible to lower the temperature or switch it off. Aros keeps a constant eye on how much you've spent on cooling each month and offers suggested settings based on your budget and the upcoming weather report, so you can save on energy costs.
Security	Connects to Internet through WiFi and Wink app.
Privacy	To gain remote access, it needs to connect to Quirky web services and register as a user there.

## 6.4.10 Sensibo

Sensibo is a small device that turns any Air Conditioner (A/C) into a smart air conditioner as well as reduces its energy consumption. This device is compatible with air conditioners which have a remote controller. The tiny device connects the air conditioner to the Internet through WiFi.

The smart features of Sensibo allows to set timer and pre cool the home automatically. User can preheat room for everyday wake up in the morning by smart scheduling. Optimizing temperature and humidity level and learning user's habits and adapting with lifestyle make the sensor smart enough. Controlling several A/C units together with Sensibo Pods by one hub that is connected with home router make Sensibo more affordable. The device itself is run with a lower consumption battery and can be stuck to an A/C wall [Sensibo, 2016].



Figure 6.12: Sensibo device stuck on air conditioner

Each Sensibo Pod is equipped with several sensors that allow it to feel its surroundings. Its algorithms allow it to bring greater comfort and save energy.

Sensibo uses IR commands to communicate with the existing A/C, just like the remote control. It works right out of the box and supports any remote controlled A/C. Each Sensibo Pod contains seven infrared emitters, covering all directions, so that the signal reaches the IR receiver in the air conditioner. When setting in the app is changed, a signal is sent through the internet to the relevant pod and translated into the corresponding infrared signal.



Sensibo has an active IFTTT channel, which lets to use creativity and innovation to create recipes that use Sensibo's abilities. Sensibo provides open API to access the device from apps or scripts. Therefore, it is well supported by Amazon Echo, SmartThings, OpenHAB and Apple HomeKit.

Table 6.10: Novel services in Sensibo

Usability	<ul style="list-style-type: none"> <li>● Small device, easy to fix on the wall of any air conditioner.</li> <li>● Supports many open smart home standard services</li> </ul>
Efficiency	Remote controlled through internet save unwanted waste of energy e.g. if you forget to switch of the air conditioner.
Security	IR communication takes place between the pod and AC. The pod communicates through Internet to provide remote access.
Privacy	Sensibo provides open API to access that needs to be safeguarded.

### 6.4.11 Kevo

Kevo (Key Evolved) from Kwikset is an electronic deadbolt which communicates with a Kevo Fob and accompanying smartphone app to lock and unlock a door. A simple touch on the deadbolt unlocks the door, and you can also use your app to send eKeys to guests, allowing them access for specific time periods - or remove them from your Kevo network entirely.

When user carries phone or Kevo Fob in a bag or purse or pocket, the user does not need to fumble for key but only touch the smart lock to open the door. The Kevo Fob, that is included with the Bluetooth deadbolt, is pre-enrolled so no additional setup is required. The app is used for initial setup, sending, disabling and deleting eKeys, viewing history of lock activity, and setting up other configurable features and options. Since the app runs in the background on the device, there is no need to open the app to enter home. User can monitor lock status from anywhere and get information by alert about the door if it is locked or unlocked.

Kevo lets Nest know when user come and go to set personal temperature preference, saving energy and reducing utility bill [Kevo, 2016].

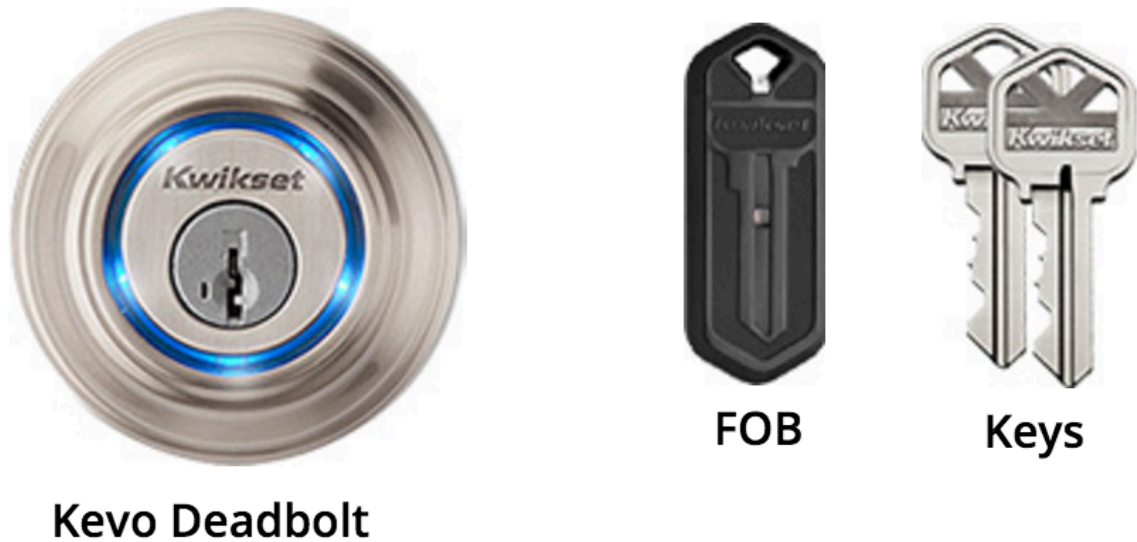


Figure 6.13: Kevo Deadbolt, Fob and Keys

Table 6.11: Novel services in Kevo

Usability	<ul style="list-style-type: none"> <li>● Respond to emergencies by giving a neighbor access to home.</li> <li>● Never wonder if the door is locked or unlocked, user can easily check remotely</li> <li>● Let friends and guests access into home remotely</li> <li>● User knows when home service providers enter and leave and give them access</li> <li>● The Kevo app seamlessly integrates with Nest account.</li> </ul>
Efficiency	Kevo belongs to a type of home security product. It can contribute to energy efficiency by incorporating with smart home gateway providing ‘home’ and ‘away’ modes.
Security	Kevo provides secure authentication technology. But physically it is very easy to break or fall apart. Each eKey is unique and assigned specifically to a Kevo user and Kevo smart lock. It is possible to add, delete or disable eKeys

	from the mobile or web app. Several levels of permissions for eKeys exist inside the Kevo mobile app. The Owner and Admin eKey types have the authorization to send, disable and delete eKeys. Other eKey types have only locking and unlocking capabilities. Through the web app you can also delete a lost or stolen smartphone from the Kevo system.
Privacy	Key management in Kevo extensively uses kwikset's network infrastructure. If not using the mobile app, Kevo can be used locally with only the fob which communicates with the deadbolt using bluetooth.

### 6.4.12 Skybell

IoT are incessantly getting new products and services. The SkyBell is an IoT device which extends the functionality of the humble doorbell with safety, convenience and control facilities. SkyBell is a smart video doorbell featured by all necessary services that one doorbell can achieved. It has HD video, hear and speak, living monitoring, motion sensor, color night vision and free video recording. All feature are to provide home security. The device can be connected to smartphone with an accompanying app and sends alerts on smartphone when the doorbell is pressed. Owner can see visitors, hear and speak to visitors, take a snapshot of visitors using the app on smartphone before going to door. Since it is connected with Wi-Fi, user gets alert from anywhere that covers Wi-Fi or Internet on smartphone. Multiple users and devices can receive alerts from multiple devices in one home. User will receive alerts if the visitor even does not press the bell button. In night vision, user can see visitors without them noticing too. Motion sensor can be on and off as per choice. Even app alert can be chosen if needed to keep silence in home. This bell can operate -50 to 150 degrees Fahrenheit [SkyBell, 2016].



Figure 6.14: SkyBell WiFi video doorbell

Skybell also works with Nest to provide additional security and monitoring inside and outside of home. While answering live video from Skybell HD, it needs to activate NestCam streaming in case it is not. NestCam records activity in home when it is in ‘Away Mode’ and detects motion or sound. At the same time SkyBell HD will be automatically turned on and start recording video at front door. It also have an active IFTTT channel.

It provides the user a high level of security at the same time it is very easy to install and operate. It requires at least 1.5 mbps of consistent upload speed and a full time fast-speed internet connection for video streaming.

Table 6.12: Novel services in SkyBell

Usability	<ul style="list-style-type: none"> <li>• Easy to install and operate</li> </ul>
Efficiency	<ul style="list-style-type: none"> <li>• Save energy with Nest’s interface in home and away mode</li> <li>• Switch on with motion sensor</li> </ul>
Security	<ul style="list-style-type: none"> <li>• Communication is protected in user’s WiFi network</li> </ul>
Privacy	<ul style="list-style-type: none"> <li>• Data and streaming is within user’s home premise</li> </ul>

### 6.4.13 Canary

Canary packs a whole security system into a sleek box that looks a little bit like a router. The box includes a camera with night vision and motion detection, accelerometer, a speaker and siren.

Any time it spots something out of the ordinary, the alarm goes off and sends a notification to the phone, the idea is that over time it learns and becomes better at working out what's ordinary and what isn't. When receiving an alert, the user can tune into the video feed straight away from the smartphone, enabling to check if it really is a night-time prowler or just a dog who have set the motion detector off [Canary, 2016].

Home health technology from Canary monitors air quality, temperature, and humidity. Combination of all of them adds up to a smarter and safer home environment.



Figure 6.15: Canary security system

#### Features:

- Stream real-time high definition video of the home
- Motion sensor - get instant alerts when activity is detected and view recorded video.
- Night vision - see what's happening day or night with automatic infrared LEDs.
- In an emergency, it sounds a 90 decibel siren or connect with the local police right from the Canary app.

- HomeHealth technology - monitor air quality, temperature, and humidity that add up to a smarter and safe home environment.
- Cloud storage - view recorded video and audio events for up to 30 days.

Table 6.13: Novel services in Canary

Usability	<ul style="list-style-type: none"> <li>● The Canary app seamlessly integrates multiple devices in the convenience of a swipe from room to room.</li> <li>● The services enable to watch home live 24/7 in HD video from smartphone using the app. It is built to learn and send intelligent alerts with HD video and audio directly to the phone. User can access living history of home, watch video, save and bookmark the ones worth keeping.</li> <li>● The device can automatically change “go” and “away” mode.</li> <li>● They have tailored security package from small home to larger home.</li> <li>● Provide home comfort by monitoring air quality, temperature and humidity.</li> </ul>
Efficiency	<ul style="list-style-type: none"> <li>● Canary does not provide any interface with power management systems.</li> </ul>
Security	<ul style="list-style-type: none"> <li>● When motion is detected, Canary records it and sends it to the phone with mobile alert. User can view recorded video and audio events for up to 30 days that are stored in cloud storage.</li> <li>● Captured data must have to be communicated through Internet to be accessible in the smart phone apps.</li> </ul>
Privacy	<ul style="list-style-type: none"> <li>● Motion activated recording with video and without video are a useful option but can expose privacy. To ensure privacy camera and microphone can be kept completely off. All the processing is done on the camera itself which takes care of any privacy concerns and the footage is locked if the microSD card that is used for storage is removed from the camera.</li> <li>● As the only monitoring solution with a built-in privacy mode, Canary lets the user completely shut down the camera and microphone at any time. When recording, Canary employs extensive security measures to protect private data.</li> <li>● The video and audio media captured in are kept in the cloud storage for up to 30 days.</li> </ul>

#### 6.4.14 Honeywell Tuxedo Touch

Honeywell has a broad range of home security and automation products. Of them the Tuxedo Touch is a seven inches high resolution graphic touchscreen and controller that integrates

security with home and business automation. It provides seamlessly integrated security with voice commands, video viewing and recording, and the ability to control Z-Wave enabled thermostats, lights, locks and shades which enhances its Lynx touch control system. It uses Wi-Fi as its communication medium.



Figure 6.16: Honeywell Tuxedo Touch

Honeywell Total Connect Remote Services provide access to control Tuxedo Touch and receive important alerts about events occurring in and around home whether user at home or away and user can opt to control from smartphone, PC, tablet or other compatible mobile devices. The press of a single button of wireless remote lets the user to operate security system, lights, garage doors and more. The remote service also provides real time events alerts by e-mails, text message or video alerts such as a child arriving home from school and recent system or sensor activity. Live video on up to six cameras at a time is a great way to keep an eye on kids, elderly relatives, pets and property.

Honeywell Total Connect Tracking Services is used to keep information about the position of vehicles, assets, and where they have been 24/7 - anytime, anywhere, from any web-enabled smart device by the real-time GPS location information. User can even get email or text alerts when vehicles exceed speed limits or predetermined geographic boundaries. It have an active IFTTT channel to trigger actions on conditions.

Environmental Sensor is ideal for kitchens and bathrooms, laundry rooms and basements. These detectors can notify you when detects floods, leaks and extreme temperatures - helping to minimize the risk of dangerous conditions and damages to your home and valuables.

Wireless theft protection sensors can be affixed to any valuable such as flat screen TVs, artwork, computers, antiques and more in home, that send alert when an attempt is made to move or disturb the object. Motion sensor is able to differentiate between intruder and pet.

Panic pendants provide secure feeling by summoning emergency help with the press of a button. This service is very effective for elder person or anyone who may require emergency assistance to send signals to the central station to summon the police or medical response personnel. Compact and water-resistant, these can be worn as wristband, pendant, belt or keychain style that is comfy for people.

The door locks can be unlocked from the comfort of office - right from the smartphone or PC. The doors lock and unlock automatically whenever user arm or disarm the security system, set scenes and schedules for added safety and convenience. Locks support also programming scene and scheduling and remote control as usual.

Programing lights to strobe on and off during an alarm to enhance security and create on and off schedules to simulate a lived-in look gives the opportunity to secure the home when users are away. It provides remote control not only to switch on and off the indoor and outdoor lights but also have option to program the lights when they will be operated by user's choice and save energy.

Security can be monitored by central system if the user wants. Provider has highly trained home security professionals always standing by, ready to send help to user's home in the event of a burglary, fire, carbon monoxide event or other emergency. Honeywell state-of-art sensor is capable to sense movement by listening sound and send alert to phone.

Honeywell systems can have the outdoor lights automatically turn on at sunset and off at sunrise. This convenient feature updates automatically and even adjusts for daylight savings [Honeywell, 2016].

Table 6.14: Novel services in Honeywell Tuxedo Touch

Usability	<ul style="list-style-type: none"> <li>User have the opportunity of centralized control of security system, video cameras and Z-wave enabled devices such as thermostats, lights, locks, shades. Making shades on the windows adds</li> </ul>
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	<p>convenience to users.</p> <ul style="list-style-type: none"> <li>• Built in voice commands can be configured to make user’s daily life easy with handsfree home control. Some configurable specific voice commands are pictured here in short. “Wake Up” is to have desired shades raise and the heat turned up to the perfect temperature. “Bedtime” contains the action to arm the home security system, turn off the lights, lock the doors and set back the thermostats. “Returning Home”, “Evening”, “Leaving The House”, “Cameras” are included in the voice command list.</li> <li>• Scene and schedules is a option that offer the user to make their own schedule in the Tuxedo touch device, where all services can be prograded as user’s choice. Users can make their daily scenario to avoid always worrying about controlling home devices, which enhances lifestyle.</li> <li>• The touchscreen hub can organize your video monitoring, smart locks, home heating and so on. It is voice controlled, so you can tell it you are leaving the house to activate home monitoring.</li> <li>• User can view cameras around the home on touchscreens, televisions, tablets, smartphones or PCs to keep an eye on kids and pets, screen visitors at the entrance and view activity occurring around the interior or exterior of the home.</li> </ul>
Efficiency	<ul style="list-style-type: none"> <li>• Tuxedo Touch helps to make an energy-intelligent home to save money, save energy and make the home more efficient with automated heating, cooling and lighting.</li> <li>• Honeywell’s Z-Wave enabled thermostats can automatically adjust with each arming or disarming of the security system. Customizing scenes and schedules, controlling thermostats on-the-go, precise temperature controlling for better comfort and fewer temperature swings are features that use the energy efficiently. User can program scenes and schedules with lights for ambience and security, and control the lights from any remote location. The Z-Wave enabled control ceiling fans can be automated to turn on or off with the security system, programmed for specific times, work in conjunction with lighting and more.</li> </ul>
Security	<ul style="list-style-type: none"> <li>• Built in web server allows for local control of the system through any WiFi enabled device. Devices communicates with control unit using Z-Wave. Remotely lock and unlock doors and schedule lock system, arm, disarm or check the security system from anywhere ensures the user not only usability but also security.</li> <li>• The four screen of each camera can be viewed on Wi-Fi enabled devices. It can also record up to two-minute video clips on an SD card for visual verification of an alarm event or system activity.</li> </ul>
Privacy	<ul style="list-style-type: none"> <li>• Data inside user premise uses Z-Wave to communicate. When using mobile apps and web based control console, data goes through Internet and use Honeywell’s server.</li> </ul>

## 6.4.15 SwannOne

SwannOne is an easy to use comprehensive security system for smart homes. It can be accessed and controlled from iOS and Android devices. SwannOne is a single platform that allows users to control video surveillance, motion sensors, alarms, locks, lighting, sound alerts, temperature, energy management etc. SwannOne provides scope for users to add extra services including professional monitoring on-demand, cloud video recording, additional sound alerts and more. The system uses the latest wireless technology such as Wi-Fi, ZigBee and Z-Wave to integrate with other leading smart home brands and devices, such as Philips Hue, GE Jasco and WeMo lighting; nest thermostat; Kwikset, Weiser, Yale, Assa Abloy and Lockwood locks; Samsung SmartThings and CentraLite Smart plugs; and Chamberlain Garage Door Openers. The sensor and cameras are clever enough to differentiate between the sounds made by stereo or TV compared to real life noises [SwannOne, 2016].

Controlling and configuring to a degree for all of the devices from one place by the SwannApp is possible. The app also lets user remotely enable one of three presets Home, Night and Away - which can be customized per as user choice. By default, Home will power down the alarm systems but keep cameras active, if parents want to be able to keep an eye on their kids. Night mode, for when user go to sleep, turns on all door and window sensors but can be set up so that any upstairs sensors are turned off, so should you go to the bathroom in the middle of the night you will not end up setting off the alarm by mistake. Away, obviously for when nobody is home, primes everything for action.

User have also option to trigger these three preset with a key fob, even when phone is not in hand or it is out of battery. All of Swann is DVR (digital video recorders) security systems provide remote viewing, so that user can view home CCTV footage remotely either from a computer, smartphone or tablet. These systems are available with between 4 and 16 channels, enabling users to connect up to 16 cameras to CCTV DVR system. Dependent on the cameras, these can record at night, outdoors and in HD quality.

Swann's wireless cameras and cloud cameras allow users to set up a security system without the need to run wires around home or business. If anyone wants to record camera footage offsite, or does not have the space for a DVR system, the SwannCloud cameras can record video to a secure cloud server allowing to review footage without the need for a DVR. The

kit features such things as indoor and outdoor cameras, movement sensors, smart plugs, and a key fob so you can activate pre-set lighting and video recording modes.



Figure 6.17: SwannOne products

Table 6.15: Novel services in SwannOne products

Usability	<ul style="list-style-type: none"> <li>● Easy to use</li> <li>● Accessible remotely, via app or key fob.</li> <li>● Can trigger automatically reading other sensors e.g. Nest</li> <li>● Self learning</li> </ul>
Efficiency	Configurable to save energy in home, away or night mode
Security	Interfaces communicates wirelessly inside user premise
Privacy	DVR use cloud server to store video.

## 6.5 Functionality Chart

Table 6.16: Functionality chart

Product	Remotely controllable	Protocol supported	Mobile apps	Web based control panel	Voice control	Alerts	Touch screen in base unit	Connect to SM/SG	Cloud service	Compatibility with	Programmable / API	Schedulable	Self learning
Nest Thermostat	Yes	Wi-Fi	Android, iOS	Yes	No	In-app push	Yes	No	Yes	Yes	Yes	Yes	Yes
Nest Cam	Yes	Wi-Fi	Android, iOS	Yes	No	Yes	No	No	Yes	Yes	No	No	No
Whirlpool 6th Sense Live	Yes	Wi-Fi	Android, iOS	No	No	Yes	No	No	Yes	Nest	No	Yes	No
Belkin WeMo	Yes	Wi-Fi, ZigBee	Android, iOS	No	No	In-app push	No	No	Yes	Yes	Yes	Yes	No
Philips Hue Product	Yes	ZigBee Light, Wi-Fi	Android, iOS	No	No	No	No	No	Yes	HomeKit, ZigBee	Yes	Yes	Yes
Samsung SmartThings	Yes	Wi-Fi, Bluetooth	Android, iOS	No	No	Notification, Alarm	No	No	Yes	ZigBee, Z-Wave, IP	No	Yes	No
SkylinkNet	Yes	Wi-Fi	Android, iOS	No	No	-	No	SG	Yes		No	Yes	No
LG Smart ThinQ	Yes	Wi-Fi, mobile Internet	Android, iOS	No	No	Phone, SMS	No	SM and SG	Yes	Only ThinQ products	No		No
Aros	Yes	Wi-Fi, Wink app	Android, iOS	No	No	No	Yes	No	Yes	Yes	No	Yes	Yes
Sensibo	Yes	ZigBee, Wi-Fi, IR	Android, iOS	No	No	No	No	No	Yes	Any remote controlled A/C	Yes	Yes	No
Kevo	Yes	Bluetooth, Ethernet	Android, iOS	No	No	Yes, push message	Yes	No	Yes	Nest	No	-	No
Skybell	Yes	Wi-Fi	Android, iOS	No	No	Yes	No	No	Yes	Nest	No	-	No
Canary	Yes	WiFi, Ethernet	Android, iOS	No	No	Yes	No	No	Yes	Wink Hub	Yes	-	No
Honeywell Tuxedo	Yes	WiFi, Z-Wave	Android, iOS	Yes	Yes	Yes	Yes	No	Yes	Z-Wave	Yes	Yes	Auto turn light
SwannOne	Yes	Wi-Fi, ZigBee, Z-Wave	Android, iOS	Yes	No	Yes	No	No	Yes	Nest, Philips, Kwikset ...	No	Yes	Yes

## 6.6 Evaluation Chart

Here we have evaluated the qualitative properties of the smart home devices in terms of a given scale of 1 to 5 stars (\*), whereas 1 represent the lowest and 5 represents the highest scale. We think that this chart can help to understand and compare similar products in a smart home setting.

Table 6.17: Evaluation chart of smart home appliances

Product Name	Efficiency	Usability	Security	Privacy
Nest products	*****	****	***	***
Nest Cam	***	****	**	***
Whirlpool 6th Sense Live	****	****	**	**
Belkin WeMo	****	***	***	***
Philips Hue Product	****	*****	*****	***
Samsung SmartThings	*****	*****	***	***
SkylinkNet	**	*****	***	**
LG Smart ThinQ	*****	*****	***	***
Aros	****	****	**	***
Sensibo	**	****	**	***
Kevo	****	*****	*****	*****
Skybell	***	****	*****	*****
Canary	-	****	***	*****
Honeywell Tuxedo	*****	*****	*****	***
SwannOne	****	****	*****	***

## 6.7 Conclusion

We have seen that many of the industrial manufacturers come up with smart products that can interact with our home environment. These devices fulfill our daily activities, learn from our behavior and contribute to a comfortable easy life. We have investigated a selection of different types of devices - kitchen appliances, lighting, home security etc. among them. Not all of them are relevant or contribute to smart meter and smart grid energy management. As for example, home security devices have less effect on energy savings. But if energy craving devices like A/C, washing machine, kitchen appliances, water heater becomes smarter and can interface with smart meter then they can contribute to save energy and expenses. Devices that are compatible with LG Smart ThinQ have capabilities to do so. Availability of more such devices will enhance the implementation of smart grid more reasonable. Out from the analysis, Wi-Fi and ZigBee has the biggest potential to become the communication interface for future smart grids, talking to smart meters and smart home infrastructures through a smart home gateway. However, the challenge is in harmonization of interfaces and standards. A further analysis of these standards is found in the next chapter.

# Chapter 7

## Standard Services for Smart Home

Smart appliances use wireless technology such as, Bluetooth, ZigBee, Z-Wave, RF, IR or Wi-Fi as their underlying communication medium. To interoperate among the devices and to have a common control center, different standard services are evolved.

Here we mention four of those which come into discussion in the previous chapter along with the features of smart home appliances:

- openHAB
- IFTTT
- Apple HomeKit
- Amazon Dash Replenishment Service

### 7.1 openHAB

openHAB (open Home Automation Bus) is a software for integrating different home automation systems and technologies into one single solutions that allows overarching automation rules and that offers uniform user interfaces [openHAB, 2016]. Bindings are optional packages that can be used to extend functionality of openHAB.

openHAB

- is designed to be absolutely vendor-neutral as well as hardware/protocol-agnostic
- can run on any device that is capable of running a JVM (Linux, Mac, Windows)
- lets you integrate an abundance of different home automation technologies into one
- has a powerful rule engine to fulfill all your automation needs
- comes with different web-based UIs as well as native UIs for iOS and Android
- is fully open source
- is easily extensible to integrate with new systems and devices
- provides APIs for being integrated in other systems

## 7.2 IFTTT

IFTTT is an abbreviation of “IF This Then That” [IFTTT, 2016]. It is a free web-based service that allows users to create chains of simple conditional statements. The conditional statements are called “recipes”, which are triggered based on changes to other web services such as Gmail, Facebook, Instagram, Pinterest etc. That is, it creates simple connections between apps. A recipe is for example, “if the user is tagged by someone on Facebook, then that photo will be added to the user’s cloud-based (e.g. Dropbox) photo archive”.

IFTTT uses ‘channels’ as the basic building block to connect the external services that triggers an action. For the above example Facebook and Dropbox should have an IFTTT channel to be connected by IFTTT service.



Figure 7.1: IFTTT channels illustration

As in case of popular web services, IFTTT have channels to connect smart home devices and perform action on conditions. For example, an IFTTT recipe, “When your Nest is set to away, your lights will turn off”, utilize the channel provided by Nest Thermostat channel and Philips Hue channel. Providing the compatibility with the channels for IFTTT recipe is the responsibility of the channel provider.



IFTTT gives power to people who do not know anything about coding but can program devices or services to work with together. It have smartphone apps to set recipes for smart home appliances that have an active IFTTT channel.

## 7.3 Apple HomeKit

Apple HomeKit enables a user to control a smart device from iPhone or iPad. It is possible to control the lighting, air conditioner or heater with Siri, the Apple's voice controlled virtual assistant. Apple introduced the home automation API HomeKit in 2014 as part of iOS since iOS version 8 [HomeKit, 2016].

HomeKit can do the following things:

- Discover accessories and add to the HomeKit collection. Have you purchased a smart plug or lamp, you can add that to your collection.
- Show, use and edit the data in HomeKit database. You can see which devices are already registered.
- Communicating with accessories and services, as for example, you can turn off the light in the living room.
- Apps from iOS 8 can access widgets, so you can quickly operate devices from the Message Center.

Hardware manufacturer who wants to produce HomeKit enabled device must have a MFi (Made for iPhone/iPod/iPad) license from Apple. Advantage of HomeKit is that multiple devices in home automation can be controlled easily without each of them having their own app.



Figure 7.2: Apple HomeKit

## 7.4 Amazon Dash

Amazon Dash Replenishment Service (DRS) enables connected devices to order physical goods from Amazon when supplies are running low - like a washing machine detergent dispenser orders more detergent when it is going to be empty. By using Amazon Dash Replenishment, device makers are able to leverage Amazon's authentication and payment systems, customer service, and fulfillment network; giving their customers access to Amazon's low prices, great selection, and reliable delivery [Amazon Dash, 2016].

DRS can be integrated with devices in two ways. Device makers can either build a physical button into their hardware to reorder consumables or they can measure consumable usage so that reordering happens automatically.

## 7.5 Scenarios for Smart Meter and Home Gateway

Smart home appliances communicate among themselves using wireless technology such as, Bluetooth, ZigBee, Z-Wave or Wi-Fi network. A well designed smart home should have a central gateway from where we can control all the smart devices available inside the home.

### 7.5.1 Appliances and ZigBee Gateway

Here we consider a scenario in which we assume that the smart home appliances support ZigBee. Supporting ZigBee is more common in IoT devices and in this case there can be a

ZigBee gateway that can act as gateway between the devices and the user. The gateway can be configured to supply different privacy level and access restriction while accessing it within the LAN and from the Internet outside.

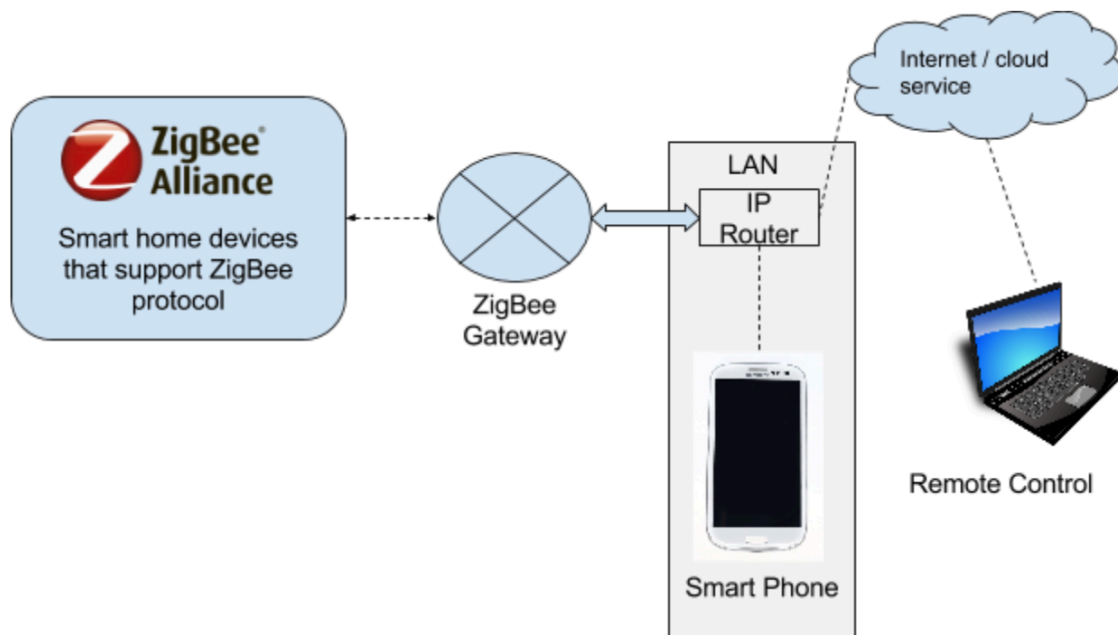


Figure 7.3: ZigBee smart home gateway and access interface

## 7.5.2 Smart Meter and Smart Home Gateway

We describe scenarios for how smart meters and home gateways can be used together as a part of the smart grid. We discuss the privacy and usability aspects of both scenarios.

One scenarios are intended to provide more privacy to the home user, whereas the other scenario would be cheaper and rely on the provider's cloud services.

Consider the functionalities of a Smart meter, as we described in chapter 4 and 5. Smart meter is planned to implement as a gateway that communicate between control center and home appliances. In smart home, appliances will be connected with some level of intelligence. To protect user privacy, we suggest three scenarios that a smart meter can address,

1. Smart meter as a metering device and gateway
2. A dedicated home appliance control device and Smart meter as metering device

### 3. Hybrid smart meter as both a home control and metering device

#### 7.5.2.1 Smart Meter as the Gateway

Smart Grid have full control and access inside smart home through smart meter. Smart meter can directly connect and control the appliances in the home. This approach incur a huge privacy issues for the home user since the utility company have full access and overview of the home appliances. Most of the user will be reluctant to use such kind of smart meter.

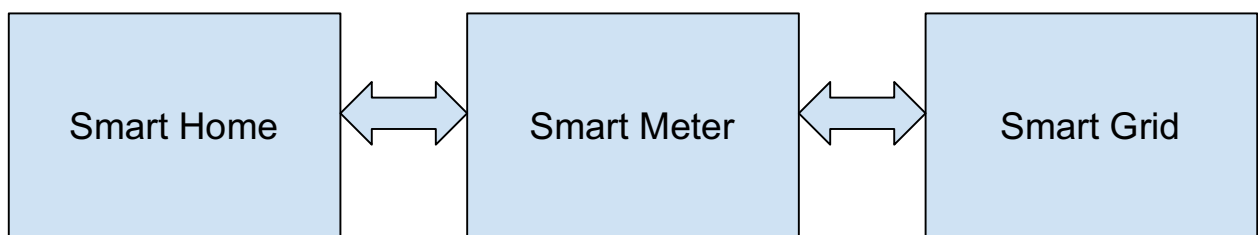


Figure 7.4: Smart meter as the gateway

#### 7.5.2.2 Home Control Center as the Gateway

Smart meter can send utility providers command requests to appliances at home with standard interface provided or developed for this specific purpose. User can configure the control center to respect the commands or ignore them. The smart home control center can use ZigBee or openHAB gateway.

This may not be so efficient and cost effective since we need another device to be developed and installed in the user's premises. But it gives more control to the consumer and privacy protection is higher.

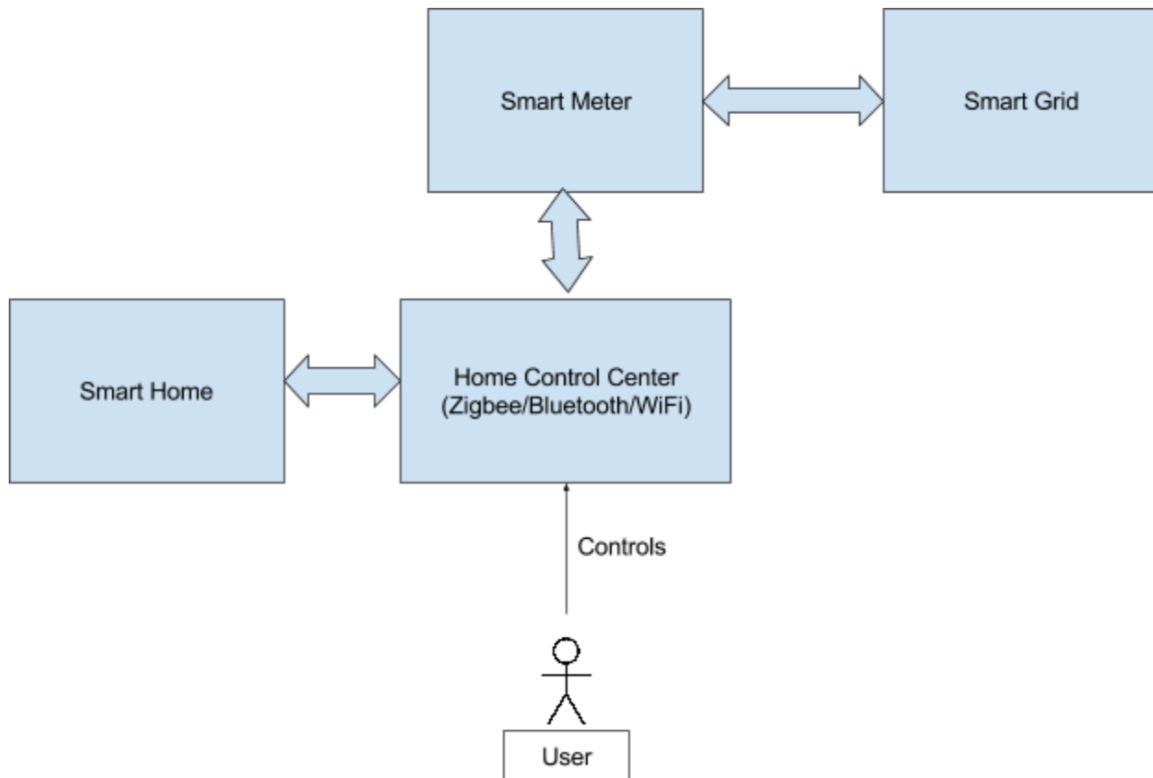


Figure 7.5: Home control center as the gateway

### 7.5.2.3 Hybrid Smart Meter

Hybrid Smart Meter can have two separate entities inside itself - home control center and metering device. Unlike the previous two approaches, these two units should be integrated inside Smart Meter. But the home control center will not be accessible from the Smart Grid. This will rather be accessible only to the user inside home network. It should be like the wireless router we use at home that bridges the connection between LAN and WAN. The LAN part can be compared with the home control center and WAN part is the smart grid. In between there can a firewall like entity that preserve user privacy hiding the interfaces of the smart home appliances from the outside attackers.

This method is more efficient and cost effective since we do not need another device to be installed in the user's premises.

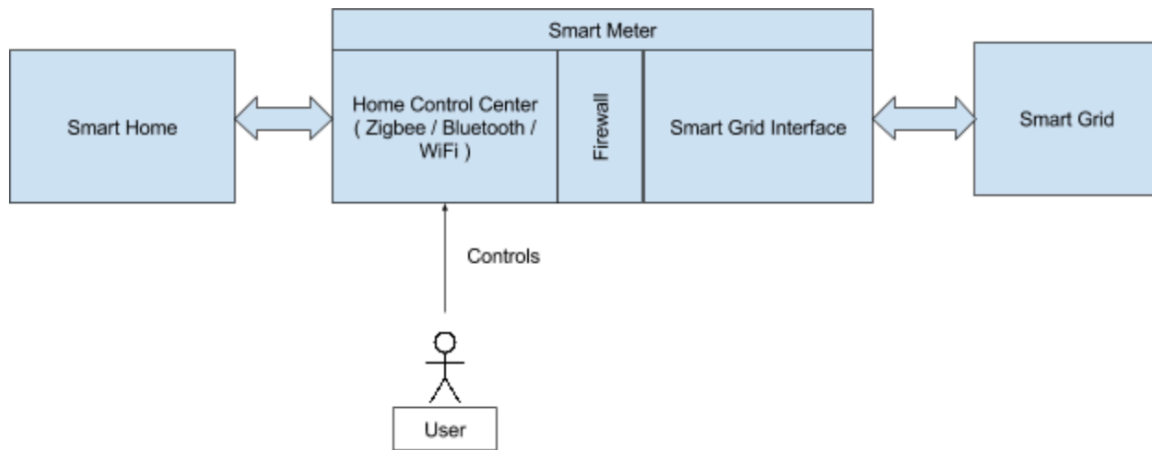


Figure 7.6: Hybrid smart meter

## 7.6 Conclusion

In this chapter we have seen that how smart home appliances can work together interactively. There are several ways to achieve the goal. Contemporary researchers investigate several approaches that meet the high security and privacy criteria that is needed for IoT devices deployed inside the home. Yet no universal solution exists that can be used with all kinds of vendors and their smart home appliances. We have also presented three scenarios that how a smart meter can be designed as a home gateway preserving user privacy and security. Of them the combined or hybrid model of smart meter has the potentiality to serve as a home gateway preserving the security and privacy of the smart home user.

# Chapter 8

## Conclusion

In this thesis we have analyzed smart home products with their ability to provide novel services in a smart grid infrastructure. We have found that most of the products are smart enough to be communicated over wireless or through the Internet. But not all of them are ready for the smart grid infrastructure. The products are capable of providing IoT services, controllable using remote interfaces in the home or remotely from the Internet. Many of the products learn from the environment and from the user behavior being smarter over time. Considering all these features we developed a framework to evaluate the qualitative values of the smart home appliances.

We have collected the product data from their respective website and product brochure. We did not use the products in practice or in the laboratory. We did not analyze how they communicate in a network environment; how long these devices survive outside if they run on batteries etc. We have solely relied on the data sheet provide by the manufacturer. However, our framework to evaluate the products can be furthered to get more accurate results when a practical smart grid with smart meter is implemented in practice.

Our survey on the smart appliances and their services give an overview of the available smart products developed in the industry. We have looked into fifteen industrial products groups, five of the different communication interfaces used by these and four of the standard services supported by these devices. We have also presented how smart meter can act as a gateway for all these appliances, interfaces and services in smart grids. This is a significant study for the IoTSec project to get an idea on the products that are capable of joining in the smart grid paradigm. The home users are also benefitted with the study having a selection of products that they can use in their smart home. For the service provider this can be a base to develop a new business model such as, developing a universal novel service provider in the cloud.

# Chapter 9

## Future Work

To control the products and services remotely or over the Internet, in most of the cases the user has to register in the manufacturer's webpage and maintain a regular subscription. A compatible mobile or smartphone apps from the producer is to be downloaded if the user want to control the appliance from a mobile device. The account with accompanying credentials is associated with the appliances owned by the customer and renders the consumers to view and control remotely. Most of the appliances use Wi-Fi network at home to connect to the wireless router and the Internet to their vendors' services. Latest smart home products use the internet connectivity and cloud service to provide their smart services.

Through smart home control in the home, service provider's application can connect with different devices and provide enhanced services to the customer. We envisioned a universal cloud services for Internet of Things devices that can be used by the users of a smart home. The user can choose among the service providers but should have the ability to get all the devices managed in a single cloud. Thus the user can get rid of opening and maintaining several user accounts and subscription expenses and overhead associated with those. The thesis opens up a scope to investigate and suggest a framework to have such a universal service in future.

We have also seen that smart home appliances need a standard gateway from where it will be comfortable for the user to control and configure the devices for scheduling, configuring, troubleshooting etc. Besides, service providers would like to interface with the appliances through the smart grid. In situation like this we have shown how a smart meter can be used as a metering device as well as a smart home gateway providing proper security and privacy to the user. Further research has to be done in this field of smart meter as security and privacy becomes the main challenges here.



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