



# TECHNICAL REPORT

## M2M/IoT ENABLEMENT IN

# SMART HOMES

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M2M SMART HOMES WORKING GROUP



TELECOMMUNICATION ENGINEERING CENTRE  
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## Executive Summary

The world has seen tremendous growth in telecom technology during the last decade. As a result of this, a multitude of new applications of the Information & Communication Technologies have emerged and changed the way we live, work, play, interact and even think. This has created a lot of momentum in many spheres that impact our lives. Latest trend is Machine-to-Machine (M2M) communication / Internet of Things (IoT) which has led to a new world of possibilities and opportunities. Smart Home is one of the focus areas in this initiative as is evident from the large number of IoT / M2M enabled nodes being created for this sector.

While ‘*Smart*’ inherently means ‘connected’ in IoT world, Smart Homes could have multiple meanings for different people and even different situations. A Smart Home is a user’s private space and each user may have different needs. The users spend a significant amount of time at their homes and may have different expectations depending on their background, taste, affordability and availability of common services.

A Smart Home is an aggregation of all the needs of its occupants while they are inside and also when they are not. Remote control, Security, surveillance, remote monitoring of premises including monitoring those who are sick, young, elderly, etc are all requirements of users. In order to meet these requirements, an integration at the Application level and scalability at the cloud level are needed.

With this kind of diverse backgrounds of users and their requirements and tastes, defining a common platform for a Smart Home is a rather challenging task. What could perhaps be possible is to create a generic platform that accepts multiple technologies as its inputs and somehow combines these inputs at the Home Gateway level and sends the information about various sensors from all the vendors on a single high speed communication link.

This document of Telecom Engineering Centre describes M2M/IoT Enablement in Homes to take into account the diverse needs of users as stated in previous paragraphs. It introduces the subject with brief illustration of M2M communication and its framework for Smart Homes.

The report has identified multiple use cases in Smart Homes e.g. Video monitoring of home, Security & Alarm, Door control, HVAC control, Smart lighting for efficiency, Controlling appliances through Smart phones, Solar lighting system, smart (electricity, water and gas) metering etc.

The report identifies key challenges: lack of standards and non-availability of high speed and reliable Internet services, indigenous manufacturing, etc. Standards will allow for a level playing field for all participants that will benefit the customers.

In the end, way forward has been suggested wherein action points on various aspects like adoption of standards, development of devices, certification mechanism etc. have been brought out.

It may be mentioned here that the needs relevant to individual apartments, homes, and small establishments like shops or small scale industries operating from small buildings are covered in this document. Industrial buildings and large complexes are not in the scope of this document. The facility management services of apartment blocks are more similar to management of large complexes, hence are generally excluded from the scope.

## 1 Introduction

A smart home is one that incorporates advanced sensing and automation systems to provide the inhabitants with monitoring and control regardless of whether they are inside or outside the home. For example, a smart home may have controls for lighting, temperature, multi-media, security, window and door operations, as well as many other functions.

A Smart home, then, may be defined as a residence or a building with equipment which can be remotely controlled and operated from any location in the world by means of Smart Devices or through a smartphone. Smart Homes comprise of Devices that provide comfort, security, convenience, energy efficiency and enhance intelligent living. The Devices communicate and interact with each other and form a connected ecosystem. Smart Home is usually understood as automated home but the actual capabilities are beyond automation. Smart Home ecosystem comprises of a set of connected gadgets with Intelligence that help them in executing the task and take necessary decisions.

The first step towards making a home smart is automation as shown in Figure 1. The automation could be related to the individual appliances or nodes being intelligent enough to take local decisions. A simple



Figure 1 : Automated Individual Components, [14]

example could be a standalone porch light that turns on only when there is movement detected or wirelessly operated curtains / blinds. Another example could be a camera that records the movements for a period of time after a gate is opened. Yet another example could be a timer in a washing machine that takes care of switching it on at preset times.

A solar roof top system that charges a battery and acts as an inverter for the requirement of the individual home is also an example of an automated home system.

We may have another scenario where these elements are connected to each other controlled by a gadget placed inside the home (that may be called as in-home display). This connectivity could enable us to take

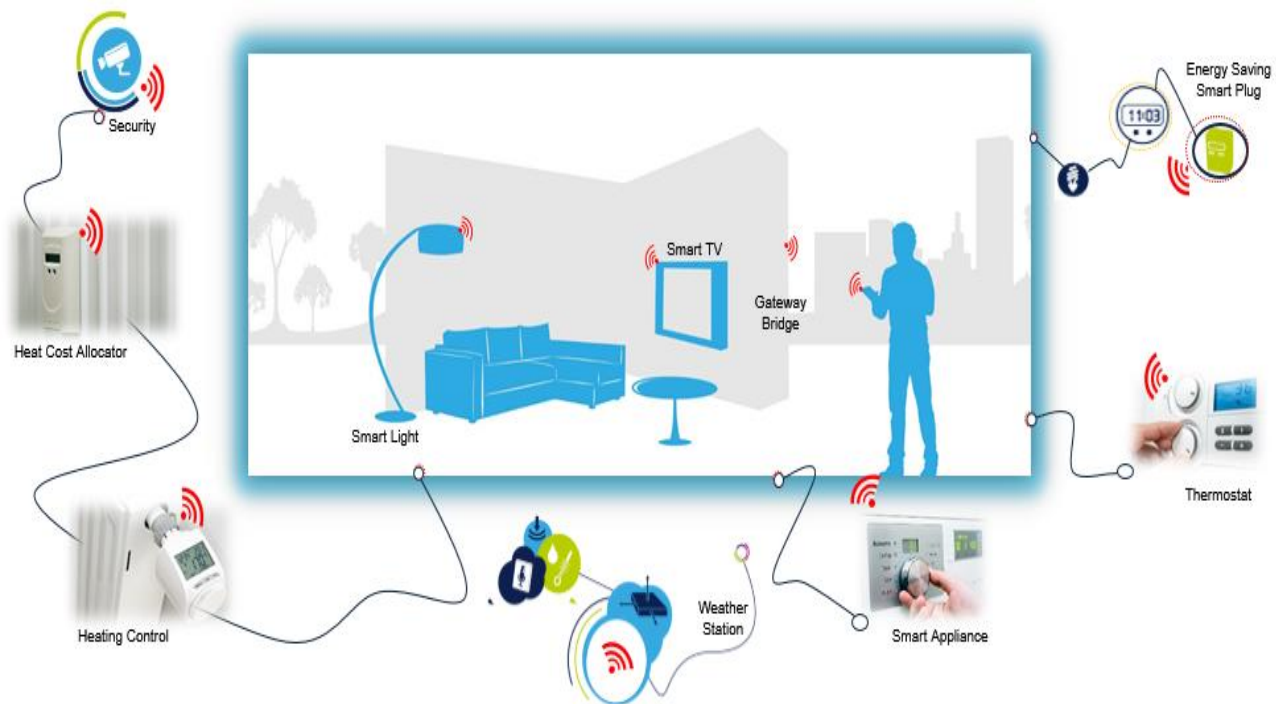


Figure 2 : Standalone Automated Home, [14]

centralized decisions and monitoring, and would make the home autonomous. These systems, even if individually smart, do not make a complete smart home. This scenario has been projected in Figure 2.

Home buildings in Indian scenario are difficult to be classified into a few categories, largely due to the economic disparity and the place of living. On one hand there is a large population that has barely access to essential requirements of water, electricity and food; and on the other hand India has a small percentage of population with income levels similar to those of developed countries. The expectations of comfort, automation, security and services by this population are same as those of the developed countries.

Smart Homes present some very exciting opportunities to change the way we live and work, and to reduce energy consumption at the same time. The owners of smart homes are empowered with conveniences like: being able to check messages, open windows, operate lights and curtains and monitor how much

money the house has made or saved from the renewable energy system or smart energy management system, through their respective smart phones, from anywhere in the world.

Further a Smart Home is a common and unifying gateway to the world for its occupants, various sensors and automating elements inside it. In fact it may be commented here that many other functions of connectivity may be considered as embedded within a Smart Home. As an example, remote patient

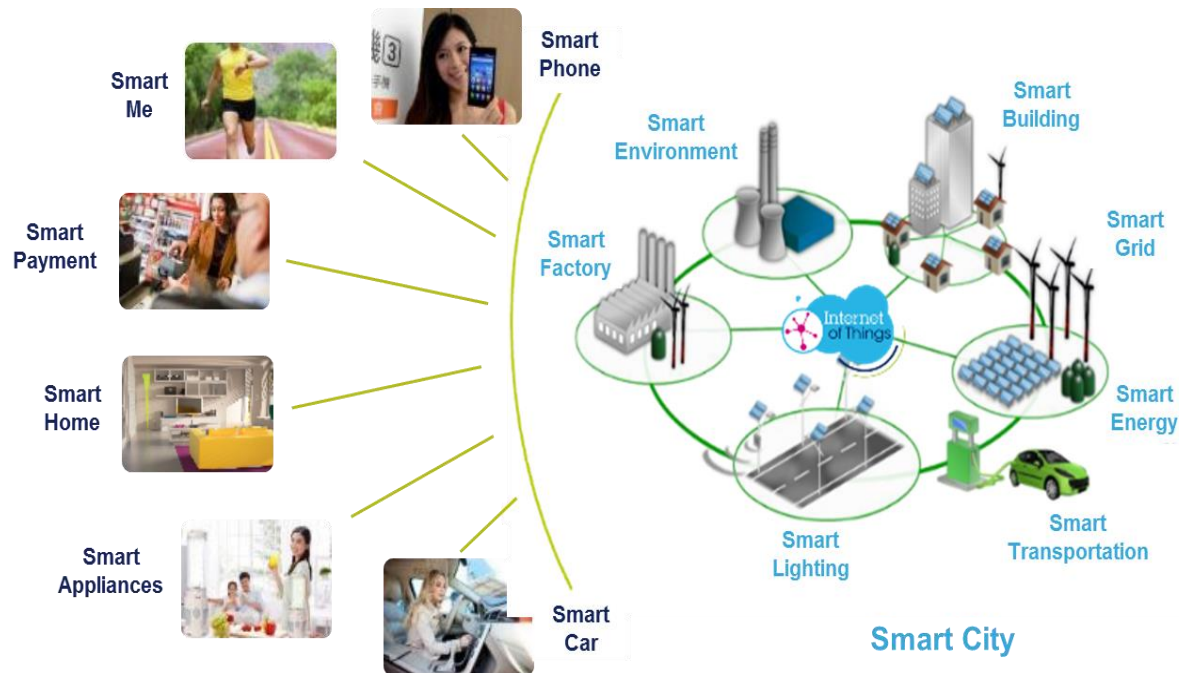


Figure 3 : A connected Home: Reference Smart Home as part of a Smart City, [14]

monitoring, vehicle charging, solar rooftops, metering, home appliances, electric and aircon controls, entertainment, health and fitness equipment and a host of other connected devices are part of a home and a Smart Home system is expected to provide a unified view of all these services. Smart home concept as described has been illustrated in Figure 3 in the context of Smart Home itself being a unit of Smart City.

Extending this concept further likewise, a Smart Home in itself may be a part of a large building complex and in a much broader sense of a Smart City. This presents opportunities and challenges for connectivity and interoperability. A large number of smart devices are now available and their numbers are increasing. At present most of the devices and gateways are working on proprietary standards. However for the fast development of the sector and to have economies of scale, devices, gateways, network and the applications are required to be developed on open standards with interoperability.

## 2 What is M2M Communication / IoT?

### 2.1 M2M Communication

It refers to the technologies that allow wired / wireless system to communicate with the devices of same ability. M2M uses a device (sensor, meter etc.) to capture an 'event' (motion, meter reading, temperature



etc.), which is relayed through a network (wireless, wired or hybrid) to an application (software program), that translates the captured event into meaningful information. A conceptual picture is shown in Figure 4.

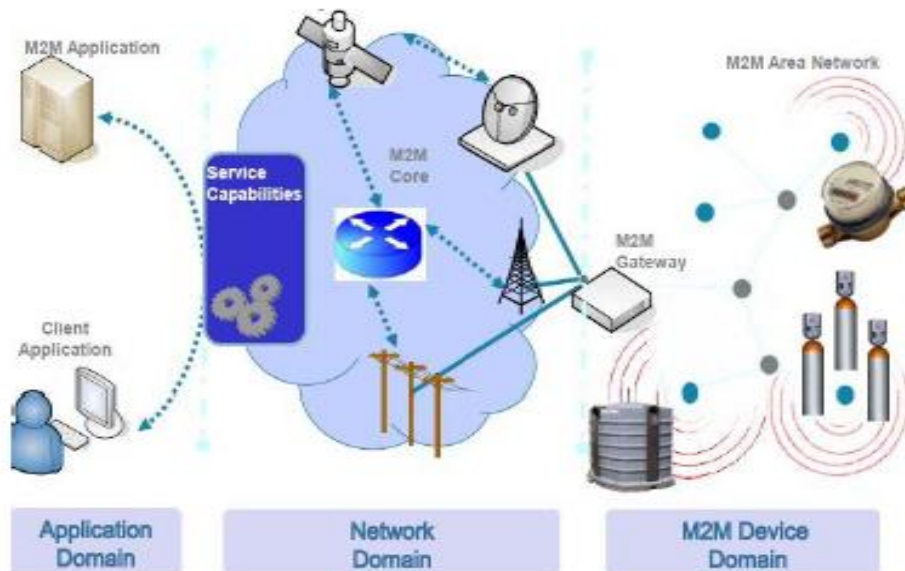


Figure 4 : M2M Concept, [1]

The enabling technologies for M2M are sensor networks, RFID, mobile Internet, wired & wireless communication network, IPv4 / IPv6, etc. In Home area network (HAN) / Local area network (LAN), low power wireless communication technologies such as Wi-Fi, ZigBee, 6LoWPAN, Bluetooth Low Energy (BLE), Z-wave etc. may be used to connect the devices with the M2M gateway. GSM 3G/ 4G or fixed line broadband / FTTH may be used for connecting M2M gateway to the server. Low Power wide area network (LPWAN) technologies such as LoRa and Sigfox are being used for transmitting very small data. Based on 3GPP release 13 and 14, NBIoT technology is expected in near future on LTE network.

IPv4 addresses are going to exhaust. Standardization and adoption of IPv6 in telecom and ICT organizations will provide an opportunity of having billions of devices which can be IP enabled and seamlessly addressable through mobile or wired broadband connections.

## 2.2 Internet of Things

The Internet of Things (IoT) will revolutionize and change the way all businesses, governments, and consumers interact with the physical world. This level of disruption will have a significant impact on the world in improving the quality of life. IoT ecosystem may have M2M devices, Gateways, M2M Communication technologies, big data and process management, IoT platform, User interface (web, Mobile, HMI) and end to end security.

ITU-T in its Recommendation ITU-T Y.2060 (06/2012) has defined Internet of Things (IoT), as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

ITU-T has also created a Study Group (SG)-20 in 2015 to study IoT and its applications in Smart cities and communities.

IoT will be having a heterogeneous network, having IP and non IP devices connected through IP Gateways. Gateways will be connected to IoT Platform. A huge amount of data will be generated by the sensors. Big data analytics may be used to create intelligence, which may be further used for various operational and planning activities. A typical network having various communication technologies and Gateways have been shown in Figure 5.

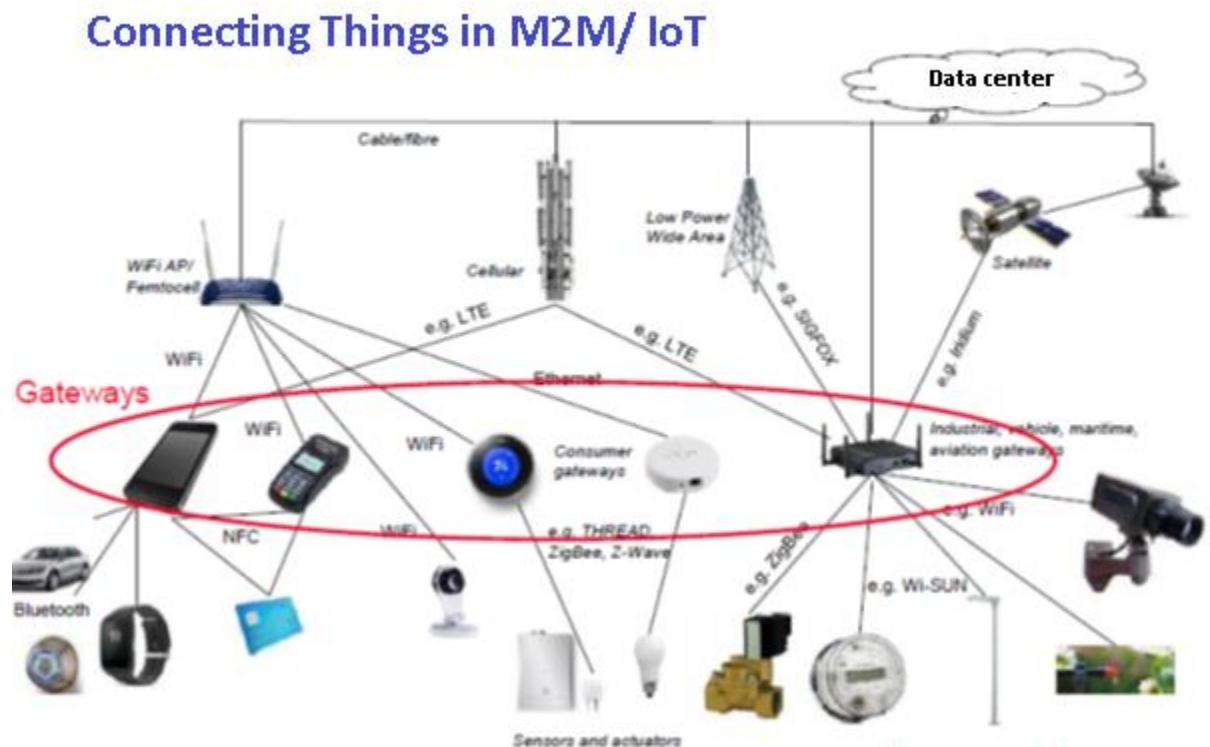


Figure 5 : A typical IoT / M2M Connectivity Network, [Keysight Technologies]

Various verticals such as Power sector, Intelligent Transport system, Remote Health management, Safety & Surveillance systems, Village & Agriculture, Homes, and Industries etc. may be transformed to become smart by using M2M / IoT technologies. This will improve the efficiency and in turn the quality of life.

### 3 Smart-Home Background Analysis

As per the projections made by CISCO / ERICSSON / ITU, there may be around 50 billion connected devices globally by 2020 [2]. As per another study by CISCO in 2015, share of computers (including PCs, tablets,



and smart phones) will be around 17 percent of all Internet connections; the other 83 percent will result from devices to be used in various verticals of IoT domain [3]. India is expected to have around 2.6 billion connected devices by 2020. The home automation market in India is expected to reach INR 8800 Crores (US \$ 1.3 B) by 2017 and is growing at a rate of 30% CAGR (Source: RedSeer consulting).

By 2022, a typical family home will contain 500 smart devices (Source: Gartner).

The idea of Smart Home was originated long back before the advent of IoT. The world has seen a tremendous change due to the invention of various devices to automate household activities during 1901-

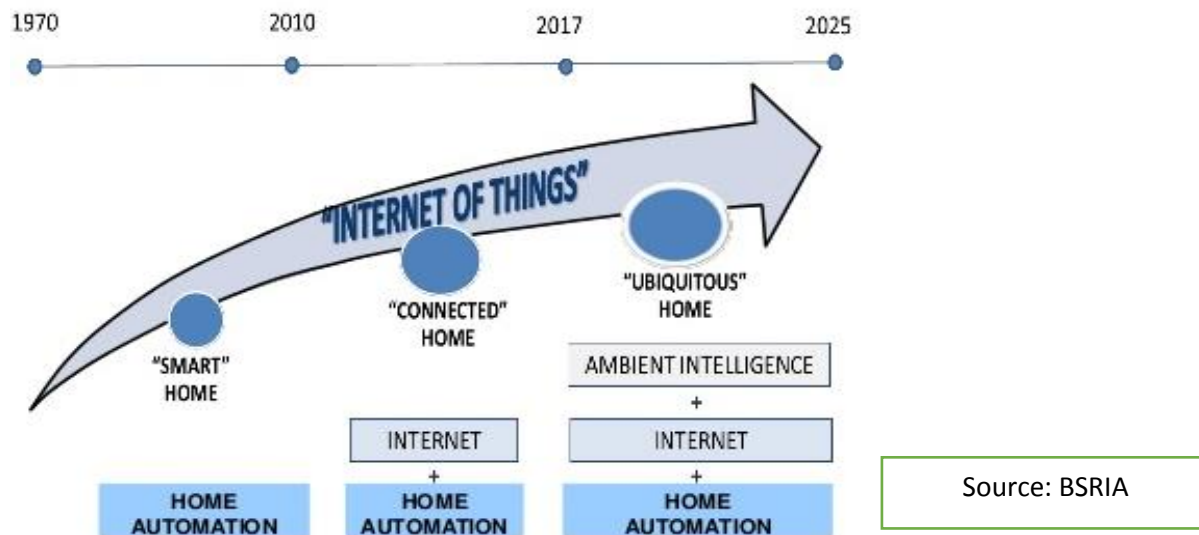


Figure 6 : Evolution of Smart Homes

1920. Among the few inventions of early twentieth century were first engine powered vacuum cleaner in 1901 followed by first generation of refrigerators, washing machines etc. In 1966, ECHO IV (Westing house) was the first smart device invented but was not sold in the commercial market. The device helped in automation of home appliances, controlling the room temperature and also assisted in preparing shopping list. This was followed by the invention of H316 Kitchen computer by Honeywell Corporation that could store recipes but was not commercially available. X10, the first commercial home automation technology was developed in the year 1975 and it used electrical power transmission wire lines for signaling and communication. Bill Gates's smart home which was built in 1995 attracted many people because of its features like temperature control, heated floors, customized preference for room lighting and climate control, monitoring his favorite Maple tree with sensors and computer to provide watering and better gardening. The major trend has started from 1990 where home automation was the basic functionality. With the growth of smart-phones and other smart devices, the smart home penetration has

increased in the world. The remote control is now embedded in smart phones in form of application to control.

Smart Homes are the integral part of Smart Cities. Connected things relevant to Smart Homes are forecasted to grow from 294 million to more than 1 billion; more than tripling in just three years, as shown in Table 1, [4]. Smart things inside the Smart Home are representing the biggest portion of the connected devices as per this report. Evolution of Smart Homes with IoT is shown in Figure 6.

*Table 1 : Connected Things Installed Base within Smart Cities (in Millions)*

<b>Smart City Subcategory</b>	<b>2015</b>	<b>2016</b>	<b>2017</b>
Healthcare	9.7	15.0	23.4
Public Services	97.8	126.4	159.5
Smart Commercial Buildings	206.2	354.6	648.1
Smart Homes	294.2	586.1	1,067.0
Transport	237.2	298.9	371.0
Utilities	252.0	304.9	371.1
Others	10.2	18.4	33.9
<b>Total</b>	<b>1,107.3</b>	<b>1,704.2</b>	<b>2,674.0</b>

Source: Gartner (March 2015)

Smart homes and smart commercial buildings represented 45 percent of total connected things in use in 2015. Due to investment and service opportunity, Gartner estimates that this will rise to 81 percent by 2020. Homes will move from being interconnected to becoming information- and smart-enabled, with an integrated services environment that not only provides value to the home, but also creates individual-

driven ambience. The home will become the personal space that provides assistance or personal concierge experiences to the individual as per Gartner report [4].

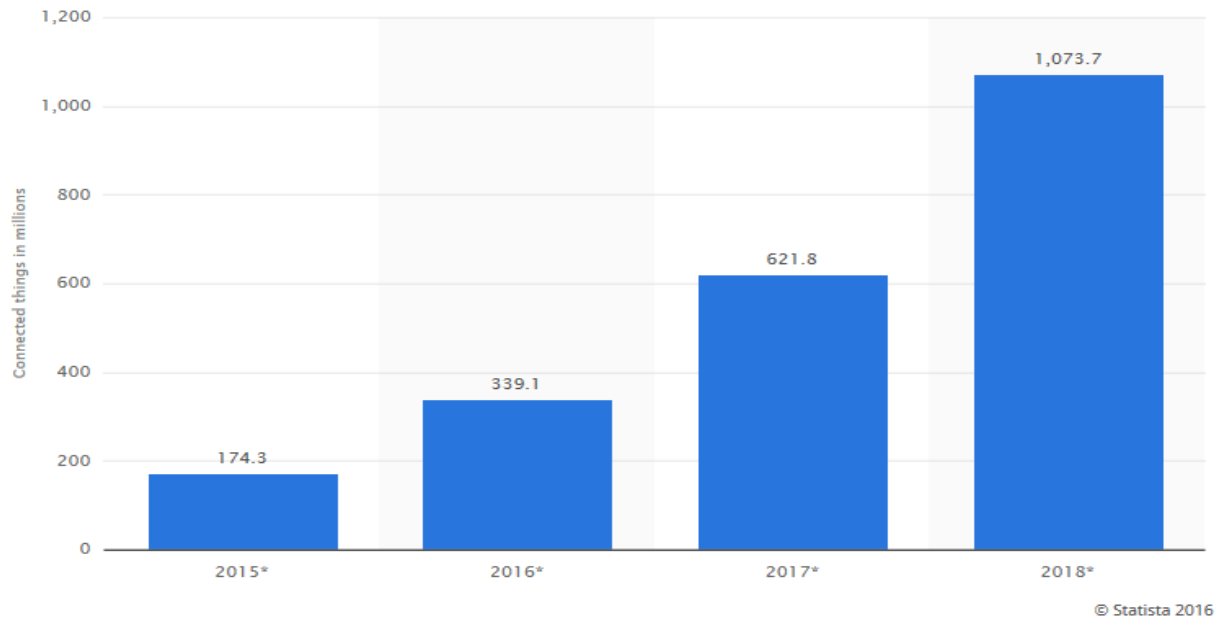


Figure 7 : Smart homes installed base of connected devices within smart cities from 2015 to 2018 (in millions)

In a similar analysis by Statista [5], the growth of installed connected devices in smart homes within smart cities from 2015 to 2018 is shown in Figure 7.

### 3.1 Current Market Scenario

According to a report [6] published in 2015, the major drivers for Smart Homes are Security, Convenience and Energy Efficiency. The awareness of Smart Homes is very high among customers from upper income segment and urban areas. Low entry barriers like open source technologies are encouraging more number of players to look for innovation and to provide better value proposition for their customers.

The Home automation market is broadly classified into Application based and Technology based. From Application perspective, the market may be segmented into Lighting, Safety and Security, Entertainment and Energy Management Systems, etc. Whereas based on various technologies used, it may be classified into Wired and Wireless technologies that may be further classified into X10, ZigBee, Bluetooth, Wi-Fi, Wi-SUN, Thread, PLC, Z-Wave etc. Presently the market is more concentrated towards luxury deployments based on specific or proprietary technologies and solutions, however there is a trend where more and more users and startups are creating Home automation platforms and systems that are cutting across the technology domains in many cases.

Region	Revenue in mUSD (2016)
Asia	2496.6
Australia	143.8
Europe	2803.8
Latin America	168.7
North America	9912

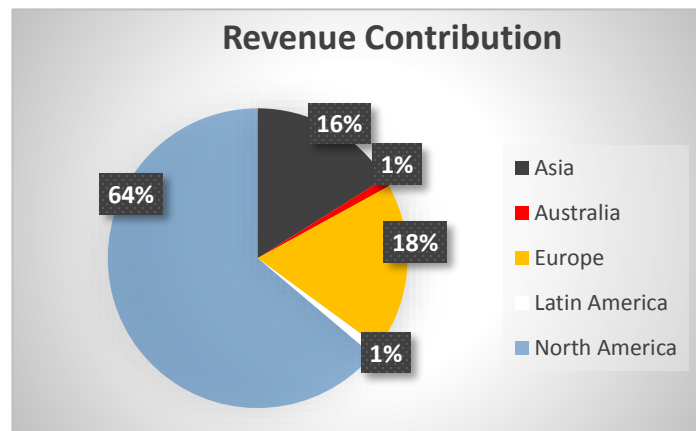


Figure 8 : Market Revenue, Source Statista

Presently the market revenue from Smart Homes is estimated as shown in Figure 8. The chart clearly shows that North American market is dominating in the revenues. This growth is driven by various Industries spread across the region. This leads to concern among the population about safety, security and creates a need of increased product offerings. European market and Asian market also show a growing trend.

### 3.2 Smart Homes Market Landscape

Smart home trend is gaining momentum day by day. Many international conferences and exhibitions are being held in various parts of the world, emphasizing the need, offerings, security issues and aspects of smart homes for a future connected home.

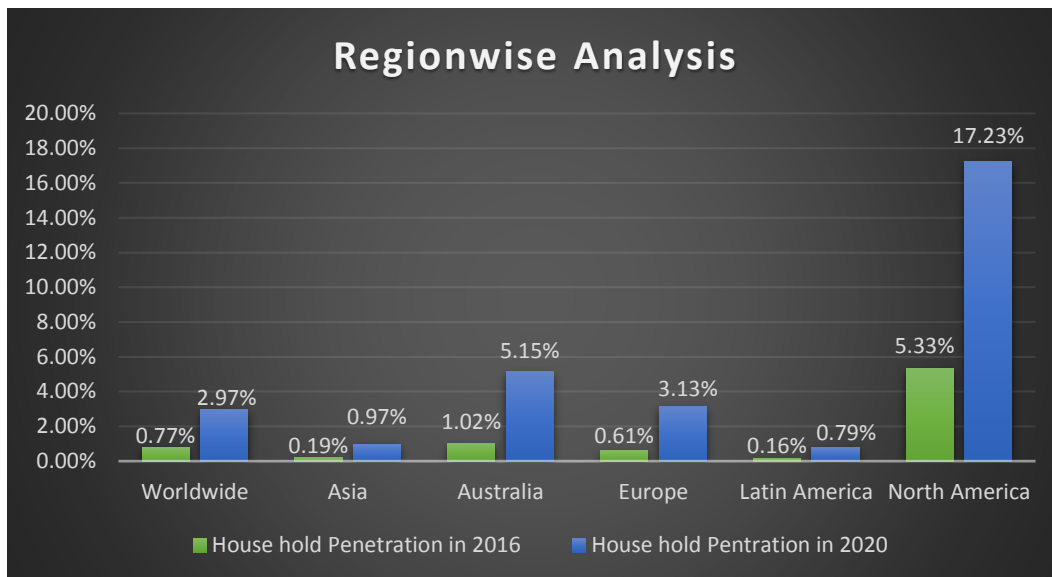


Figure 9 : Region wise Smart Home Market

In Asia, Smart homes and building market is one of the fastest growing market at a CAGR of 37.7 percent. India is one of the fastest growing Smart Homes markets in Asia Pacific. The home automation market in India is expected to reach INR 8800 crores by 2017.

### 3.2.1 Smart Homes Market Landscape-Global Perspective

The chart in Figure 9 shows the house hold penetration of Smart Homes across the world. The trend shows an increase in household penetration for North America which is dominated by US market.

## 3.3 Major Characteristics of Global Smart Home Market

### 3.3.1 US leads in Smart Homes Penetration

The US market is dominated by all the major value chain players and they focus on serving the US customers that are rich, willing to pay for comfort, luxury and convenience. This is resulting into increased innovations also originating from US.

### 3.3.2 Smart Homes is a requirement, not a luxury

There has been a myth that Smart Home is a luxury item. While this has been true previously, the modern day needs have moved Smart Homes from a luxury to required category. This has happened mainly on account of Smart Devices penetration at more affordable prices and integration into the IoT ecosystem. The low entry barriers, especially with Do It Yourself (DIY) kits are further aiding this.

### 3.3.3 Market Penetration is less and needs to be increased

The idea of Smart Homes is presently limited to Home automation and this need to be updated in customers' mind.

### 3.3.4 Fragmented Market & estimation of Return on Investment

Due to the lack of standardization, many players are competing in the market, some with their proprietary technologies. Return on investment is difficult to estimate because of many players and availability of devices based on standard and proprietary technologies. There is a need of interoperability at device, network and application levels in order to provide unified solutions and economies of scale. This will help all the players and finally the consumers.

## 3.4 Major Trends in Global Smart Home Market

Figure 10 shows the concept of Smart Home in another manner in an immersive experience to the user. Various trends in the global market are explained below.

### 3.4.1 Global IoT segments are growing- Smart Home is becoming a trend

M2M/IoT technologies are proliferating and Smart Homes vertical is witnessing a major action. Variety of sensors that can be easily connected to the cloud at affordable prices are resulting into this proliferation.

### 3.4.2 Investment Research & Development

The connectivity technologies for home are the ones that are applicable in other sectors as well. This helps every sector to enjoy the benefit of the technological advancements. Smart Home sector is getting attention of major players. Players like Google, Apple, Nest Labs, Amazon (Echo), AT & T (Digital Life), Xiaomi, Xfinity (Comcast) etc are already having their offerings in this sector.

### 3.4.3 Trend in Smart Wearable Devices with Smart homes

Smart Gadgets with Augmented reality and Virtual reality platforms are now interacting with customers in day to day life. As these wearable gadgets are closely associated with the users, the Smart Home value chain players are targeting these smart gadgets for integrating their smart appliances.



Figure 10 : Smart living in a Smart Home, [2]

#### 3.4.4 Convergence of Consumer and Enterprise Technology.

Mobile consumer and enterprise technologies are converging in most industries. Smart Home will be equipped with features similar to that of an enterprise. Analytics, Smart TV, Gadgets will be a part of this ecosystem. A parallel to this can be drawn with the fact that earlier, automation or surveillance was part of only commercial buildings earlier but it has started to become a requirement in an ordinary home today.

#### 3.4.5 Smart Homes and Automobile market

Smart home scope is getting extended to automobiles too. Many automobile manufacturers like Ford, Toyota are working to synchronize their automobile with smart home gadgets. Most of them have invested in their R&D to establish a fool proof system. A Smart Home will provide not only charging to the automobile in case of Electric Vehicles, but may also be powered by it in certain situations. An automobile roof may provide solar power to home or for net-metering in future.

### 3.5 Major Technology Trends

#### 3.5.1 Décor- Friendly Gadgets

The gadgets are aesthetically more appealing than normal gadgets. This helps to make a fashion statement as good looking sensors / nodes placed at various locations in the house are considered as desirable elements. The small size further adds to this feeling.

### 3.5.2 Programmable Devices

The smart gadgets can be programmed and customized according to the user preference. For example, programmable thermostats that can be controlled using the smart gadgets and can be used to control the temperature based on occupancy. The programming capability also adds to personalization.

### 3.5.3 Wireless controls

More and more devices are now connected through wireless. This makes the installation simple. A further element of wireless is portability as devices or nodes can be moved easily to another location in the house or to another house.

### 3.5.4 Advanced Security Systems

The Smart Home gadgets provide a better home automation with enhanced security. These gadgets can track the activity of human beings especially monitoring children and elderly people and activate the security systems in case of an emergency. Security systems and remote monitoring can be further thought to aid remote patient care also.

### 3.5.5 Automated door locks

The automated door locks are configured in such a way that these doors unlock based on the user and his access criteria. These smart locks can be configured with wearable gadgets also. These are considered to be aiding to safety also as depending on the category of the visitor, one may unlock the lock for different time durations and auto lock when needed. The remote door locks are expected to create several different use cases and at present these are in various stages of experimentation even if deployment has already started.

### 3.5.6 Smart Appliances

Currently, household appliances are responsible for about two thirds of the energy consumed by buildings. Industrial appliances are also major energy users. In the future, such appliances will no longer be stand-alone items. By communicating between themselves and with energy control systems, the impact of these devices on the environment can be managed and optimized. Smart appliances will include white goods, heating, ventilation and air conditioning systems and storage systems [7].

### 3.5.7 Solar Roof tops

It is pertinent to mention that roof-top solar, net metering and electric vehicles would play a huge role in the Smart Home, thereby creating a micro grid. Electric vehicles would not only provide a clean and efficient means of transport, but would act as virtual power plants which could supply power to the grid in case of an outage [8].



### 3.5.8 Wearable Devices

Furthermore, with the proliferation of wearable devices for improved healthcare, the quality of life of citizens will substantially enhance [9] .

## 3.6 Customer Expectation from Smart Homes

The customer expectations from a Smart Home are depicted in Figure 11.



Figure 11 : Customer Expectations of a Smart Home

### 3.6.1 Security

Security of the home is of paramount importance. This applies to both the situations when the occupants are inside or away. Increasingly people are required to monitor their homes for intrusions from outside or to have a look at the well-being of their children or elderly relative staying at home.

### 3.6.2 Hassle Free system

The system should not be too complex to operate or understand. The home owner or user expectation is a bug free and threat free system. Overall expectation is that automation must result into more comfort, more personalization of the space and lesser hassles.

### 3.6.3 Cost Effective

Majority of the customers are always price sensitive. They need solutions which are value for money. Smart Home adoption and penetration will increase if the price are reduced.

### 3.6.4 Convenience

With the growth of technology products a customer expects to solve his problem within short period of time and without much human intervention. In general, a customer prefers an automated environment that improves the quality of life for him.

### 3.6.5 Pro-active technology

A customer expects a better quality of life, convenience, and smart automation in accordance with the preferences selected. A personalized Home with an intelligent system that understands the occupants' requirements and perhaps moods should not be considered as a distant dream with virtual reality making its inroads everywhere.

### 3.6.6 Smart Energy Saver

Energy cost is one of the major costs in most countries. Customers are hence cautious about the Energy consumption. They need to control and customize their energy consumption and patterns.

### 3.6.7 Safeguard Privacy

While connectivity and automation are required, no one would like to compromise privacy and security. With most smart devices being able to communicate with each other either locally or through cloud, the information leakage is required to be blocked at every level. Customers are worried about security threats, vulnerabilities that may jeopardize their privacy. Privacy includes safeguarding and protecting the user information from unauthorized access. Key challenges related with the technology have been described in Section 12 of this report.

## 4 Value Chain Players

Various players in the value chain of M2M / IoT domain are depicted in Figure 12.

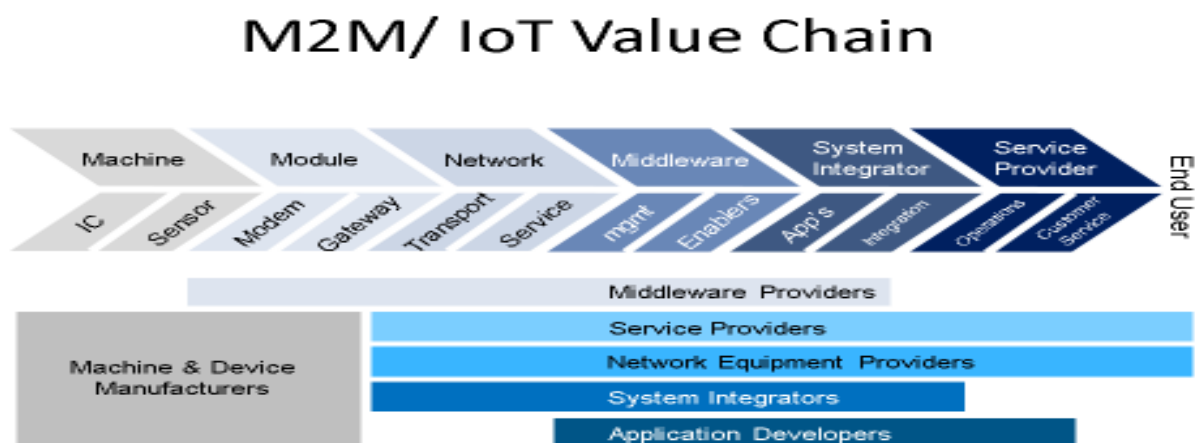


Figure 12 : M2M / IoT Value Chain

#### 4.1.1 Chip/ Module Makers

The Chip/Module Designer includes the main vendors who design semiconductors and modules (chipset for the appliances / gateways) for automation systems. They design the components and help to integrate software applications in the end products as proof of concepts. These reference designs demonstrate the data gathering and sharing concepts.

#### 4.1.2 Device/Appliance Manufacturer

They comprise of the appliance manufacturers that help to provide the useable systems to the customers. Usually they may start with one of the reference designs available from Chip / Module makers and bring in the necessary user experience, form factor, casing and other requirements to embed in the products.

#### 4.1.3 Mobile/ Telecom Service Providers

Telecom Service providers (TSPs) play an important role in connecting the devices / Gateways on wired (fixed line BB / FTTH) / wireless (3G/ 4G) networks to the M2M service providers. High speed and reliable internet services are required at Home Gateway and also at the Smart phones for connecting the home remotely.

#### 4.1.4 Cloud service provider

Cloud service providers enable accessing data from anywhere in the world. Cloud helps in maintaining and managing data remotely. The cloud provider helps by offering shared pool of resources and services like Platform and Software. They provide features of accessibility and recovery.

#### 4.1.5 Application Provider

They help to deliver the web application or mobile based application providing interaction with consumer and appliances. These applications help to access the device and control them remotely.

## 5 Indian Market Landscape

The Indian Market for Smart Homes is sized at US \$ 355.4 Million. The market is expected to grow at 43.75% (CAGR) from 2016 to 2020. Smart Homes market is expected to grow by 30% year on year and is expected to double its revenue in a span of around 3 years [6]. Another report on this subject [10], estimates the home automation market size to grow to INR 8800 crores by year 2017.

### 5.1 Major Characteristic of Indian Market

#### 5.1.1 Emerging Indian Market- Tremendous Opportunities

The favorable economic conditions are enabling the growth of Smart Homes in India. Smartphone penetration has created a positive impact in the market and now customer is aware about the power of smart gadgets, internet, e-commerce and the underlying benefits. This technology adoption helps the market to grow further and embrace Smart Home technologies

**5.1.2 Market Penetration is low or limited-Focused on urban customers**

Currently Smart Home market in India is limited. Presently the market caters primarily to the upper income segment. More and more users are already buying the home surveillance and security products. Newer buildings are having home automation elements already as part of the apartment deals. There is however a general lack of understanding of the home automation products and how these could be served / serviced in case of need.

**5.1.3 Trends in Design**

Many start-ups and also established companies are creating products for Home Automation. The Do-it-yourself (DIY) category of home automation platforms are being created and used by many startups as also individuals. Several sensors are now available as standard fitments to the development platforms and this is helping many a developers. The downside is that Indian market or Smart Homes is not having a specific standard or even preference for a specific standard or technology as yet.

**5.1.4 Big data Analytics & Cloud Service will lead the IoT market-Data Driven Market**

When many devices operate simultaneously, the amount of data generated is high. Processing this structured and unstructured data is a challenge and Big Data analytics is an opportunity in the Indian Smart Home space.

## 5.2 Major Trends in Indian Market

### 5.2.1 India's Internet Spread is increasing

With the growth of Smartphone market, and its availability at affordable rates, Internet users are increasing sharply and are expected to cross 400 million in the current year. Penetration of Internet services will help in development of eco system for various verticals of M2M/ IoT domain including Smart Homes. Smart homes trends, expectation and challenges have been shown in the Figure 13.

### 5.2.2 Smart Homes technologies will see a boom with Government initiatives

Government of India has planned to create 500 smart cities in a phased manner. In the first phase,

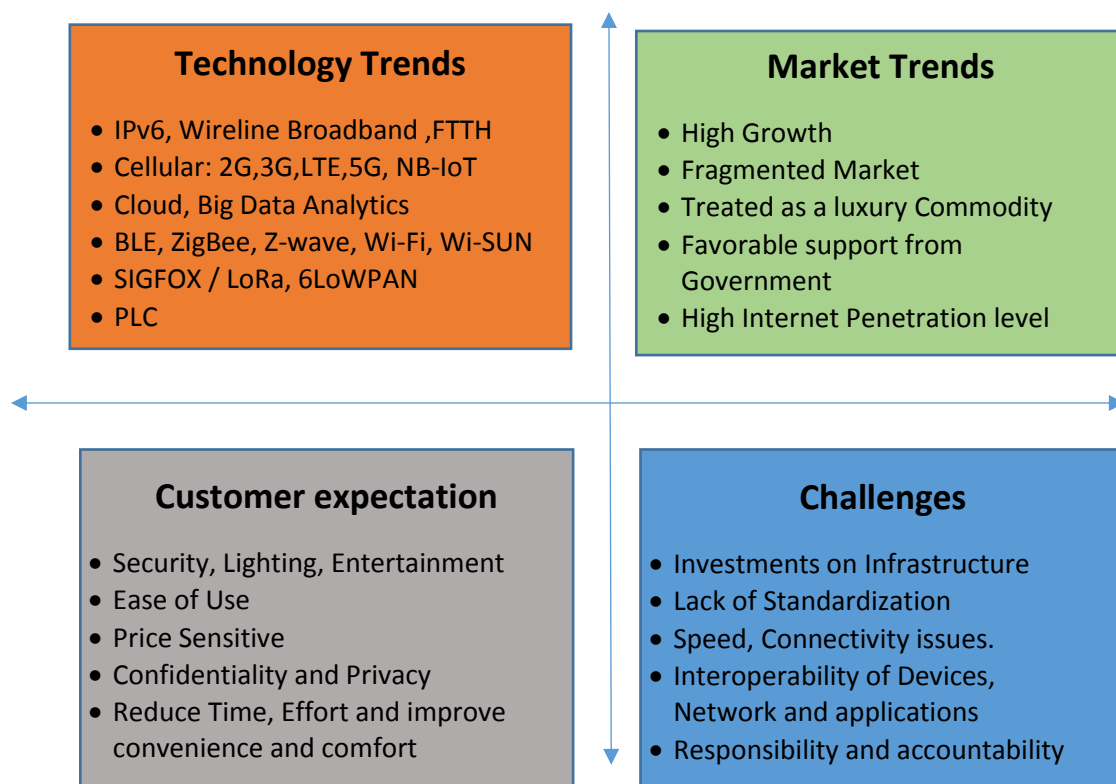


Figure 13 : Smart Home Trends, expectations and challenges

100 cities will be developed and 20 of these were named in the first list. Second and third lists of 13 and 27 cities respectively have also been declared recently. Smart Homes is an important entity of a Smart city and hence the market is favorable for Smart Home players.

**5.2.3 Cyber security gains attention with more number of devices**

With the IoT penetration more and more connected device will appear in the market. The more the number of the device the stronger should be the security aspects to protect from threats. This creates an opportunity for cyber security companies.

**5.2.4 DIY kits are gaining attention and leveraging the sales through e-commerce**

Do It Yourself kits are gaining attention in India and many Smart Homes enthusiasts have already purchased these devices from market and installed at Home. These kits include Smart sensors that can be integrated to Home appliances and can be controlled remotely with the Smart gadgets. These kits are now available through e-commerce websites also at affordable rates.

**5.2.5 Workshops / Seminars on Smart Cities popularizing Smart Homes.**

Smart Home workshops and seminars are being conducted in various parts of the country to promote the concept. The statistics obtained from these exhibition shows an increase in number of visitors to the stalls as also increased number of vendors / exhibitors.

## 6 Communication standards / Technology

A no. of alliances/ technology providers are working in the Smart Home vertical. A pictorial view has been shown in Figure 14.

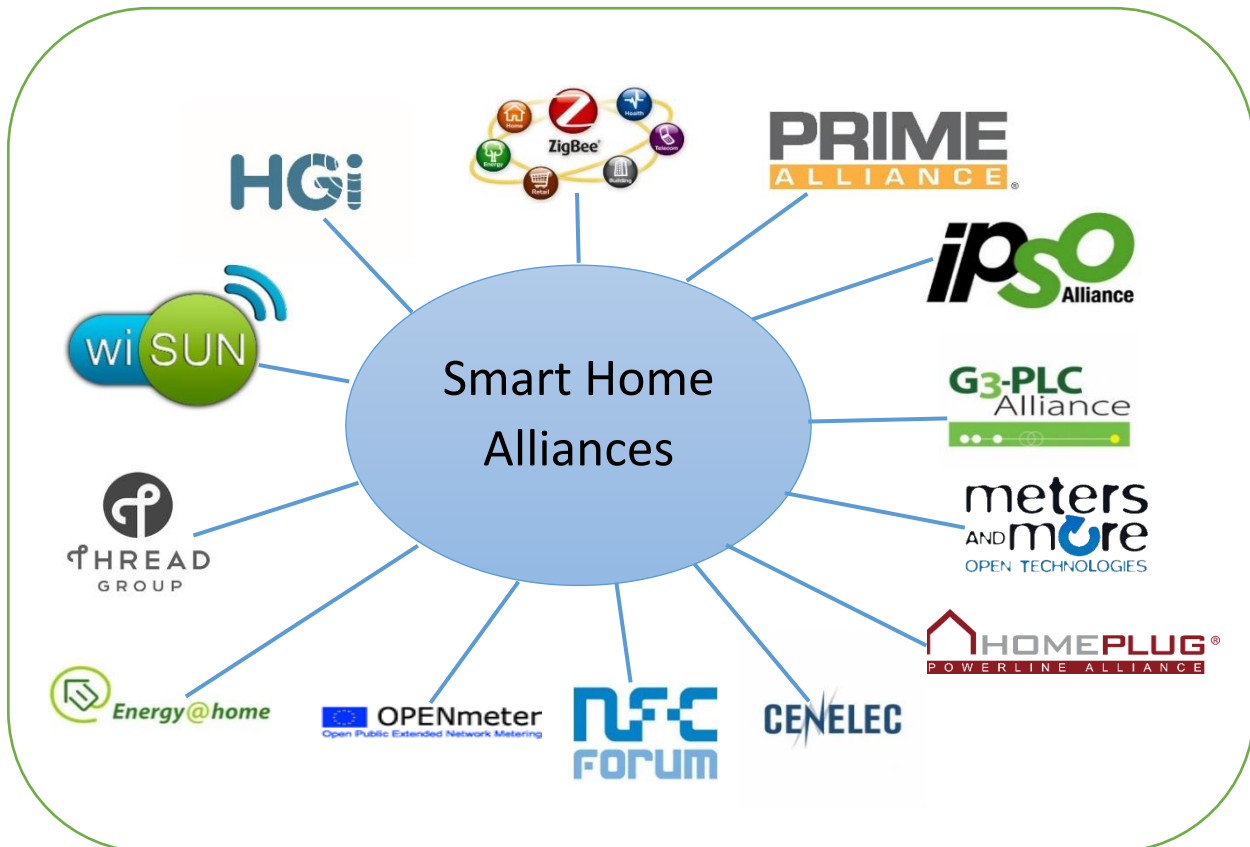


Figure 14 : Alliances active in Smart Home

The following are the key technologies, but not limited to, relevant to Smart Homes:

- Bluetooth, Bluetooth Low Energy, Wi-Fi, NFC
- PLC, KNX, W-KNX
- Sub-GHz, M-Bus, WM-Bus,
- ZigBee, Z-Wave, Wi-SUN
- HomePlug, HGI
- DLNA, HPNA, MoCA
- Weightless
- Thread, EnOcean
- LoRA, SIGFOX
- Wireline Broadband, FTTH
- Cellular technologies - 2G/3G/4G/ 5G, NB-IoT

It should be noted that above list is by no means complete or necessarily applicable to Smart Homes in all scenarios. The new standards are emerging and getting added at rapid pace and technology adoption is a result of number of factors outlined in earlier sections. Standards released by ETSI and CENELEC are as given in Table 2.

Table 2 : Available Global Standards

Standard No.	Title
TS 103 267 v1.1.1 (2015-12)	SmartM2M; Smart Appliances; Communication Framework, ETSI
TS 103 264 v1.1.1 (2015-11)	SmartM2M; Smart Appliances; Reference Ontology and oneM2M Mapping, ETSI
CTC/TC 205	Home and Building Electronic Systems, CENELEC
ETSI TS 103 424 V1.1.1 (2016-11)	Smart Home architecture and system requirements
ETSI TS 103 425 V1.1.1 (2016-11)	Wireless Home Area Networks
ETSI TS 103 426 V1.1.1 (2016-11)	Requirements For HGI Open Platform 2.1

A lot of work related to standardization in M2M / IoT domain is going on in various Standardization organizations such as IEEE, ISO, IEC, ETSI, OneM2M and ITU.

The adoption of various technologies and in different applications is shown in Figure 15

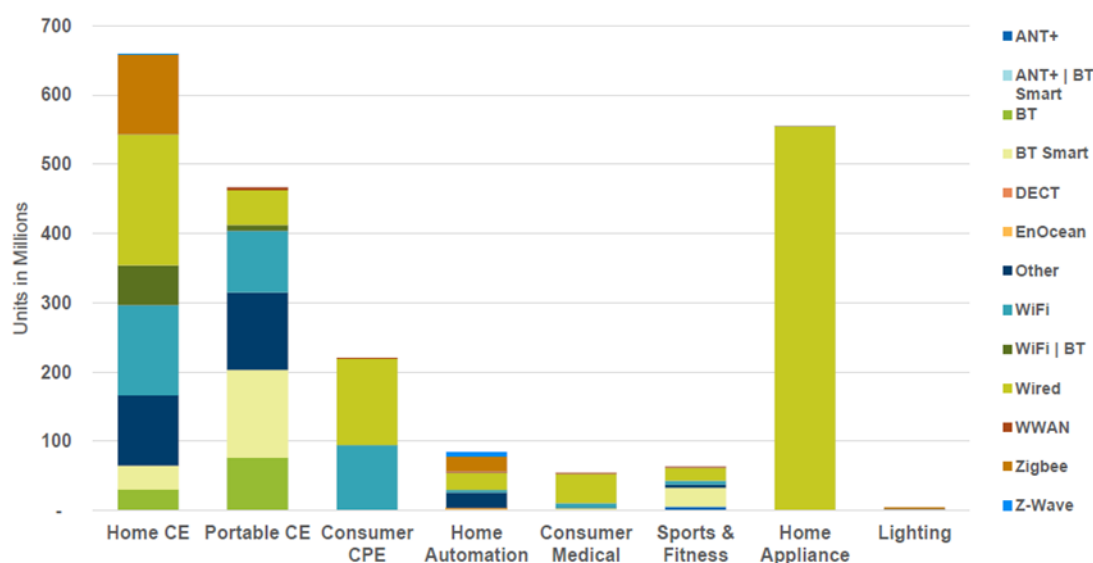


Figure 15 : Installed base of Smart Devices and Technology adoption, [IoT Connectivity, 3Q15]



## 6.1 Comparison of the Communication technologies

Table 3 : Communication Technologies for M2M

Technology/ Protocol	Frequency band (s)	Advantages	Limitations	Suitable for
<b>Wireless</b>				
Bluetooth Low Energy	2.4 GHz	<ul style="list-style-type: none"> <li>• Mature technology</li> <li>• Easy to implement</li> <li>• Low Power</li> <li>• Powered by coin cell</li> <li>• Longer battery life</li> </ul>	<ul style="list-style-type: none"> <li>• Small data packets</li> </ul>	<ul style="list-style-type: none"> <li>• Healthcare devices</li> <li>• Fitness devices</li> <li>• Smart Metering</li> </ul>
NFC	13.56 MHz	<ul style="list-style-type: none"> <li>• Consumes less power</li> <li>• Almost instantaneous connectivity between devices</li> <li>• No power is required in-case of passive Tags</li> </ul>	<ul style="list-style-type: none"> <li>• Extremely short range</li> <li>• Expensive</li> <li>• Low information security</li> <li>• Low market penetration</li> </ul>	<ul style="list-style-type: none"> <li>• Healthcare devices</li> <li>• Fitness devices</li> <li>• Smart Metering</li> </ul>
Wi-Fi	2.4 GHz	<ul style="list-style-type: none"> <li>• Mature technology</li> <li>• High home/office penetration</li> <li>• High data rates achievable</li> <li>• Easy to implement</li> </ul>	<ul style="list-style-type: none"> <li>• Limited range</li> <li>• Poor building penetration</li> <li>• High interference from other sources</li> <li>• Power consumption higher than those technologies that operate in the sub-GHz band</li> </ul>	<ul style="list-style-type: none"> <li>• Base station in Health Clinics</li> <li>• Smart Metering</li> <li>• Home Automation</li> </ul>
ZigBee	2.4 GHz, 920 MHz, 915 MHz, 868 MHz, 780 MHz	<ul style="list-style-type: none"> <li>• Full support of IEEE 11073 device specialization profile</li> <li>• Longer battery life from low cost coin cells for wearable devices (source: ZigBee alliance)</li> <li>• Wireless range up to 70 meters indoor and 400 meters outdoor (source: ZigBee alliance)</li> </ul>	<ul style="list-style-type: none"> <li>• Not widely adopted</li> <li>• BLE is the direct competition for ZigBee providing different modes/profiles of operation. BLE is getting adopted faster than ZigBee within short span of time</li> </ul>	<ul style="list-style-type: none"> <li>• Health Monitoring and Safety</li> <li>• Client Activity Monitoring</li> <li>• Health and Wellness monitoring</li> </ul>

Z-Wave	Sub 1GHz for India (865-867 MHz)	<ul style="list-style-type: none"> <li>Standardised by CSR 564 (E)</li> <li>very successful due to its ease of use and interoperability</li> <li>Majority share of the Home Automation market</li> </ul>	<ul style="list-style-type: none"> <li>Proprietary radio systems available</li> <li>Limited Range drives up costs</li> </ul>	<ul style="list-style-type: none"> <li>Security systems.</li> <li>Home automation.</li> <li>Lighting controls</li> </ul>
Wi-SUN	Sub 1GHz for India (865-867 MHz)	<ul style="list-style-type: none"> <li>Open standards based</li> <li>Interoperable</li> <li>High data rate</li> <li>Long Range</li> <li>Widely adopted in Japan. Currently being adopted in USA and other regions</li> <li>Low power consumption</li> <li>Operates as RF mesh network</li> </ul>	<ul style="list-style-type: none"> <li>New Technology</li> <li>Not widely adopted in India</li> <li>Based on latest IEEE standard which is not yet adopted widely</li> </ul>	<ul style="list-style-type: none"> <li>Smart metering</li> <li>Smart Home</li> <li>Smart City</li> <li>Industrial automation</li> </ul>
ANT	2.4GHz	<ul style="list-style-type: none"> <li>Low power mode supporting longer battery life</li> <li>Adopted by major mobile manufacturer</li> <li>Supports mesh capability which is an edge over BTLE</li> </ul>	<ul style="list-style-type: none"> <li>BLE is giving direct competition to ANT as it is already supported by all the mobile manufacturer</li> <li>Not all mobile Manufacturer is supporting ANT hardware</li> <li>Low penetration in market is less due to present eco-system of other Wireless Technologies</li> </ul>	<ul style="list-style-type: none"> <li>Fitness device</li> <li>Healthcare device</li> </ul>
Cellular (2G,3G,LTE, NB-IoT and 5G)	For India, 900 MHz, 1800 MHz, 2100 MHz and 2300 MHz is allocated.	<ul style="list-style-type: none"> <li>Mature technology</li> <li>Rapid deployment</li> <li>Communication modules are low cost and standardised.</li> <li>Roaming</li> </ul>	<ul style="list-style-type: none"> <li>Coverage not 100%</li> <li>Reliability not the best</li> <li>Short technology life-cycle (2G, EDGE, 3G, LTE etc.)</li> </ul>	<ul style="list-style-type: none"> <li>Tele-Health</li> <li>Remote Health Monitoring</li> <li>Smart Metering</li> </ul>
LoRa	Sub GHz	<ul style="list-style-type: none"> <li>Network can be defined by the individuals / owners</li> </ul>	<ul style="list-style-type: none"> <li>Own deployment with no subscription fees</li> </ul>	<ul style="list-style-type: none"> <li>Smart Metering, Lighting</li> </ul>

SIGFOX	Sub GHz	<ul style="list-style-type: none"> <li>Infrastructure being deployed. Several countries SIGFOX ready</li> </ul>	<ul style="list-style-type: none"> <li>Deployment by Network Operator</li> <li>Subscription fee</li> </ul>	<ul style="list-style-type: none"> <li>Smart Metering, Lighting</li> </ul>
Wireline				
DSL	0-2.208 MHz	<ul style="list-style-type: none"> <li>Inexpensive (installation and use)</li> <li>High SLA</li> <li>Less installation time</li> <li>Bonded DSL provides inherent redundancy</li> </ul>	<ul style="list-style-type: none"> <li>Low data security</li> <li>Lower throughput</li> <li>Higher latency</li> </ul>	<ul style="list-style-type: none"> <li>Gateway for Remote Health Monitoring</li> <li>Concentrator for Tele-Health</li> <li>Home Automation</li> </ul>
Ethernet	16,100,250,500,600 MHz 1 GHz, 1.6-2.0 GHz	<ul style="list-style-type: none"> <li>Inexpensive (installation and use)</li> <li>Excellent throughput</li> <li>Low installation time</li> <li>Easily scalable</li> </ul>	<ul style="list-style-type: none"> <li>Lowest data security</li> <li>Lowest SLA</li> <li>Highest latency</li> <li>Bursts of additional bandwidth not possible</li> </ul>	<ul style="list-style-type: none"> <li>Gateway for Remote Health Monitoring</li> <li>Concentrator for Tele-Health</li> <li>Smart Metering</li> <li>Home Automation</li> </ul>
PLC	No defined frequency band in India	<ul style="list-style-type: none"> <li>Ready infrastructure</li> <li>Communication possible in challenging environments such as underground installations, metal-shielded cases etc.</li> <li>Long technology life-cycle</li> <li>Many standards and protocols available</li> </ul>	<ul style="list-style-type: none"> <li>Point-to-point communication</li> <li>Can cause disturbances on the lines</li> <li>Not suitable where power cables are not in a good condition; initial and ongoing line conditioning and maintenance can add significant O&amp;M costs</li> <li>Highly trained manpower required for O&amp;M</li> <li>Communication not possible in case of an outage</li> <li>Absence of regulations on use of frequency bands</li> </ul>	<ul style="list-style-type: none"> <li>Smart metering</li> <li>Home automation</li> </ul>

In addition to the Table 3, there may be other competing technologies relevant to Smart home applications. Again this list is not exhaustive.

## 7 Smart Home Offerings and System Components

The various system components of a Smart Home are depicted in Figure 16 and described below:

### 7.1 Lighting

This comprises of smart lighting solutions that controls the lights of smart homes. These solutions include controlling the intensity, dimming the light, changing the schema of light in a room depending on the mood and preference of the user. Using motion detection sensors and light detecting sensors, more options can be customized like auto switch on and off, of the lights depending on proximity.

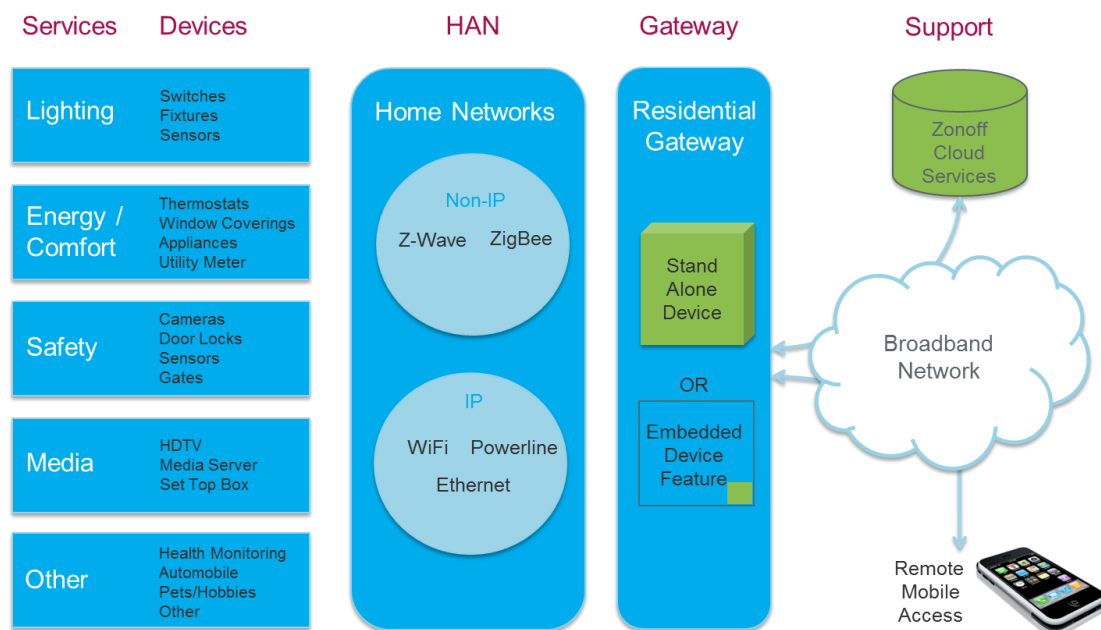


Figure 16 : Smart Home Offerings and System Components

### 7.2 Energy/ Comfort

These solutions include gadgets to monitor, control and use energy efficiently. Smart meters act as the fulcrum for monitoring and controlling the energy usage. Smart meters can also act as important elements in demand response, wherein, the consumption pattern of consumers is envisaged to vary as per the needs of the utility. Smart thermostats can be used to control the temperature being a critical tool for energy efficiency. Smart curtains, window coverings etc. provide a better comfort level.

### 7.3 Security & Safety

This is one of the crucial segment that needs to be catered. Security cameras for surveillance, smart locks that locks and opens based on preference, Smart sensors that monitor elderly people and children to estimate the activity level, are some of the offerings.

### 7.4 Media and Entertainment

Smart TVs are already available in market and the penetration is increasing day by day at an affordable price. These devices help to interact with the external world through IP or Wi-Fi technology and enhance the quality of living. Now YouTube and Skype can be enjoyed using a smart TV.

### 7.5 Hybrid Broadcast Broadband Television, [11]

Hybrid broadcast broadband TV ('HbbTV') is a global initiative aimed at harmonizing the delivery of broadcast TV and broadband TV to the home through connected TVs (smart TVs), set-top boxes and multiscreen devices.

The Hybrid broadcast broadband TV specification improves the video user experience by enabling interactive services such as catch-up TV, video on demand, interactive advertising, personalization, voting, games and social networking, as well as program-related services such as digital text and electronic program guides.

Hybrid broadcast broadband TV uses a single user interface. This creates an open platform as an alternative to proprietary technologies, which increases user choice.

Hybrid broadcast broadband TV is easy to implement and compatible with other hybrid TV technologies such as MHEG-5. Products and services using the Hybrid broadcast broadband TV standard can operate over different broadcasting technologies, such as satellite, cable and terrestrial networks.

Hybrid broadcast broadband TV is being deployed globally. A broad set of Internet and broadcast services have already been tested and implemented.

### 7.6 Miscellaneous Services

These services include features like E-health, Tele-medicine etc. These services help focusing individual health and allied services. With these services, the patient's health report can be sent to a doctor at regular time intervals, who can suggest meaningful proper medication which makes the statement "Prevention is better than Cure" much more clearer. Also these can be used for life critical services like whenever the patient is down or severely ill, these gadgets can be used to gather attention or send SOS mails to the configured number and help save life.

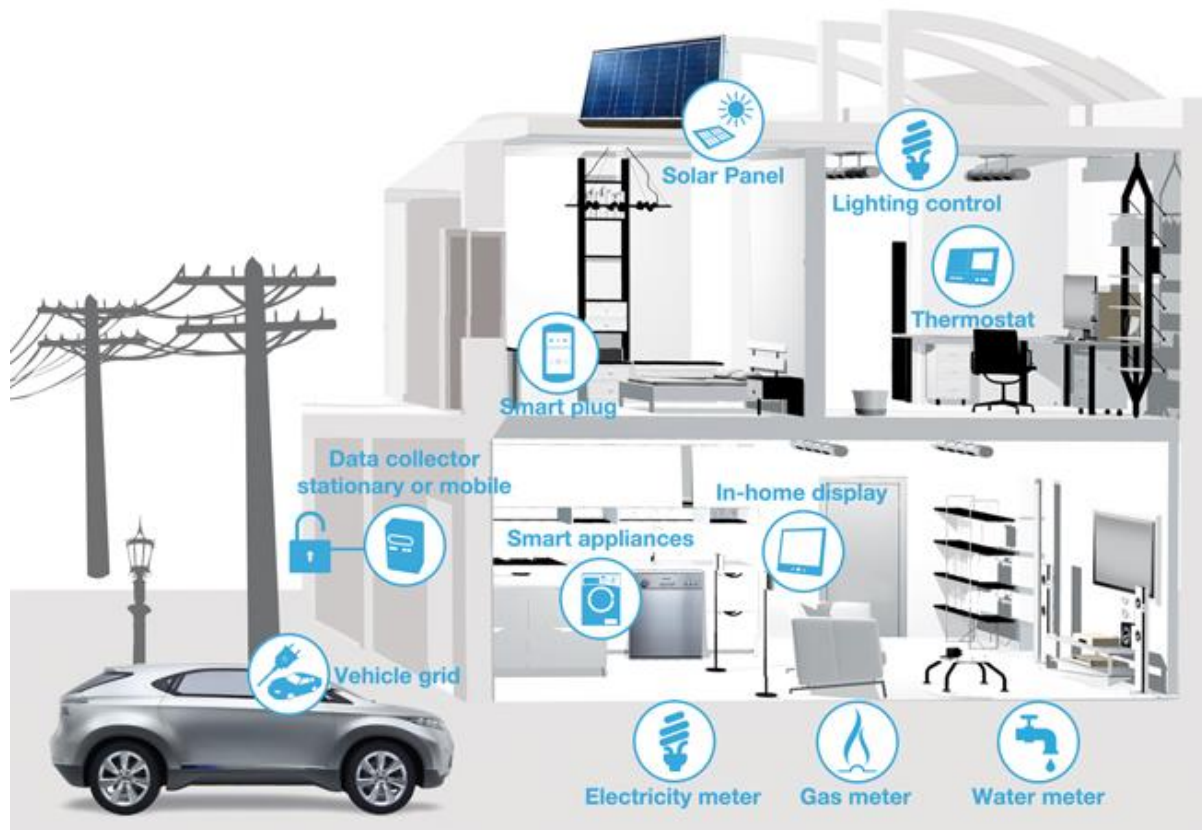


Figure 17 : Smart Home with Power Line and Solar and Vehicle Charging, [14]

## 7.7 Smart Home Components and Concepts

There is a lot of thrust on green energy and clean energy and smart systems to measure the energy consumption. Figure 17 shows a typical smart home that has electricity coming from Solar Panel connected to the grid. The lights are smart and can be controlled by Smartphone/tablet. Utilities such as gas meter, water meter and energy meter are connected to central database of the area and we have charging stations for electric vehicle coming from dedicated line. Bluetooth low energy can be used to control Smart appliances and Power Line Modem can be used for the communication within the home.

## 7.8 In-home Display and Control

Figure 18 shows the concept of in-home display which acts as a concentrator unit for the home. The display may consists of multiple wired and wireless technologies as per Smart home requirement such as Bluetooth Low Energy, Power Line Modem and Wi-Fi. The display gives all the information regarding the energy consumption and different energy related information. The display can give information

regarding the ambient temperature, weather, online news, in-home camera. The user can also control the appliances from the display supporting touch control.

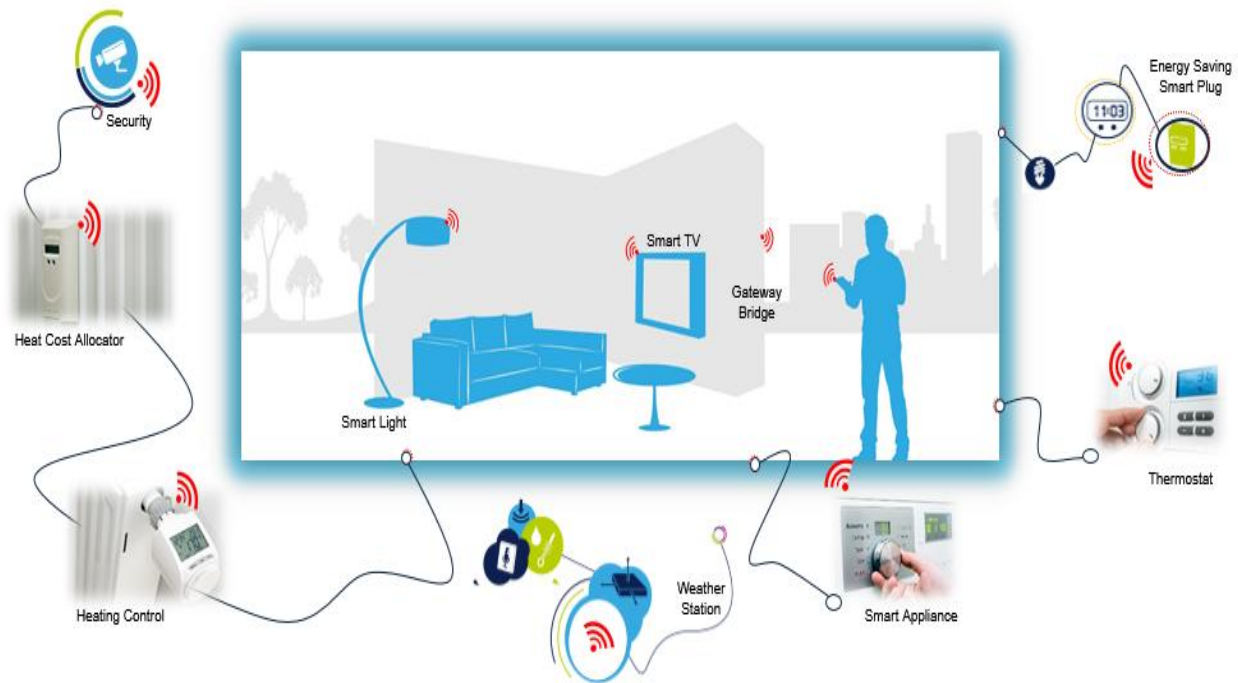


Figure 18 : Smart Automated Home with In-Home Display, [14]

## 7.9 Cloud Connected Home

Figure 19 shows an extended use case of Figure 18. There is an in-home display with Wi-Fi connectivity. The in-home display acts as data concentrator for each home and is also connected to Wi-Fi router. The concentrator unit sends the sensors data to the Cloud Application so that user can view information of their home on internet. There will be provision to actuate sensors (switch on/off air conditioner etc.) in the home using the Cloud Application.

## 8 Automation Platform

Home automation devices is a network of multiple devices which can serve different purpose and are offered by different vendors. Hence they are heterogeneous in nature and there is a need to have /invest multiple gateways to communicate and transform the data and push the data to cloud.



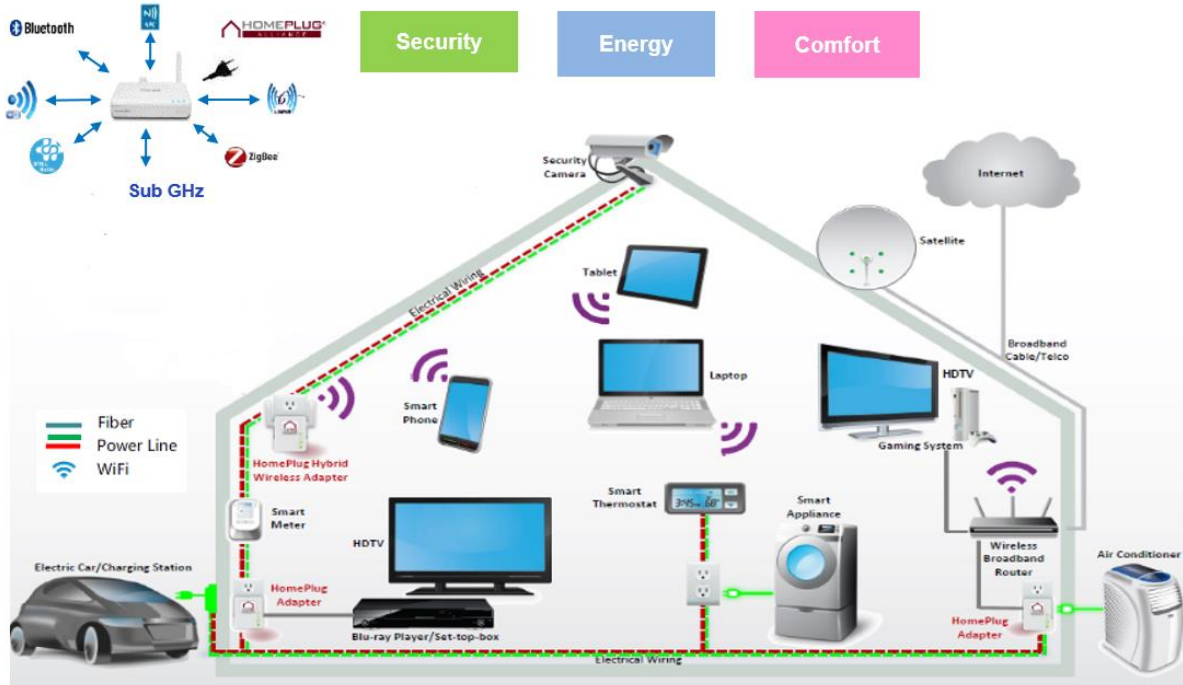


Figure 19 : A Concentrator / IHD / Gateway for a Smart Home, [14]

If there is centralized middleware it will ease communication, monitoring, maintenance and support and upgrades to the standards.

## 8.1 Architecture and Protocols

The home automation network will contain IP based embedded devices which can be wired or wireless following standard protocols. Each device can communicate with the other or with server over COAP based application protocol. COAP is lightweight protocol which can be used on embedded devices with limited processing power and memory. It uses which itself is very lightweight and supports things like multiplexing. It also uses *get*, *post* and *observe* like *http* and hence used to support *REST* based service. Each device can be embedded with a middleware stack on its own which can convert the data to be consumed by the consuming server(COAP or MQTT) hosted in cloud. Each middleware should have a persistent database to store the data still it gets pushed to the hosted consumer. If a device does not have embedded middleware, a separate gateway will be used which can convert the protocols to generic oBix protocol and transfer the data to the cloud server.

The data transfer to and fro between devices and server can be done by pull and push mechanism over *http/rest/soap* in xml or JSON supported by the vendor of the devices.



Distributed nodes by the cloud could be identified by a framework using URLs. The cloud vendor should have a platform which comes with standard APIs or services for all sorts of devices, protocols and data format. Support for additional features such as security, automation, device controls, monitoring and alerting can be built on top of them. An indicative picture of protocols is shown in Figure 20.

#### 8.1.1 Pros:

- Data is centralized
- Multiple protocol support and uniformity in data format
- Ease of setup
- Reduces the cost for customers

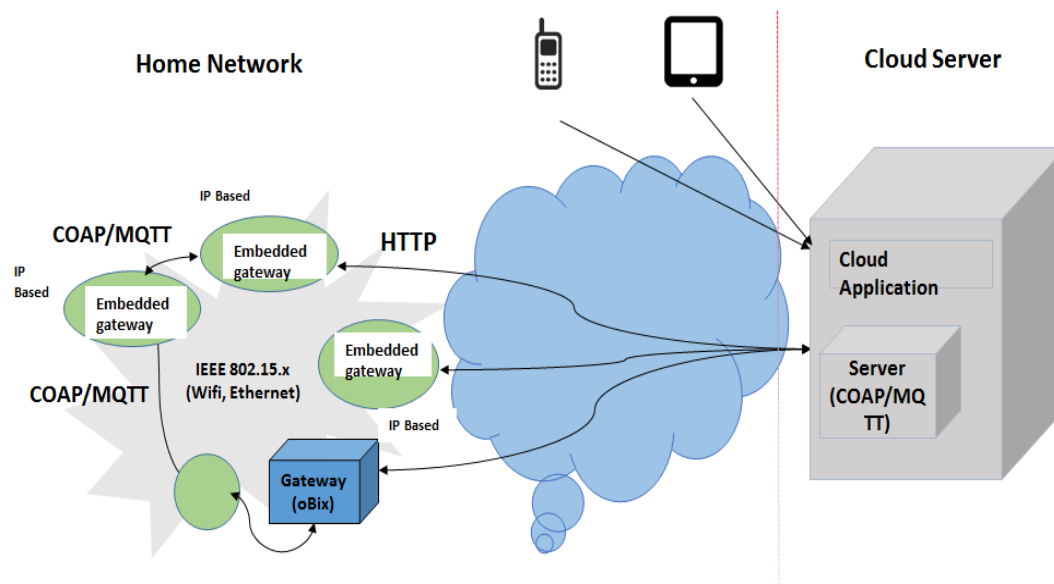


Figure 20 : A Smart Home Platform Architecture and Protocols

- Reduces the number of gateways to be used.
- Data lost is reduced and no need to manage locally
- Private or public cloud can be set up
- Reduces overhead of maintenance.

#### 8.1.2 Cons:

- Since data is over the cloud, there is a need to be cautious about middle man attack / use by third parties for sale / Use by third parties for behavioural analysis or finding out routines in a home.

## 8.2 Components to build a Smart Home Gateway

### 8.2.1 Components of Gateway unit:

The Gateway unit which also known as concentrator unit consists of many other components apart from the wired and wireless technology as shown in Figure 21. They are:

- **Power Management Unit:** The Power management unit is one of the important components of Gateway or concentrator unit. There would be provision of different kind of power inputs to the Gateway making it a portable unit
- **MCU / MPU:** The micro-controller unit or micro-processor unit is the brain of the concentrator unit that controls the in-home display unit. The controller / processor will talk with other supporting devices using various board level protocols.



Figure 21 : Smart Home Gateway Components, [14]

- **Touch Display (Human machine Interface):** Human machine interface is essential element for the Human Machine Interface system as user will be able control different appliances and see different logs / dumps on the concentrator side. The user will be able to make changes in the settings

- Security: Security of the system is one of the important requirement for the Smart Home Solution. As all the devices are connected to internet, Security of the System from any external attack becomes important. There are different mechanism to prevent external attack and hacking of data. There can be different method of providing security to our system. Some of them are :
  - Secure booting
  - Access Control
  - Firewalling and IPS
- Software / Apps: Human Machine Interface (HMI) at the Gateway makes the usage of the system easy for the end user. There can be provision of Mobile Apps which can simulate the functionality of HMI system on the Gateway using the wireless connectivity available on the Gateway
- Firmware / Libraries : are the software running on the MCU / MPU that gives functionality to the Gateway
- Sensors : Motion and Environmental sensors available on the Gateway gives environmental information of the Gateway

Protection: is the usage of the protection mechanism on the DCU from sudden surge in current and voltage that may damage the board.

A Smart Home Platform is illustrated in Annexure 2.

## 9 Smart Home Vertical use-cases

### 9.1 Safety

Under this category the residents are provided with the following functionality with smart home systems.

- a) Single touch panic alarm to alert monitoring station and family members during medical, fire or any other emergency situation
- b) Motion detection in secured area while family is asleep or away
- c) Detection of hazardous LPG/CO (Carbon monoxide )gas leakage
- d) Early detection of fire using smoke detectors to ensure timely response

### 9.2 Security

- a) Intrusion detection through Door/Window
- b) Remote locking and unlocking of the doors
- c) Access to the visitor/family based on face detection ( very advanced function)
- d) Multiple Indoor & outdoor IP cameras to keep an eye on home.
- e) View live video from anywhere on any smart phone/ tablet /Laptop /PC to monitor activities inside the house
- f) View who is outside the main door on touch screen or smartphone
- g) Scenario based and event driven recording of video clips with ease of configuration of alerts for each event.

- h) Ability to archive video locally or on the cloud with tagging making retrieval archived video easy
- i) Access to all home videos, including live streams and recordings as well as the ability to organize, save, search, tag, and share them

### 9.3 Automation

- a) Switch on/off lights using smartphones/tablets
- b) Configure and save mood lighting settings best suited for occasion. Activate mood lighting as required with touch of a button.
- c) Control appliances like storage boiler, ACs, curtains, garage doors, etc. using smartphones/tablets
- d) On/off control of water pump based on the water levels in OH/UG tanks
- e) Automatic illumination while entering a dark hallway
- f) Schedule periodic triggers to switch on /off lights when away from home, set them to replicate normal usage pattern when on holiday or out of town so it looks like home is occupied
- g) Configure and program sprinkler system

### 9.4 Energy Management

- a) Remote reading of the energy consumption using the Smart energy meter( by the utility)
- b) Monitor and analyze energy consumption patterns per device per day / week / month with trend reports.
- c) Remote connection/disconnection of the energy supply to the customer premises via smart meter
- d) Smart net metering using solar arrays which enables customer to obtain incentive from utility
- e) Adjust luminous intensity as per ambient conditions for optimal energy usage
- f) Adjust room temperature and configure preset temperature parameters as per comfort.
- g) Automatically turn off lights when rooms are unoccupied using occupancy sensors

### 9.5 Entertainment & Personal Lifestyle

- a) Personalized support with the help of smart Gadgets and wearable devices.
- b) Smart Curtains
- c) Smart TVs and other Gadgets
- d) Streaming, IP support on smart gadgets and music players.

### 9.6 Common Customer interaction

#### 9.6.1 Home Management

- a) One touch 'AWAY' button to switch off lights/audio/video systems while moving out of house
- b) Interactive touch screen with user friendly interface to check status of home.
- c) Video playback , searching of recorded video from any device
- d) User shall have flexibility to create scenes, scheduled events, get alerts and notifications to meet their needs

#### 9.6.2 Mobile management

1. Real time two –way communication with a Gateway connected home allowing user access her security features from her smart phone
2. Remote appliance control like turn the air conditioning or boiler on before arrive home
3. View live video and control pan , tilt and zoom features of camera from smart phone
4. Manage all connected devices

#### 9.6.3 Remote Assistance

1. Receive Real time continuous video and or video clips on smartphones
2. Remote arming and disarming of alarm system
3. All registered users of family to remotely access and share home data anywhere from any device
4. Web and Mobile control of home

#### 9.6.4 Monitoring, Alerts and Notifications

1. Central monitoring station for 24\*7 alarm monitoring and verification
2. Programmable Notifications of events (like their children coming home from school) via text message, e-mail, instant message on multiple cellphones & email accounts as registered
3. Co-ordinated third party emergency response - Medical, Fire, Police
4. In case an alarm goes off, an alert to authorities with message to user cell phone
5. Wrong passcode alert
6. Duress alert
7. Pet alert
8. Device health update alerts like low battery, tamper, fault, etc.

#### 9.6.5 Access Control

1. RFID based access control system
2. Automatic Gate & Door Opener
3. Smart Locks

## 10 The Big Picture: Smart Home as a unit of a Smart Building and a Smart City

With the evolution of the converged & networked society, further fueled by the 'Internet of Things' era, a multitude of new applications of the Information & Communication Technologies have changed the way we live, work, play, interact and even think. The Smart Home paradigm's true evolution & proliferation depends entirely on the End-to-End interoperability. Just like our Electrical Plugs, Sockets, Switches, Lamps and Lamp Holders etc.; or like the IT & Networking equipment. Any component/part of one Make can be replaced by the same part from any other manufacturer by the consumers themselves without any compatibility issues. The situation becomes much more complex when we consider Smart Homes in context of Smart Cities & Smart buildings. A major disconnect which has recently become apparent is: the technological trends in 'Smart Homes', 'Smart Buildings', 'Smart Cities' and 'Smart Grid' are being

considered and pursued in isolation from each other with ‘silo’ approach, by the respective stake holders. In fact, they form a very tightly interwoven and homogenous confluence of similar technologies being applied in different domains for a common cause of making our planet earth ‘smart, green and secure’. Each application ecosystem like smart home, smart building, smart street lighting and smart grid have, over the years, developed their own respective sets of standards and last mile communication protocols. Even some ecosystems like smart grid and smart home have got multiple sets of standards and protocols being advocated as the most appropriate for their respective applications.

## 10.1 SMART BUILDINGS

At the most fundamental level, smart buildings deliver useful building services that make occupants productive (e.g. illumination, thermal comfort, air quality, physical security, sanitation, and many more) at the lowest cost and environmental impact over the building lifecycle. Reaching this vision requires adding intelligence from the beginning of design phase through to the end of the building’s useful life. Smart buildings use information technology during operation to connect a variety of subsystems, which typically operate independently, so that these systems can share information to optimize total building performance. Smart buildings look beyond the building equipment within their four walls. They are connected and responsive to the smart power grid, and they interact with building operators and occupants to empower them with new levels of visibility and actionable insight and information.

Enabled by technology, the smart building connects the structure itself to the functions it exists to fulfill:

- Connecting building systems
- Connecting people and technology
- Connecting to the global environment
- Connecting to the smart power grid
- Connecting to an intelligent future.

## 10.2 SMART CITY

The relationship between Smart Grids and Smart Cities needs to be understood in this context: “In a smart city, energy, water, transportation, public health and safety, and other key services are managed in concert to support smooth operation of critical infrastructure while providing for a clean, economic and safe environment in which to live, work and play”. Hence, the perspective in Infrastructure Design for any city has undergone a paradigm shift with advent of convergence and networking technologies, solutions for information, communication, entertainment, security and surveillance; which are beginning to have a profound impact on the way we look at the buildings’ design (be it residential or commercial) and town planning.

Cities are intricate composite environments and the manner in which cities are operated, financed, regulated and planned are extremely complex to say the least. City operations are multidimensional and comprise of multiple stakeholders whose dependencies and interdependencies affect and ultimately determine the built environment.

The various departments mostly overlook these dependencies and interdependencies though known, in their efforts and focus of providing their services and of being answerable only for the services they provide. Part of the answer to making cities 'smarter' is a more all-embracing coordinated management of resources and infrastructure, a collaborative approach to a cleaner greener environment, and harmonized governance that result in a better quality of living of its citizens.

### 10.2.1 From a vertical, silo's approach

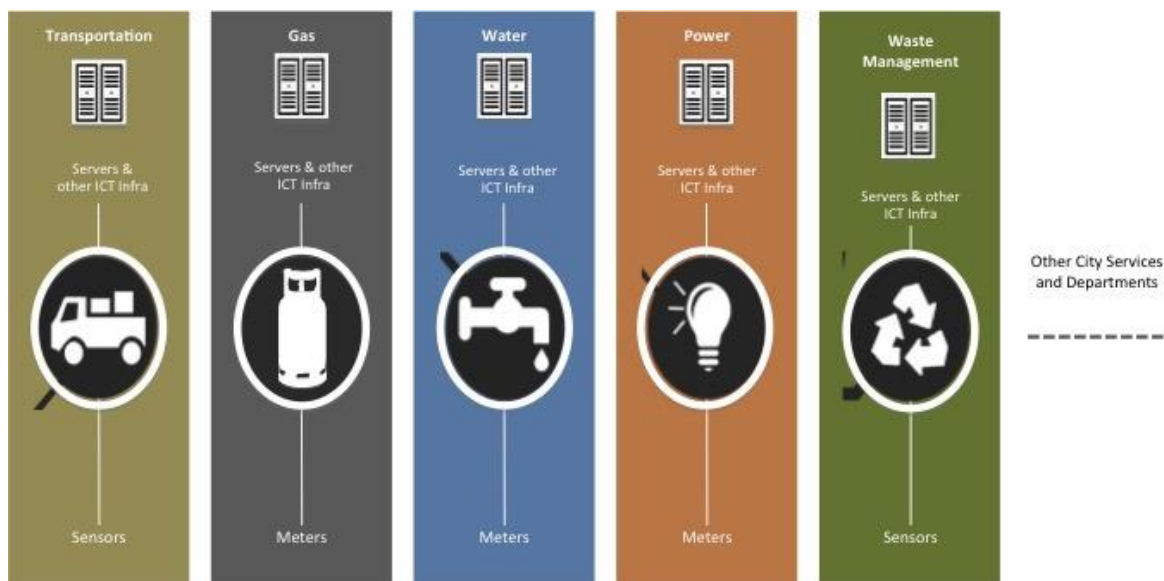


Figure 22 : Isolated and Independent Infrastructure, [Gaia Smart Cities]

Coordination, collaboration and harmonization can be better implemented by the effective use of open, common and shareable, information and communication technologies that allows the creation of a truly interconnected system with seamless communication between services. Even though the services and applications can be diverse, they could leverage the use of common infrastructure to achieve this objective. Cities have to move from isolated Silo'd systems as depicted in Figure 22 to a more unifying, common model as depicted in Figure 23.

### 10.2.2 To a converged common ICT infrastructure pool

A common infrastructure pool allows the creation of a truly interconnected system with seamless communication between services. Even though the services and applications can be diverse, they could leverage the use of common infrastructure or common data models and semantics.

The interconnection or adoption of ICT by different government departments and agencies or the means to do so is not the realm of this document. However, the sharing of infrastructure, unifying the information infrastructure or even the sharing of meaningful information/data such that it can improve efficiency and the quality of life of its citizens is an opportunity that will be recommended.



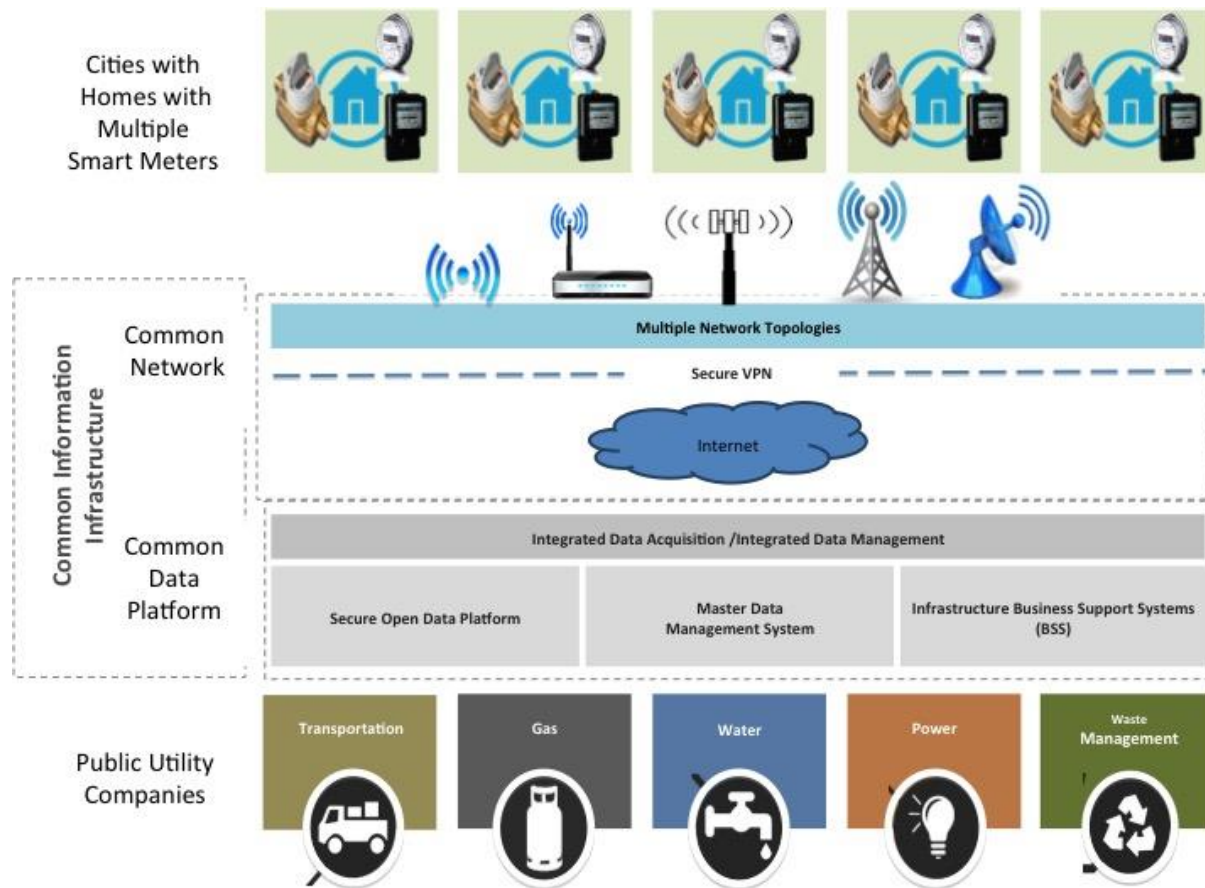


Figure 23 : Common Infrastructure, [Gaia Smart Cities]

Such a systems level approach in design and standardization is likely to not only enable newer and better services, but also allow far greater synergies and cost-effective deployments, reducing the lifecycle (total) cost of ownership of any Infrastructure, be it the smart grid, a home, a building or even a city, with attendant environmental benefits, including carbon reductions.

In order to promote interoperability and enable the developers to bring out innovative solutions at a much faster pace and with considerable ease, a common service layer is required. The common service layer shall replace the common data platform. The M2M Gateway and Architecture working group of TEC is carrying out an exhaustive study of the One M2M standards for implementation of a common service layer platform [12].

### 10.3 Integrated View of Smart Homes / Buildings as part of Smart Cities

The Smart Home is an integral unit within a Smart City and each Home is like a cell within the Hive. Contribution of intelligence to the whole Hive comes from these individual units as a building block.



As outlined earlier, a Smart home has several Needs which Smart City must provide and vice Versa a Smart City has many requirements which a Smart Home must fulfill.

Figure 24 shows key needs of the Smart Homes (for the users), in the context of interaction with the



Figure 24 : Smart City Scenario, [Schneider Electric: Smart Infrastructure – Xperience Efficiency]

Smart City. A Smart city comprises of several smart components, of which the Smart Home is an integral part and must interact with Smart Water Infrastructure, Smart Mobility services, Smart Energy to ensure that the user gets improved infrastructure and services and also has a safer and more comfortable Home.

The broad objectives of a Smart Home are as given below:

- To Make Homes Smarter and more responsive to User Requirements
- To Make Homes more efficient in energy and resource usage
- To Make homes more livable, safer and comfortable



Figure 25 : Objectives of a Smart Home

These broad objectives, Figure 25, can be further classified into the below areas which can be implemented at the Smart Home level and integrate with the Smart City Infrastructure.

### 10.3.1 Security and Safety

Safety and security remains one of the top priorities for a smart home and a Smart City must enable a Home to become Safer and more Secure. Interactivity and technology in the home must enable Emergency service providers to offer quick assistance in case of emergencies like fire, Medical Emergencies or distress calls when triggered by the users of the smart home. An Automatic response system to the incoming triggers must also be available which captures the exact location, type of distress (Fire, Medical Emergency, and Burglary etc.) based on which the request for response can be sent to the corresponding emergency services provider. For example, in the Home Automation system outlined earlier, Emergency modes need to be available which will connect with a nodal government response agency which can then process the alerts and ensure fastest response time. This can save many lives and also potential damages especially due to fires.

A simple smart home system at a most basic level can be outlined as a system as shown in Figure 26.

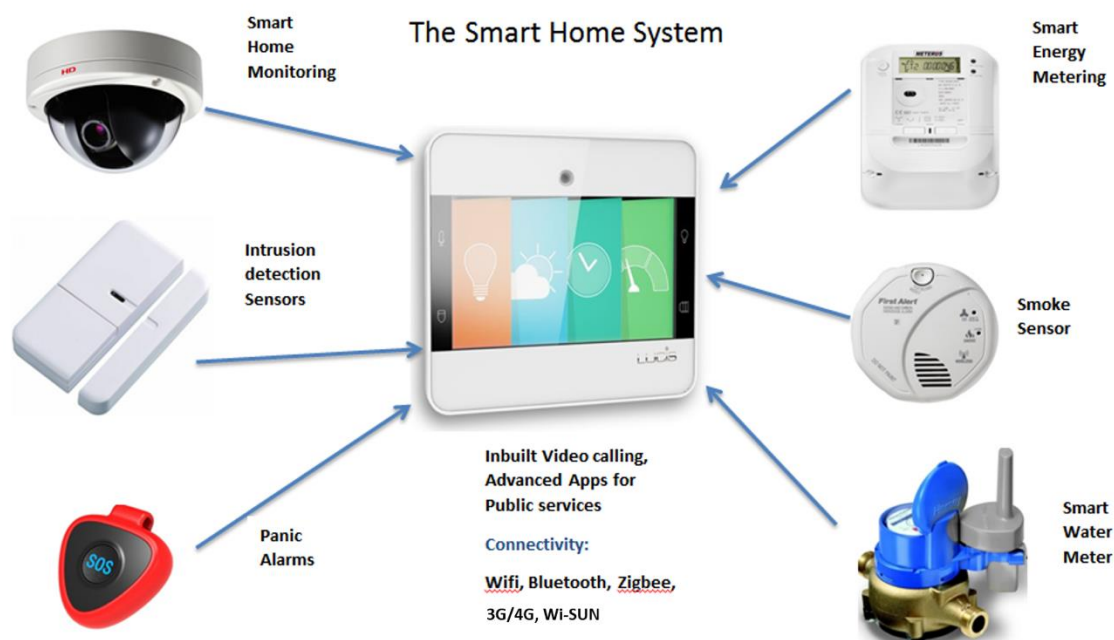


Figure 26 : A Smart Home System with various sensors

### 10.3.2 Energy availability and Reliability

Energy Availability and Quality is a very critical area where the Smart Home can play a major role in not just reducing the Power requirements on the grid but also to generate surplus power. The surplus power can then be fed back into the Grid for its usage.

The Smart Home, must at a basic level have Energy Analytics built in at the Energy Meter level, which can capture details of Load, Power factor, Daily patterns of load, Renewable Energy Generation, Diesel Genset generation and Net Metering. Solar Rooftop solutions will be very useful in all parts of India to generate surplus power and substantial benefit and Subsidy as well as policy change can help bring about increased adoption of Renewable energy generation. These renewable energy sources when monitored through the Smart Energy metering solutions can show clear and measurable benefits and savings as well as reduce the load on the Electrical infrastructure, which would otherwise have to be developed to cater to the full Consumer load. When cascaded to the city level, this reduced electrical load and excess power generation can completely transform a city from power deficient to power surplus.

This is one of the biggest areas where a Smart Home can contribute towards a Smart City and will help make the City power cut free and the energy can be utilized for other infrastructure like: Metro Trains and even Electric Cars, apart from Industries and Offices.

As the solar technology evolves and makes homes and buildings viable as “power generation units”, a virtual ‘energy market network’ shall be created that will require support for different energy exchange models at city level. It will also require that a methodology is defined for (I) citizen empowerment (II) municipality engagement (III) energy companies and (IV) construction parties in participative decision-making to achieve the energy generation and management objectives for Smart Homes and Buildings.

Figure 27 shows how a Smart Home manages the Energy generation and metering and optimises the use of energy for domestic consumption as well as mobility requirements.

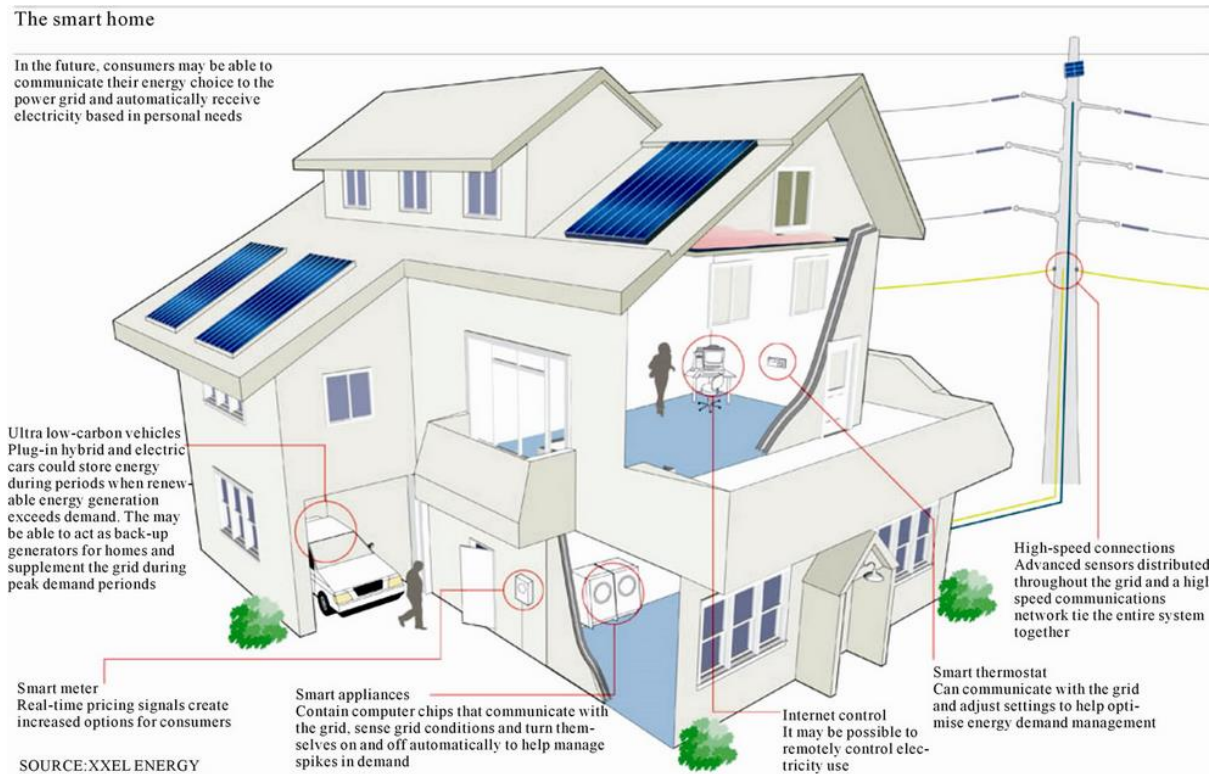


Figure 27 : Integrated view of various aspects of a Smart Home, [XXEL Energy]

### 10.3.3 Water quality and availability, and Waste Water management

Water scarcity and management is already a big challenge in most metro cities and the water table has fallen drastically over the past 15 years due to rampant extraction of ground water. This situation is extremely alarming and unless we take solid steps now to manage and control the Water usage and recharge, most metro cities will suffer extreme shortages of water.

A Smart Home's contribution to water conservation and management is critical and this where sensors at the Water Meter level need to be intelligent and collect water usage data. Based on specific slab levels, the metering of water can also be dynamic based on weather (for example water usage charges can be higher in summers and less in Monsoons and winter). Figure 28 shows a simple integration of a smart Water Metering system with the Utility service provider for better water management and metering. This system is already adopted in several countries like US and Germany as part of pilot projects.

### Typical Smart Water Meter System

A wire runs from the water meter inside the home to a communications module located outside the home which in turn wirelessly communicates interval data to the smart electric meter. The smart electric meter later sends the data back to the utility.



Figure 28 : A water meter system [www.smartgridawareness.org]

Additionally, rain water harvesting systems are important for a smart home and if the amount of rain water recharged can also be measured with sensors, the water charges can also be at a net metering basis (Similar to power net metering) to increase the adoption of rain water harvesting systems.

The sensors at the home owner's level can be connected through the cloud to the Public water supply agency who can with accurate analytics forecast water demand requirements and corresponding supply sufficient water.

The waste water discharge (at a building level / cluster level) also needs to be measured for Quantity and Quality to ensure that Pollutants are not released in the waste water and the sewage can be treated appropriately. Every cluster / condominium / complex must install Sewage and waste water treatment plants to recycle and reuse water for gardening and landscaping. Remote monitoring of these STP plants should be done through the cloud to ensure that they are operating optimally as in many cases the STP plants are installed but after some time they are not maintained and start discharging polluted water into the environment. Even at an individual Home level, Mini STP plants should be encouraged to reduce the amount of BOD discharge into the drainage water. Figure 29 illustrates how the Sewage Treatment plant at a community level or apartment complex level can be made intelligent and measure the amount of waste water treated and recycled and used for requirements such as landscaping, thereby reducing potable water usage. Waste water treatment is also a key initiative that the Smart Home can be an enabler for and help save precious water.



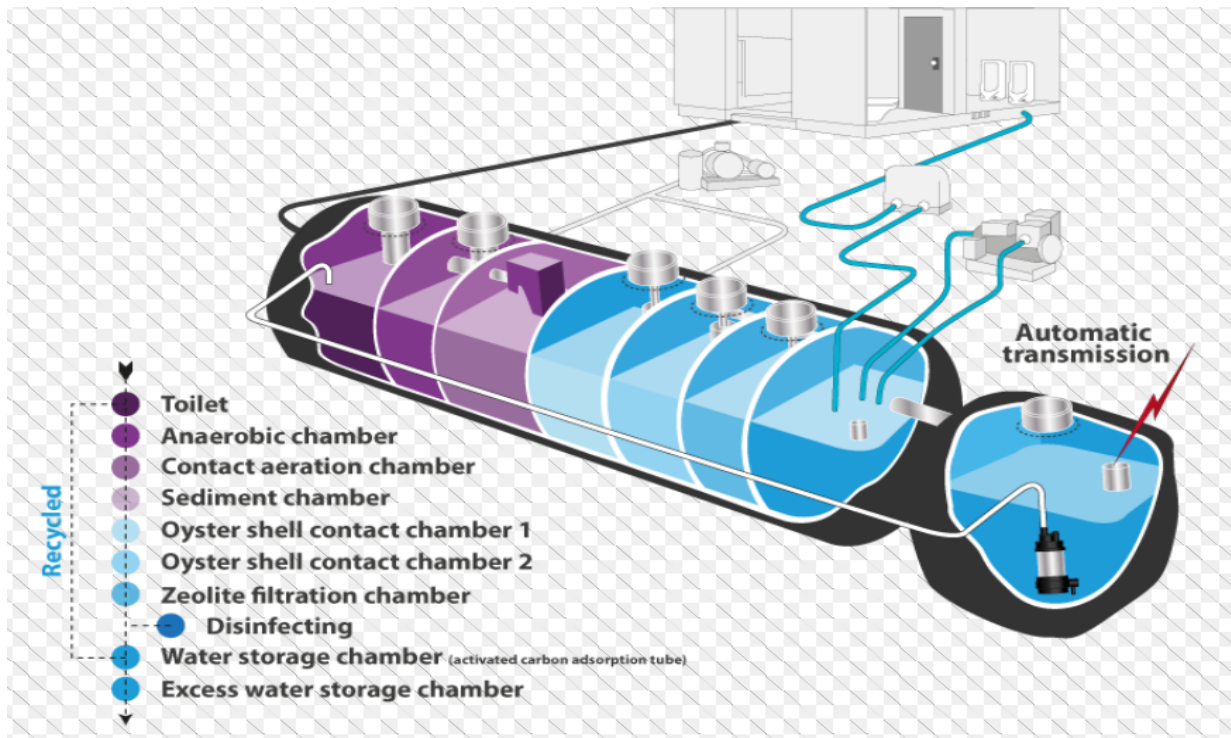


Figure 29 : Water Management System, [IEEE Report on Smart Sensors]

#### 10.3.4 Data Connectivity and user Internet experience

This is one of the most fundamental needs of a Smart home and having High Speed fiber based Communication backbone is critical for the Smart home setup. The Smart Home, being connected to the internet with High Speed communication can then leverage various technologies like High Speed Video Conferencing, which can reduce the need for the home owners to travel and reduce load on public transport. Also, internet connectivity of the Smart home's Remote monitoring sensors needs to be 24x7 so that the data collected can be aggregated and analyzed appropriately. The scenario is shown in Figure 30.

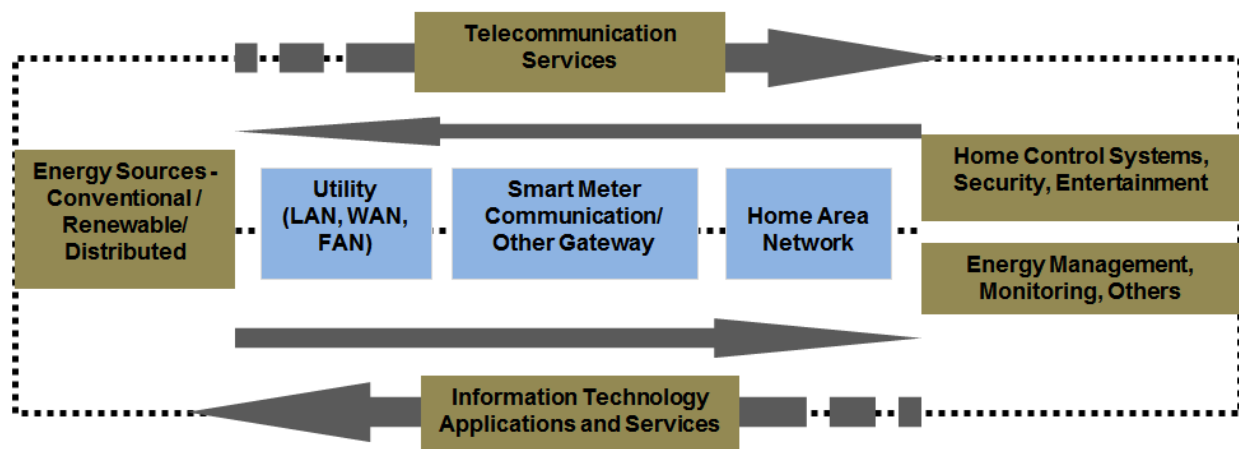


Figure 30 : Smart Home and Remote Monitoring

### 10.3.5 Physical Mobility and Transport Access planning

The Smart home of the future will also be integrated with advanced mobility systems like Electric cars and also Public Transport systems like Metro Trains. A smart home should be capable of offering alternate travel modes which will save the user time and also reduce the load on the roads. For Example if a user wishes to go from Point A to Point B and has the options to go by own car, Bus or by Metro train, the Smart home system should suggest the best options to the user (similar to Google Maps, but integrated into the Smart home itself) so that the user can take the decision based on the Traffic and also the time taken amongst the Transport modes available. At a city level, this can help reduce the loads on the roads and also boost Eco-Friendly Transport mode adoption like Metro Trains. A Smart Home should also be an enabler for Electric vehicles and should have Charging facilities and also analytics built into the car or the charging device. This data can then be used at a city level to further promote adoption of electric vehicles and reduce congestion on roads. Figure 31 shown the scenario.

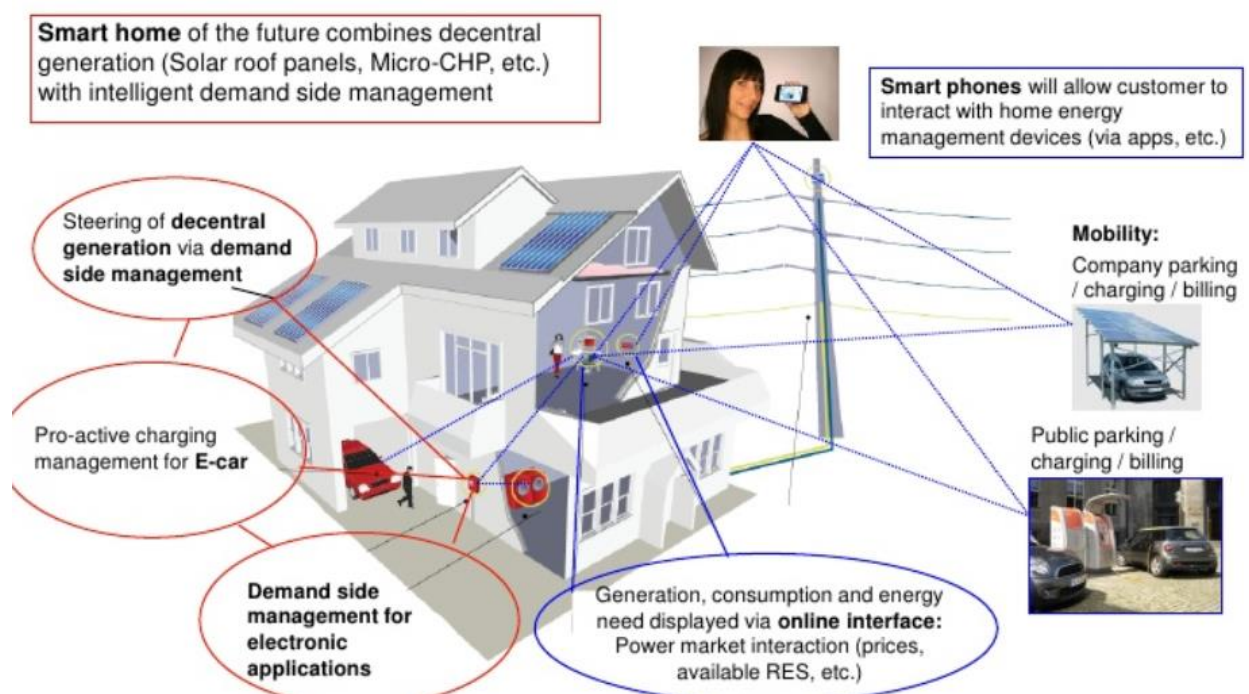


Figure 31 : Modern Home and Integration, [B. Mollstedt, "E.ON Mobility," in *Electric Vehicle Integration into Modern Power Networks*, DTU, Copenhagen, 2010]

At a City wide level, Smart Homes can help contribute significantly towards the Smart City initiative.

Smart Homes can be resource efficient (Water, Electricity), More Secure and also help with Smart Mobility initiatives. In the Indian context, the biggest needs which will drive Smart homes adoption is the need to conserve our limited resources and also improve the quality of life in the metro cities.

Smart Homes need to be supported by the Government by building a comprehensive framework for resource optimization and also an Operation centre for remote data management and response (Specifically for Fire and Security and medical emergencies.)

Smart cities can only be made by integrating all the discrete components of the Smart Infrastructure into an ecosystem which uses Integrated and intelligent devices to make residents lives easier, safer and more comfortable.

#### 10.3.6 The Smart Complex/ Building (Cluster of Smart Homes)

While an individual home can be a Smart Home, significant benefit can be derived from making Smart Clusters of smart Homes which can be in the form of Apartment Complexes or Smart Buildings.

At a collective level, the Energy Usage, Water usage and Waste Water Generation and many other parameters of the smart homes can be consolidated. Based on this data, additional benefits can be provided to residents based on the overall performance of their Smart Cluster / Building.

- 1) If a large residential complex is able to generate 25% of its energy consumption through Renewable energy sources, it should be given additional incentives in the form of energy rebates.
- 2) Say a Residential Complex is treating all its waste water and has a 0% discharge into the sewerage system as all the waste water generated is used for landscaping and the solid waste remaining is treated using natural technologies to make compost, the apartment complex should be rewarded and given additional incentives as a Green Building.

These parameters can be defined by the government and set as a benchmark standard, however for the success of this program, incentives must be given to the residents, which will accelerate the adoption of Smart Home systems and also aid in the development of Smart Clusters.

A Smart City needs to be developed simultaneously from both sides:

The Residents taking action to develop Smart Homes and Smart Clusters and the government developing Smart Infrastructure for Smart Cities. Without either of these initiatives, a Smart Home or a Smart City program cannot be effective.

The benefits to the government from the Smart Home Program will be:

- 1) Safer Homes and hence happier Citizens
- 2) Better Energy management and less power failures and thefts and lesser investments required in Power Generation and Distribution
- 3) Better City Wide water and waste water management
- 4) Better planning and cost optimization of infrastructure upgrades
- 5) Creation of Seamless future platform for providing public services



## 11 Smart Community

The genesis of smart community is at the nexus of infrastructure, communication and analytics is shown in Figure 32 and further elaborated in Figure 33.

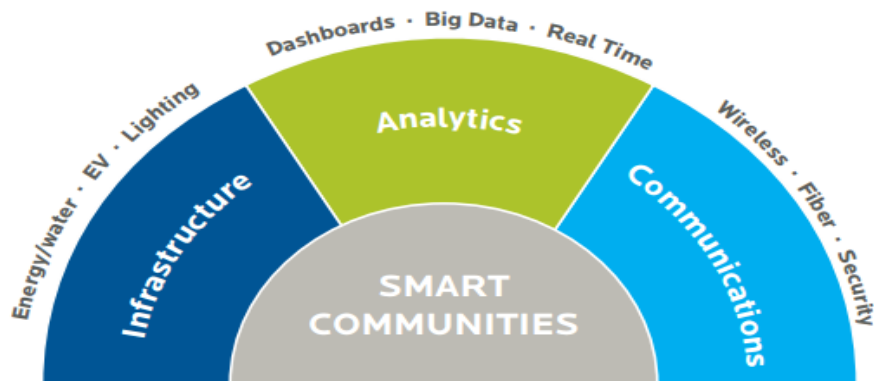


Figure 32 : Smart Community

### 11.1 Smart Community Use cases

The Smart Community use cases have been mentioned in Figure 33.

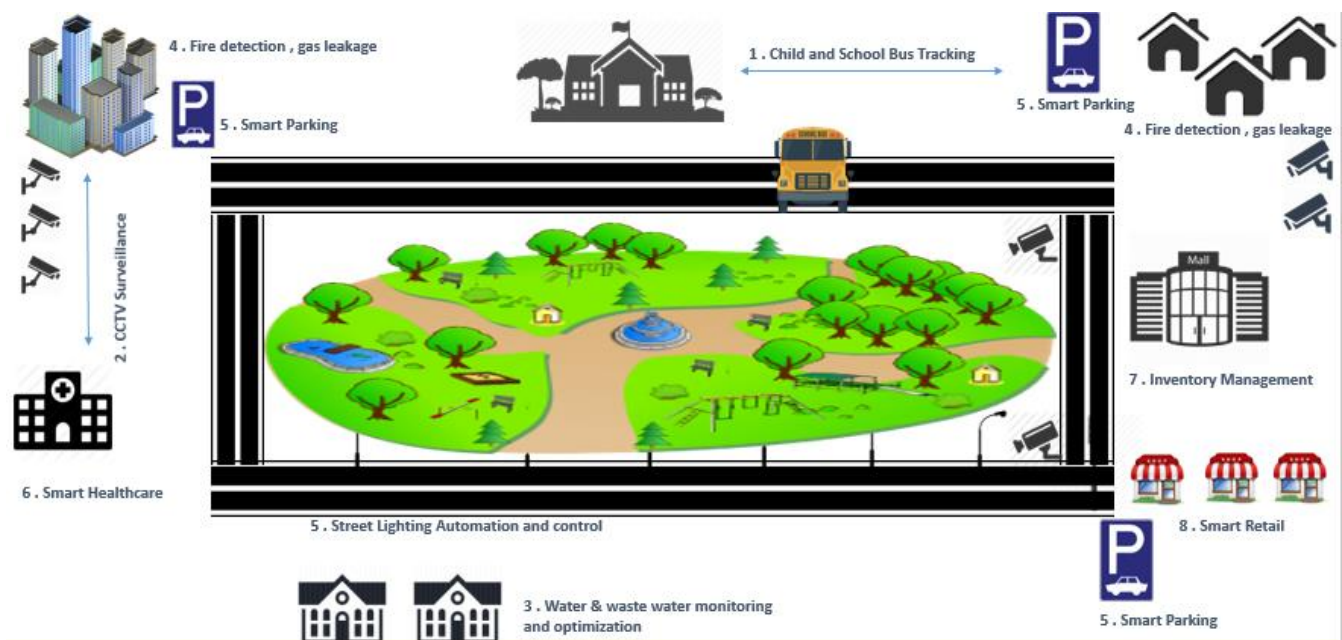


Figure 33: A Smart Community illustration

## 11.2 Smart Community Components

- **Smart Energy** uses digital technology through Advanced Meter Infrastructure (AMI), distribution grid management, high voltage transmission systems and for demand response for the intelligent and integrated transmission and distribution of power.
- **Smart Buildings** are green, energy efficient, and intelligent with advanced automated infrastructure that controls and manages aspects such as lighting and temperature, security, and energy consumption independently or with minimal human intervention.
- **Smart Mobility** enables intelligent mobility through the use of innovative and integrated technologies and solutions such as low emission cars and multimodal transport systems.
- **Smart Technology** will connect the home, office, mobile phone and car on a single wireless IT platform. Smart Technology includes adoption of smart grid system, smart home solutions, high speed broadband connection, and roll out of 4G technology
- **Smart Healthcare** is the use of e-health and m-health systems and intelligent and connected medical devices. It also involves implementation of policies that encourage health, wellness and well-being for its citizens and health monitoring and diagnostics as opposed to treatment.
- **Smart Infrastructure** includes intelligent and automated systems that manage, communicate and integrate different types of intelligent infrastructure such as energy grids, transport network, water and waste management systems and telecommunications.
- **Smart Governance** includes rolling out of policies and digital services from the government that help and support adoption of green and intelligent solutions through incentives, subsidies, or other forms of promotional schemes.
- **Smart Citizens** possess Interest to embrace smart and green solutions in the day to day work schedule. More proactiveness of citizens in adopting smart concepts and smart products which includes making “smart” lifestyle choices

## 12 Challenges

As the industries are working in silos and also on proprietary standards, it is required to define open standards at device, network and application levels to have interoperability for sustainable growth and economies of scale. Figure 34 shows the various Emerging challenges in relation to IoT at the technical and policy level. This report is focussed on the Technical aspects, hence policy matters shown in Figure 34 are useful only for the broader context.

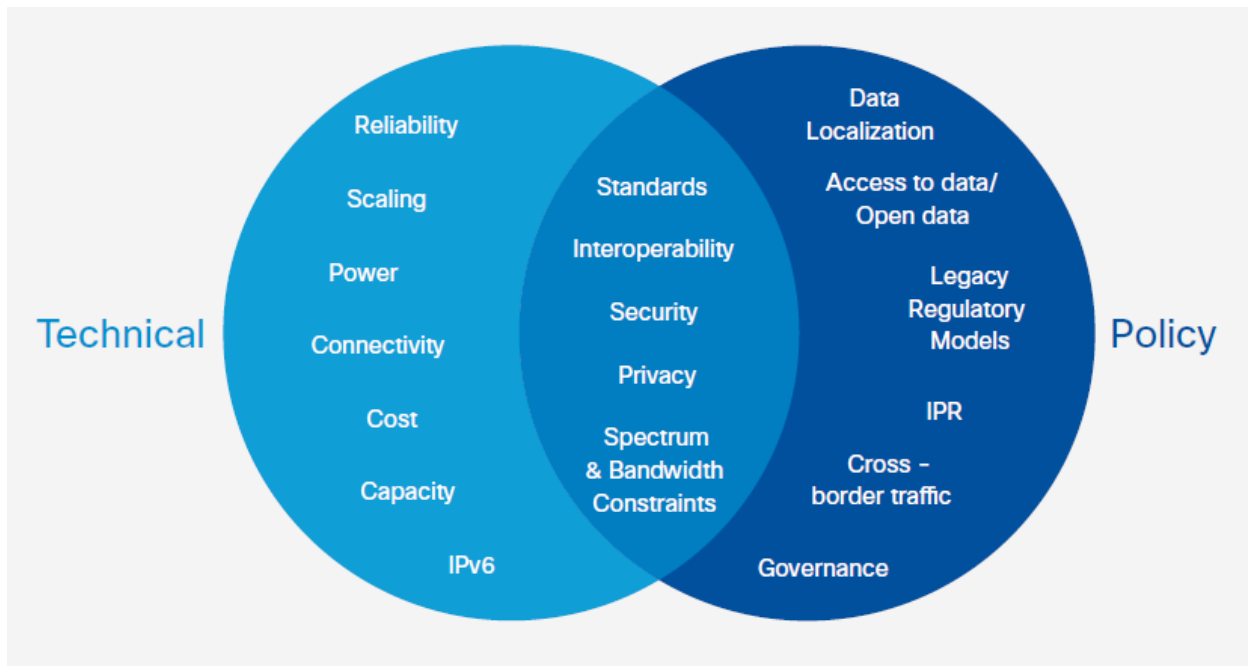


Figure 34 : Harnessing the IoT for Global development, ITU, 2016 [3]

The key challenges are listed below:

1. Lack of standards and interoperable technologies : Industries are working in silos and on proprietary solutions. For the smooth development of the vertical and also to have economies of scale, devices based on open standards should be used. Interoperability is required at all levels, be it device, network or application level.
2. Technologies for low power consumption are required for ensuring longer life for batteries especially in case of wearable devices. This becomes specially important as these devices are required to be usually equipped with some kind of wireless to be able to communicate with the nearest available authorised gateway or master.
3. Slow deployment of IPv6: In view of high volume of devices being deployed and expected to be deployed in M2M/ IoT domain, the device and Gateways connected directly to PLMN or PSTN network should have IPv6 or a seamless mix of IPv4 and IPv6. As IPv4 are going to exhaust, early adoption of IPv6 will be better.
4. Low cost devices (affordability): The adoption and penetration of smart devices is still less and the cost is high. This is partly due to the fact that proprietary devices are being sold from multiple vendors. This often requires specific implementation for specific use case. Standardization is necessary in order to bring down the costs and ensure interoperability as discussed above.
5. Data Security & Privacy : As larger number of devices are getting connected in the home, security and privacy are becoming increasingly important for the consumer. Whether it is businesses using behavioral data for their own commercial purposes, or criminals illegally hacking into and controlling the devices connected to the home network, consumers need to feel confident that

they are adequately protected from any malpractices. For this, end to end security is required with security features implemented at all levels.

6. Health care regulations are required for use of wearable health devices for remote monitoring of vital parameters of the individual / patient at home. It will be helpful in reducing the burden on the hospitals.
7. High speed and reliable internet services: For the development of Smart home / connected home vertical, there is a need of high speed and reliable internet services on fixed line broadband as well as mobile connections. All the data from smart devices can be assumed to be concentrated on a single pipe from the home. High speed is important but reliability and availability are equally important for faster adoption of the services.
8. Smart home gateways, having multiple protocols for HAN is required as the appliance may be having different types of communication protocols.
9. Fragmented Market - Fragmentation slows down market development as the vendors' hedge their bets on which technologies to back. It also increases equipment costs as multiple solutions need to be incorporated, and leads to consumer frustration when solutions do not work together.
10. Cost of Implementation - Introducing more and more connected devices into the home is an expensive business for the average consumer. While costs remain high, implementation of many solutions will remain limited – especially ones that do not provide any perceived real value.

## 13 Future of Smart Homes and Community – The Road Ahead

The connected home of the future will naturally be an evolution of today's connected home, which is built on the key foundation of broadband Internet access both in the home and on the move, with the latter typically provided by smartphones and other portable devices.

Many players are converging into the connected home and there would be a radical shift from isolated domains to interoperability and cross domain functionality.

Some of the prominent domains of Smart Home are as shown in Figure 35.

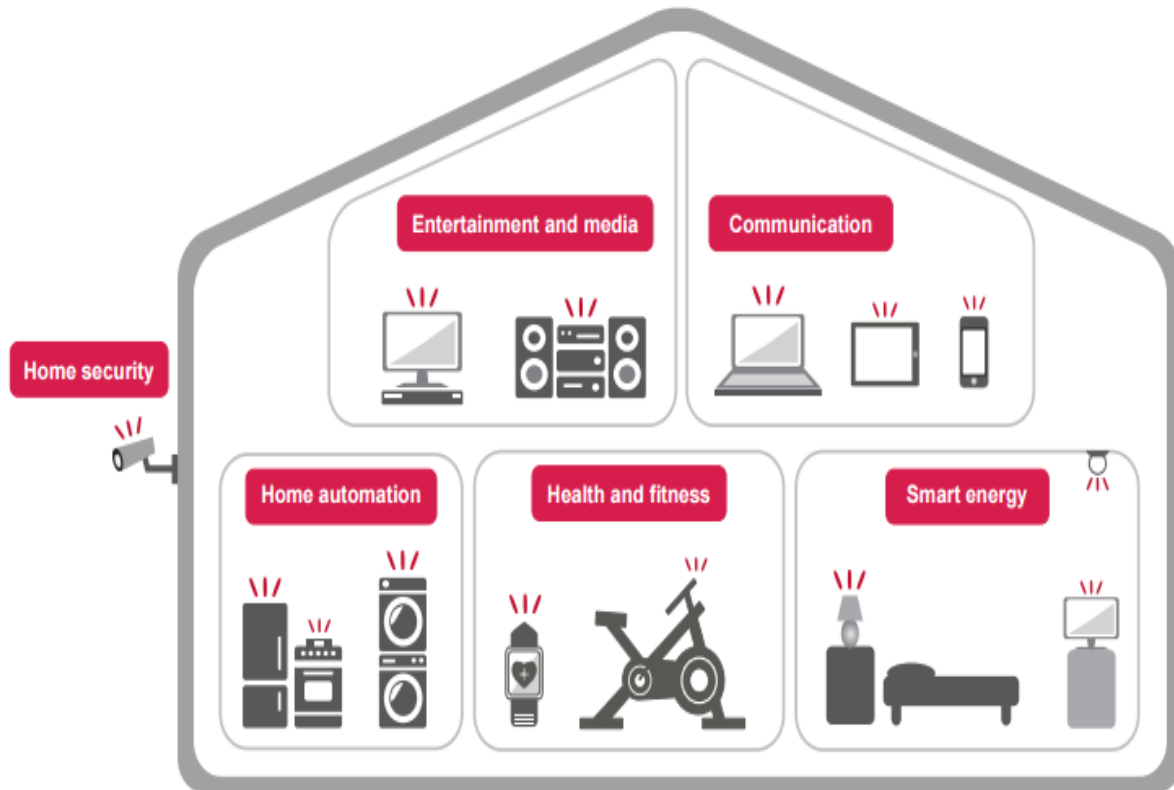


Figure 35 : A use case illustration for a Smart Home, [13]

Needs and wants would drive the connected home and community adoption going forward

### 13.1 Salient Features of Smart Home and Connected Communities by 2025 [13]

- By 2025, superfast broadband will enable more flexi working and home working, reducing the amount of time we spend commuting. It will also enable more people to improve their quality of life by living.
- Home security is likely to become part of a larger family security system that will include location and health tracking, on-demand communications, and safety-aware recommendations on everything from driving routes to hotels and restaurants
- Basic home systems, such as water, electricity, lights, heating, air conditioning, and appliances, will be highly automated and optimized to support personal preferences while reducing costs and the environmental impact
- Virtual reality will be mainstream entertainment in 2025, with technology allowing us to attend events virtually rather than physically. This will be supported by the widespread deployment of cameras and microphones capable of transmitting increasingly rich experiences between homes, event venues, and elsewhere.
- Media will be far more tailored to both individual taste and context, and will be delivered via a host of new systems and devices. For example, you will be able to ask your kitchen to suggest the

best dinners you can make based on the ingredients and time you have available, and who is having dinner.

## 13.2 Conclusions and Way Forward

Looking at various aspects dealt in this report, it is clear that there are positive elements present that are supporting and encouraging the adoption of M2M in the context of Smart Homes and also there are bottlenecks as pointed out in the previous sections. The following are the suggestions and Way Forward that this group suggests:

1. Unified Gateway is required to be developed having Wi-Fi and Sub GHz based network (Z-wave, 6LoWPAN, BLE etc) in the home area and fixed line broadband / FTTH / cellular on the WAN. Gateway should be based on open standards and with static IP capability (preferably IPv6/ dual stack)
2. Existing BB modems working on fixed lines / FTTH may be converted to Gateways by adding additional hardware module via the existing either of the available ports like serial, Ethernet, USB or Wi-Fi etc. An additional memory thus could be used to create a home network in the sub-GHz band (for Z-wave / 6 LoWPAN etc) depending upon the requirement. This requires further feasibility as adding a module to the existing devices would require the design details of the existing devices.
3. Indigenous technologies may be developed in the Sub GHz band.
4. TEC may work on point no. 1 and 2 for creating GR / IR based on related standards.
5. Standards for the common service layer are required.

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## Abbreviations

6LoWPAN	IPv6 over Low power Wireless Personal Area Networks
CAGR	Compound Annual Growth Rate
CDMA	Code Division Multiple Access
CoAP	Constrained application protocol
DECT	Digital Enhanced Cordless Telecommunication
DLNA	Digital Living Network Alliance
FTTH	Fibre to the Home
GHz	Giga Hertz
HAN	Home area network
HGI	Home Gateway Initiative
HMI	Home Machine interface
HPNA / HomePNA	Home Phone line Networking Alliance
HTTP	Hyper Text Transfer Protocol
HVAC	Heating, Ventilation and Air Conditioning
ICT	Information and Communication Technology
IoT	Internet of Things
IP	Internet Protocol
ISM	Industrial, Scientific and Medical
KNX	OSI-based Network Communications protocol for building automation
LAN	Local area network
LPWAN	Low Power Wide Area Network
LoRa	Long Range
M2M	Machine to Machine Communication
M-Bus	Meter Bus
MoCA	Multimedia over Coax Alliance
MQTT	Message Queuing Telemetry Transport
OSI	Open Systems Interconnection
wM-Bus	Wireless M-Bus
NFC	Near Field Communication
REST	Representational State Transfer
RoI	Return on Investment
SH	Smart Home
SOAP	Simple Object Access Protocol
WG	Work Group
XML	Extensible Mark-up Language



## Annexure 1

## Use Case: Connected Smart Home

## 1. Title

1.1. Name of the use case: Connected Smart Home

1.2. ID of the use case: Home Automation/001/16-17

1.3. Version / revision history: 001/ October/16-17.

1.4. Source: INDIA/Indicus Software

## 2. Glossary

Term	Description
IoT Platform	<p>Cloud based platform (or in some cases deployed on-premise) that enables home automation solution to leverage services offered by ecosystem.</p> <p>The IoT platform provides data ingestion, big data storage, high speed distributed big data processing, data analytics, rule engine and application enablement features along with integration capability with enterprise systems, databases and third party APIs (weather, map).</p>
Smart Home Gateway (referred as gateway in this document)	<p>Hardware device facilitating communication between IoT enabled devices and cloud. The gateway referred to in this document will provide HMI (Human Machine Interface), for the home owner to control IoT devices.</p> <p>Although rule based decisions are carried out by IoT platform, the gateway will be capable of executing certain decisions in case of emergency.</p>
IoT enabled devices/sensors (simply referred as "IoT enabled devices" or "IoT devices" in this document)	<p>Devices capable of communicating with <i>smart home gateway</i> using industry standard protocols such as ZigBee, WiFi, Bluetooth, TCP/IP, etc. Some of the examples are smart switches, smart energy meter etc.</p> <p>These devices are supported by smart home service providers.</p>
Appliances	<p>Typical home appliances. e.g. electrical appliances (air conditioner, refrigerator, boiler, microwave), lights / tubes / CFL, etc.</p> <p>It may be possible to control/monitor these appliances by connecting them to an IoT enabled devices (E.g. A/C connected to a smart switch).</p>

Smart appliances	Off the shelf appliances available in the market, usually supporting proprietary or standard protocols. Smart appliances those support standard protocols may be integrated with the smart home solutions relatively easily.
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### 3. Objective

This use case describes a “pay as you go” smart home solution integrated with “Smart City Services”.

Solution service provider takes complete responsibility of deployment and maintenance of the system, covering all of the key areas of the ecosystem, viz. hardware, software and services.

Uninterrupted supply of utilities such as power, water, gas, etc. will be ensured through the nexus of third party public and private service providers associated with the smart home solution.

Using the proposed solution, home owners can monitor and control IoT devices locally or from remote locations in a hassle-free, reliable, secured yet cost-effective manner and get timely alerts in emergency situations.

### 4. Background

#### a. Current Practice

Majority of homes in India are not equipped to have home automation solution installed due to infrastructure limitations.

Home owners interested in deploying smart home solution, either hire a solution provider or procure and install DIY home automation kits themselves. Although some of the solution providers design their own hardware components, many other pick and choose readily available components from the market.

Most connected home vendors focus on one or two categories of products or services. Also, typically vendors do not engage with home owners once the installation is carried out. From home owner’s angle, up keeping home automation system takes a low priority, unless the home owners’ past experience has led them realize real value from the solution. This situation may result in homes where the system becomes non-functioning over a period of time.

#### b. Need for the Use Case

With rapidly changing lifestyle in India there is a huge need for home automation solution. Some of the main reasons behind deploying home automation solution are want of security, safety, convenience, comfort, energy saving, etc.

In smart city projects initiated by central government or integrated townships, a connected home becomes a part of the ecosystem consisting of (but not limited to) numerous city assets such as utilities, security, transportation, healthcare, law enforcement, waste management, etc. By becoming a part of the larger ecosystem, smart and connected homes can help the entire ecosystem function more efficiently.

**c. Roadblocks in leveraging full potential of home automation solution**

With the steady growth in wearables, home entertainment and BYOD (Bring Your Own Device) trends, home owners and at times even solution providers, select components from a plethora of proprietary smart appliances to create home automation system. This however results in creating a fancy application rather than a purposeful solution. Although, such systems may allow home owners a means to control a set of smart appliances, they usually fall short in the area of analyzing and providing valuable statistical data in a usable format to home owners. Such solutions typically work in silos, failing to take advantage of the overall IoT ecosystem described in the earlier section. Using smart appliances from different vendors poses yet another problem. Each appliance usually is bundled with its own proprietary application. Managing multitude of such devices becomes a nightmare for home owners.

Connected home devices and solution vendors need to prove their reliability before they can break into the mass market. Fragmented ecosystem, price and perceived value, lack of high-speed reliable network coverage and interoperability between disparate network technologies that are still evolving are seen as roadblocks in quick adoption of home automation solutions.

**d. Proposed solution**

Proposed home automation solution will allow home owners to remotely monitor and control IoT devices, and receive alerts via the gateway installed inside a house. Home owner will be able to take cognizance of an unannounced visitor by streaming images from a surveillance camera attached to the door bell, at a remote location. Emergency alerts requiring immediate attention will be sent not only to the registered home owner but also to concerned third parties such as security office, healthcare provider or fire brigade via a call centre/provider network. The system can solicit home owner's consent before notifying third parties. Rules to raise alerts and send notifications will be configured through a rule engine, provided by ContineoNX, a cloud based IoT platform.

For home owner's convenience, responsibility to upkeep various IoT enabled devices inside the house will be handled by service provider's call centre. The gateway will monitor health of IoT devices such as smart switches, smoke/gas detector, motion sensor, beacons, microphone, siren, etc. and inform the call centre when an IoT device needs to be repaired or replaced. This model will ensure that the home automation system takes the hassle of maintaining the system away from the home owner. Home owners will be charged monthly based on subscription or pay-per-use- model for these additional services.

Communication between gateway and home owner will be carried out over secured channel. Users will also be able to monitor multiple homes, provided each home has its own gateway. Additionally, one home can be managed by more than one family members.

The system will provide analytics and reports such as overall energy consumption, month wise consumption, etc. to home owner. Communication with third party agencies will be handled by ContineoNX using various communication channels.

The system will provide customized weather alerts or configure wake-up alarms based on the family members' calendar along with other parameters such as preferred mode of transportation, weather, etc.

**e. A typical use case fulfilled by the proposed solution**

It is normal for an individual to own multiple real estate properties in different geographical locations. It is impossible for the owner to be aware of *property health* from a remote location. *Property health* can be defined as availability of utilities such as water or electricity and home appliances in working condition.

This solution will

- Enable home owners to perform various operations remotely. Remote operating is especially useful for appliances such as water pump; which gets jammed if not used on a regular basis.
- Help keep the home in functioning condition by keeping the owner informed about the status of appliances.
- Send emergency alerts to the owner as well as to the concerned third parties in case of incidences such as fire, break-ins and flood.
- Provide essential third party services to the family members. For instance, in case of medical emergency, the gateway can be used to contact nearby ambulances or hospitals either directly or via a call center.
- Periodically provide usage history of utilities, in order to avoid unpleasant surprises at the end of billing cycle and help detect miscalculations in billing if any. In the future, the home automation gateway may also be integrated with utility providers and payment gateway to make utility payments; relieving the property owner of such regular chores

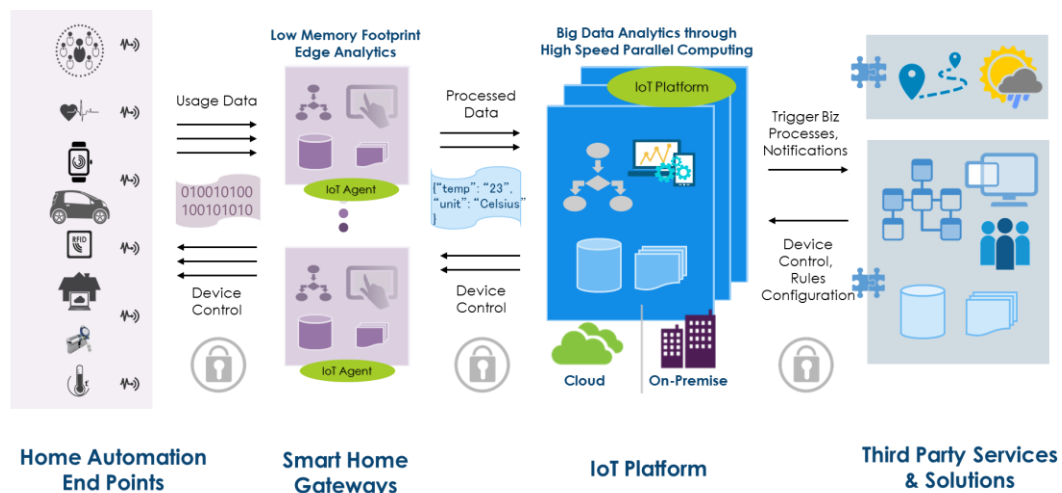
**5. Description**

- b. **Ecosystem description in terms of actors and business roles:** The solution involves an Internet enabled gateway, Service providers (or call center) network, Telecommunication Service Provider (TSP), IoT platform, owners' smartphones or tablets, third party services, society office (optional) and of course the home owners.

*Table ANN1: Actors' Description*

Actor Name	Actor Type	Role Description
Internet enabled Home Gateway	Device	Allows the home owner to monitor and control smart home appliances locally and interprets local rules to perform critical actions such as switching off long running appliance.
Home Owner	Person	Main stakeholder. Manages and controls various aspects of real estate property.
Service Provider/Call Centre	Organization	Facilitates services on behalf of the home owner
TSP	Organization	Provides telecommunication network infrastructure for home gateways and owners' smartphones to communicate with the cloud based IoT platform
IoT Platform	System	Facilitates remote control of smart home appliances, storage of usage data, alerts, remote commands and provides home automation management system to the service providers to effectively orchestrate their workforce
Owner's Smartphones and tablets	Device	Devices using which the owner will monitor and control smart home appliances locally or from remote locations in a secured manner
Society Office	Organization	Township or society office that offers security and maintenance services to the residents
Third Party Services	Organization	Ambulance, fire extinguisher, police, utility companies, etc.

### c. Contextual Illustration

*Figure ANN1 -1: Home Automation System Textual Description*

#### d. Pre-requisite

Highly available Internet connection is present for the gateway to communicate with stakeholders for them to be able to remotely monitor & control smart home appliances. Or the gateway is capable of storing the data locally and send it when connectivity is restored.

#### e. Triggers

- Events occurring inside the home; events can be as simple as switching on a boiler or as critical as smoke detector raising an alarm.
- Control commands invoked by home owners or service providers such as “turning on the AC”

#### f. Scenario

1. Service provider deploys smart switches, IoT enabled sensors, surveillance equipment, smart home gateway, etc. and configures the system by registering the gateway and smartphones that are entitled to operate the system and standard rules.
2. The home owner can change the configuration as per his preferences and installs smartphone app on the registered phones.
3. The gateway controls smart appliances as per the rules in order to save energy or ensure safety.
4. The home owner operates smart appliances through the HMI interface provided by the gateway or through smartphone apps.
5. The home owner receives usage reports from the system by email.
6. The home owner receives push notifications from the system in case of emergency. Notifications are also sent to third party service providers depending on the configuration.
7. The home owner can communicate with guests at the door in case the whole family is away.
8. Usage and operational data is stored in IoT platform for trending and analysis

#### g. Process Flow Diagram

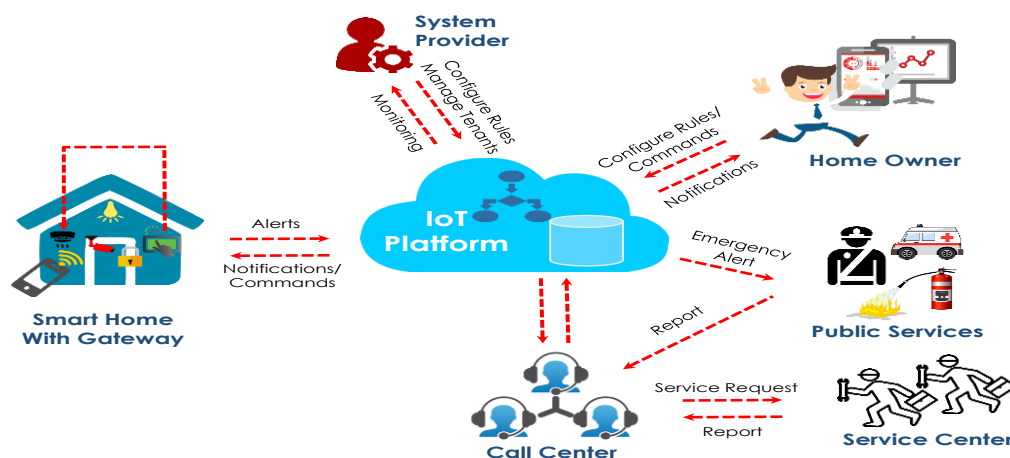


Figure ANN1-2: Home Automation System Process Flow

From Smart Devices to Gateway:

- Device / smart appliance health status
- Device specific data
- Usage history

From Gateway to IoT Platform

- Consolidated device / smart appliance health status
- Consolidated device data
- Consolidated usage history
- Rule execution log, Alerts log and Device control commands log

From IoT Platform to Smartphone

- Consolidated device / smart appliance health status
- Consolidated device data
- Consolidated usage history
- Alerts

From Smartphone to IoT Platform

- Device control commands
- Rules configuration

From IoT Platform to Gateway

- Software Updates
- Rules configuration

From Gateway to Smart Devices:

- Health check polling
- Device control commands

## **6. Architectural Considerations**

### **a. Deployment Considerations**

Home Automation gateway as well as IoT enabled devices should be installed inside the house. Location of the gateway should be such that it will ensure uninterrupted Internet Connectivity. From

the installed location, the gateway should also be able to communicate with IoT devices either through hard wired connection or industry standard communication mechanisms.

**b. Geographical Considerations**

None

**c. Communication Infrastructure**

The Gateway will use home Wi-Fi or will have a SIM of its own to exchange information with the cloud IoT platform using MQTT/HTTP protocol. Smartphones carried by home owners will use GSM/GPRS/Wi-Fi to send and receive messages. IoT devices & smart appliances will communicate with the gateway over industry standard protocols such as ZigBee, Bluetooth, Wi-Fi, etc. Possibility of using VSNL broadband router as a home gateway should be evaluated.

**d. Performance Criteria**

The system should be able to raise critical alerts or execute rules in near real time subject to availability of connectivity.

**e. Interface Requirements**

- 1) Gateway should be able to send alerts/notifications and receive commands using Wi-Fi or GPRS connection
- 2) Smartphones carried by home owners should be able to exchange information with Gateway via IoT platform either through GPRS/GSM or Wi-Fi
- 3) Service providers should get alerts on their devices
- 4) Service provider should be able to communicate with the home owner for emergency or service calls
- 5) MQTT / HTTP will be used for exchanging messages among different parties to ensure scalability and high performance

**f. User Interface**

Web based responsive application will be provided for the service providers to carry out functionalities such as home owner registration, IoT device provisioning, monitoring, etc. Smartphone app will be provided for home owners to perform various activities such as viewing alerts, monitoring/operating smart appliances, etc.

**g. APIs to be exposed to the application from Platform**

The application will provide REST API for third party integration



**h. Data Management**

Data rate, payload size, frequency of communication, synchronous or asynchronous session types, request-, request-acknowledge-, handshake-request-, response types, and broadcast constitute data management in addition to data integrity and payload sizes

**i. Data backup, archiving and recovery**

ContineoNX will keep a log of data exchanged between gateway and home owner's smartphone or tablet. Live data will be maintained only for the duration defined in the SLA between the home owner and the service provider; old data will be purged. SLA will also guide when backups are performed and data is archived.

**j. Remote device management**

The solution will allow the home owner to provision, configure, monitor and control smart appliances. Service providers will be able to monitor health of the gateway, IoT enabled devices/sensors and smart appliances.

**k. Start-up/Shutdown Process**

Start-up/shutdown process is specific to gateway, devices and smartphones carried by home owner. Cloud platform is highly available.

**l. Security requirements**

Communication between home owner's device and gateway should be encrypted. Gateway as well as smartphones will be authenticated during each transaction with the IoT platform preventing malicious intrusion.

**7. Potential Market Growth forecast**

By 2020, more than 40% of the Indian urban households which are increasingly becoming tech-savvy, will use home automation/energy management solutions mainly as a way to increase home security, status symbol and convenience and also as a way to conserve energy. Also, regular replacement cycles for switches and light bulbs provide an opportunity for sensor-based lighting. Falling costs in embedded radio chipsets and sensors, reduced costs of app-based delivery models and personal cloud services, and the sizable penetration of wireless technologies (wireless Internet penetration of urban households will increase to be more than 50% the next five years) — will drive growth in the market.

By 2018, 40 devices and things per household in mature markets will talk to one another. (Third party source)

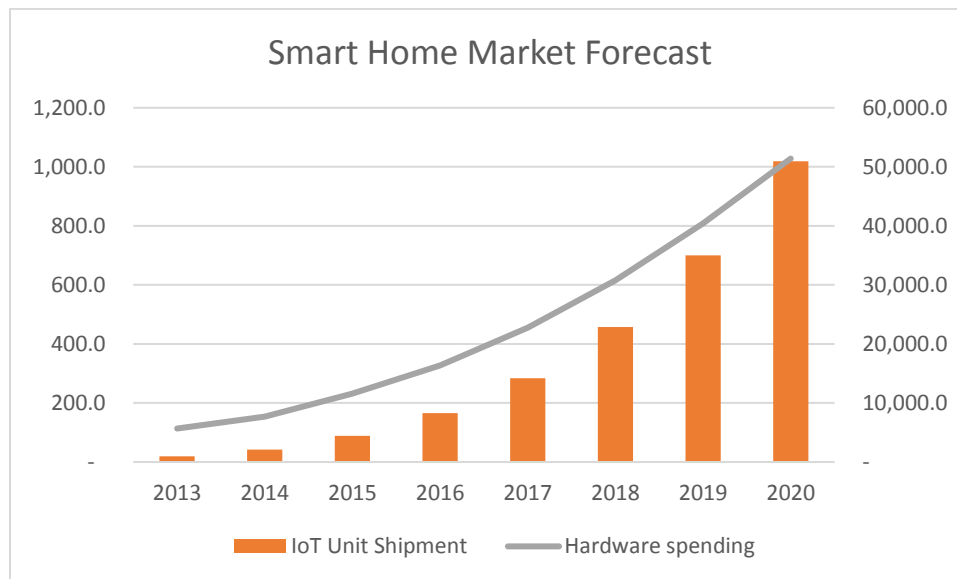


Figure ANN1-3: Smart Home Market Forecast

Note: Wearables are not included in IoT unit shipment.

## 8. Implementation constraints

Some of the challenges anticipated are as follows:

- 1) Availability of service providers, especially in semi urban and rural areas
- 2) Lack of high-speed reliable network coverage
- 3) Interoperability between disparate network technologies
- 4) False emergency alarms detection or not detection
- 5) Replacement of batteries in IoT enabled devices or smart appliances if any
- 6) Privacy concerns of consumers

## 9. Available Global Standards

[ETSI TS 103 264 V1.1.1 \(2015-11\) SmartM2M; Smart Appliances; Reference Ontology and oneM2M Mapping](#)

[Google Thread](#): Global ecosystem of connected home developers

## Annexure 2

# IoT Home Gateway

Source: India/ STMicroelectronics

*The promise of efficient and intelligent use of resources enabled by IoT has raised the expectations of the technical as well as the consumer community. However it's not always possible to connect the IoT nodes directly to the public internet due to power or computational limitations. IoT Gateway help connect Things to broader internet by using connectivity technologies suitable for resource limited Things. There are a myriad of technologies and protocols available to communicate between Things, Gateway and Cloud Application. It is not trivial to make the correct choices for a specific application. In this paper, we present a flexible architecture for Internet of Things Gateway Platform known as "Wireless Bridge" which supports different wireless technologies. We will also discuss various connectivity technologies and protocols available for IoT based applications.*

### Introduction:

IoT is a network of connected objects (Things) with embedded electronics that allows to sense, report and controlled remotely and sometimes take simple decisions. IoT seeks to connect every device (things) that we interact with, including those which are generally not connected to the network. While the premise of connection to the internet increases with reach of IoT, it also poses unique challenges. One such challenge is that many IoT nodes have limited memory, storage and computation capabilities and are not able to connect to the IP based networks directly. An IoT Gateway fills this gap by acting as bridge between IP based public network. It also provides additional security, storage and processing services allowing the end nodes to be as cost effective and power efficient. The IoT space is very fragmented and there are too much literature available on this subject. This paper aims to provide a holistic view of all available protocols and connectivity technologies.

### Challenges in designing an IoT gateway

**Node Connectivity:** We need to select a short range Radio Frequency (RF) technology to connect to the IoT nodes. This selection is dependent on the various parameters like frequency band, modulation scheme, channel number, data-rate, latency, robustness etc.

- a) Backend Connectivity:** The IoT Gateway may use short range radio technology to connect to the IoT nodes but a long distance link is needed to connect to the internet. This selection is based on bandwidth requirements, available connectivity options in the area and criticality of the application.
- b) Management Server:** IoT nodes are not generally accessed (through the gateway) on the internet as standalone entities. It's more prevalent to have a central server managing the nodes, while IoT gateway facilitates this communication. We need to identify protocols for communication with the management server.
- c) Local intelligence:** The IoT Gateway can take most of the decisions locally and send only the filtered data to the cloud. This can make the system more efficient. The gateway decision logic may be programmed by the server for flexibility.

- d) Power considerations:** The power source of gateway also affects our decisions related to the above points. As sensor networks become more prevalent and embedded in Things, they would need to be as unobtrusive as possible and scavenge power from its environment.
- e) Security:** This is a factor that can make or break the success of large scale IoT networks. As these networks become part of application (some of them critical in nature), security will assume paramount importance.
- f) Serviceability:** There must be a provision to service and to update the IoT gateway (and nodes) in the field. There should not be sole dependence of remote serviceability and we should have additional connectivity options to service the installation.

### **Node Connectivity Technologies:**

In current landscape, many communication technologies are available such as Bluetooth, Wi-Fi, NFC, ZigBee. There are also several new emerging networking options such as Sub-GHz, Thread, ANT, Z-Wave that can be readily used for IoT Applications.

Depending on the applications factors such as operating range, power consumption, data rate, operating frequency, battery life will dictate the choice of one or more from combination of the technologies. The table 1 below draws a comparison of features of the major communication technologies on offer today.

**a) Backend Connectivity:** Connectivity to the management server (backend) involves selection of backhaul connectivity technology as well as protocols for connecting to backend. Backhaul connectivity refers to the long range connection of the IoT Gateway to the ISP endpoint. Cellular technologies like 3G/4G/LTE are the most popular options. Power Line Communication) can be used for smart street lights or other similar applications. Optical fibers can be used for applications requiring high bandwidth. For remote areas not covered by cellular connectivity, options such as satellite links or microwave can be used.

**b) Communication Protocol:** There are many communication protocols that can be used by the IoT gateway to communicate with the Cloud application. Some of the popular protocols are:

**Plain HTTP:** This is by far the most ubiquitous protocol. It's widely accepted by servers and is backed by Internet Standards, and has the least compatibility issues and maps with the RESTful APIs.

**CoAP:** Constrained Application Protocol is binary version of HTTP. It has very concise headers and supported binary data format. It can be used on top of TCP or other transport as well. CoAP packets can be easily translated to a HTTP packet.

**Web sockets:** It is a new protocol backed by World Wide Web Standards. It has the same addressing and handshake mechanism as used by HTTP. It's especially suited in shared hosting environments and gateways operating behind proxies.

**MQTT:** Is also a popular protocol running (optionally) on top of TCP and works in subscriber model. It more suited for broadcasting messages to interested gateways.

**AMQP:** This is the most suited protocol for gateway server communication. It acts as a storing queue and ensures that packets are not lost, even in case of temporary outage.

**XMPP:** Extensible Messaging and Presence Protocol is a popular protocol used by chat clients for real time communication and has standardized a lot of parameters.

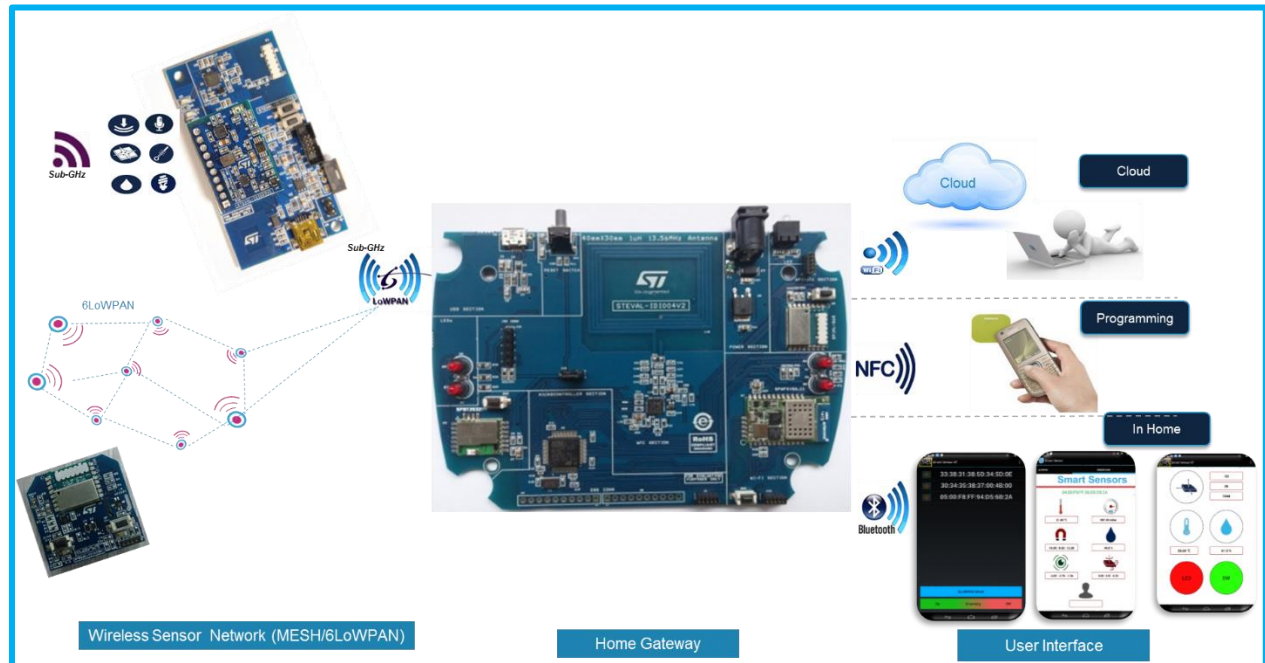


Figure ANN2-1 : IoT Home Gateway Solution

## IoT Home Gateway Architecture:

Home Gateway device is MCU based IoT Platform as shown in Figure ANN2-1 having different connectivity technologies. The system comprises of Bluetooth, Wi-Fi, Sub-GHz and Near Field Communication. Wi-Fi is used for exchanging Things or Node data with the Cloud Platform through IoT Home Gateway Platform. Bluetooth is used for communicating the Things or Node data with the Android App through Gateway Platform and Sub-GHz is used for exchanging data between Gateway Platform and Things. An Application layer is added on the Gateway solution that acts as bridge between the Cloud Application and Things.

### Key Communication Elements:

- a) **Sub-GHz Module:** The communication between Home Gateway and Things is based on 6LoWPAN using Sub-GHz module. Sub-GHz module is ultra-low power & fully integrated RF module operating respectively in the 868 MHz / 915 MHz ISM bands.
- b) **Wi-Fi Module:** The Wi-Fi module connects the Home Gateway device to Microsoft Azure based cloud application. Wi-Fi module works as STA mode and connect to AP and upload the sensors data on cloud server.
- c) **Near Field Communication:** The Gateway has NFC transceiver used as NFC reader/writer device to communicate with the NFC Passive Tag on the Things for configuration purpose.

- d) **Bluetooth Module:** Bluetooth module is used in home automation applications for communicating with Bluetooth devices and smart phones.

## Things Architecture

'Things' in this solution are based on Multi Sensors-RF platform which has 2 parts (Sensor Board and RF board). RF board is the master board consisting of a low power MCU device, Dynamic NFC Tag (M24LR) and Sub-GHz. MCU runs Contiki3x based 6LoWPAN for connectivity with Gateway.

"Sensors Board" consists of a multiple sensors such as accelerometer, pressure, humidity, microphone and light sensor.

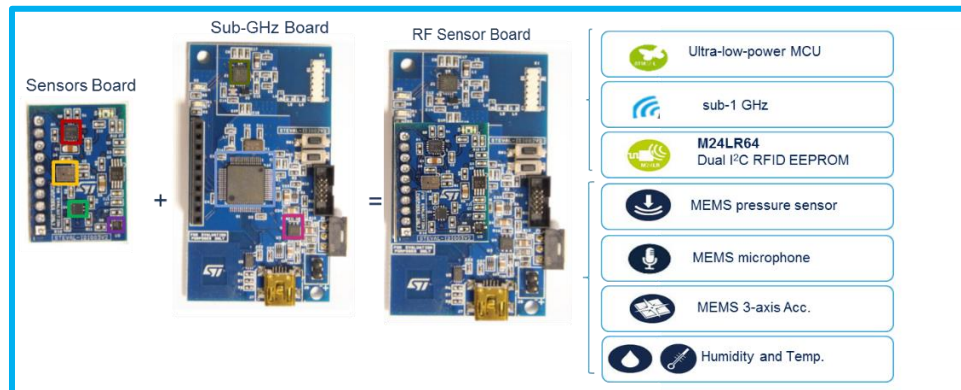


Figure ANN2-2 : RF Sensor Node (Thing)

The Home Gateway has local and remote connectivity options to access sensor data and actuator on the nodes (Fig: 5)

**Android Application:** A local user can access the nodes using the Bluetooth connectivity on smart phones by pairing with the Home Gateway device.

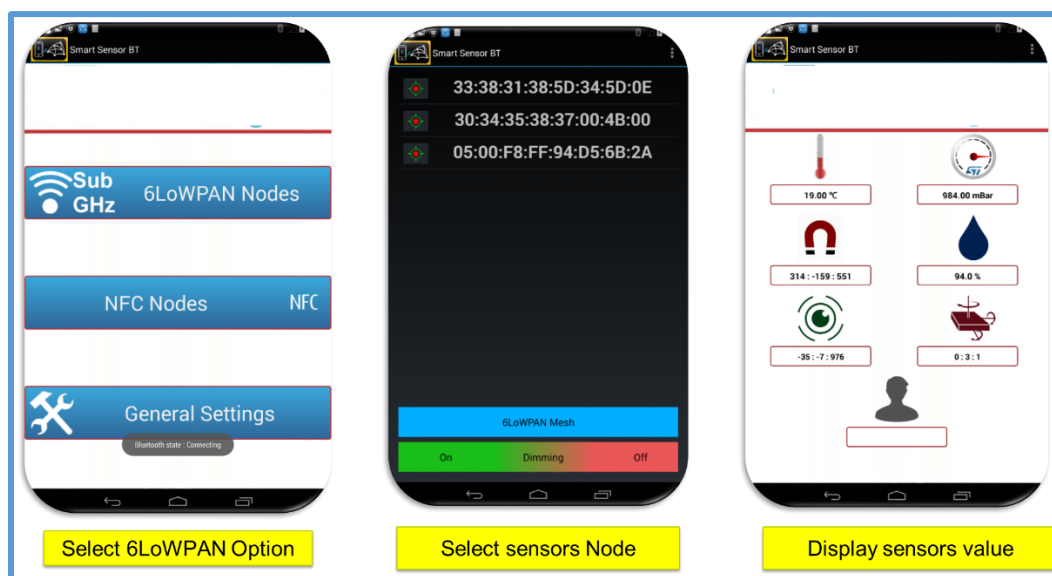


Figure ANN2-3 : Android APP



The android application provides the facilities to set alias name for each of the sensor node. The user need do long click over the IP address which pops up a dialog box to set alias name

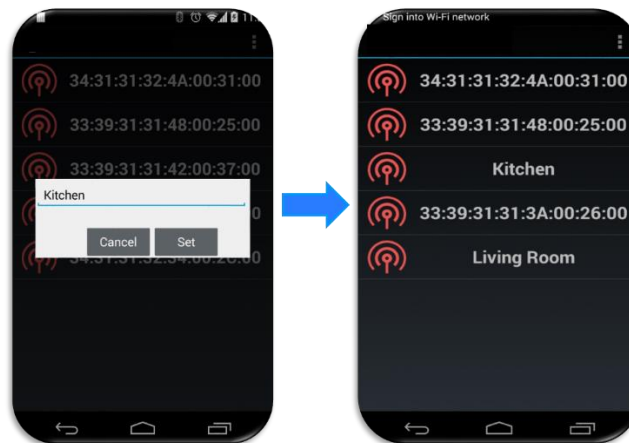


Figure ANN2-4: SET Alias name

**NFC Application:** The Sensor nodes also have the NFC Passive Tags. The passive tag stores the sensor values for each node. If the 6LoWPAN network is not available, the user can put sensor node's NFC antenna on top of Home Gateway NFC antenna and read the sensors values through NFC interface. The communication between Android App and Home gateway is on Bluetooth communication.

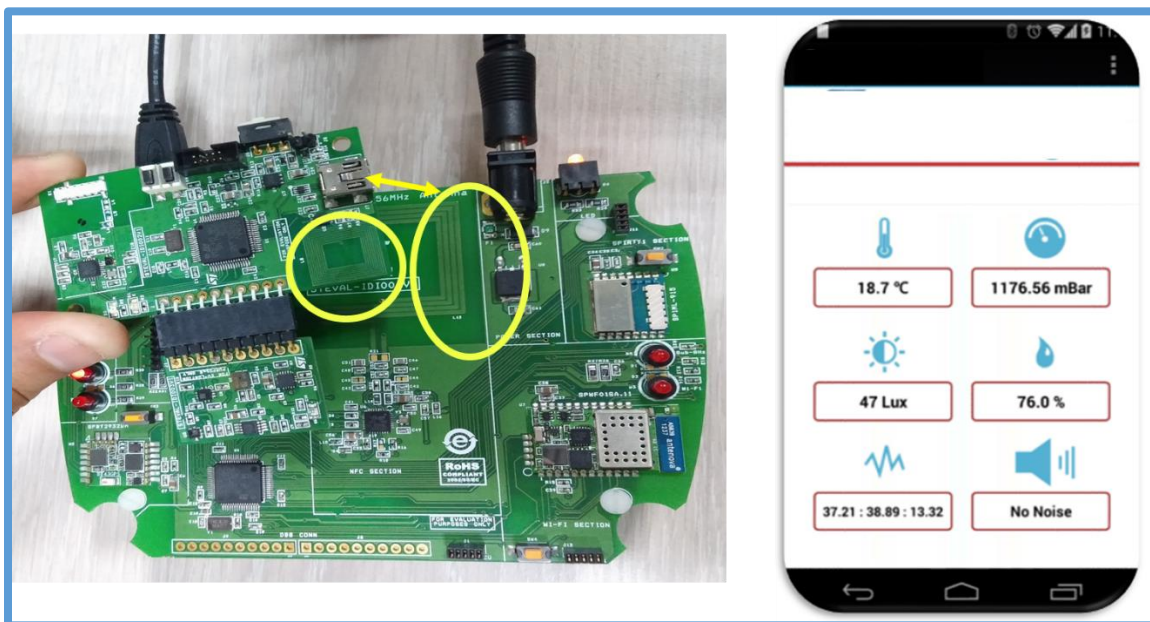


Figure ANN2-5: NFC Communication

**Cloud Application:** User can register sensors node on cloud server and can view sensor data and control actuators using the cloud application.



Figure ANN2-6: IoT Home Gateway Interface

Cloud Bridge Home About Contact Node Command Node List Log off					
Node Details					
Node ID	Node Name	Description	Read Key	Write Key	Operation
5	6663.3030.3030.3030.3731.3037.2500.2f00	Channel for node with IPAddress = 6663.3030.3030.3030.3731.3037.2500.2f00	AMTTVXKAE20DAKJ1	4VR7MY0M64L87B3M	<a href="#">View</a> <a href="#">Delete</a>
7	6663.3030.3030.3030.800f.5ffc.d323.2cd0	Channel for node with IPAddress = 6663.3030.3030.3030.800f.5ffc.d323.2cd0	30TPOCYACE9PCMWL	K8A8TL06SG2M0U2	<a href="#">View</a> <a href="#">Delete</a>
8	6663.3030.3030.3030.3034.3538.3700.4b00	Channel for node with IPAddress = 6663.3030.3030.3030.3034.3538.3700.4b00	FUJWUUJ4C1SXUYTJ	DJK0IQ7L0SDOCJ56	<a href="#">View</a> <a href="#">Delete</a>
23	6663.3030.3030.3030.3034.3538.3400.1400	Channel for node with IPAddress = 6663.3030.3030.3030.3034.3538.3400.1400	FNL5AVAN514503SJ	7CKMTDVTPTSIK9F8S	<a href="#">View</a> <a href="#">Delete</a>
24	6663.3030.3030.3030.3731.3037.2300.4600	Channel for node with IPAddress = 6663.3030.3030.3030.3731.3037.2300.4600	T8UGDH589BKPTVXR	YVXUMPRLFD9FH7W	<a href="#">View</a> <a href="#">Delete</a>
25	6663.3030.3030.3030.3731.3037.2500.4300	Channel for node with IPAddress = 6663.3030.3030.3030.3731.3037.2500.4300	0FU0XXAJIKMDLN9F	YUX0XXQL325V1L1B	<a href="#">View</a> <a href="#">Delete</a>
30	6663.3030.3030.3030.3439.3037.4a00.2e00	Channel for node with IPAddress = 6663.3030.3030.3030.3439.3037.4a00.2e00	9L3JLY06AOT2VQJQ	T0M9NW8USA0BNFXR	<a href="#">View</a> <a href="#">Delete</a>
31	6663.3030.3030.3030.400f.9ff.3b51.c4ae	Channel for node with IPAddress = 6663.3030.3030.3030.400f.9ff.3b51.c4ae	7TLOGCLAS6L0TH7R	E13A4M8CX71X6A87	<a href="#">View</a> <a href="#">Delete</a>

Figure ANN2-7: Node details on cloud



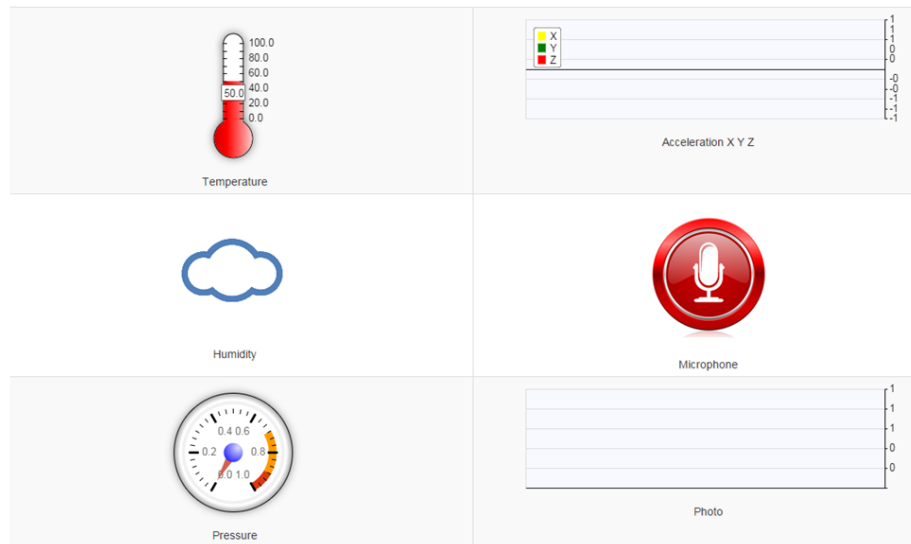


Figure ANN2-8: Sensor data on cloud in pictorial manner

## Applications of Internet of Things

**Smart Home:** These applications allow users to monitor and control security devices and home appliances remotely and conserve energy when the appliance is not required.

**Smart City:** Wirelessly connected meters enable remote meter reading along with applications like differential tariffs and two way metering. Monitoring of parameters such as ambient light and traffic can allow us to control and conserve energy.

**Industrial:** IoT can play an important role in monitoring and optimization of industrial processes. The availability of low power sensor nodes open new avenues in the Industrial automation where human presence is possible.

## Conclusion and Extending the concept to include more communication technologies

We proposed a general-purpose IoT gateway working with Smartphone and Cloud Application connected to Things on 6LoWPAN network. High quality open source mesh networking stacks such as Contiki has helped the proliferation of IoT. Security still remains a challenging subject to be explored. The existing security techniques are holding well, but as IoT networks become more prevalent we would unearth more challenges. Advances in the semiconductor manufacturing process, decreasing cost and better power management along with energy harvesting would be another gate opener in IoT space.

In this gateway it is possible to have sensors connected to the cloud that can communicate using Bluetooth, Wi-Fi, Sub-GHz and NFC. This concept is generic and can be extended to any of different wireless and wireline standards. The architecture is based on a Microcontroller Platform. Likewise an MPU based platform can be designed with operating system ported as well using the same approach.



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