# IoT for Peace of Mind

A Technical Paper Prepared for SCTE/ISBE by

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# Introduction

The telecommunications industry is hard at work to innovate, design and develop products that help consumers. What does a consumer look for when he/she plans to introduce a new product into his/her lifestyle? For example, the advent of smartphones changed the way mobile phones were used and perceived. What did these smartphones offer that influenced a paradigm shift in the industry? Mainly they led to a new era of computing. The influx of many applications helped solve some of the important, yet not necessarily critical, needs of consumers. The “app store” became a crucial platform where application developers and consumers could interact and share views. The main contributions of these technologies in consumers’ lives were ease of use, and, importantly, exposure to various tools that made life easier. One thing that the consumer looks for in any technology or product is “peace of mind.” Although the term “peace of mind” is decidedly subjective, it will be one of the major driving factors in product development, and is enormously applicable for the Internet of Things (IoT.) For example:

* It would be immensely helpful for a consumer to know that his/her home is secure, while the family is out on a vacation. Design goal: That family members could remotely monitor the house and thus be less worried about security.

* Beyond “just” security, the IoT can help making lives safe and efficient, with reduced anxiety. A busy mother would be relieved to know that she could check or turn off the stove remotely and need not worry about having left it on. Likewise, for that moment of fear about the garage door: Did I remember to shut it? And, from an efficiency point of view: Managing energy costs with smart bulbs and thermostats.

When IoT is applied to health and wellness applications, the peace of mind impact that the technology brings to the consumer is enormous. According to Forbes, “it costs families more to care for a frail older adult than to raise a child for the first 17 years of life.” This is a growing concern. An AARP publication reported in late 2015 that the population of adults 85 and older in the U.S. will roughly triple between 2015 and 2060 – making it the fastest-growing age group over this time.

Apart from Eldercare, the IoT will help individuals to track personal health and well-being, with the use of various fitness-based devices. In examining the most prevalent home security and tele-health providers, one thing is paramount: Providing “peace of mind.” Figure 1 illustrates how this premise surfaces in brand marketing.

 

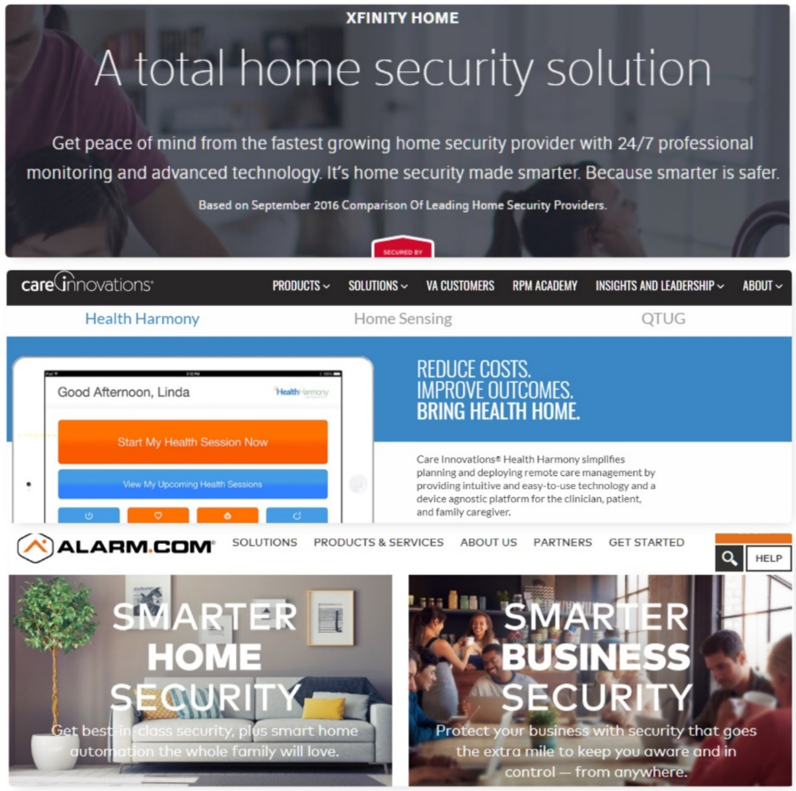


**Figure 1 - How most IoT systems market their solutions**

In this paper, we examine how IoT technologies can offer solutions to consumers to enhance lifestyles. This includes connectivity technologies, use cases and the perspective of a cable Multiple System Operators (MSO.)

# IoT for Peace of Mind

## 1. Internet of Things

This term needs little in terms of elaborate definitions, at this point in time, a simple search shows that it can be defined as "interconnection, via the Internet of computing devices embedded in everyday objects, that enables them to send and receive data". IoT can be applied to wide variety of applications, as characterized briefly here.

The number of connected devices is growing at a seemingly exponential pace -- and even modest estimates point to tens of billions of connected devices within the next 2 years. Any stroll across any home electronics store indicates that most of the new arrivals are connected, in some form, and have some amount of computing power inside --, be it refrigerators, washing machines, or vacuum cleaners, to name a scant few. The number of connected cars is increasing; autonomous cars are no longer science fiction.

The roster of IoT-related applications that relate to MSOs includes:

*Home and Business Security Applications*: To secure the premise, providing alerts based on rules established by consumers. That includes sensors that dectect motion, for, doors, windows, and other ingress/egress locations, via cameras. Rules can be easily set and modified to generate multi-dimensional (multi-screen) alerts.

*Home Health and Tele Medicine Applications*: Bridging between FDA-approved home health devices (blood pressure cuffs, glucometers, asthma dispensers, etc.) and medical professionals/caregivers, via Bluetooth-to-LPWAN adaptors.

*Health and Wellness applications*: To parallel and extend people's health/wellness goals.

*Remote Patient Monitoring*: To extend the reach of Internet-connected devices by bridging between short- and long-range networks.

*Aging in Place applications*: To extend the range of ADL (Activities of Daily Living) that are often stressed by age-related consequences, such as falling.

*Responding to Emergencies*: To make it faster and easier to get urgent care.

*Home Automation*: To enable smart home applications, connect and control third-party smart devices, and incorporate the sensing equipment used for monitoring and automation.

*Automotive*: From connected cars to the autonomous vehicular future, the existence of voice control, heads-up displays, and self-parking systems are proliferating. Car-to-cloud connectivity is the enabler of vehicles that are safer -- which makes roadways safer, less congested, and more accessible.

*Smart Energy:* Through the "things" of the IoT, the power grid can share information in real time to distribute and better manage energy more efficiently. The IoT is already active in terms of Smart Cities, smart/connected communities, and long-range IoT networks.

*Smart Manufacturing*: IoT technologies can enable factories to unlock operational efficiencies, optimize production, and increase worker safety.

*Retail*: For retailers, the IoT offers substnantial opportunities to increase supply chain efficiencies, develop new services, and reshape the customer experience.

## 2. Applications and Use Cases

The implications and intersections between the Internet of Things and peoples' lives is considerable, if not infinite. The scope ranges f ar wider than this paper can address. For that reason, this paper focuses on Home Automation/Security and Healthcare applications that have successfully used IoT in ways that provide peace of mind.

In the following sections, a brief case study is presented that combines the IoT with analytics and machine learning to solve for enhanced product/service performance.

## 3. Health and Wellness

Health and wellness applications, generic or specific, could target a large set of population. Examples include fitness-based applications that help consumers track and organize their health data, and to plan daily activities and exercise routines.

Another major area where the IoT could play a major role is in eldercare. Most studies show that there is significant growth in the Senior population in the coming years, as the Baby Boomer generation enters its twilight years. The IoT is poised to build applications to facilitate facilitate aging-in-place -- because personal independence is a high priority for Senior citizens.

The following images illustrate the trend in population growth, as well as technology adaptation and penetration by among age group.

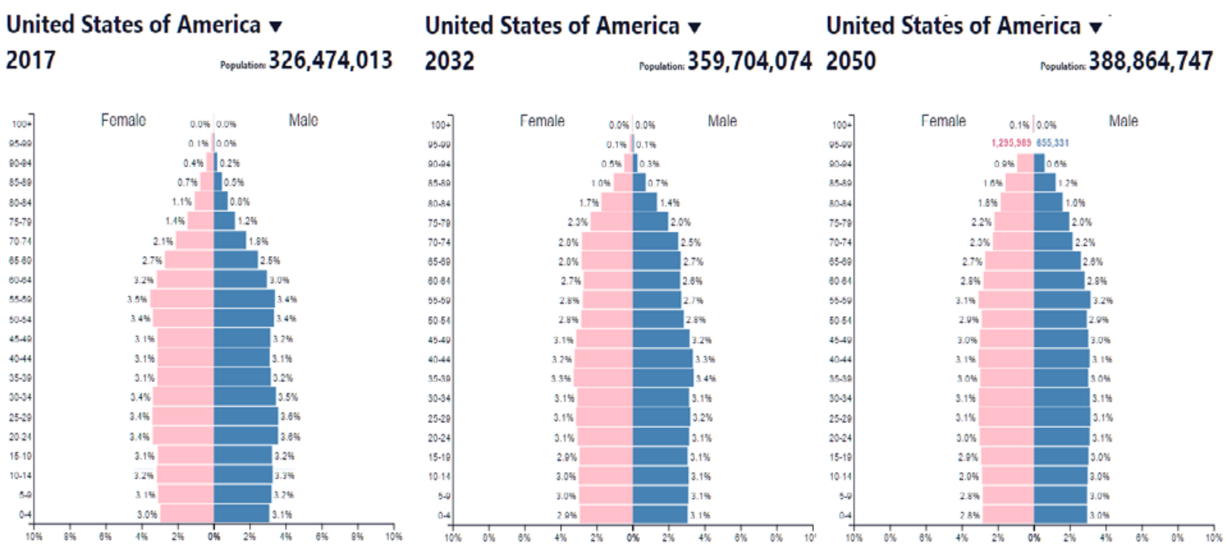


**Figure 2 - Population Pyramid of USA in 2017, 2030 and 2050**

Figure 2 shows overall trends in population growth. We can see that there is a constant increase in the Senior population, which is an indication that IoT and related technologies could play a major role.

Also, the technological advancements surfaced by industrial revolution have enabled most of us with Internet connectivity. It follows that technology adoption is rising among the Senior community. Soon enough (2050), “digital natives” (loosely defined as those born after 1985) will be in their twilight years.

 

**Age 75+ non-Internet use since 2000**

| Year | Percent | Base Count |
|---|---|---|
| 2015 | 50% | 757 |
| 2014 | 57% | 624 |
| 2013 | 60% | 1392 |
| 2012 | 62% | 2315 |
| 2011 | 65% | 804 |
| 2010 | 71% | 1873 |
| 2009 | 71% | 1033 |
| 2008 | 74% | 1762 |
| 2007 | 77% | 1304 |
| 2006 | 78% | 1739 |
| 2005 | 82% | 1450 |
| 2004 | 88% | 1127 |
| 2003 | 88% | 1157 |
| 2002 | 89% | 1482 |
| 2001 | 93% | 1370 |
| 2000 | 93% | 2771 |

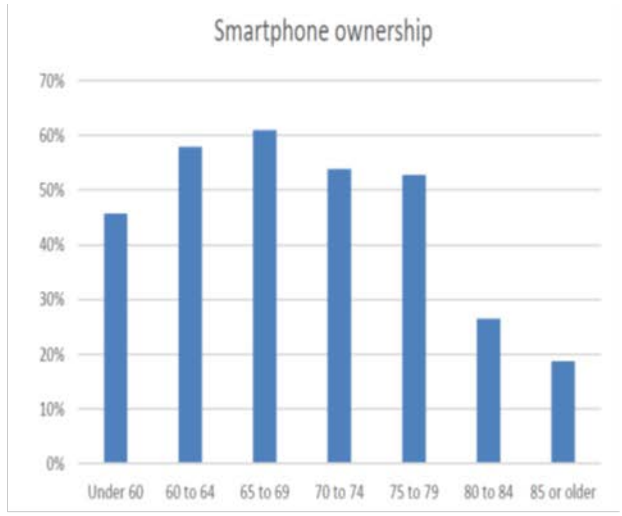


**Figure 3 - Technology Adaptation among Seniors**

Figure 3 shows a gradual reduction of non-Internet users among people aged 75 years and older, as well as an increased level of smartphone ownership. This growing segment of connected Seniors similarly indicates that IoT could play a major role in enhancing lifestyles.

Notably, the population of those aged 65 and over has increased from 36.2 million in 2004, to 46.2 million, in 2014 -- a 28% increase. The Senior population is projected to more than double, to 98 million, by 2060.

## 3.1. Why IoT for Healthcare/Eldercare?

As Internet adoption increases within the Senior community, it represents a major tool for providing value-based services:

- Applications like ADL monitoring and remote patient monitoring would help reduce the number of visits to a care provider. This would also help reduce the burden on conventional healthcare systems (such as hospitals and clinics.)
- Medicare has begun implementing incentives to reduce hospital re-admissions, which has stimulated the growth of remote patient monitoring. Efforts like the Hospital Readmission Reduction Program (HRRP) actually penalizes hospitals, financially, if they exhibit high rates of Medicare readmissions.
- Remote patient monitoring could be used to source and convey health and wellness information, so as to:
  - Provide first-hand information to users and care providers (family members, medical personnel)
  - Encourage patient adherence to medical protocols (medications, exercise)
  - Enable caregivers and medical providers to plan and adjust the course of action
  - Help individuals to make lifestyle choices fueled by individualized data
- Apart from eldercare, these technologies could also be tailored to assist patients with chronic conditions.

 

### 3.2. Connected Health Applications

Connected health applications offer services to consumers and caregivers (professionals & personal/family members.) These applications provide a platform on which the patient and caregiver could interact, exchange data and configure alerts.

Such services would provide appropriate information and alerts to a family member or care provider, so that corrective action could be taken. For instance, it is invaluable source of peace of mind for a son or daughter, who no longer lives near an aging parent, to know that medications are being taken as scheduled, or that something abnormal or problematic is happening (or, preferably, not happening!)

Remote patient monitoring typically includes:

*Activity Monitoring*: Tracking activities and detecting abnormal or emergency situations, like a fall event or incapacitation; fall detection or incapacitation could be used to trigger a PERS (Personal Emergency Response Systems ) event

*Biometric Monitoring:* Measuring body vitals like, blood sugar, BP (blood pressure), weight; establishing a secure health data record which is monitored constantly; predicting future anomalies; redicing risks.

*Patient Adherence*: Ensuring that patients adhere to doctor prescriptions; providing appropriate reminders to patients and family members, like reminders for medication refills.

*Virtual Visits:* Meeting doctors or care providers over a video conference, rather than a face-to-face meeting, which with Seniors often involves collapsible wheel chairs and a considerable amount of extra effort for everyone involved.

Other applications include access to electronic health records (EHRs), to help doctors and care providers optimize a patient's health with vital information.

## 4. Home Monitoring and Security

IoT-based applications for home monitoring can be grouped into two broad buckets: Home Automation and Home Security.

### 4.1. Home Automation

Home automation or monitoring is loosely defined as local and remote access to in-home IoT devices that provide information about the home. Examples include:

- Motion detection (sensors or cameras) and monitoring equipment (possibly linked to local or remote recording)
- Sensors for changes in windows and doors
- Catastrophe sensors, for fires, floods, and weather-related danger,
- Sensors to indicate events that are of concern (out of normal ranges)
- Alerting end users .

With the known and predicted increase in the overall number of connected devices, there is a need to provide applications and services that utilize these resources and improve quality of life. These services also help manage energy efficiently and help proactively manage the safety of the premises.

 

Most operators provide smart home applications packaged with sensors and detectors, like motion sensors, door window sensors, door locks, fire sensors, flood sensors and others.

Most applications also provide hooks to add third party devices like door locks, thermostats. A typical smart home would look as shown below:

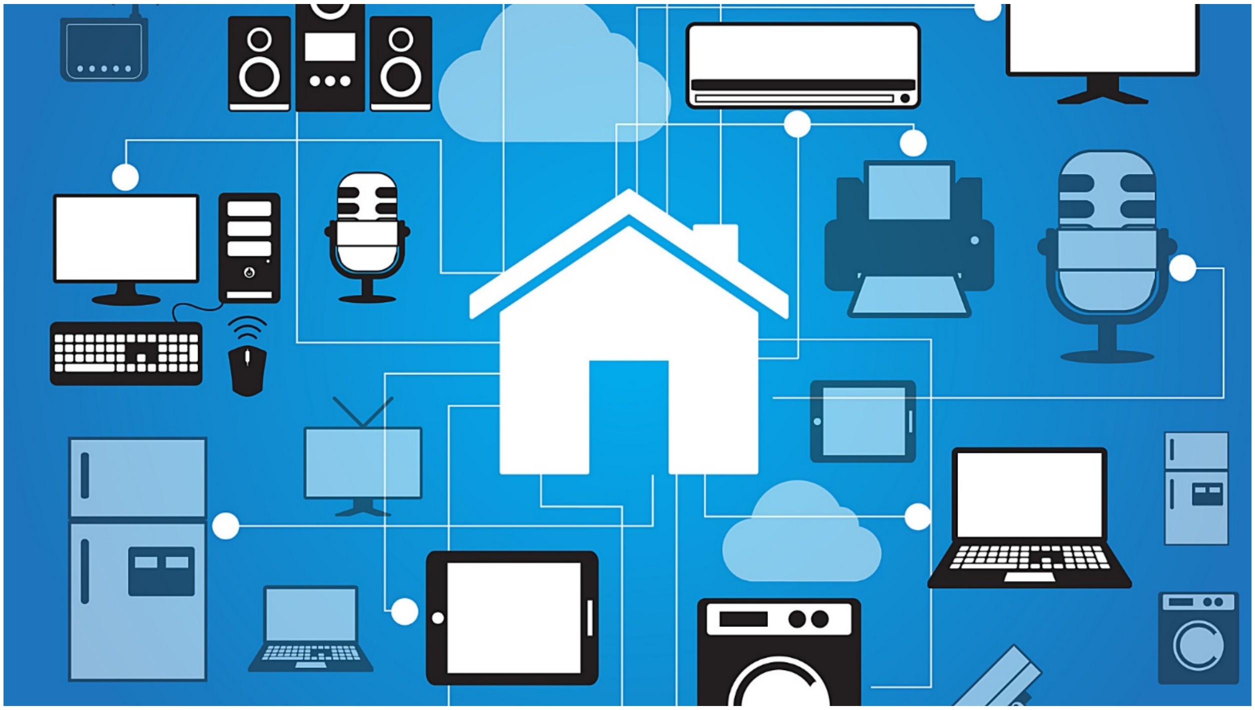

**Figure 4 - A Typical Smart Home with Connected Devices**

Most research indicates an increase in the volume of smart devices. The graphic, below, shows the ranking of devices that are most desired in a home monitoring application:

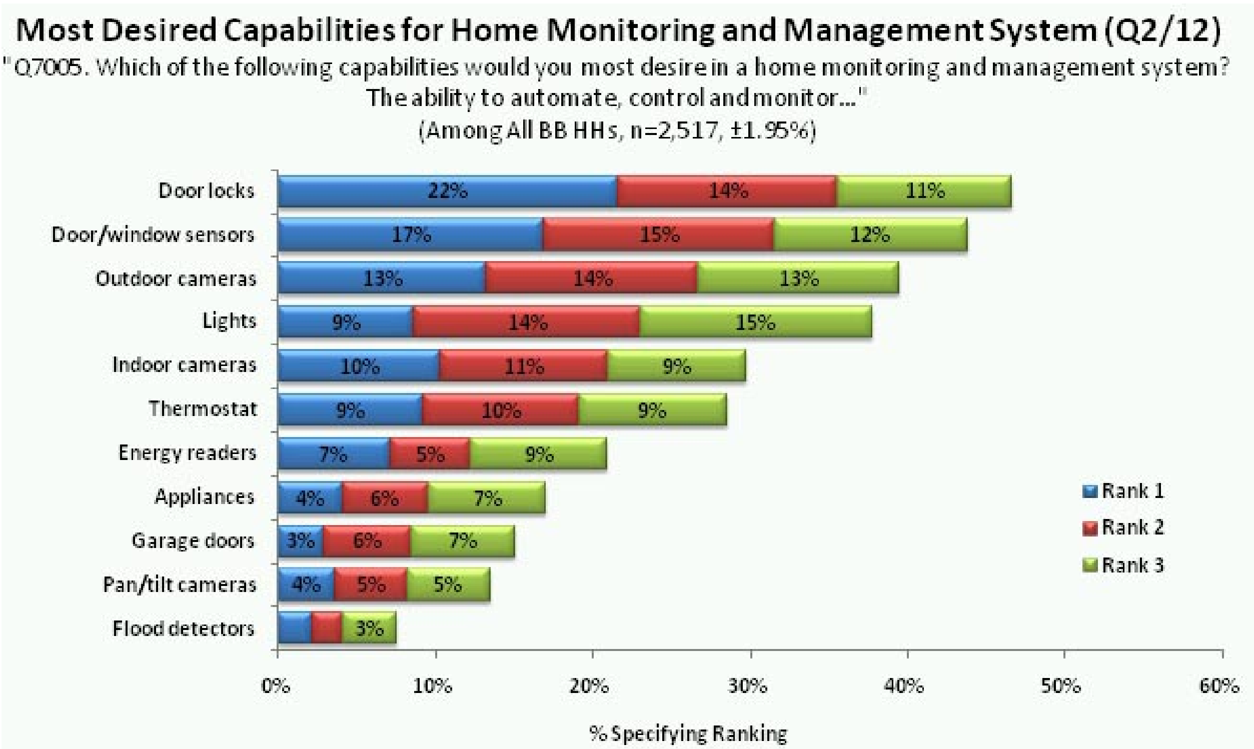


**Figure 5 - Most desired capabilities in a smart home**

## 4.2. Home Security

The evolution of IoT and smart home applications has increased the demand for residential security products. Apart from traditional security requirements, IoT security is also gaining importance to ensure data and device integrity in a smart home.

Various research findings suggest an increased need for home security systems to reduce burglary-related emergencies. In most cases where burglaries have been reported, one of the major causes is that the home owner has forgot to close doors or windows. A typical home security system, when set in "armed" mode, will detect any of such anomalies and alert the user. This is a huge relief for the home owner.

From a home security perspective, it is more important to know presence of a potential intruder, if there is a window breakage. Also important is redundancy in connectivity, like a backup connectivity option in case the main connectivity (usually cable Internet) is down.

 

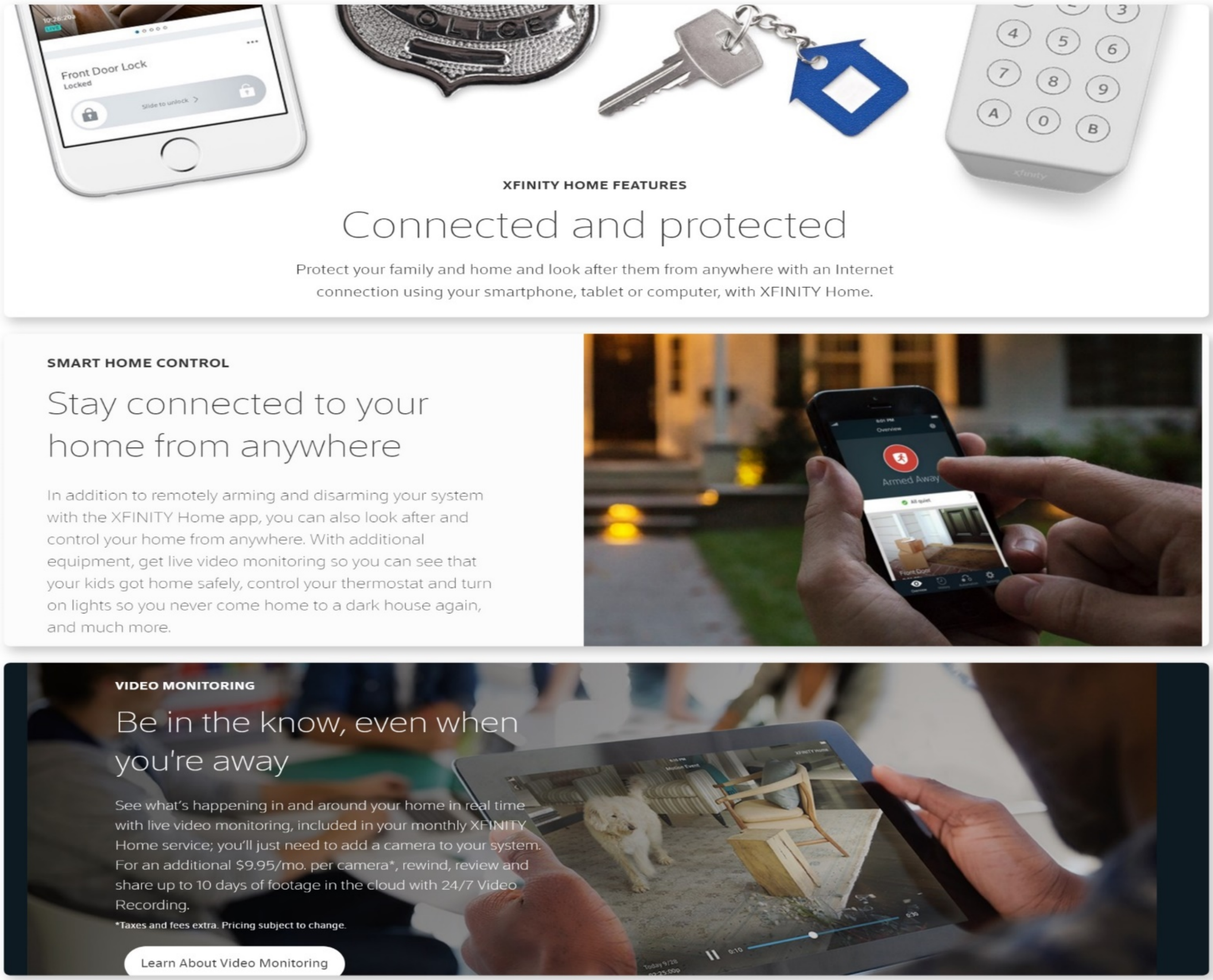


**Figure 6 - Xfinity Home offerings for Home Security**

# 5. Technology Overview

## 5.1. Network Topology

Most IoT solutions and applications discussed in the previous sections rely on a similar technological base, in terms of devices and network architecture. What differentiates the solutions are the end user applications and rules of operation. In this section, we describe a brief overview of the technology and network architecture. We will also look at security implications.

Like any other application stack, an IoT application also involves multiple layers implemented in hardware and software. The complexity and internal architecture of the hardware and software components depends on the protocol being implemented by a device or gateway. In order to understand this better, we need a network topography of a typical IoT network:

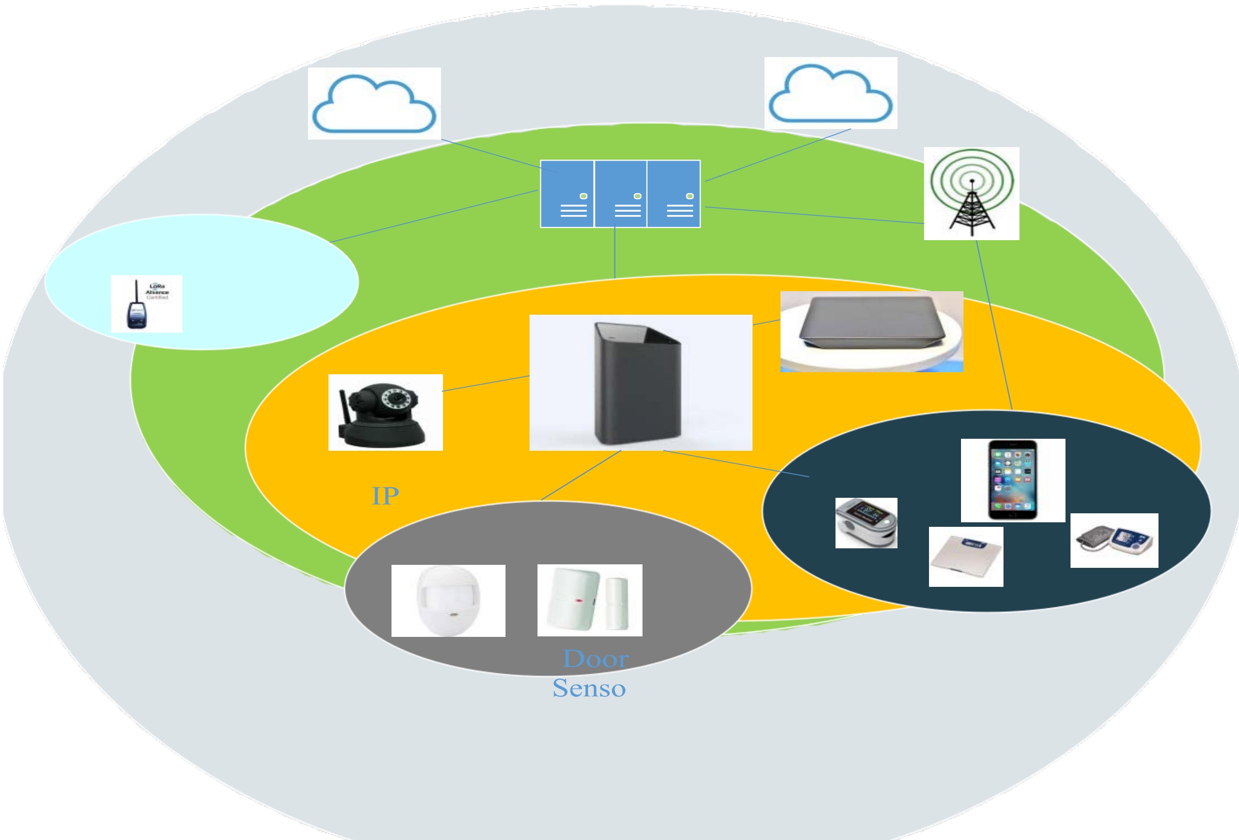


**Figure 7 - A typical IoT Network Showing Multiple Network Protocols**

In any IoT network, multiple network protocols are involved, hence the need for a central gateway that can translate between protocols and forward packets for analysis. In the example above, the home gateway would be the IoT gateway, as it would have the necessary hardware and software to interact with devices which may use a different protocol.

For example, there may be a rule set to turn on a light bulb upon detecting motion in the hallway. In this case, the motion detector could be a ZigBee-based device, and the light bulb could be based on BLE (Bluetooth Low Energy). In this case, the gateway would bridge the connection between the lightbulb and the motion sensor. The illustration, below, shows a sample sequence diagram of an IoT application:

 

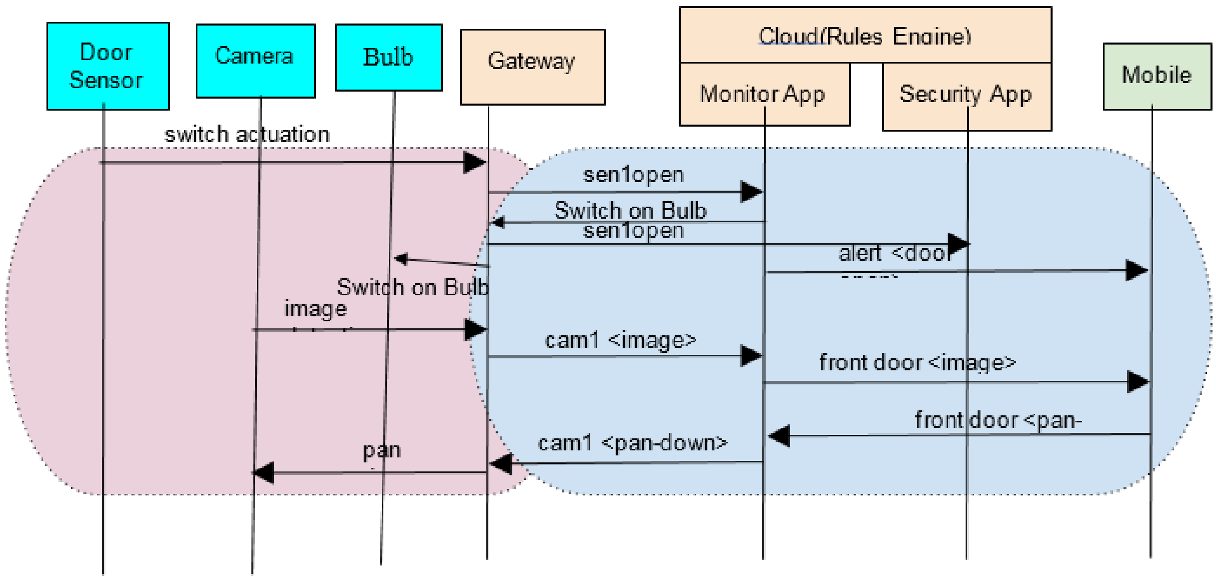


**Figure 8 - Sample Sequence Diagram of IoT Use Case**

As described above, the gateway needs to handle multiple network protocols. Table 1 shows the list of protocols and messages the gateway handles in the above sequence diagram:

**Table 1 - Table Showing Network Protocols Handled by an IoT gateway**

| Gateway | |
|---|---|
| **Camera** | Wifi(TCP/UDP) |
| **Bulb** | BLE |
| **Door Sensor** | Zigbee |

As seen in Table 1, the gateway handles messages from multiple devices, implemented using different networking protocols. The gateway implements these protocols, and the devices are paired with the gateway. Once paired, the devices (sensors) would function and exchange messages with gateway. The gateway would decode these messages and pass them to the cloud or rules engine for processing.

## 5.2. Technologies of great promise

In the previous section, we discussed about how a typical IoT network can interact to implement the desired use cases. In this section, we highlight technologies that show promise in enhancing the connectivity and performance of IoT applications.

## 5.3. RF sensing for IoT applications

Most IoT networks employ passive infrared/PIR-based motion sensors and cameras for surveillance applications. While these sensors work well, and provide the desired results, there are some challenges. These are line-of-sight sensors, for starters, and thus cannot detect motion through a wall. Cameras are used mostly for outdoor surveillance, and are often perceived as being intrusive for indoor tracking (activity monitoring).

 

These challenges could be easily overcome by using RADAR (Radio Detection and Ranging)-based sensing. Radar has been historically used in aviation and military applications, but holds a lot of promise for residential and commercial applications. Radars can detect presence and motion through walls, while providing good coverage, without cameras.

Microwave devices that are compact, accurate, reliable, and inexpensive are currently commercially available. Over the past few years, attempts to apply such devices to biomedical measurements has increased. Although some studies applied these devices to medicine and health care, such research is still in its infancy. Nonetheless, radio-frequency sensing techniques -- originally developed for military applications, and later applied to search and rescue operations locating earthquake survivors buried under rubble -- all carry plausible applicability for health care and home monitoring use cases, like aging in place and smart homes.

Doppler Radars could be used to implement motion classification, which could be used for applications like activity monitoring, fall detection and personal emergency response systems/PERS.

Traditionally, fall detection applications employ a wearable or push button device that needs to be activated after a fall occurs. The intent is to help the patient to trigger emergency assistance. Using radars for fall detection is non-intrusive and does not need require manual intervention (pushing the button) to trigger an alarm.

This matters because in many cases, people lose consciousness after falling, which obviates the applicability of such “push to enable” help calls. A radar, by contrast, monitors activities and can both auto-detect a fall, and raise an alarm. With machine learning capabilities, radar-based devices can also learn over time, to then more accurately detect falls.

Another form of activity monitoring enabled by radar is biometric, or the application of statistical analysis to biological data. Specifically, radar can provide effective, non-invasive and non-restrictive sensing techniques to acquire vital signs. For instance, radar could be used to monitor characteristics including body surface vibrations, mental state, and sleep apnea.

For instance, radars can detect minute vibrations on the body surface, such as those induced by heartbeat and respiration. Simple equipment can be used to self-monitor certain medical parameters or conditions, as well as to acquire related data required for Senior living homes as well as medical facilities.

The diagram below shows a sample application of radar installed in a room. The radar detects the presence, position and posture of people. This would be helpful to build an activity monitoring application

 


**Figure 9 - Sample of a Radar based application used for activity monitoring**

Radars have already been used in cars to provide features like collision warning and prevention systems, parking assistance and blind spot warnings. Extensive research has been done to ensure human safety while using radar systems, and have been proven to be safe.

Radars are thus a promising sensing technology that IoT systems could use to enhance range and performance.

## 5.4. Sensors to Insights

Most, if not all, sensors generate data of some form. In order to build an application that can learn using the data from the sensor, we need to add data analytics and deep learning to the IoT system. With this the system will learn over time, and will help improve performance and reactions to events. By incorporating machine learning and data analytics skills, the system could know the local environment better, which helps in building a sophisticated and customized application.

Consider, as an example, the use of a sensor-based IoT application, deployed to monitor activity in a Senior care facility. If we implement deep learning, using the data provided by the sensors, then the system would better learn more about the individual being monitored, which in turn would help build a better ADL monitoring application, customized to the individual. The system can learn that the patient needs to take glucometer test, or a medication, at 8 AM, every day, and can issue alerts if data is not available -- indicating that the test or medication wasn't taken. Apart from that, the system can also check for any drastic change in readings and could initiate appropriate actions.

There three important steps in deep learning that should be part of any deep learning system, as shown in the diagram below:

 

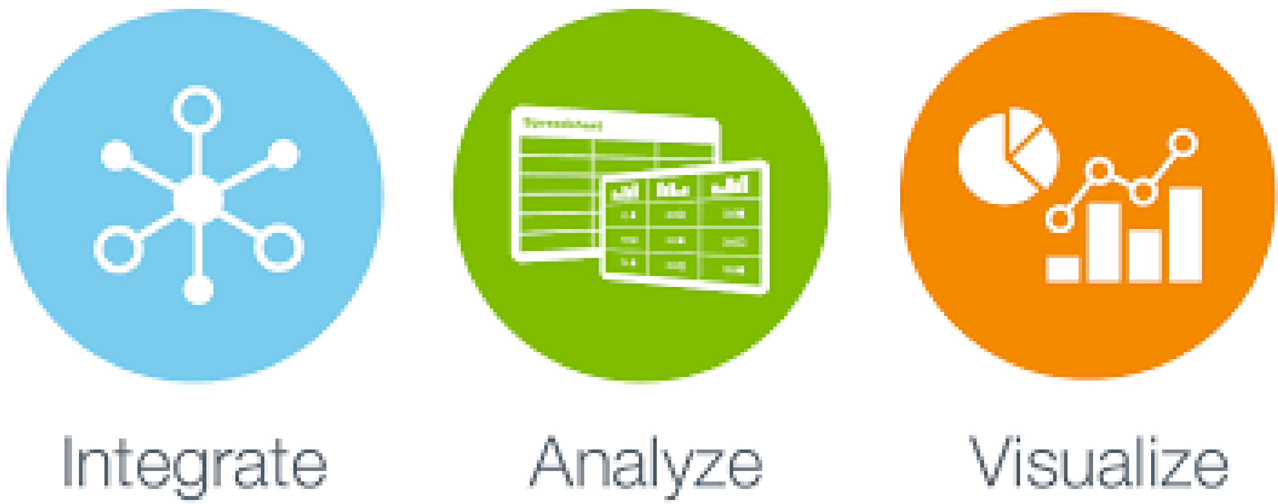


**Figure 10 - Important steps in deep learning**

Data analytics of critical health data comes with challenges, particularly related to how data security is handled. Most of these requirements are regulated by HIPAA compliance. In particular, secure data storage and analytics engines need to be implemented.

## 5.5. Using Video and Audio Analytics

Machine learning algorithms and AV analytics also hold promise in implementing monitoring solutions. With the advent of far-field microphone devices, there are methods available to train a system to look for specific sounds and trigger alerts. This could be used in a variety of applications, like home monitoring and smart cities.

Video analytics, on the other hand, uses a deep learning system that learns objects and people as seen from a video camera. Although using video is sometimes perceived as being intrusive, it could be used in certain applications to give a better description of a scene, and to help construct an IoT-based application.

## 5.6. Long Range IoT Networks

Most IoT services and applications currently rely on a broadband network (cable or wireless) to backhaul data. This setup would need a gateway to pass the data along to the cloud for processing (See example in Section 5.1)

However, long range IoT networks like LTE-M, LoRa or LoRaWAN, provide IoT environments in which the devices can directly connect to the Wide Area Network, without a gateway. Devices could be battery operated and could connect to a network that could span a wide geographical area. The following are some of the Long Range IoT networks that help enhance connectivity and improve IoT services:

### *5.6.1. LoRa*

LoRaWAN™ is a Low Power Wide Area Network (LPWAN) specification intended for wireless battery operated things in a regional, national or global network. Communication between end-devices and gateways is spread out on different frequency channels and at different data rates. The selection of the data rate is a trade-off between communication range and message duration. The license-free, sub-GHz frequencies used in North America (915 MHz band) are as follows:

- Upstream: 64 channels numbered 0 to 63, DR0 to DR3
- Upstream: 8 channels numbered 64 to 71, DR4
- Downstream: 8 channels numbered 0 to 7, DR8 to DR13

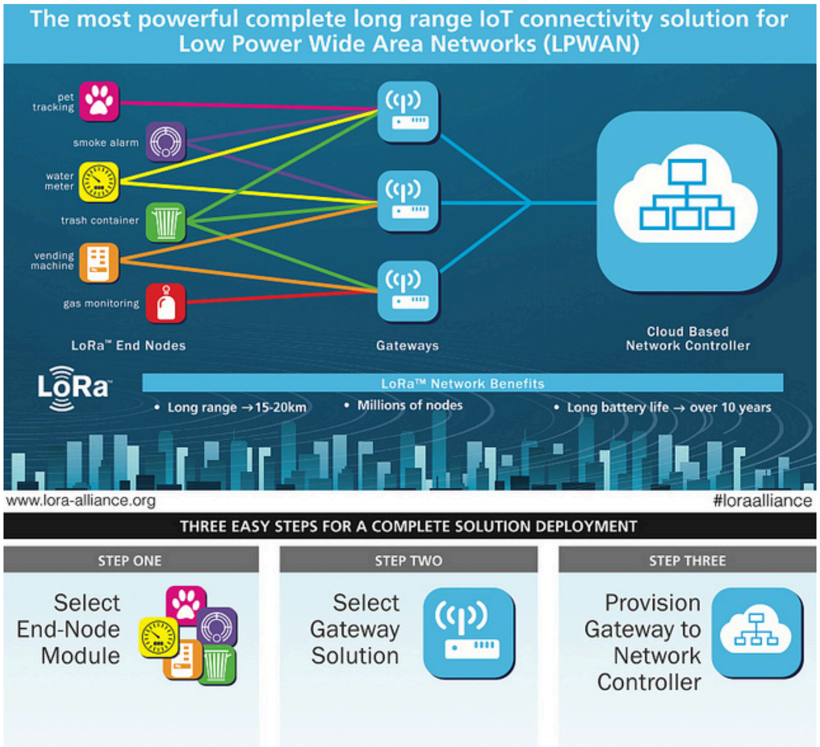


**Figure 11 - LoRa Network disagram**

### *5.6.2. LTE-M*

LTE-M is the abbreviation for LTE Cat-M1, or Long Term Evolution (4G), category M1. This technology was designed for battery-powered Internet of Things devices to connect directly to a mobile 4G network, without a gateway.

LTE-M is a low power wide area technology which supports IoT with lower device complexity and extended coverage, while allowing the reuse of the LTE-installed base. This allows battery lifetime as long as 10 years or more for a wide range of use cases, with the modem costs reduced to 20-25% of the current EGPRS (Enhanced Global Packet Radio Service) modems.

Some of the advantages that long range networks provide include:

- Cost efficiency: Devices can connect to networks with chips that are less expensive to make, because they are half-duplex and have a narrower bandwidth.
- Long Battery Life: Devices can enter a "deep sleep" mode called Power Savings Mode (PSM) or wake up only periodically while connected.

 

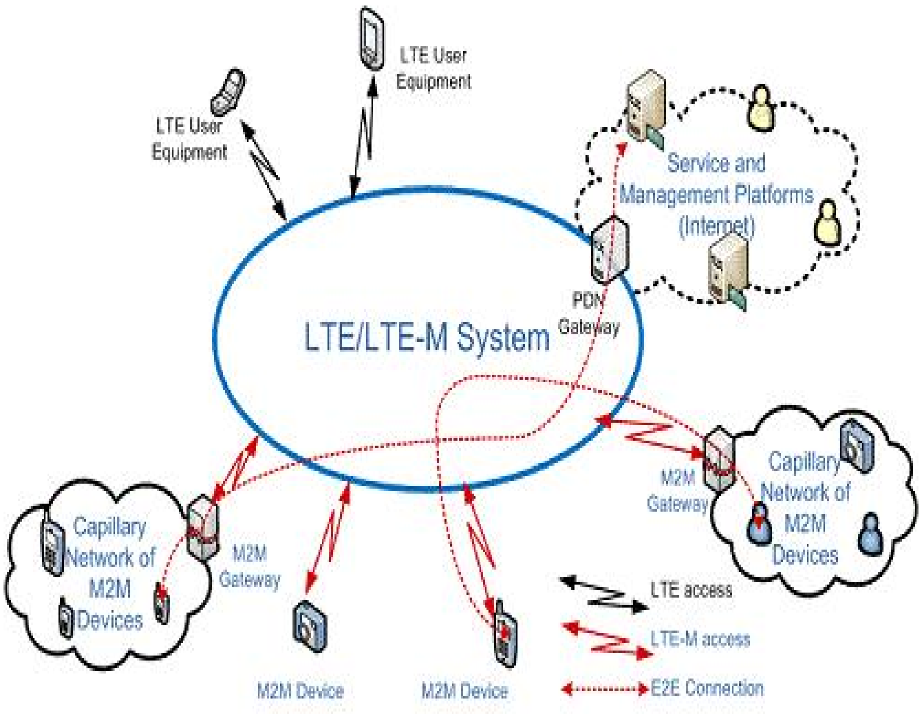


**Figure 12 - LTE-M System diagram**

# Conclusion

Multiple potential use cases and technological viability indicate that IoT technologies can definitively provide *peace of mind* to consumers. There can be innumerable examples that can address peace of mind factor in a consumer's life -- whether it involves tracking a child, to ensure that he/she left school and reached home, or being able to check on elderly parents to ensure that they're doing ok, and, most importantly, to be alerted when they need help.

We examined the technical overview IoT networks, and how the IoT is solving current problems, including how operators could incorporate other newer technologies to improve the system.

We explained how devices using different protocols can be implemented in a way that facilitates suitable communication, and reviewed how machine learning and data analytics could help to more accurately predict any anomalies in the system, identify corrective actions.

The role of machine learning and data analytics is key to the longer term enhancement of IoT services, as is the continued work to adapt known technologies, like radar, to add value to IoT based services.

 

# Acronyms and Abbreviations

| | |
|---|---|
| IoT | Internet of Things |
| HIPAA | Health Insurance Portability and Accountability Act |
| LoRaWAN | Long Range Wide Area Network |
| LTE-M | Long Term Evolution (4G), category M1 |
| RADAR | Radio Detection and Ranging |
| IP | Internet Protocol |
| STB | Set Top Box |
| 6LowPAN | Internet Protocol (IPv6) and Low-power Wireless Personal Area Networks (LoWPAN) |