



**LIVON**  
LIVING INNOVATION

# The Internet of Things in the future home

Current applications and future developments



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# 1. Introduction

## 1.1 What is the Internet of Things?

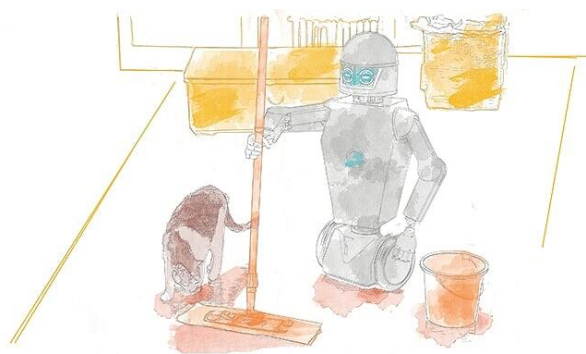
The Internet of Things is a technology that connects different “things” – digital and mechanical machines, devices, objects – with one another via the Internet, using unique identifiers. With built-in sensors, these devices continuously collect data and exchange them over a network without the need of human-to-human or human-to-computer interaction.

The term “Internet of Things”, or just “IoT”, was first introduced by MIT researcher and technology entrepreneur Kevin Ashton. At the time, Ashton was working in brand marketing at Procter & Gamble. He had been researching electronic sensors and RFID tags (wireless printed circuits that allow objects to identify themselves automatically to computer systems). During his research, he realized the big potential inherent in everyday objects and machines if they were to communicate through a standard computer network.

One well-known example of such connected products is the connected refrigerator using RFID tags to detect the contained products and their respective age. However, this field of application of the Internet of Things was widely rejected by society, as were a range of other products listed below (see 3.1). Despite that, the Internet of Things is expected to offer highly beneficial fields of application in the future, especially in the industries of e-care at home or home security.

## 1.2 How does it work?

The “thing” the term “Internet of Things” refers to anything from a person or animal to a robot or computer, and is something to be tracked, measured or monitored. In order to connect things, it is necessary to identify them and tell them apart. The above-mentioned RFID technology allows objects to identify themselves to a network automatically using radio waves, with little or no human intervention. A very substantial part of IoT technology is the built-in sensor, which routinely transmits automatic measurements and thus enables the collection of valuable information. Just as computers communicate via the Internet, the communication of “things” is conducted on a network by using the Internet Protocol (IP), a standard communication method. The core concept of IP is the assignment of unique addresses, IP addresses, to every “thing”; and through communication, data is exchanged in little bits. When things communicate using IP or WIFI to talk to a router connected to the Internet, they can be controlled from a web browser regardless of their location. Data mining supports this process by analyzing the billions of things the sensors are collecting and tries to find patterns that help users work, move, and live more smartly, in a cost-saving and energy-efficient manner - at least in theory. The amount of data collected from so many things, so regularly, is likely to be enormous and therefore cloud computing (powerful computer services supplied over the Internet) plays a major role in the Internet of Things.



## 2. Current IoT applications

### 2.1 IoT applications in the smart home

IoT in smart homes offers a broad field of application. It ranges from monitoring elderly people and home automation to air conditioning control and monitoring or lightning control to consumption monitoring and saving or even solar greenhouse production. Cost savings is the focal point of IoT applications for “smart buildings” or “intelligent buildings” which provide the building with some intelligence through building automation. These applications mainly focus on air conditioning and lighting monitoring and control, and on consumption monitoring and energy saving. Security is also an important issue; therefore, fire and intrusion monitoring are play a major role regarding the future home. Technology firms like IBM, Telit, Intel, and many others have several solutions for smart home implementations<sup>1</sup>. Figure 1 shows how consumer spending on smart home systems has developed worldwide in recent years, including a prognosis for the future.

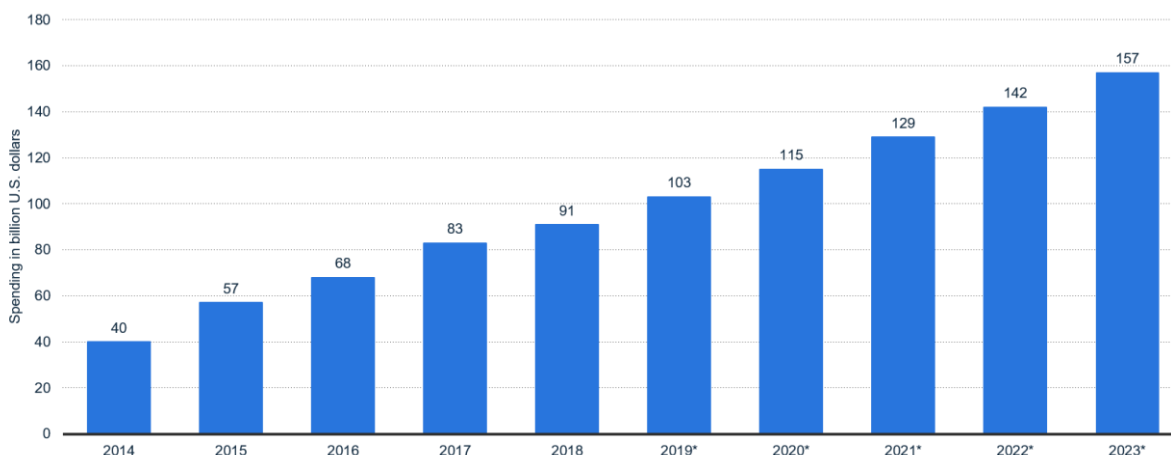


Figure 1: Consumer spending on smart home systems worldwide from 2014 to 2023 (in billion U.S. dollars)<sup>2</sup>

<sup>1</sup> <https://permalink.obvsg.at/wuw/AC15131652>, p. 23

<sup>2</sup> <https://www.statista.com/study/27165/smart-homes-statista-dossier/>

## 3. Examples of IoT products

### 3.1 Unsuccessful IoT products

Sometimes, despite appearing useful at first glance, IoT products fail to establish themselves on the market. Quite often, this is related to security risks and insufficient data safety. Some examples of such unsuccessful projects with (data) security issues are:

- **Bitlock**, a smart keyless bike lock that posed an enormous security risk as it enabled hackers to track down and steal bikes<sup>3</sup>,
- **Trendnet IP cameras**, security cameras accessible via Internet without sufficient security that were thus easily hackable<sup>4</sup>,
- the **Insteon home automation system** that allowed users to remotely control lights, hot tubs, cameras, TV, fans etc. but did not require passwords for all of the products and was therefore easy to hack as well<sup>5</sup>, and
- **Nest Protect**, a smart smoke alarm that could be shut down in cases of false alarm by waving your hand at it instead of having to manually turn it off, which posed a serious danger during an actual fire as this could unintentionally turn off a real, life-saving alarm<sup>6</sup>.

In other instances, IoT products simply do not facilitate users' lives but instead try to solve problems that could easily be resolved another way, or even create new ones. Here are a few examples:

- **GasWatch**, a smart gas-level indicator for gas canisters that tried to introduce a smart solution to checking gas levels that could be achieved easily otherwise<sup>7</sup>,
- **Petnet**, an automated pet feeder operating via a third party server service rented from Google which once crashed for 10 hours, leaving pets unfed and hungry<sup>8</sup>, and
- the famous **smart refrigerator**, which was introduced in 1999. The so-called "screen fridge" lets users send and receive emails, watch TV and offers a storage management system. However, before your refrigerator can use RFID technology to keep record about your milk and yoghurt and their expiry dates, these articles need embedded RFID chips to benefit from the technology. Smart refrigerators often have a big touchscreen as the interface to the various "apps" (family calendar, weather report) that additionally serves as the interface for the water and ice dispenser. Users have often complained about software bugs and about needing to reboot the whole system occasionally to get for example the ice to work. Most IoT projects, especially the smart fridge, are designed to make your life easier and should not make you perform reboot operations when you simply want a glass of ice water. The built-in complexity in these products lead to more potential points of failure. More complexity also leads to the IoT risk discussed above: more security vulnerabilities. It seems that often, appliance companies are trying to rush connected products to the market before even finishing the validation and testing<sup>9 10</sup>.

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<sup>3</sup> <https://permalink.obvsg.at/wuw/AC12150233> p.94-95

<sup>4</sup> <https://www.csoonline.com/article/2223785/microsoft-subnet/unpatched-trendnet-ip-cameras-still-provide-a-real-time-peeping-tom-paradise.html>

<sup>5</sup> <https://www.forbes.com/sites/kashmirhill/2013/07/26/smart-homes-hack/#769ba9f9be426>

<sup>6</sup> <https://gizmodo.com/nest-is-recalling-its-protect-smoke-alarm-1579734411>

<sup>7</sup> <https://permalink.obvsg.at/wuw/AC12150233> p.89-91

<sup>8</sup> <https://readwrite.com/2016/08/01/petnet-shows-happens-iot-fails-dl1/>

<sup>9</sup> <https://www.arrayent.com/2014/07/22/real-world-smart-fridge-fail-story/>

<sup>10</sup> <https://www.theguardian.com/technology/2014/jan/07/internet-fridge-ig-ces-2014>

## 3.2 Successful IoT products

In contrast to the unsuccessful applications discussed above, many IoT products have managed to establish themselves on the market successfully. While their success appears to stem from a combination of usefulness, problem-solving capacity, sufficient protection from hackers and good marketing, data security surprisingly enough is not always a requirement for success, as some of these examples show:

- **Amazon Echo** is a brand of smart speakers developed by Amazon, better known as "Alexa". Alexa continuously listens to everything being said in the room or the house and responds when asked about anything. The application is based on cloud processing, which means Echo runs on Amazon web services and requires a good WIFI connection to work. Due to the voice recognition technology in this device, a good internet connection will not only help minimize processing time but also reduce any miscommunication between the user and the gadget. Among its capacities are playing music, answering questions for example on weather reports or home automation (e.g. remotely controlling lamps, fans or heaters). One of the reasons for its success is Alexa's continuous self-adaptation – the more it is used, the 'smarter' it gets, continuously updating itself and accustoming itself to the user's home and person<sup>11</sup> – capacities that can both be seen as convenient for the user and as the beginnings of an Orwellian nightmare. However, Amazon echo has successfully established itself on the market despite many data security concerns and criticisms of Surveillance Capitalism<sup>12</sup>.
- The **Ring Video Doorbell** is an IoT device that allows users to remotely see who is at their door and to talk to visitors via smartphone or other devices. The idea is to keep an eye on legitimate visitors and anyone else who might be visiting. When someone rings the bell or when the built-in sensor detects motion nearby, the device automatically connects with the user's phone and starts a live video stream. The reason for its success can at the same time be viewed critically in terms of data security: In several instances, Ring provided data for the police in order to solve cases of burglaries, which has led to a lower burglary rate in certain neighborhoods, such as Wilshire Park in Los Angeles in 2016<sup>13</sup>.
- **Philips Hue** is a smart lighting system that consists of wireless LED bulbs in different colors, connecting several bulbs and a phone app via WIFI. It allows for a remote control of bulb colors and brightness<sup>14</sup>. Despite its high equipment price, it has been a successful product so far, and prices are likely to drop once more competitors enter the market<sup>15</sup>.
- **Rachio**, a smart WIFI sprinkler, is an irrigation system that adapts to different weather circumstances, for example going on standby mode when it is raining<sup>16</sup>. Its success is probably due to its ability to adapt itself not only to the weather but also to the properties of the plants and the fact that it is integrable with other smart home devices<sup>17</sup>.
- The **Nest Learning Thermostat** is a thermostat that adapts itself to individual daily life routines by collecting data on the user's daily life and programming itself accordingly. Routines like turning down the heat at a certain time of day are recorded during a trial phase and used for building a personalized schedule. Employing sensors and phone location, the system checks whether the respective home is currently occupied or if the user has left the building, using the data to adapt the heating and to save energy. Thus,

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<sup>11</sup> <https://padtronics.com/what-is-amazon-echo-alexa/>

<sup>12</sup> <https://www.theguardian.com/technology/2019/oct/09/alexa-are-you-invading-my-privacy-the-dark-side-of-our-voice-assistants>

<sup>13</sup> (<https://www.forbes.com/sites/susanadams/2018/02/27/amazon-is-buying-ring-the-pioneer-of-the-video-doorbell-for-1-billion/#2ba5c11c706c>)

<sup>14</sup> <https://huehomelighting.com/philips-hue-worth/>

<sup>15</sup> <https://www.online-tech-tips.com/smart-home/philips-hue-vs-the-competition-which-are-the-best-smart-lights>

<sup>16</sup> <https://rachio.com/>

<sup>17</sup> <https://www.homeandsmart.de/dropcam-pro-wi-fi-kamera-deutschland-test>

the thermostat is another instance where the enormous amounts of personalized data collected has not prevented an IoT product from market success<sup>18</sup>.

- The **August Smart Lock** is a household IoT device that lets users replace their house key with their smartphone, automatically unlocking the door when approaching it. The feature uses different technologies of the user's phone, not only the firm's app but also Bluetooth, WIFI and GPS. The App will enter Home Mode and disable Auto Unlock when you are at home, and activate Away Mode after being a certain distance from home<sup>19</sup>.
- The **Neurio Smart Home Box** is an electricity sensor that connects to a home's breaker panel and keeps track of electricity usage. It does so by sending data to a cloud storage via WIFI, transforming the data and then sending it to the user's smartphone. The main purpose of this device is to give homeowners a better picture of where the electricity in their home is being used. The system is able to identify individual appliances used via training with a homeowner, determining devices by the uniqueness of the amount of power they draw. Thus, big energy users such as ovens can be identified, allowing users to reduce their energy usage by focusing on the energy hogs in their house<sup>20 21</sup>.



<sup>18</sup> <https://nest.com/thermostats/nest-learning-thermostat/overview/>

<sup>19</sup> <https://august.com/blogs/home/auto-unlock-how-it-works-on-august-smart-lock>

<sup>20</sup> <https://techxplore.com/news/2015-05-successful-kickstarter-neurio-home-electricity.html>

<sup>21</sup> <https://www.homeandsmart.de/neurio-smart-home-box>



## 4. Future IoT applications

### 4.1 IoT products for the future smart home

This section provides a peak into the potential future of IoT applications, showing what the smart home might look like in the coming years. A few examples of potential future IoT products are:

- The **Amazon smart mirror**: Amazon was granted a patent describing a mirror that shows how outfits will look on you without having to actually put them on. The technology uses mirrors, screens, displays, projectors and cameras in order to combine a person's likeness with virtual images and present a blended-reality reflection that displays them in various virtual background settings and wearing virtually created outfits. Amazon already launched the Echo Look, the voice-controlled camera that can take photos or videos of your outfits and includes a style check to get a second opinion on your outfit. The Amazon mirror thus is a follow-up to the Echo Look and its acquisition of Body Labs, a 3D body model startup<sup>22</sup>.
- **Moley robotic kitchen** is the first fully-automated intelligent cooking robot. It is able to learn recipes, prepare and cook them and even clear up after itself. Moreover, Moley offers an extensive digital library of recipes. User select their menu remotely and then let Moley take over, where two highly complex, fully articulated hands are supposed to reproduce the exact movements of a human hand. The invention is designed to reduce the amount of food we waste and to minimize our dependence on pre-packaged food, which requires energy intensive processing, packaging and transport. By 2021, the company expects to sell the kitchen for 35,000\$<sup>23</sup>.
- **Kohler Konnect** is a line of smart bathroom and kitchen appliances. Kohler integrated Alexa in order to control its smart appliances via voice commands. Kohler's goal is to integrate their products with other IoT products existing in home. Each product communicates with the user's phone to allow for setting specific preferences. One of their smart products is the Verdera Voice Lighted Mirror. According to Kohler, it is the first mirror integrating Alexa directly into the unit offering its own lights which can be adjusted via voice. Additionally, Kohler has developed "PerfectFill", a smart bathtub technology enabling users to pre-define temperature and to tell the bathtub to fill with water. Moreover, Kohler is going to launch the first smart toilet, called "Numi". The built-in sensor recognizes when you are approaching and automatically offers up a foot warmer and heated seat. Numi also has a bidet, ambient lighting and can play music<sup>24</sup>.
- **Artificial Intelligence video chat device** from Facebook: Facebook is working on a touchscreen and smart technology that connects people digitally through the device, making them feel like they are in the same room. This project is the first major product from the company's experimental Building 8 lab for new hardware products. The device will come with a wide-angle camera, microphone, and speakers supported by artificial intelligence, and will be geared for communal use in the living room.

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<sup>22</sup> <https://www.engadget.com/2018/01/03/amazon-patent-mirror-virtual-clothes/>

<sup>23</sup> <http://qeprize.org/createthefuture/introducing-moley-robotic-kitchen/>

<sup>24</sup> <https://techcrunch.com/2018/01/08/kohler-wants-to-make-your-bathroom-smarter-with-konnect/>

## 4.2 Prognoses for the future

Whether or not these products will be successful remains to be seen. However, some general predictions for the future of IoT applications can draw a clearer picture of future smart living<sup>25</sup>:

- **Prediction 1:** The amount of IoT devices will drastically increase. Going back in time, in 2016 there were more than 4.7 billion things connected to the internet, accord to IOT Analytics. In 2021 the number of connected devices will increase to nearly 11.6 billion devices and by 2025, it is estimated that there will be more than 21 billion IoT devices.
- **Prediction 2:** Artificial Intelligence will continue to gain importance. Smart home hubs, thermostats, lighting systems and even smart coffee makers collect data on user habits and patterns of usage. Voice-controlled devices allow the system to record everything and store those recordings in the cloud in order to help develop what is called machine learning. Machine learning is a part of artificial intelligence that helps computers “learn” without human help to program them, collecting data on user preferences and adjusting themselves accordingly.
- **Prediction 3:** Routers will play a key role and become smarter and more secure. Most consumer IoT devices currently do not have a security software installed on them and so they can be vulnerable to attacks. That is because many smart device manufacturers rush their IoT product to the market as quickly as possible and security is secondary at first. Routers will be an important factor in improving that. The router is essentially the entry point of the internet into the user’s home and therefore plays a very important role. While many connected devices cannot be protected properly, the router has the ability to provide protection at the entry point. Router makers will have a major impact on the future development of IoT devices, especially in the future home market.

Further prognoses for the future of IoT applications are illustrated in the following graphs. Figure 2 shows the forecast for smart home revenue per segment worldwide until 2024, while Figure 3 depicts the future of worldwide IoT spending in general.

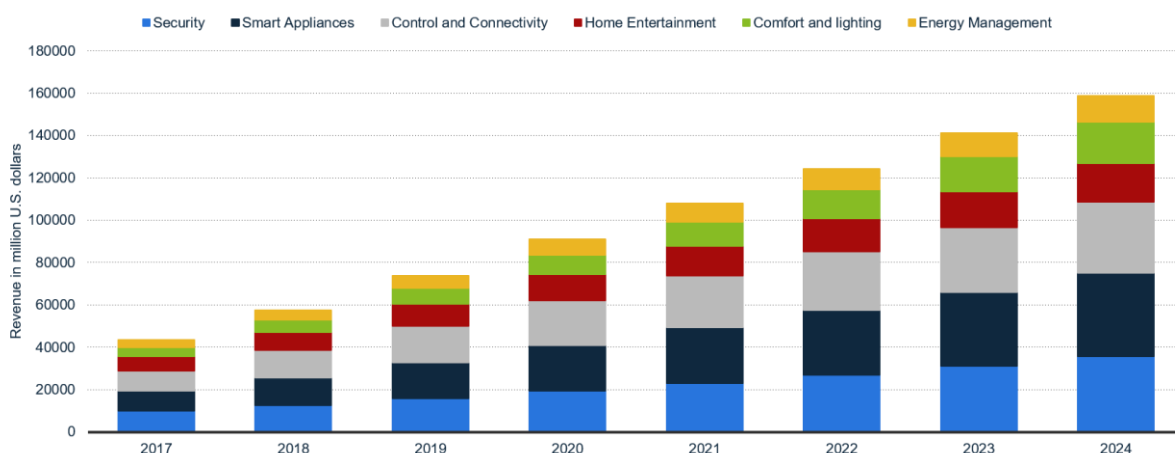


Figure 2 Smart Home revenue forecast per segment worldwide from 2017 to 2024 (in million U.S. dollars)<sup>26</sup>

<sup>25</sup> <https://us.norton.com/internetsecurity-iot-5-predictions-for-the-future-of-iot.html>

<sup>26</sup> <https://www.statista.com/study/27165/smart-homes-statista-dossier/>

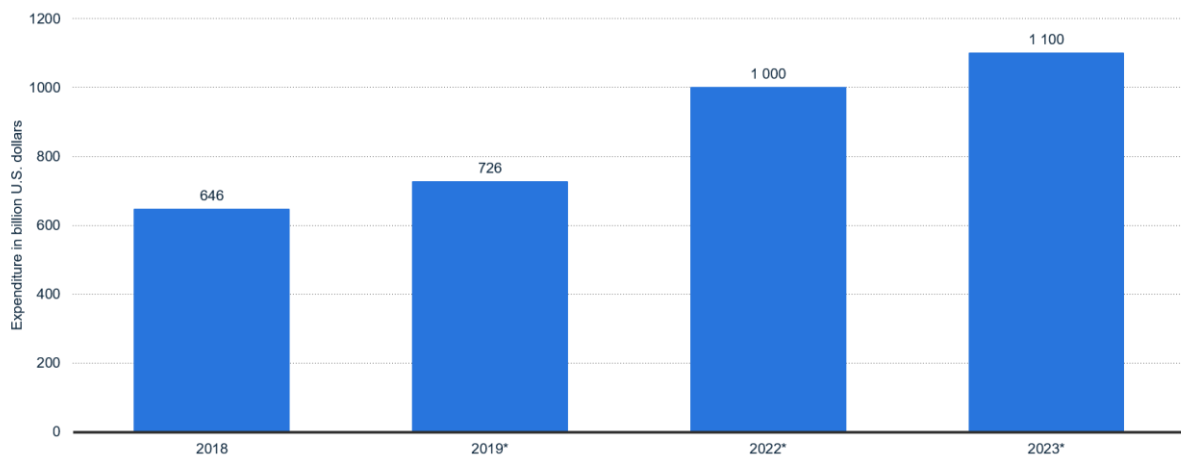


Figure 3 Prognosis of worldwide spending on the Internet of Things (IoT) from 2018 to 2022 (in billion U.S. dollars)<sup>27</sup>

## 5. Conclusion

The Internet of Things holds immense capabilities for shaping our future living in a potentially positive way. By integrating isolated devices into larger, communicating systems, it has the potential to facilitate the way we live at home – a capacity that is particularly relevant for the elderly and for people with disabilities or chronic diseases.

Moreover, the Internet of Things has the potential of rendering our energy management more efficient; not only in smart home systems but especially when applied to a bigger scale, for example as smart city applications.

Despite these advantages, uncertainties concerning the social desirability of the Internet of Things remain. When it comes to privacy, cyber-security and the sustainability of the production of IoT devices, legitimate criticisms are yet to be resolved. It is therefore more important than ever to subject both existing and emerging technologies to close scrutiny and to involve stakeholders in IoT innovation processes that are responsible, sustainable and inclusive.

<sup>27</sup> <https://www.statista.com/study/27915/internet-of-things-iot-statista-dossier/>