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**New opportunities in electrical engineering as a
result of the emergence of the Internet of Things**

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Abstract text:

The objective for this thesis was to investigate the current state of Internet of Things in general and in building services and how the development of IoT will impact electrical engineering and what new business opportunities might arise from it.

The Internet of Things is the idea of connecting everything and analysing the data these things generate in order to make more informed decisions or automate monotonous tasks. There are many companies researching and developing IoT applications on all levels from electronics manufacturers to software developers, creating IoT platforms for their customers to use.

There are many challenges with IoT in building services, for example how to handle big data, privacy and security concerns, the diversity of protocols etc.

Many of the current lighting and HVAC control systems will become obsolete with IoT systems since they are based on inferior technology and require independent cabling and control systems. The integration of these systems will change the role of the electrical engineer to a point where automation design, traditionally with emphasis on HVAC control, will become more focused on electrical systems, and is thus more convenient to include with electrical engineering than HVAC engineering.

Electrical engineering firms must build reliable partner ecosystems in order to succeed with IoT adaption due to the complexity of these systems. The introduction of a data engineer in the building services team is currently not possible but should be investigated since the data from sensors and devices is going to grow exponentially in the coming years.

Keywords: Internet of Things, IoT, building services, smart buildings, big data, data engineer, electrical design

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Tiivistelmäteksti:

Tämän työn tarkoitus oli kartoittaa teollisen internetin tämänhetkinen tilanne pääasiassa talotekniikan kannalta. Tutkimme miten teollinen internet tulee muuttamaan sähkösuunnittelualaa ja mitä uusia liiketoimintamalleja se tuo tullessaan.

Teollisella internetillä tarkoitetaan laitteita ja esineitä jotka ovat kytkettynä yhteen internetin välityksellä. Nämä laitteet tuottavat dataa joka kerätään ja analysoidaan jotta yritysten päätöksentekoa voidaan tukea paremmilla analyyseilla. Järjestelmällä voidaan myös helpottaa ihmisten jokapäiväistä elämää automatisoimalla yksinkertaisia tehtäviä.

Monet suuryritykset, prosessorivalmistajista ohjelmistotaloihin, tutkivat ja kehittävät teollisen internetin järjestelmiä ja alustoja heidän asiakkailleen käytettäväksi.

Teollisen internetin käyttöönotossa talotekniikassa on vielä haasteita, esimerkiksi suuren datan käsittely, yksityisyys ja turvallisuushuolet, yhteisen rajapinnan ja protokollien puute jne.

Monet nykyiset valaistus- ja LVI-ohjausjärjestelmät tulevat tulevaisuudessa menettämään asemansa teollisen internetin tarjoamien etujen myötä. Vanhentunut tekniikka ja järjestelmäkohtainen kaapelointi tulevat poistumaan. Järjestelmien integrointi tulee muuttamaan automaatio suunnittelijan roolia palvelemaan enemmän sähkötekniikkaa LVI-tekniikan sijaan, kuten tilanne on tänä päivänä. Tulevaisuudessa automaatio suunnittelijan on järkeä olla tiiviimmässä yhteistyössä sähkösuunnittelijan kanssa, jopa samassa toimistossa.

Sähkösuunnittelutoimistojen tulee rakentaa uusia luotettavia suhteita muiden teollisen internetin sidosryhmien kanssa, koska uusi ajattelutapa on liian suuri kokonaisuus yhden henkilön tai toimiston hallittavaksi. Suunnittelijaryhmään voisi tulevaisuudessa sijoittaa erillisen data-suunnittelijan suuren datamäärän takia. Datamäärä tulee kasvamaan eksponentiaalisesti teollisen internetin myötä.

Avainsanat: Teollinen internet, talotekniikka, älytalot, datasuunnittelija, sähkösuunnittelu

Preface

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Abbreviations

API	Application programming interface
BAS	Building Automation System
B2B/B2C	Business-to-business/Business-to-customer sales
CIO	Chief information officer
DIY	Do-It-Yourself
FIIF	Finnish Industrial Internet Forum
HVAC	Heating, Ventilation and Air Conditioning
IANA	Internet Assigned Numbers Authority
IFTTT	If-This-Then-That
IIoT	Industrial Internet of Things
IEEE	Institute of Electrical and Electronics Engineers
IoE	Internet of Everything
IoT	Internet of Things
IPv4/IPv6	Internet protocol version 4 and version 6
Li-Fi	Light-Fidelity
6LoWPAN	IPv6 over low power wireless personal area networks
M2M	Machine to Machine
NFC	Near Field Communication
PLC	Programmable logic controller
R&D	Research and Development
RFID	Radio Frequency Identification
SCADA	Supervisory Control and Data Acquisition
SOC	System on Chip

1. Introduction

The Internet is an integral part of today's society, connecting people and sharing information from all around the globe. It has changed the way people interact and communicate. We can conduct research across geographical boundaries, access information and news instantly across the globe, discuss politics and share ideological ideas with likeminded. The next evolution of the Internet would be to enhance computer systems and computers' interactions and communications with each other in the same magnitude as we have enhanced human communications in the last decades. Larger cloud based systems will be able to collect data from sensors, analyse the data and make decisions without human interaction. The systems will find new patterns and dependencies we are not aware of, and can further optimize routines and processes that humans have developed for decades. This machine revolution is only possible if we allow machines to communicate through the Internet. We will have to change our mind sets of what the Internet is, and what it is used for. We will have to decide who can use the Internet, machines as well as humans. This way we can have an "Internet of Things". If we can redefine what we are using the Internet for, and incorporate systems and things to the Internet as users, it is expected that the amount of Internet connected devices will skyrocket with estimates of 25 billion [1] devices just in the next few years. This is an expansion that is partly already happening with more and more connected devices per person. This rapid expansion will undoubtedly bring many challenges, some of which we can prepare for today, and many that will surface as the technology matures and develops.

In building and home automation, the Internet of things is the thought of everything, from light switches to large HVAC machines, being connected to the Internet and working together with other "things" without the need for human intervention. The term "things" incorporates everything from sensors, appliances and microcontrollers to smart devices and PCs. Future everyday "smart" objects will become equipped with microcontrollers and transceivers and will thus be able to connect to larger system networks. It is not uncommon today that many devices in building automation are already connected to the Internet, either directly or via gateways, for remote control and monitoring. The idea with IoT is to bring everything together with a common interface that is relatively easy to expand as needed. The connected systems are sharing their data which is collected and analysed in local or remote servers. The results can then be used for optimizing these systems, or even for finding new patterns which aren't obvious from the beginning [2]. Even expanding on this idea, the things could have identities or even virtual personalities that are self-configuring and are expected to become integral parts of businesses' decision making [3].

Lighting is currently for the most part controlled locally, or by a central control station on-site. It is still fairly uncommon for lighting control to be connected to the Internet since it rarely has benefits that overcome the costs of more advanced systems. Home and larger building HVAC automation systems on the other hand can often have an

interface that can either be monitored or directly controlled via some sort of remote connection. These systems however, are seldom sharing their data or using outside data to control their process.

The purpose of this work is to identify what challenges traditional electrical and lighting engineering will face with the emergence of Internet of things and what possibilities it can bring to companies ready to embrace the technology. Electrical engineering is currently focused on the physical aspects of the electrical infrastructure, with everything being built according to ruling standards, laws, and safety regulations, not to mention customer desires. How will electrical engineering change when the Internet is introduced into traditional control systems, and should companies expand from hardware oriented engineering to software engineering when everything is connected to the Internet?

This work will describe the current lighting and HVAC control systems available, and how they differ from one another. After this, we will describe the current state of Internet-connected things. From this it is natural to explore how Internet-connected things could communicate together to form an “Internet of Things”. Lastly we will talk about future prospects, what lies in the immediate future and what could be done on the horizon of technology. This gives insight into the question how electrical engineering should prepare for the ever growing connectivity of things.

This work can be used as a reference or guide at electrical engineering companies as how to prepare for the coming of this new technology. This will not give specific answers to problems, but give the reader an idea of what to expect, what is currently being done and how the playing field could change in the immediate future. By acknowledging these changes, companies can scout for new markets and make their own decisions whether to pursue the growing business and expand into the software side of engineering, or reinforce their hardware engineering competence and infrastructure knowledge of what is needed for the growing data requirements. Either way, it can be a crucial change in an industry in which every player needs to be one step ahead of the competition.

The possibilities with Internet-connected things that can talk to each other and not just within their own system, opens up a plethora of opportunities for manufacturers to develop their products. The HVAC and lighting system can get access and adjust according to population density throughout the building, lighting levels are controlled partly by outside light conditions, and colour temperatures and lighting levels are optimized throughout the day. Fresh air is pumped to the factory floor if production levels decline at the end of the day. Ventilation is lowered during non peak hours to conserve energy. Non-critical loads can be disconnected or reduced if systems anticipate large momentary loads, which in turn evens out the energy consumption and lowers total costs for building owners. The heating and air conditioning can be adjusted for specific tasks and changed throughout the year with information from different sites of what similar metrics have shown to be effective.

On a smaller scale, smart homes can have automatic air conditioning to turn down the heat when you leave your home, and turn it up again a short while before you are expected to be back. When you leave, your automatic robot vacuum crawls from beneath the bed to make sure you come home to a clean house. On your way home, your fridge might remind you that you have no milk or give you suggestions on tonight's dinner based on food you already have available. In factories, every machine and every room gives information to better optimize the production lines. Hotels know your preferences on lighting, radio and TV-stations and the concierge knows your favourite champagne, chilled to the optimal temperature even before you enter the room.

In electrical engineering, these new opportunities can enable smarter energy consumption while at the same time raising the comfort and security of its customers. Electrical engineers must be able not only to design building automation systems, but also to consult customers in what IoT has to offer in other areas of their businesses.

2. The Internet of things

The Internet of Things is still in its infancy with a lot of confusion and uncertainty attached to the name and concept. The actors in both hardware and software aspects of IoT are still trying to find their way towards a common definition of what IoT means. Many consortiums and alliances have been formed and the definition is becoming coherent among all participants. In this chapter we will take a look at how IoT and similarly named systems are defined by different vendors and organizations, what the scope of an IoT system is and the components needed for it to be considered “IoT”. Then we will explain how IoT is defined in this work. After this, we will explain the history of IoT and control systems in general. Lastly we will take a look at some applications of IoT and some of the largest actors that are actively developing IoT strategies and products.

2.1 *Definition*

There have been a lot of hype around “Internet of Things” during the last few years, with everyone waiting for and talking about the digitalization of the world. Even though many have heard the phrase in many different contexts, it is still somewhat unclear what it actually means, and how it will impact our everyday lives. There are no clear rules or tried and proofed business models for us to follow and with them leading to instant success. Therefore, companies have made their own definitions of what IoT means, some better than others. This new way of thinking has brought down the benefits for larger companies with leading market shares, even to the point that small agile companies with their faster market adaption might have the upper hand in this disruptive technology innovation. The most important factor is to accept this new technology and to adapt to it [4]. A research report by McKinsey Global Institute “estimate a potential economic impact—including consumer surplus—of as much as \$11.1 trillion per year in 2025 for IoT applications”. [5]

There are a lot of different definitions and acronyms for the system that “Internet of Things” refers to, and this might lead to confusion among both experts and more importantly consumers and non-professionals. Some of these definitions are more sophisticated and serious, while some use the term more loosely mainly for marketing purposes without actually implementing the “Internet of Things” in their products.

There are a quite a few phrases used to describe the same phenomenon as the “Internet of Things”. Cisco for example uses the phrase “Internet of Everything” [4] to emphasize that every little thing will be connected to the Internet; “Industrial Internet” is used in the process industry to describe sensor and actuator networks that essentially communicate in the way as described for IoT, but with emphasis on industrial applications; M2M-communication (machine to machine) is used to describe the philosophy of IoT but not the medium in which information flows. As with any new technology, there will be many different variations and phrases to describe what the

system is about, but with a little bit of research you often notice that they all describe different parts of the same ecosystem. Cisco's catchphrase "Internet of Everything" expands the connectivity of things to everything, as to describe that everything will one day be connected to the Internet, and thus mentally preparing the consumers (and themselves) for the coming revolution. Since the Internet of Things is based on the sheer amount of connected devices and users, the use of Internet of everything might be well justified. The whole IoT philosophy falls apart and fails to deliver the promised experience if there aren't enough connected devices, so the end goal is to have everything connected. By some suggestions, we are already in the age of "Internet of Things" and rapidly moving into Ciscos utopia, or dystopia depending on the viewer.

Since the phrase "Internet of Things" is somewhat clumsy to use in a marketing context, the acronym IoT is often used instead of the whole name. The acronym is also appropriate to use since its use is established across many languages, in research and in the marketing of different systems.

In this thesis we will use the term "Internet of Things" (or the acronym IoT) and define IoT as a common name for systems of devices that are connected to the Internet and are communicating with each other without the need for human interaction. These interconnected devices can be any "thing" and hence the name "Internet of Things". These devices are connected in such a way to "make the system intelligent, programmable and more capable of interacting with humans and each other" [2]. The systems can become more intelligent by collecting data and analysing this data in an unprecedented way to create new and more accurate predictions and optimizations.

Without a clear definition of how we want to use the Internet for devices, and what Internet of things is, it will be difficult to define problems, let alone solve these problems on a larger scale [2].

2.2 Scope of IoT systems

There are some major components in any IoT system. The first main component of all devices in an IoT system is *interconnectivity*. As the name implies, the medium of this connectivity is through the Internet and this lies in the very heart of all IoT systems. It should also be noted that these systems are communicating specifically over the Internet, thus suggesting that localized systems are not true IoT systems. [3] Current technologies are often connected to the Internet via gateways, and while these devices are technically connected, the long term goal is to have unique identifiers for all devices, that is unique IP addresses.

The second main component of IoT are the *things*. The things can be anything from computers, phones and other things already connected, to car tires to monitor tire pressure, concrete blocks to monitor the structural health of buildings and roads among other traditionally unconnected things. One very important set of connected things is

sensors. The sensors are responsible for collecting data to the IoT system and monitor the environment or processes. [6]

This brings us to the third main component that is *data*. [6] The use of data analytics is crucial for IoT systems. The use of big data and finding patterns and correlations that are previously unknown will make the IoT systems smarter than traditional “smart” systems, which are often working by pre-set rules and configurations. By connecting data from many different sources, unexpected relations will definitely be found.

A fourth component, the *presentation and programmability*, or simply the user interface, can be counted as an integral part of any IoT system [6]. This is often, but not always, the most important part of the system. Without proper user interfaces, the benefits and optimizations of a process can be lost even though calculated and optimized. As with any technology, the ultimate goal is to serve us humans with better and more efficient solutions to enhance our standard of living. There are though some IoT systems that might not need *human* user interfaces if they serve other IoT systems. This is where the very first component of IoT, *interconnectivity* comes in play. This is in essence the Internet of Things, machine to machine, system to system communications.

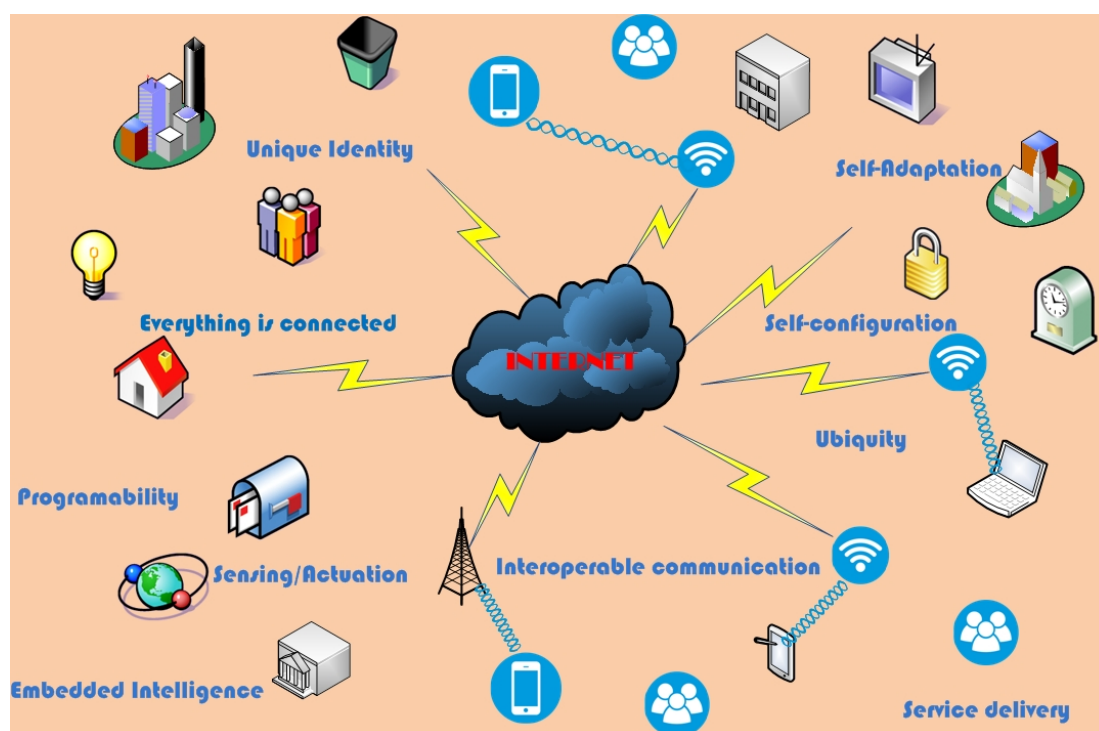


Figure 1 Features and scope of an IoT system [3]

Figure 1 shows the IEEE definition of the features and the scope of an IoT. The characteristics that IEEE describe as important in any IoT system are required for it to differentiate itself from current smart systems. These characteristics are:

All devices in IoT systems must be *uniquely identifiable*, for example having their own IP address. [3]

Another important feature of IoT systems is the ability of *self-configuration* and *self-adaptation*. This is due to the high number of different devices from many different manufacturers that are to be connected to the same framework, that is IoT. With these different devices, ranging from sensors, actuators, storage devices, mobile phones, tablets and computers to utilities, smart grid and even home appliances, the remote control and coordination of these systems is virtually impossible on a larger scale. The natural direction of the IoT device development lies towards self-configuration and adaptation. Self configuration consists of discovering neighbouring devices and networks and resource provisioning to these networks. [3]

Ubiquity will become one of the major features of IoT, and large scale adaptation is essential for the success of IoT systems. In much of the same way as the Internet for humans is ubiquitous, available anytime, anywhere and with any device, the IoT systems need to be available anytime and anywhere for it to have the tremendous impact that is expected. In the same way as the Internet can't properly connect people if only a fraction of people has access to the Internet, the IoT can't serve it's purpose if it is not ubiquitous. [3]

The different parts of the IoT system must be able to communicate with each other without technology barriers. This means that every device uses standardized and *interoperable communications* protocols. [3]

One of the more important aspects of making the “things” intelligent, is to have them sense their surroundings. The addition of *sensors and actuators* in the IoT systems is crucial in making the systems autonomous [3]. The IoT system gather information from sensors and things to monitor the status or behaviour of the system [4]. The objects need to be smart and dynamic, and have *embedded intelligence* to be able to perform simple tasks without the need for further data analysis [3]. The information they gather is used to automatically optimize processes or resource use, and to improve on the business decision-making process [4].

The things also need to be *programmable*, at least on a level that they can behave in a variety of manners at a user's command without requiring physical changes. [3]

2.3 *History*

The concept of the Internet of Things is not something completely new, but has rather developed since the beginning of the Internet and control systems in general. This concept has slowly incorporated more and more “things” to create complete system of interconnected devices. There have always been Internet connected devices and online control interfaces, but the idea of machines communicating with each other on a larger scale is something that is new and revolutionary, and which defines the Internet of Things. One of the first uses of the term “Internet of Things” was Kevin Ashton, an executive at Procter & Gamble, who said in 1999, “we need an Internet for things, a standardized way for computers to understand the real world” [7]. This was when a growing number of devices, especially RFID tags and other logistics monitoring systems, were starting to connect to main servers with proprietary systems, not through the Internet. With the introduction of automated communication between devices via the Internet, the logistics monitoring could easily be scaled and therefore made much more effective. When the benefits from machine to machine communication was apparent in logistics, more and more industries have adopted the technology and began moving in the direction from closed systems to larger interconnected systems.

The IoT-movement and hobbyists got a great boost in 2002 with the Italian microcontroller company Arduino, which started out with the goal to “teach students to create electronics, fast” [8]. The emergence of small, cheap DIY (do-it-yourself) electronic kits set the stage for an embedded ecosystem and soon there was open source versions of everything from home automation, lighting control and other building systems to autonomous robots and drones. In the coming years, more and more of home projects have been connected to the Internet, and open source projects like openHAB can bring them all together and create a true Internet of Things [9]. With processing power rising even on small microcontrollers and general purpose processors at the same time as prices are falling, the need to produce optimal code for simple processes is not an issue anymore, and thus enabling hobbyist to create real world applications.

2.4 *Applications*

With the introduction of true IoT systems, many areas in society will change. The possibilities for us to analyse many different aspects of our lives can affect all possible industries and cultures, much in the same way the Internet has changed our lives. There are a lot of different applications already available where IoT systems are applied. For IoT to really make an impact though, it will need a much larger market penetration in all areas since the sharing of data by different systems is key to its success.

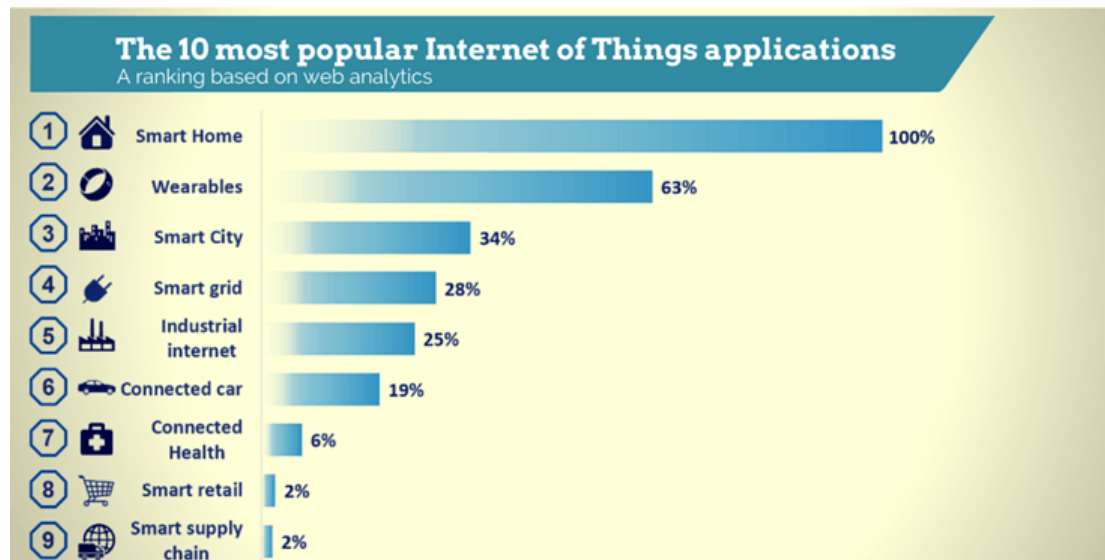


Figure 2 Most popular IoT applications today [10]

The most popular IoT applications based on searches on Google, Twitter and LinkedIn is presented in Figure 2. From this we can see that smart homes are leading the searches [10]. But with further analysis the scope of a smart city can include smart homes, smart grid, connected cars and connected health. From this we can conclude that the interconnectivity of things is an important factor in all IoT applications.

In this work we will concentrate on building services and lighting control, even though other applications are also shortly described based on their importance in a larger macro scale. It is important to notice that to achieve a true Internet of Things, these systems cannot be separated from other applications and thus reverting back to the current way of thinking, but should be opened up with the intention of sharing data. It is of outmost importance that many systems from different disciplines have a common interface to connect devices to each other, and create an ecosystem that is not dependent of any one manufacturer or industry.

2.5 Actors

Many hardware and software manufacturers have realized the potential business growth with the emergence of the Internet of Things. The IoT market is rapidly expanding, but still with a lack of a common goal, and therefore it is still fragmented. Companies are creating IoT applications but often with proprietary solutions, which can become de facto industry standards. The trend is to expand new applications with neighbouring industries [2].

In 2008, Atmel, Cisco, Intel, SAP, Sun Microsystems and other companies created an alliance to advance the IoT infrastructure. The alliance made an implementation of IP for low powered devices over wireless networks. The goal of “IPv6 over Low Power Wireless Area Networks” (6LoWPAN) is to enable IPv6 support using the 802.15.4 wireless standard. [3]

In this section, we will look at a few of the largest companies and how they enable the IoT with their development of either hardware or software, and in some cases, both.

Intel

Intel is mostly known for its microprocessors and is to this day, the leading manufacturer in the world in terms of revenue [11]. In recent years, Intel has acquired other companies in different industries (e.g. the Finnish security company Stonesoft) in order to diversify their portfolio. Intel has also released small computers named Edison and Galileo, and with them Intel has made a stride towards taking a piece of the IoT market. A move especially targeting against established DIY-manufacturers like Raspberry Pi and Arduino. Intel has together with McAfee and Wind River developed a gateway solution to connect larger sensor and actuator networks to the Internet [12]. This will enable existing legacy systems and devices, which are not optimized to be connected directly to the Internet, to have a direct connection to the cloud services without compromising security. This gateway solution enables a faster adaptation of IoT services especially in already established sensor networks.

Cisco

Cisco Systems Inc., is a technology company that designs, manufactures and sells mainly network equipment. Cisco is the world leader in networking equipment and infrastructure [13]. The company has devoted significant efforts towards developing and promoting IoT systems. Cisco recently helped develop the “IoT World Forum Reference Model”, which goal is to unify the IoT terminology and bring clarity to the process of developing IoT systems as a whole [14]. The model is a collaboration among 28 members which include Intel, GE, Itron, SAP, Oracle and Cisco, among many others [4].

IBM

The vision of IBM is to “make a new future for [its] clients, [the] industry and [the] company” [15]. The company manufactures and markets both hardware and software components.

IBM have announced a cloud based IoT service for electronics. The goal is to provide electronics manufacturers a means of collecting data from sensors and easily combine it with data from other areas for real-time analysis [16]. IBM will invest \$3 billion over four years towards its IoT unit, whose first task is to build the cloud based service [17].

ARM

ARM is an architecture for computer processors. The name is originally Acorn RISC Machine, and the architecture is developed by the British company ARM Holdings. The architecture of the ARM computers is designed in a way that requires significantly less transistors than in processors that are used in most personal computers [18], which translates to lower power consumption and less heat.

ARM has recognized the importance of their low powered architecture with all microcontrollers potentially being connected to the Internet. ARM has together with partners created a software ecosystem for a common platform to all developers of IoT devices. [19]

Arduino

Arduino is an Italian microcontroller designer and manufacturer. All Arduino hardware and software is open-source, which has led to many clones being available for cheap prices. The Arduino microcontroller has a standard set of I/O pins that can be interfaced to expansion boards, or shields. The open source nature of Arduino has made it a popular choice by DIY enthusiasts creating their own embedded and IoT experiments.

Texas Instruments

Texas instruments is an American semiconductor manufacturer. Like many other electronics manufacturers, the rise in number of IoT devices means larger sales. Texas instruments have introduced their ecosystem for IoT devices, which lets users of Texas Instruments devices connect to their cloud easily. [20]

Microsoft

As one of the largest software developers in the world, Microsoft already has a large customer base to whom it can offer new IoT services. Microsoft has several projects in development for IoT systems, one of the more important is the “Azure IoT Suite”. The Microsoft Azure IoT hub establishes a two-way connection with the users’ devices. Azure analyses and presents the data collected from the connected devices as usable information to people who can use it for better decision making.

Microsoft has also released a lightweight version of Windows 10, aimed towards lower powered devices, like the Raspberry Pi mini computer. The version is also available for devices typically deployed in industrial environments [21]. This lets developers

prototype on cheaper systems, like the Raspberry Pi before committing them to industrial processes.

Google

Google is one of the largest technology companies in the world and Google is one of the most valuable Brands in the world [22]. One could argue that Google is already living in the IoT age since it collects data from all possible sources, smartphones, internet searches, image and voice recognition etc. Google is estimated to process over 100 PB (100×10^{15} bytes) worth of data every day in 2014. The same estimate proposes Google to have 15 exabytes (15×10^{18} bytes) of data stored in its data centres [23]. With this large capability of data storage and analysis, Google have a strong argument in why consumers should use their cloud based IoT systems to store data.

Google has started many projects revolving around the IoT themes, of which two of the largest ones are Brillo and Weave. Googles project Brillo is an operating system for IoT devices, meant to be used in small devices with significant hardware constraints [24]. Weave on the other hand, is a platform independent protocol meant to be used by, but not constrained to, Brillo devices [25]. Google have other IoT services also available mainly considering data analytics, for example Big Query tools, which allow users to make SQL like queries on large big data sets, and many other similar tools [26]

Samsung

Samsung is a Korean company who mainly is known for their consumer electronics manufacturing, even though Samsung is active on many other fields also. Samsung have invested in IoT on different levels. Samsung recently acquired SmartThings, who develop and manufacture a home automation system for use in residential buildings [27]. SmartThings is one of the more promising IoT applications for homes on the market at the moment. More on SmartThings in section 3.1.3. Samsung has also released their version of a system on chip (SOC), the Artic. The Artik chips have built in connectivity and an open source environment for developers to build their applications on. [28]

These companies are just a few examples of IoT developers while many more are either developing, or at least investigating the possibilities with IoT. The common topic across these major companies is that IoT will be a revolutionizing force and that preparation for it will be needed. On the hardware side of IoT, electronics manufacturers have immense pressure to lower prices with component prices falling.

This is also one of the prerequisites for widespread IoT adaptation, as we will discuss later.

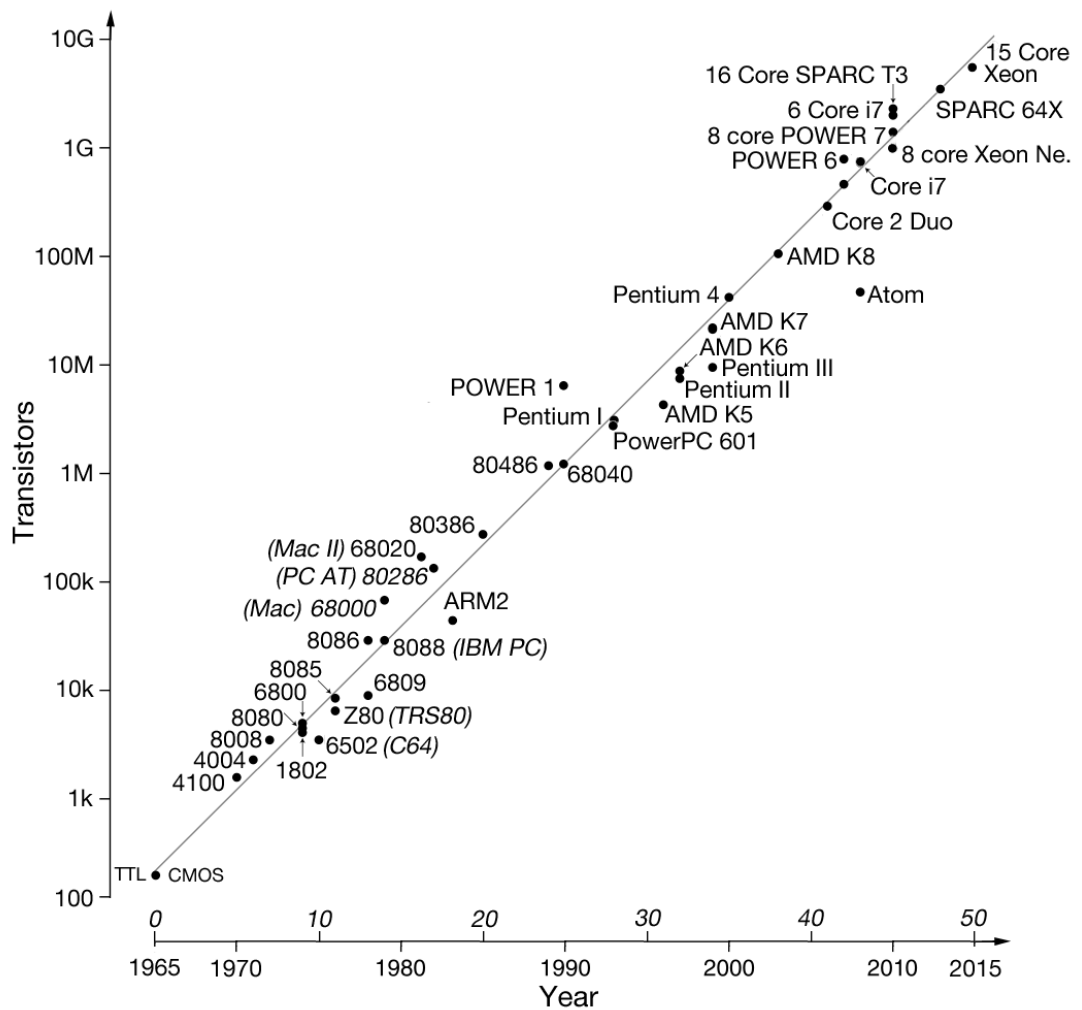


Figure 3 Moore's law 1965-2015 [29]

Software especially written for embedded systems, which IoT depends on, will become more accessible to everyone, not only for big software companies. This has historically been an area where the learning curve is relatively steep, and there has been a need for specialization on programmable logic controllers (PLCs) and machine programming. The actors in this field have mainly been big companies with large budgets and dedicated software engineers and research and development (R&D) departments, ruling out almost all hobbyist programmers in the process. In recent times all this have changed. Gordon E. Moore, co-founder of Intel and Fairchild Semiconductor, suggested in 1965 and revised in 1975, that the transistor count would double every two years. This has been the trend ever since Moore saw the current trend in the '60s and '70s, even though physical limitations have been a concern every now and then. Figure 3 shows how modern processors are situated around the prediction [29]. The hypothesis is so widely used that it is called Moore's Law. The current processing speeds of small, and more importantly cheap microcontrollers have in

recent years reached a threshold where for small, simple systems, the quality and speed of the programing code is not an issue. This major boost in processing power has made it possible for do-it-yourself enthusiasts to create their own software from scratch with high level programming languages, like Java, without lacking in speed in the physical realm, a challenge that has been the issue for many newcomers to PLC and microcontroller programming.

Another stride forward in making programming available for everyone is the simple programming style “If-This-Then-That” (IFTTT). This lets users program their own routines with no advanced knowledge of programming languages. [3] IFTTT lets users take data from different web services, such as Facebook and trigger actions with this information.

3. Current lighting and HVAC control systems

To understand what the Internet of Things can do in building automation, it is essential to understand what control systems are in use and how they are used in modern buildings today. Only with an understanding of what is used, and how these systems work and are connected, can we have an idea of how IoT can be integrated or replace these systems. In this chapter we will take a look at current lighting control systems followed by HVAC control systems and how current smart buildings are using this technology. Lastly, we will take a look at the role of electrical engineering today in building services, what the responsibilities are and how automation engineers differ from electrical engineers.

3.1 *Lighting control*

It is not uncommon for buildings to have many different lighting control systems in use at once. The current philosophy in lighting control is not geared towards ubiquitous control systems, instead most parts of a building are controlled locally. Some areas may have more advanced control systems, like auditoriums, conference halls, classrooms etc. For building owners today, the strive to make more energy efficient lighting systems is one of the main accelerators of renewal of old control systems. There are major energy saving possibilities in lighting control systems and it is estimated that with effective lighting control it is possible to save a large part of the total electricity consumption [30]. One of the important implementations of IoT in building services would be to even further enhance the already smart lighting control systems. The rising electricity prices has led to more and more property owners starting to take interest towards efficient lighting control and lighting sources, and to replace their current outdated lighting systems. We will take a look at a few analogue control systems followed by the most common digital lighting control systems, DSI, DALI and KNX. New buildings often rely mainly on digital control systems, but since many older buildings still have analogue control systems, we will also take a look at them.

3.1.1 Analogue control systems

The simplicity of analogue control systems is the biggest advantage over more complex, and therefore more expensive systems. The simplest and most common analogue control system is a simple on/off switch.

When shifting focus from the simplest method, switching, to electronic ballasts, 0-10V (or 1-10V) is the most common control system. The controller applies a voltage between 0-10V to the ballast, which in turn varies the intensity level of the lamps accordingly from 0-100%. There are two versions of the 0-10V control system, which are both broadly used in the lighting industry but are not compatible with one another. One system which operates with voltages from 0V to +10V and the other which

operates from 0V to -10V. The principle is the same, but one is a current source, and the other a current sink, making them incompatible.

Some digital systems have the ability to incorporate analogue control systems into their digital domains. The digital control system KNX, often use relay switches instead of lighting fixture specific intelligent ballasts. This way, larger areas for example hallways are controlled by a single digital address, but from the lighting fixtures perspective, still in the analogue domain.

3.1.2 Digital control systems

The main advantage with digital control systems over analogue control systems is the lower voltage over the signal line, and the nature of the digital domain allows it to maintain the desired control value even on longer cable runs. A drop in voltage on a longer cable run does not affect the digital control value, whereas the analogue counterpart will be changed. Without complex compensation for the voltage drop, the analogue systems may produce a slight dimming which may be seen for example in longer hallways or halls. The downside of digital control systems is their complexity compared to analogue systems. This hurdle is not much of an issue since they are commonplace in most of today's buildings.

DSI

DSI (Digital Serial Interface) is one of the most widely used lighting control systems available. It was developed by Tridonic in the 1990's as a means to digitally control lighting fixtures with low voltages, enabling longer cable runs than with traditional dimming methods. The 8-bit digital signal is used to send the lighting level to the luminaires, which can range from 0-255.

The DSI protocol is very simple to use and easy to implement since the system doesn't need any programming on the field since DSI is an address-less system. At the same time this is one of the shortcomings of the protocol because there is need for one wire per control program. In many of today's complex control systems, this would lead to very many wires, which is both economically and maintenance-wise not the optimal solution.

DALI

DALI (Digital Addressable Lighting Interface) is a data protocol used to connect networks of devices in building automation. DALI is mainly used for lighting control, but can also be used to control other various clients, such as shutters or blinds where a special interface called SMI (Standard Motor Interface) is needed.

DALI is an expansion of the former DSI-standard to which DALI brings two-ways communication and addresses. The two-way communication enables DALI-ballasts to send back information to the central unit, for example energy usage, dimming levels or maintenance needs.

In contrast to DSI, the addressable DALI makes it possible to wire all devices with a single pair of wires, the DALI loop. This makes more complex systems more sensible to implement with DALI instead of DSI.

The maximum number of devices in a single DALI network is 64 with the specified master/slave configuration, which can limit the use of DALI in larger projects. It is however possible to connect multiple networks together with gateways and create a multi-master mode. This mode allows DALI to have more than 64 devices connected, but this increases the complexity of the system, and is thus harder to manage.

It is also possible to connect these networks with Ethernet.

The protocol is an open interface specification which allows manufacturer independent lighting systems to be controlled with the same controller.

KNX

KNX is a protocol for building automation that has derived from several older standards, mainly the EIB, EHS and BatiBUS.

There are several methods defined for communication within the KNX protocol, wireless (IR and RF), twisted pair, Ethernet (IP) and even power line networking. The standard allows devices to be controlled by a variety of control devices, as long as it complies with the KNX standard. This could mean anything from a small microcontroller to a larger, more complex centralized server.

The bus devices that connect to the KNX system can be sensors or actuators (or network components). There are a lot of different manufacturers for KNX components offering products in all building services, from lighting, A/V controls, home appliances, HVAC and many more. With intelligent control systems and a sufficient amount of sensors, a building can be made very energy efficient or user friendly.

3.1.3 Internet connected lighting control systems

The current state of Internet connected lighting is still very much in its infancy. There are some systems that have an Internet interface, but most of which could not yet be classified as Internet of things with some exceptions. Lighting manufacturers have not yet deemed IoT to be an investment worth pursuing in terms of cost versus possibilities.

Many of the current Internet connected systems use one of the several technologies for connectivity, some of which have been introduced to the market only in recent years. These new technologies include ZigBee, Z-wave while many of the older and still used protocols include WLAN and Bluetooth with many others. There are also proprietary protocols running on available open source technology, XBee that is running on ZigBee technology but is a proprietary protocol by Digi [31]. The one thing that these technologies have in common is the need for a centralized access point. The devices in these systems connect to a gateway, which in turn have Internet access to send and receive information from other systems and often incorporate a graphical user interface (GUI). Many of the companies offer an Internet connected service to control the lighting.

With the open protocols, it is indeed possible for device to device communication, but as it seems today, the use of gateways is becoming standard practice as the large protocol stack might induce problems in low communication speeds of the devices.

Philips HUE is one popular example of new thinking in the lighting industry. The screw on E27 LED bulbs are meant for retrofitting to current lighting fixtures (or new buildings for that matter), and are controlled wirelessly via a central bridge that connects to up to 50 “bulbs”. By connecting your mobile device (phone, PDA or similar) to the bridge, there are scenes or alarms that can be connected to the bulbs. By connecting the bulbs to the phone, the lights can be set to go on whenever a wakeup alarm or oven timer goes off. The user can control the white colour temperature or RGB colour of the bulb along with dimming the light, all from their smart phone. [32]

Osram Lightify is another system of proprietary Internet connected home lighting. As with HUE, Lightify has a mobile application from where the user can control the lighting [33]. Both Philips HUE and Osram Lightify use the open source ZigBee protocol for their connections to the gateway, meaning it is possible to control these lights using third party gateways. More on HUE and Lightify in section 4.1.1.

Another Internet connected lighting and home automation system is SmartThings, which was recently acquired by Samsung. SmartThings is essentially a hub for connecting both SmartThings branded products, and third party products via popular protocols, such as ZigBee, to the user’s smart device [27]. There are many third party products available for SmartThings, and with the vast portfolio of Samsung branded home appliances, the system is expected to grow quite rapidly. The main difference from SmartThings and other similar commercial systems, is the openness of the hub. The SmartThings hub is capable of ZigBee, Z-Wave and IP/Wi-Fi protocols, expanding the range of products that work with the hub many fold. The SmartThings hub also has an open API, which makes it capable of IoT applications. [27]

The oBIX (Open Building Information Exchange) specification is an open standard that is aimed to give access to building automation via standard XML and Web Services. The standard is an effort by OASIS, which is founded in 1993, and has more

than 5000 participants representing 600 organizations in 65 countries [34]. These industry leaders' goal is to enable true systems integration by giving easy access to building automation and other systems for developers of other existing management applications. The oBIX specification had become a de-facto standard by 2010 when the draft for oBIX 1.1 was released. There have been revisions to this specification as the standardization effort has progressed. Mostly the additions have focused on predicted future trends, such as smart houses and smart building automation [35]. oBIX provides a simple and secure XML protocol to obtain data from HVAC, access control and other systems.

3.2 HVAC control systems

Heating, ventilation and air conditioning (HVAC) control systems can vary tremendously in complexity, from a single temperature sensor controlling the heaters, to larger centralized systems with hundreds, if not thousands of sensors and actuators. These complex systems monitor everything from inside and outside temperature to CO₂ levels and determine the appropriate levels for all HVAC systems. Many of these larger systems are a part of the building automation system (BAS) which is used to control HVAC as well as lighting and other systems. The BAS is also used to monitor, but not control other systems, for example emergency systems (fire, emergency lighting, security and access control etc.). A building with an advanced automation system is often marketed as a “smart building” or “smart homes”. These advanced automation systems are often not uncommon since they are found in most larger buildings, but to use them in homes is not widespread, mostly due to the higher price.

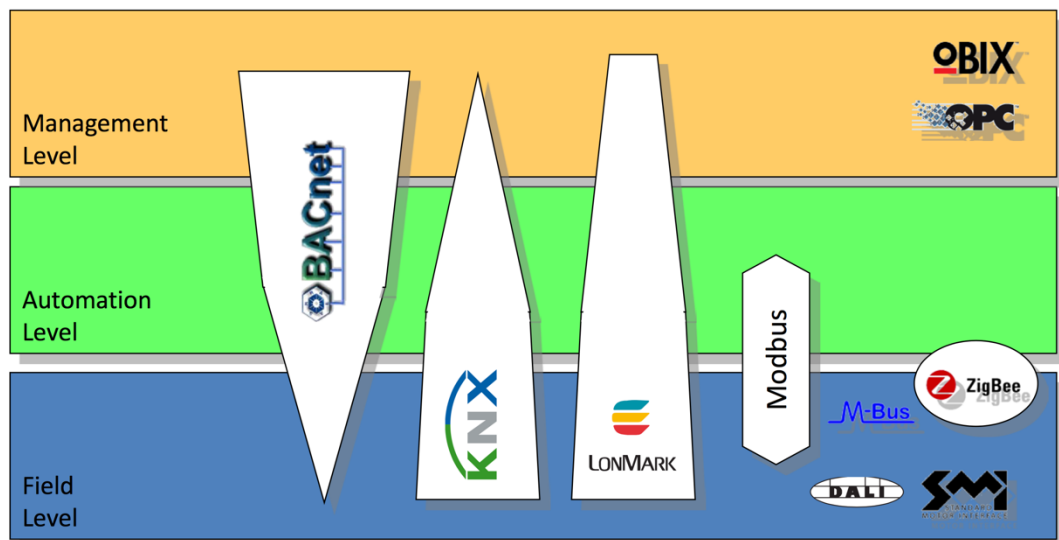


Figure 4 3-layered model and technologies [35]

Larger scale BAS (Building Automation System) that are used in many buildings are traditionally made with a 3-layer approach as shown in Figure 4 [35]. The lowest level, or field level, consists of sensors and actuators. The field level devices are controlling

and monitoring the process constantly. All the devices in the field layer are most commonly connected to DDC (Direct Digital Control) stations. These DDC stations collect all the data from the sensors and actuators, while controlling local applications. In more complex buildings, there can be more than one DDC station. The multiple DDC stations are connected and communicating at the automation level. The highest level of this hierarchy is the management level. This level is the main interface to the system as a whole. There can be any number of visualizations at this level for different purposes and the system configuration is often done here. In newer Internet connected systems, where the system is sharing or accessing other BAS', the APIs are on the management level.

In smaller systems the 3-layered BAS is slowly giving way to the 2-layered counterpart. This is largely due to an increasing amount of embedded systems in today's processes. Many sensors and actuators are equipped with microcontrollers, giving them the capability of taking over many of the DDC's tasks. The second layer of traditional BAS', the automation layer, is slowly merging with the field layer. [35]

For IoT this is a much welcome development, since the communication between devices must be standardized. It is much simpler to connect embedded systems into a IoT service than sensors directly. This development is changing slowly but with lower component costs, the evolution is both economically and technologically valid.

There are many building automation systems that already have an Internet interface and off-site remote control is common. These systems have a great adaptability to open interfaces and the IoT-model, possibly giving the building an application programming interface (API) to enable software developers to access the buildings functionalities and information.

SCADA (supervisory control and data acquisition) is a computer system used to control remote equipment in the process industry or infrastructure networks, such as water and electric utilities. It gathers information from a complex sensor network, which monitor the process in real-time and presenting it to the user via a sophisticated interface. SCADA systems can be found in almost every large scale process. In recent times, SCADA has expanded to the building industry and are controlling larger HVAC systems.

One example of a more advanced automation system that connects multiple protocols is Niagara. Niagara is a proprietary system, and is a typical web-browser based BAS, which makes it possible to control and monitor many automation systems in a building, both sensors and actuators through one common interface on a web browser. The main features in Niagara is the possibility for energy consumption metering and management, remote monitoring and management and easy scalability. All systems in a large commercial or office building can be monitored and managed through the web interface of Niagara. The Niagara is designed with same mind set as IoT systems, that is to connect multiple systems into one coherent interface, but the proprietary of the

systems makes it a cumbersome option. The price of a complete Niagara system often exceeds that of an open system, especially in smaller installations, and the programming has to be done by an accredited employer in some of Niagara's partner companies.

3.3 *Smart buildings*

With a higher level of comfort and automation in recent buildings, larger building companies have begun to market their more advanced houses as “smart houses” or “smart buildings”. Like many other marketing buzzwords, “smart buildings” have many definitions depending on the service provider or builder. However, there is still a consensus that all smart buildings often have similar properties, for example they have intricate automation systems and advanced control systems with intuitive user interfaces. These houses are today regarded as smart buildings, but with these control and automation systems beginning to be more common, the preposition “smart” is becoming more insignificant with residents expecting a certain automation standard in today's new buildings. In a smart building, the various systems can interact, much in the same way as it is envisioned for IoT to communicate, but only in a local setting, that is, within the building. The user can have remote access to the system, for example to turn the heating on or off.

A feature of many smart buildings is the real time monitoring of electricity and water consumption [36]. This enables building owners to have accurate invoicing of tenants at the same time as tenants are inclined to lower their consumption due to the feedback of their consumption in regards to similar peers. The lower the level of which the consumer has access to their consumption, all the way down to individual devices, then they are more likely to actively promote energy conservation [36] [37]. Another energy saving device found in many smart homes is a home/away switch. This switch allows the residents to turn off any non critical loads, and to ensure that any devices needing supervision, for example the oven or other devices with fire or water hazards, are switched off before leaving the building [36].

3.4 *Current role in electrical engineering*

The main building services engineers, or engineering groups involved in projects in Finland today are HVAC-, plumbing, electrical and automation engineers [38]. There can be many areas within these disciplines, for example electrical engineering might be divided into lighting, low current and mains engineers. However, these are the three disciplines (with HVAC and plumbing considered to be one discipline) stated in TATE 12, a part of the Finnish “RT-kortisto” which publishes up to date information and instructions for contractors and building owners.

Other engineering disciplines in the building design groups might include architects, structural engineers, geotechnical engineers, construction engineers and interior

designers among others. The amount of different designers in a project is highly dictated by the size of the project and the knowledge of the building developers. With highly skilled contractors running the building site, the need for engineers in small projects can be minimal. Again, in large projects, the engineering contracts are often split up in many parts.

The TATE 12 description of areas of responsibility for these three main building services disciplines are very precise, and widely already in use in Finland. TATE 12 states that the automation engineer is responsible for all building automation design. This refers to all HVAC and plumbing automation. The electrical engineer is responsible for lighting control and lighting automation. TATE 12 replaced the older TATE 95, which had issues with the division of responsibilities. The goal was to have a more uniform understanding among all stakeholders of what systems are included and who is responsible for them, as to minimize confusion and possible disputes. The lines between building automation and lighting automation are still somewhat blurry, especially in larger buildings where some of the lighting is controlled partly with the same parameters as the HVAC system. This is not seen as an issue and the problems that arise from this diffusion are often solved in good spirit, but it is to be noted that this could be an issue for the uninitiated.

There are tens of other systems defined in TATE 12 which the electrical engineer is responsible for, security and ICT systems etc. These systems all have their own control centres and cabling networks, or shared with one or two other systems by the same vendor if in use in the same building. This requires many different sets of instructions and maintenance routines for the building owners and designers. The main issue with moving towards an Internet of Things, is that system manufacturers are unwilling to open up their systems in fear of competition. The common practice is to bind the customer with one system, often offering benefits when connecting multiple systems from the same vendor. These systems are for the most part proprietary.

4. Current state and future prospects of IoT

The IoT is still a new term on the field with not many engineering firms giving it much thought as how it will impact their business. On a broader scale, the term IoT has begun to gain some traction, and as we concluded earlier, many companies are starting to use IoT in their marketing. But as with any new technology, the hype for all the possibilities and improvements it is going to bring is much larger than the real world applications.

The hype cycle for IoT is very similar with almost every new technology that is introduced. After the initial trigger, the expectations are very high for this technology to deliver and even surpass its promises. This often results in undelivered results and public disappointment. The consumers start to question the benefits while forgetting about the technology and abandoning any thoughts of development projects. The technology often falls in a “hype dip”, before finally maturing enough to reach mainstream acceptance and feasible productivity. The hype for IoT services has been fairly large in recent years and as with other similar technologies is expected to follow this very same hype cycle. The advisory firm Gartner have branded their visual presentation of the hype cycle as “the Gartner hype cycle”. Figure 5 is a representation of “the Gartner hype cycle” with regards to new emerging technologies. Gartner publishes hype cycles for many different applications and industries. The figure clearly shows how different emerging technologies are perceived and how long before they reach the “plateau of productivity”. From Figure 5 we can also see that IoT is past its trigger point in which the term “Internet of Things” has been coined. The term is beginning to be accepted on a larger scale and is at moment on the “peak of inflated expectations”. This means that companies and the public in general are envisioning the technology to bring new and life changing possibilities on a relatively short notice. When emerging technologies fail to deliver those high expectations, as with virtual reality [39] and crypto currency [40], the broken promises brings down the hype drastically. With IoT on the peak, it is expected to have a major dip in hype before reaching its “plateau of productivity” where IoT technology will be adopted by a broad market and the benefits are becoming clear. [41].

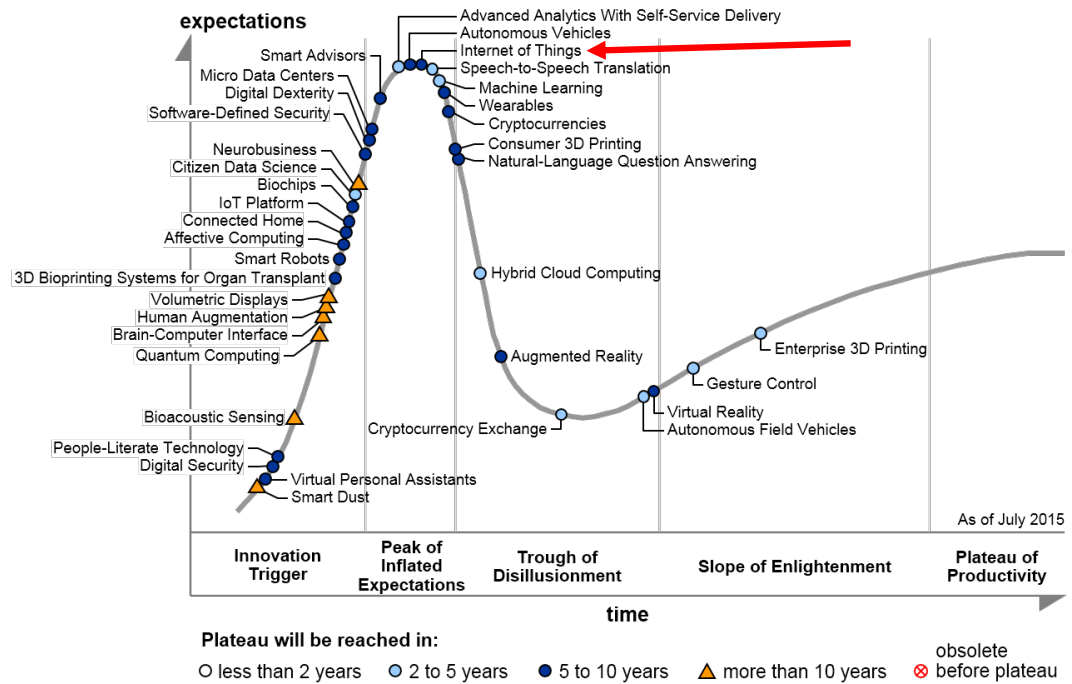


Figure 5 Hype Cycle for Emerging Technologies, 2015 [41]

The situation at the moment with IoT being on the peak of the hype is the time where some companies are taking action and preparing for the emerging technology, but most are just spectating. Underlying technologies, such as sensors, microprocessors and data analytics are preparing for what lies ahead. The needed infrastructure is being prepared and set up. There will be successful systems with real world applications, but the main broad market penetration will happen when the technology has reached the plateau of productivity. This is also the time when the majority of companies and consumers are starting to adopt IoT systems into their processes. The Gartner analysis suggests that IoT will reach the plateau in 5-10 years. However, even though IoT is predicted to flourish several years from now, the technologies on the hype cycle are still technologies that Gartner suggests should be monitored at least once a year [41].

4.1 *Current implementations of IoT*

While being a relatively new technology, IoT systems have become more common in recent years and some of the more technology driven companies have started to deploy IoT systems in their enterprises. According to a study conducted by Zebra Technologies, the amount of companies with IoT deployments have risen from 15% of respondents in 2012, to 65% in 2014 [4]. Even though there are quite a few centralized building automation systems that have Internet connectivity there are still very little machine to machine communication over the Internet. Most of the M2M communication is happening in closed systems inside buildings. The closed systems can have a gateway or another interface to the internet, but the device to device communication is not happening through the Internet, therefore the systems are not to be considered as IoT systems.

The most common application of IoT in building systems today, is still in smart home usage, where hobbyists and tech-savvy people can turn their properties into unproved test-grounds with relatively small investment costs. Larger buildings can have already field-proven systems in place, which have a higher price tag, but downtimes are almost non-existent since these large-scale systems have major R&D and support departments. The available IoT applications are very much in their experimental phase, and while some large companies, e.g. Konecranes [42], have implemented IoT in their processes, many are still waiting for stable systems which require significantly less effort to keep these support systems up and running.

4.1.1 Lighting

Individual lighting fixtures are rarely connected to the Internet neither directly nor via gateways. There are some lighting control systems that are possible to connect to the Internet, and more important, they are able to communicate with other devices and sensors. This is thought to change in the next five years with smart lighting market expected to reach 50 million euros by 2020

Philips HUE and Osram Lightify are two similar systems for retrofitting “smart” light bulbs into existing lighting fixtures. These systems work with ZigBee technology to communicate with a gateway. The user can control these lights with their smartphones either directly via LAN or the cloud and set different scenes to activate at certain times or conditions. The main difference between the HUE and Lightify is that the gateway of Lightify is proprietary with no API [33], whereas the HUE bridge have an open API [32], making it a much more IoT like system. However, since both HUE and Lightify use the same open source protocol ZigBee, it is possible to control lighting fixtures by both manufacturers with third party gateways, such as SmartThings or even home made Raspberry Pi computers.

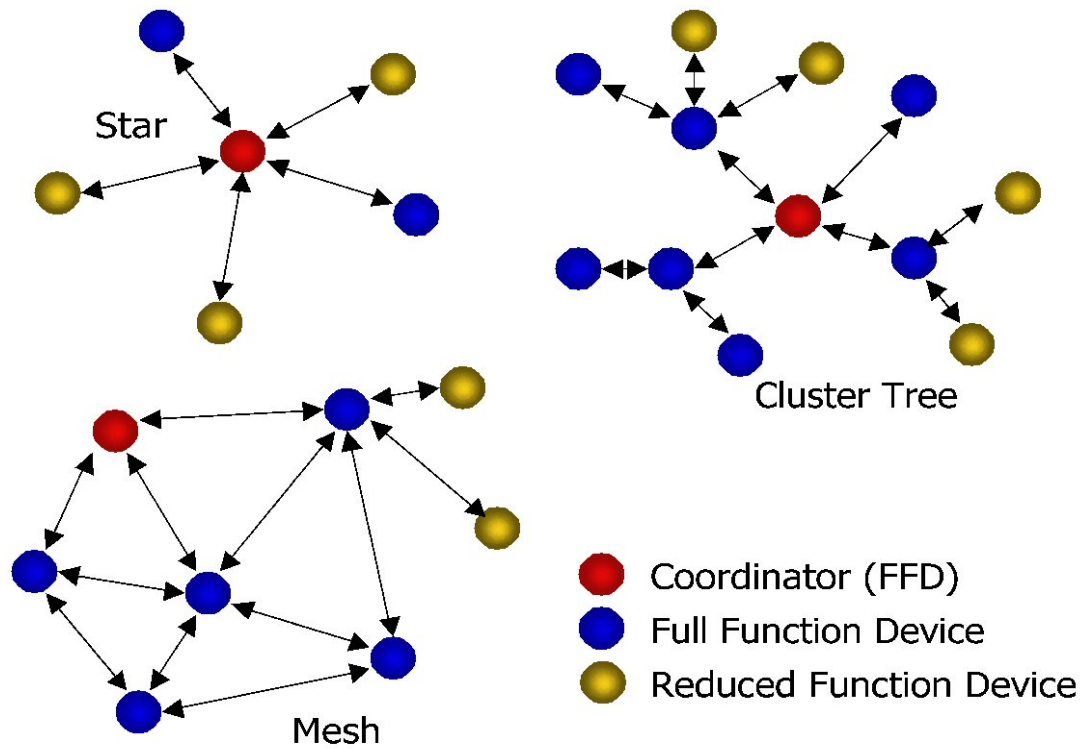


Figure 6 ZigBee network topologies compared [43]

The ZigBee protocol will probably see a lot more of applications within lighting, building automation and sensor networks. This is much due to the fact that the ZigBee devices require only approximately 20-60mW of power and they work with a range of 10-100m depending on the environment. The devices can go to sleep between transmissions and therefore save power, enabling them to run on AA batteries for several years. [3] The devices are connected in a so called mesh network as, meaning that each device in the network acts as a node. Figure 6 shows the difference between topologies. This way the network can be made fairly large if the devices are within range from one another, and the distance is not dependent to the gateway or hub as in star topologies like Wi-Fi or Bluetooth [43]. This is ideal for sensor networks in buildings where sensors are placed in adjacent rooms, but the furthest point of the network can ultimately be very far from the main gateway, especially in multi-storey buildings made of concrete that attenuates the signal significantly.

While IoT systems are taking their first steps, there will be older, current lighting control units in use simultaneously with new IoT lighting fixture while the new technology is penetrating the market. Many of these systems, such as DALI, does not have enough flexibility to be deemed sufficient in the future [44]. This is mostly due to DALI requiring dedicated wiring throughout the whole network and that DALI is bound to one type of controller and thus limiting the IoT principles of all control and information being open.

4.1.2 HVAC automation

There are a few home HVAC systems that are considered IoT on the market today. One of these is Nest, which produces programmable, connected but most significantly, self-learning thermostats. The company was founded in 2010, but acquired by Google in 2014. Nest also produces smoke and CO-detectors which can be connected to the same home automation system as their thermostats [45]. The Nest thermostats have features that are not found in ordinary thermostats for home use [46]. These features include:

- Auto-away: The thermostat detects that the premises will be vacated for a longer period of time
- Auto-schedule: The system automatically learns the patterns of the user's preferred temperatures and based on this can replay the calculated pattern.
- Nest Leaf: Where the thermostat indicates to the user when she is making energy efficient decisions. This is to encourage and educate users to conserve energy.
- Time to target temperature: An indicator to the user of how long before the desired temperature under current conditions is achieved. This is to prevent users from exaggerating their setpoint in hopes of heating (or cooling) the house faster. [46]

Other similar system as Nest are Honeywell's Wi-Fi thermostat, Venstar Colortouch and Ecobee. These are thermostats that the user can retrofit into their current homes by swapping out the thermostat. The thermostat is connected with Wi-Fi to a central cloud server which gathers and analyses the data and sends back actions to the thermostat. [47]

4.1.3 Smart grid and electrical vehicles

The Finnish government have obliged all electricity utilities to renew their energy meters to so called "smart meters" which enable two-way communication with the meter and the utilities. The meters send data at least daily back to the utilities about consumption for billing and metering purposes. The two-way communication enables utilities to send out control signals to the meters which can turn off non critical loads in buildings in cases of severe load imbalance. This is used in larger industries but not yet on a larger scale in residential housing [48]

In the future, the load control from the smart meters can be used to charge electrical vehicles in off peak hours [48]. Tesla, a company that manufactures electrical vehicles and batteries, will bring to market their "Powerwall" in 2016, which stores energy during low peak hours or from solar cells during sunny hours, to be used during high peak hours or at night when solar power isn't available [49]. The same principle as in the Powerwall could be used with the batteries in electrical vehicles. [50]

4.2 Challenges

There are still many obstacles to overcome before we are able to implement IoT into a larger scale. Here we will describe some of these obstacles. While these might be some of the more common technical difficulties that we encounter, there are also economical difficulties in unproven business models or lack of knowledge to promote these new IoT applications to customers. This is also made worse by the global financial situation, which at the moment is not encouraging companies to be pioneering new solutions. Generally, the investments in public services are shrinking, which prevents the needed infrastructure to be built. This might be solved by proving the technology in smaller scale and installing applications that have a very clear return on the investment. Some of these might include smart parking, smart buildings and so forth, which would exhibit proof for the need of infrastructure and act as a catalyst.

4.2.1 Big data

Big data can be defined as “data sets so large and complex that they become awkward to work with using standard statistical software” [51]. The size and variety of the data gathered by sensors and devices are increasing exponentially, and IoT is one of the main offenders in this aspect [4]. One of the problems with big data will also be the speed of which new data is acquired. With thousands of sensors feeding new information from a building potentially every second, the speed at which this data needs to be processed requires dedicated data storages on site. The data can then be transferred to larger data centres for further processing and big data analytics, which requires building to have high bandwidth connections. The size of the big data is from several TBs up to PBs. [52] Even though current systems can handle large quantities of data, challenges with IoT applications will come when scaling the processing of this data into the PBs, and to integrate data from multiple sources [4].

Many of the applications of IoT have different protocols to communicate to central hubs or gateways. This is to be expected as different protocols and technologies have different options available, for example low power versus short distance. This often means that the gateways and servers can potentially create massive data streams when collecting data, and depending on the data, the sharing of this data can become a problem. The use of data centres will be more common which must also be taken into account when calculating the impact of IoT energy consumption on a macro scale.

One of the potential new business opportunities is big data processing. Companies will have to acquire data either by direct collection or buying data from data vendors. However, the question of who is owning the data and who only have rights to access the data is still not solved and have no common guidelines.

4.2.2 Privacy and security

With big data comes the problem of storing the data in a secure way. Strong security measures and privacy policies must be taken to enable the IoT visions. Much of the value created from IoT applications are under the assumption that security measures are developed in the same manner as the IoT technology [53]. Historically businesses and consumers have reacted to security when it is noticed lacking. With the amounts of data generated by IoT, security breaches might not be detected as easily as with traditional computer systems, thus increasing the risk of late security measure adoption. Designers and implementers of this technology must address this issue from the start. Failure to keep information secure will have a dramatic effect on the reputation of the companies providing products and services, even more so than the effects of data breaches today [2].

Another concern is the healthcare market, which could be life threatening under an attack. Even if the devices themselves wouldn't be directly hacked, a denial of services (DoS) attack could prevent a monitoring devices to create an alarm if there would be any danger to the patient.

4.2.3 Common interface

One of the main problems with today's Internet connected devices and systems are that they are mostly closed proprietary systems. This means that the user experience is all based on one manufacturers offering of devices and services, which essentially doesn't differ too much from conventional "smart" systems with each having their own control centre and user interface, even with the potential Internet connectivity. A larger building often consists of tens of different low voltage systems. Many of the different systems applications are done with data silos, where data is protected with strong barriers for horizontal data sharing [2]. These silos are mainly used to prevent competitors from creating applications and devices to the same system, thus preventing open and expandable data sharing. Especially the home automation market is using silos which has led to consumers being committed to the system provider of choice.

There are some smaller home automation systems commercially available today. Two of these are Z-Wave and ZigBee, which both uses wireless sensors and actuators connected to a gateway that is connected to the Internet.

The novelty of the technology is still very much an obstacle for the development of IoT. There are many different protocols and practices that are competing, some of them open while most are proprietary. The industry as a whole lacks best practices since most companies are developing their own protocols and have different views on how to implement IoT into their devices.

4.2.4 IPv6

The IP address space is managed by the IANA (Internet Assigned Numbers Authority). It has become a problem that the IPv4 address space is depleting because of many reasons. One of these reasons is the inefficient use of addresses. Many class A addresses were given to large companies or universities as the class B block would only accommodate 65536 IP addresses. This led to many companies and universities to have 16 million addresses assigned, which led to many of them being unused. The depletion of IP(v4) addresses is a problem that has been anticipated since the late 1980s. If all addresses of IPv4 would be used, it would still only accommodate 4,3 billion devices, well under the projected spread of IoT devices, which means there is an urgent need of adopting IPv6 in new devices. IPv6 uses a 128-bit address, which means approximately $3,4 \cdot 10^{38}$ addresses.

IPv6 is the next de-facto standard in scaling the current Internet's addresses.

IoT6 is a European research project on IPv6 and the Internet of Things, and how the future will be defined. The research programme is looking for exploits of IPv6 and related standards (6LoWPAN, CORE, COAP etc.) and how they can be used in the implementation of IoT in the IPv6 realm. [54] The main objectives of this project are:

- To research the potential of IPv6 and related standards to support the future Internet of Things and to overcome its current fragmentation and lack of interoperability.
- To develop a highly scalable IPv6-based Service-Oriented Architecture to achieve interoperability, mobility, cloud computing integration and information as well as intelligence distribution among heterogeneous smart things, components, applications and services.
- To explore innovative forms of interaction with multiprotocol integration, mobile and cellular networks, cloud computing services (i.e., SaaS), RFID and a Smart Things Information Service. More on this subject in section 4.3.1.

4.2.5 Technology

As the price for electronics are decreasing, the implementation of electronically controlled systems is becoming more and more common [2]. The predicted growth of Internet connected devices, which is tens of billion devices, will only be possible if the prices of components continue to drop at the currently predicted rate. Low-cost sensors are crucial for the implementation of a wide-spread network which can accommodate the applications we are currently envisioning as IoT.

There are a lot of different non-connected systems in use today. Many of these have sophisticated control systems and sensor networks, but aren't sharing their data nor using outside data to control the processes. These systems could be relatively easily substituted for IoT systems with a gateway switch. This would obviously require some

effort by the systems manufacturers, but would be significantly cheaper than to build new IoT systems upon the existing hardware. In new buildings this is not an obstacle as the designers must take connectivity into account from the beginning of the design process.

The networking and communications protocols that are used in IoT applications are evolving to better data transfers and lower costs. Technologies as Bluetooth low energy (Bluetooth LE) and NFC are becoming widely used in IoT systems [2]. These devices tend to use protocols that are not able to relay IP traffic and are therefore dependent on gateways to access larger IoT systems. The disadvantage is that end-to-end connectivity is lost due to the gateway needed to convert the IP traffic to the protocol in use of the system. [3] The gateways would also make the network more complex in terms of maintenance, if the gateway fails, the whole system fails. However, there are microcontrollers that can run on very low spec devices with full TCP/IPv6 stacks [3].

4.3 *Future prospects*

The future prospects of IoT are very hard to imagine and companies and researchers around the world are trying to figure out how IoT will change their lives. The IoT technology will impact many different areas as can be seen in Figure 7. The social impact of IoT will change how we interact with our environment and each other. IoT will bring new business models and create new ecosystems with completely new services and applications. The amount of connected devices and the data these devices generate will impact the software architectures that are used today. Besides these industry changing impacts, IoT will also completely change our way of thinking about security and privacy and the management of these new processes. [3]

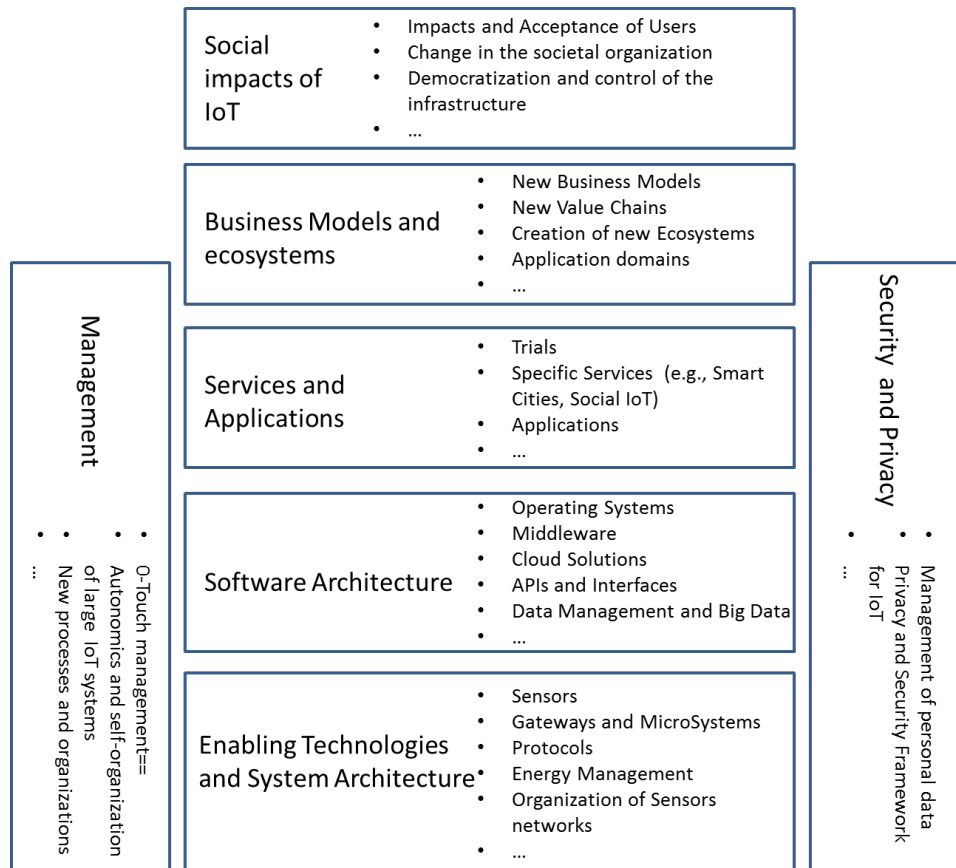


Figure 7 Technological and social aspects related to IoT [3]

There are many visions of what the Internet of Things can do and how we can capture value from this new technology. The widespread use of IoT is dependent on companies from all industries wanting to invest and build the new infrastructure. There is always the need of monetary benefit for a technology to break through and the five main general areas where costs can be reduced in all industries are [53]:

- Asset utilization, where we can reduce expenses in selling, general and administrative expenses. The improvement of business processes and efficiency overall will reduce costs.
- Employee productivity, where the higher efficiency of workers results in fewer and more productive man-hours.
- Supply chain and logistics, where IoT can eliminate waste and improve efficiencies.
- Customer experience, to increase customer lifetime value for the company and thereby growing the market share.
- Innovation, where a developed IoT infrastructure can reduce the time to market for new products, thus creating new opportunities for businesses.

When IoT device manufacturers start to offer more standardized products to help consumers and companies to adapt IoT services on a larger scale, the devices

themselves will become more intelligent. Devices will become autonomous and will be self-configuring and adaptive [2].

On a smaller scale we can take a look at the end-users. The emergence of IoT can lead to new daily rituals for the users. There is a possibility to free up time with the help of the new technology just like the washing machine did, by removing some of the repetitive chores with automation. Some of these technologies are already available and becoming more common, e.g. vacuum and lawn mowing robots. These robots are relatively smart and can monitor their surroundings, but are not yet connected to the outside world to learn about the owner's habits or weather reports. It is estimated that household activities such as cleaning, food preparation, home goods purchases and more, require 230 billion labour hours per year. By an estimate, there could be up to 100 hours of labour cut from household chores per household per year, which would equal up to 120 billion euros per year globally in 2025 [5].

4.3.1 Building services

Most of today's HVAC systems are made up of hundreds of sensors and actuators, which are usually feeding information to each other. Information from one sensor is sent to one system which will use this information in real time to control said parameters in the process. The information is seldom stored and is almost never available for other operations, i.e. is not open beyond the system itself. A typical example is an offshore oil rig with 30000 sensors where only 1 percent of the data is used and stored. Most of the data is only captured for real time control or for alerts to the control room. The sensors and other environmental monitoring will be one of the first sources of data for new IoT systems since the infrastructure is already available [6]. Much of the information could also add value to other IoT systems if captured and enable performance metering and optimization, detailed problem analysis and automated and predicting maintenance scheduling. This does naturally bring the issue with handling big data, which is discussed earlier. [5]

There is also a large market for different security systems to be made interconnected. These systems can reduce losses and costs for customers by alerting of possible break-ins, fires or equipment malfunctions like fridges losing power, water leaks and more. By having a better connected safety and security system, the user can also lower insurance premium costs.

Other building services might also benefit from IoT, like sensing the structural health of buildings, especially in larger complex facilities where maintenance and regular checks are difficult. Owners of multiple properties can have a database of their buildings' structural measurements, like vibration and deformation readings. A sensor can detect moisture and temperatures of the concrete in buildings and provide data throughout its service life giving accurate information of the state of the building [55].

Many sensor networks that are traditionally wired networks, can be replaced by wireless systems [6]. These systems can be security, automation and climate control among others. The future building IoT systems will have a strong interaction with smart grids and react on peak load shedding. Heating system can check for low energy prices and adapt the heating cycle to create lower costs for the user. It is expected that local building maintenance tools will start to shift away from local operation to managed operations, even off-site. [35]

The IoT architecture discussed in section 4.2.4 addresses the problem with many different technologies communicating with each other. The aim is to provide a common interface amongst the technologies. Figure 8 shows the architecture of the findings of the IoT6 project. With a common protocol stack, the gateway which these systems lie behind can have a browser interface or connect to other services in the cloud. [35]

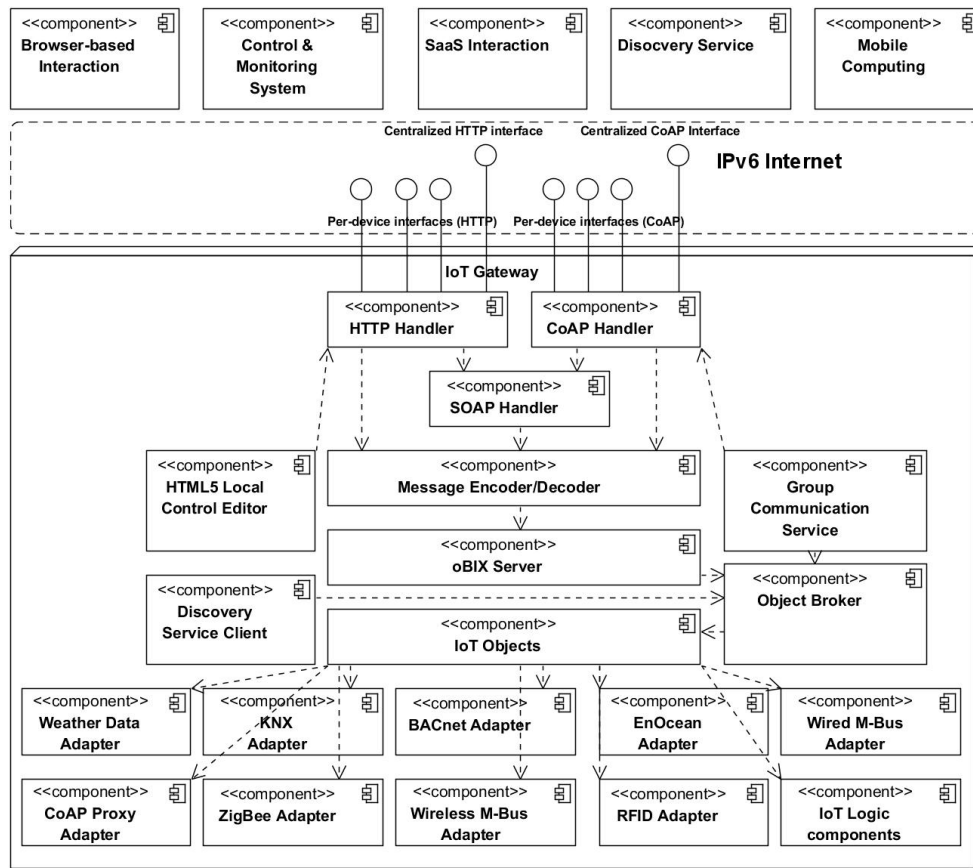


Figure 8 Multi-protocol integration architecture [35]

4.3.2 Lighting industry

The lighting industry can change dramatically with the emergence of IoT. IoT can open up new business opportunities and models for lighting manufacturers. Smart lighting manufacturers could start selling their fixtures with part of the payment made by how much energy and money the smart light is saving the building owners [5]. Lighting manufacturers will have data available for predictive maintenance and product life-time behaviour analysis for product development.

With sensors becoming more common, VTT (the Technical Research Centre of Finland Ltd) predicts that lighting will become the backbone of IoT, with sensors integrated into lamps and luminaires. With wireless connectivity, the lamps will have an Internet interface and be integrated into larger IoT control systems. VTT offers R&D and consultancy services for companies that want to develop their IoT systems [56]. Wireless communications in general are very widespread today and used in almost every, even critical applications, and it is very essential in today's society.

According to Harald Haas, University of Edinburgh, the main four issues with wireless transmissions are capacity, efficiency, availability, security [57] [58]. However, by using visible light to transmit data, so called light-fidelity (Li-Fi), these issues can be defeated, especially in IoT applications where non critical data will be gathered in large quantities with wireless transmission. Using light as a communication medium between lighting fixtures and sensors would lower the need for cabling, and thus the costs. Li-Fi uses visible light to transmit data instead of traditional radio frequency. The transmitter is located in every Li-Fi enabled light bulb [59] and is capable of both transmission and reception with the same transceiver [58], but can also be used in unidirectional mode.

The first issue of capacity is solved with Li-Fi having real world tests done with over 1 Gbit/s speeds [59]. This is well above the most widespread 802.11n standard speed of 54 Mbit/s.

The energy consumption of the transceivers compared to that of LED bulbs is minimal [58]. The energy consumption of the Li-Fi devices by retrofitting old light sources is non-existent [57], since the gain the customer has in new efficient LED bulbs is many times higher than that of the Li-Fi consumption.

Since lights are available everywhere indoors, and many places outdoors, so is the possibility for Li-Fi. [57] The lights must always be turned on for Li-Fi to operate, but can be dimmed to a level where they seem to be off, but are actually transmitting data [58].

Since light doesn't penetrate walls in the same manner as radio frequencies does, the Li-Fi network is constrained within a room or an area. Security can be enhanced by blocking or directing the light much in the same way as an ordinary flashlight, and does thus have a strong security. [57] [58]

There are already companies developing new Li-Fi LED bulbs with successful results in consumer grade products. [60] The real world applications of Li-Fi networks can be public internet access, wireless networks in areas where radio frequencies are impossible (high risk areas) [57], traffic control with car headlights communicating with traffic lights [57] or wireless sensor networks in buildings where the sensors communicate with the lighting fixtures.

The prerequisite for Li-Fi is that every lighting fixture is connected to the Internet, most likely via Ethernet. The adaption of Li-Fi by lighting manufacturers would enable HVAC (and many other) sensors to communicate with the already “mandatory” lighting fixtures in the buildings, but this would also require sensor manufacturers to add Li-Fi transceivers in their products. The Li-Fi technology is still very new and have not yet gained much mainstream popularity. The concept is proven but must overcome these hurdles before larger deployments can be made.

4.3.3 Other industries

Currently, 99,4 percent of physical objects that can potentially be classified as the Internet of Things if connected are still unconnected. [53] [5]

In Figure 9 we can see an example of different markets and stakeholders contributing to the IoT framework [3]. The interaction between these different devices from a variety of services, and the availability of data from completely different areas, such as vehicles and weather stations; logistics and management etc., will lead to the development of a number of new software applications and services that are still very hard to predict today. It is very important that adaptors of IoT understand the importance of analysing the data from many different industries to get the most benefit. As big data becomes more important, the need for data understanding and cooperation becomes more clear.

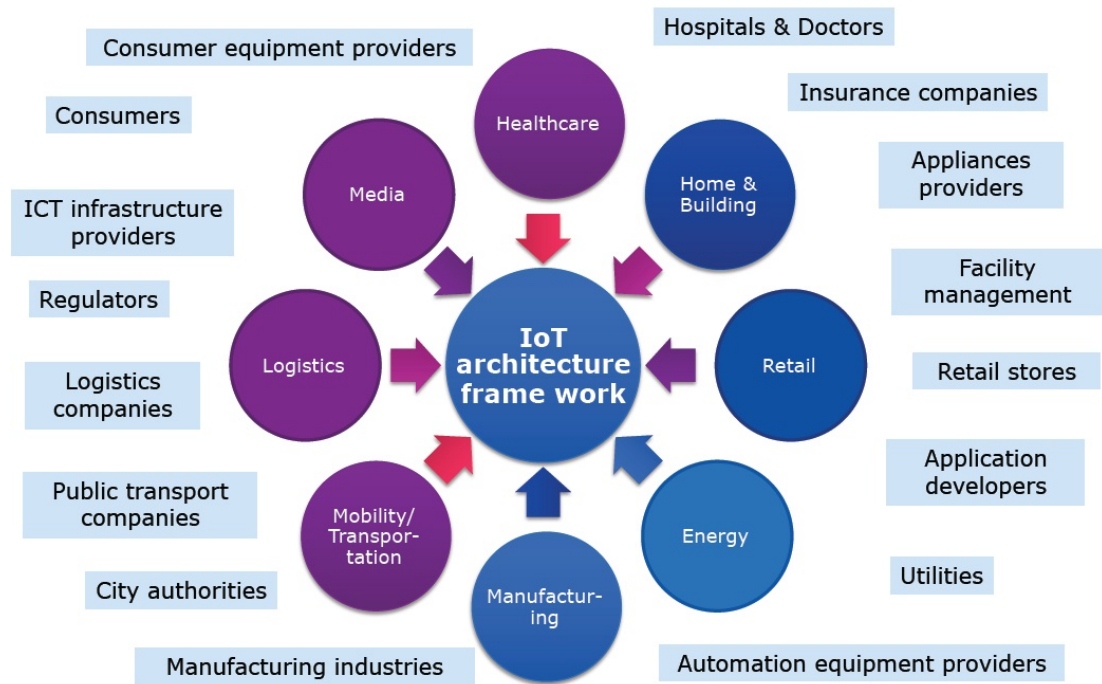


Figure 9 IoT markets and stakeholders [3]

4.3.4 Smart buildings and cities

While most companies and developers will look for solutions to integrate their own products and services into the IoT realm, the impacts on a larger scale will also become apparent as more and more new applications of IoT systems are made available. Many smart, interconnected systems can together create a smart building, or smart house, while many smart buildings and the surroundings can create a smart city. There are a lot of current issues and annoyances that can be tackled with connected devices, ranging from parking to social services and commerce to logistics. These systems can together create smart cities. The goal with these systems is to make better use of the resources available, or to increase the value of these resources while reducing the costs. It is estimated that as near as 2020, the smart city market is at hundreds of billions of euros [61]. This market comes from many interconnected smaller systems and different sectors. These sectors have been noticed in the European Smart Cities project, which also include several Finnish cities. [61] The project defines a ranking criterion that assess the level to which a city is ready to adopt smart systems.

Forum Virium Helsinki is a collaboration by the city of Helsinki, companies in the area and multiple public sector organizations. The goal of this entity is to manage different development projects in areas like “Smart City, New Forms of Media, Growth Company Services and Innovation Communities” [62]. One of the projects that have started is the new Kalasatama district, which will be built as a test bed for a larger scale “smart city”. The vision of Kalasatama is to be able to save one hour of each resident’s time every day.

There are five main ideas for the smart city that are planned to become reality by 2020 in the district, that rely on technology made possible by IoT applications. These ideas are: [62]:

- Restaurant Day every day, with IoT providing the platform for finding restaurants.
- Shared (electric) vehicles, where users can see the position of available vehicles in the area
- A solar panel cooperative, which are situated on rooftops or balconies. Residents can buy shares of the production capacity.
- Flexible space service, where companies and residents can rent their spaces much more flexible than before. Renting is done by hour, day or month.
- Boat share and ride, for the same applications as shared electrical vehicles.

Other applications in smart cities could for example be waste management, that is an area which is already in use in some cities as pilot projects. By having a sensor in every waste bin, the system can monitor when a bin is full and with this information only collect waste when needed. With this information, it is also possible to calculate the optimal collecting routes for cars, and thus lowering transportation costs.

The energy consumption of cities can be monitored with sensors on the field. This way authorities and the public can get a view of how much each different service requires energy and with this information make better decisions. These systems could also be used for predicting power peaks and controlling short term power production in advance. The sensors can include weather, presence and daylight sensors, and optimize street lighting with this information. The European union directive for energy efficiency has a goal of reducing energy consumption by 20% from the projected consumption in 2020. The monitoring and increased efficiency this technology can provide can help cities achieve this goal. [61].

IoT systems can control and monitor home appliances such as AC-units, washing machines, refrigerators etc. This will give the user information about the energy consumption of these units as well as the condition and possible maintenance needs in advance [6]. As the homes become more connected, the residents are helping in realizing the IoT paradigm by enabling more and more devices to be connected to the Internet.

4.3.5 Cases

The city of Padova, Italy, is one of the first city-wide installations of IoT as a proof-of-concept. The technology is used for ICT solutions in the public administration, but the data is open for the public. The systems around the city are collecting environmental data and monitoring street lighting through wireless nodes with an array of sensor configurations installed in the existing street light poles. These nodes are connected to a gateway and making it possible to monitor the city from a centralized

location. The system will alert city authorities if it notices light intensity dropping, indicating a broken street light. The applications in the city are relatively simple, but the system is built as a proof-of-concept of IoT devices communicating with each other with the required link layer technologies for large expansions. The paper concludes that the enabling technologies have already reached a level of maturity to make IoT applications possible, and that the installation in Padova is a practical example of this. [61].

The city of Boston has released an application for smart phones that help their residents to improve the road conditions on their daily commutes. The application uses the phones accelerometer and GPS position to determine where potholes are situated in the city. Whenever a user with the application installed in their smart phone drives over a pothole, the accelerometer detects the bump and sends the current GPS location to a central server. The system uses big-data analytics to determine the location of potholes and cross references it with speed bumps, and thus giving road maintenance an up-to-date map of pothole locations throughout the city. [2]

5. Impact of IoT on electrical engineering

5.1 *Changes in the macro environment*

The increased globalization of companies and heightened customer expectations through all industries are creating immense pressure on organizations to renew themselves [4]. While there are many new applications emerging throughout every industry that will change the everyday lives for most people when breaking through, the users of IoT technology and systems are the ones capturing the value. It is estimated that IoT-customers will capture 90 percent of the value created in forms of smart and optimized business processes. This value comes both in direct and indirect values, such as the prevention of losses in the supply chain or more efficient machinery. [5] This is an important part and must be considered in electrical engineering as to be able to present available options to the customers. Electrical engineers have traditionally been the engineer in the building design group that is on the cutting edge of technology especially with regards to computer systems and network planning [38]. Electrical engineers need to have the knowledge and anticipation of how pioneering customers might develop their businesses and help them achieve their goals in terms of enabling the technology.

5.2 *Preparations for IoT*

Even though it is still a few years into the future before we will start to see serious IoT applications on scale [41], companies must find ways to innovate faster [4]. While there are a lot that can be done with the current business models to prepare for IoT, there is also a need to acknowledge that IoT may force businesses to see over their business models in terms of where the real value for the customers lies. The ability to monitor already installed products in the field can give designers clues to how the systems are being used and what can be done to improve on current practices. Designers may also be able to identify other needs and systems that the customer might not even be aware of, thus increasing sales.

By acknowledging that IoT and automation in general will play a much larger part in electrical engineering, one can prepare by being able to offer some of these services which might traditionally be included in the automation or HVAC-engineer's business models. The fusion of HVAC and lighting control with other building services, e.g. access control, fire alarms and such, is a real possibility in the near future. With this, more of the automation and even HVAC controls are treading into the realm of electrical engineering. This fusion of different systems will also have a direct practical impact on electrical engineering, mainly by changing the way systems are configured. Most of the currently individual systems information are wired with separate cables or buses, whereas a fused system can share the same bus or with TCP protocol enabled

devices, use the same generic ICT cables that are used for Internet access. This also means more centralized systems, with easier to manage control rooms.

The current ICT commissions to electrical engineering consists almost entirely of cabling and racks built in specific places. The customer is almost always responsible for any switches and routers the network might need, since they are also responsible for the maintenance of the systems [63]. This role might be challenged if some of the building systems start to use ICT cabling and therefore the electrical engineer will be liable for the system configurations and how different systems are able to be interconnected.

Companies should continue to identify how to gain the most value from IoT emergence. There should be widespread knowledge throughout the company in order to be able to identify possible business opportunities, and to be able to contact the right partners outside of the usual scope of business to consult about new ideas. The advancements in wireless protocols and data gathering in building services will become more pronounced and keeping up with recent changes will become vital [41].

Devices and everyday appliances will be addressed and controlled via the Internet, which would help get rid of special communications protocols and proprietary gateways. This makes devices more versatile and easier to manage on a larger scale and they will begin behaving like Internet nodes with their designated IP address. This will also allow devices to communicate with each other, as earlier stated that it is one of the prerequisites for IoT. The use of IP protocols will use existing Internet services which also allows them to be monitored and controlled from anywhere. [3]

The complexity of IoT systems will undoubtedly become an obstacle for many companies and therefore organizations will need to look for outside assistance and partnerships. The ability to create the right relationships with outside partners will be much more important than the ability to create the technology. [4]

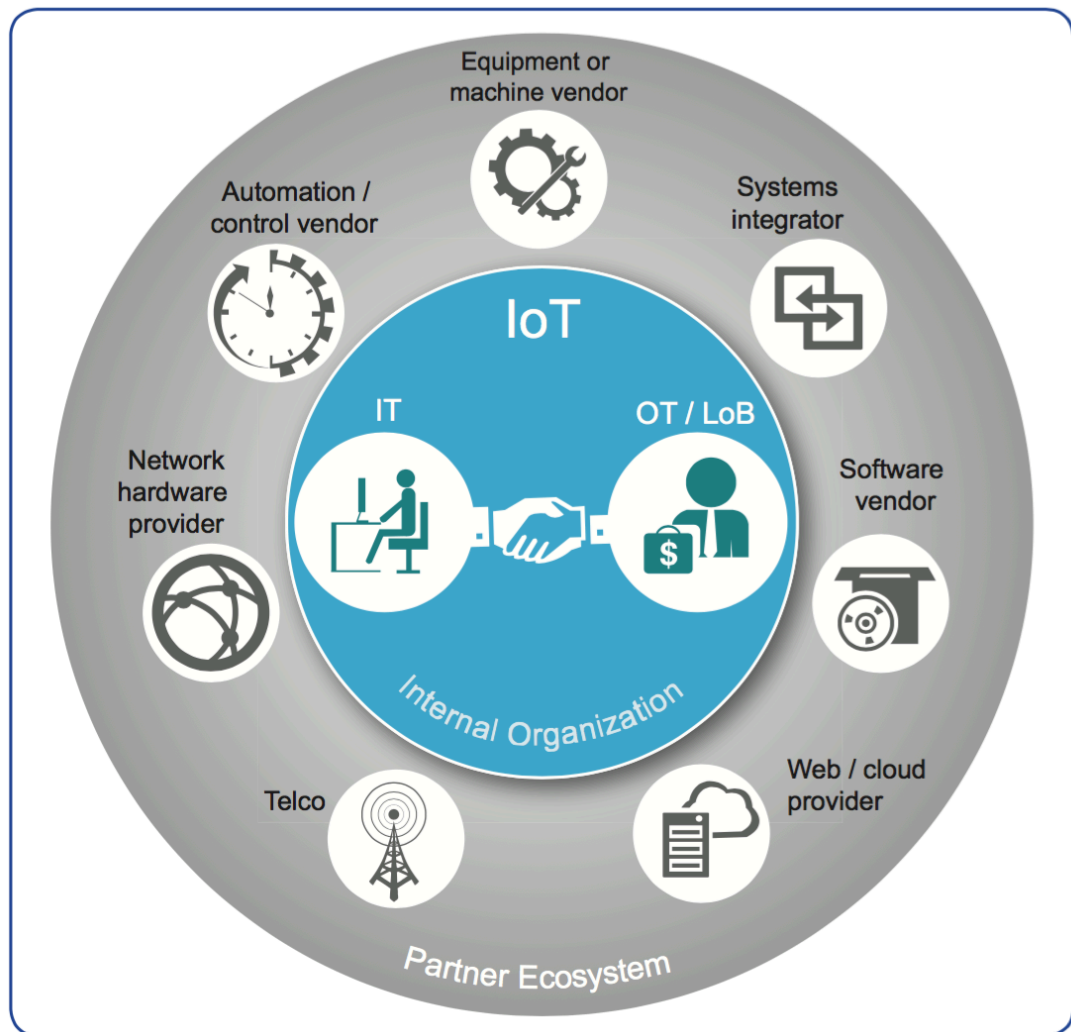


Figure 10 Success requires an ecosystem of internal and external partnerships. [4]

Figure 10 illustrates some examples of typical partners an organization will benefit from acquiring. These partners range from technical network and telecom providers, software and data/cloud providers, to equipment and machine vendors and related automation vendors. A company will have to be open to new partnerships outside of the current partner ecosystem in order to pursue IoT opportunities.

There are several test-beds and think-tanks around the world devoted to IoT, both collaborations and internal organizational tanks. One of the more prominent ones in Finland for companies interested in IoT is the Finnish Industrial Internet Forum, or FIIF. The goal for FIIF is to create “growth paths for Finnish companies” [64]. The forum organizes events and discussions among members. The three main activities that FIIF organizes are:

- Jam sessions, where members can pitch their ideas and share their success (or failure) stories.
- Hot spots, for rapid prototyping of ideas, where members can test their ideas in practice and “learn or fail fast”

- Future avenues envisioning, for discussion and identification of possible future scenarios.

Companies that decide to develop IoT applications should join forums like FIIF in order to share ideas and gain new ones from companies in different industries. As there is no right answer on how to proceed with IoT development, idea sharing is essential.

5.3 *Big data in building services*

In a survey conducted by Cisco, the responding companies acknowledged that data is the area that they most need to improve upon. The majority understood that the “things” are just tools to gather data. The insights from the data can give businesses the means to drive transformation and renewal of business models and practices. [4] The survey show that only 13% see the “things” as challenges when moving towards the Internet of things. Figure 11 shows that an overwhelming 40% see data as the area that is the most challenging.

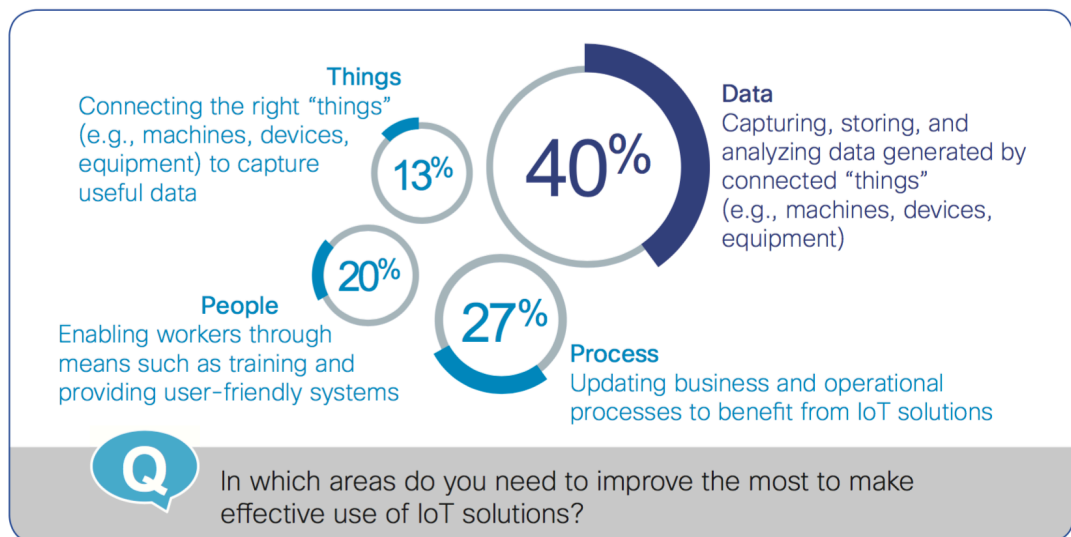


Figure 11: Survey conducted by Cisco regarding IoT solutions [4]

Big data can analyse very large volumes of data of unstructured information. The goal is to find unknown correlations and hidden patterns which lead to more effective use of the customer’s resources. The sensor data from building services is today mostly used to control real time processes and alerts for maintenance. There are many applications where storing data can for example lead to predictive maintenance schedules both for the building owners as well as device manufacturers. The data collected from multiple sites could also be sold to other services providers or manufacturers to help them develop their current product line-up or to create new services based on the collected data, and how their customers are using their products in real life situations [2].

While the first applications of big data processing are going to be horizontal applications, the true value of the data is when combining building services data with information from other systems, such as customer/sales data, production line sensors, tenant information etc. The industry in which the customer operates dictates which data is on hand, and what is most sensible to use. The results can help companies make better business decisions, offer more effective marketing strategies or even open new business areas.

5.4 *New discipline: data engineer*

There are many new possibilities for technology suppliers and engineering firms to capture value from the IoT emergence. One of the largest opportunities is for software and service providers [5]. By collecting raw data and converting it to valuable knowledge, companies with big-data analytics can give their customers new services [2], not currently offered in the building services industry.

Businesses should consider the new discipline of a data engineer when designing new buildings. The data engineer would be responsible for planning the sensor/actuator network in the building by consulting both the electrical and HVAC engineers. The data engineer would also be responsible for the storage, processing and distribution of the data and actuator control.

The data engineer would also be responsible for the network infrastructure, which could later on be offered as a service to customers, thus creating a longer contracts and higher customer lifetime value. This might also help in securing future electrical engineering contracts with the same customers. While the data engineer would be responsible for the service part of the customer experience, the electrical engineering department could concentrate on the same things they have been doing to this day. This is beneficial in engineering firms, where the employees consist of many different age groups with different attitudes towards new IoT technology, both in terms of learning the new technology and to be able to suggest it to the customers.

In all industries, the value of IoT data will become more apparent and with careful preparations, companies can have strategies in place for protecting this value [65]. Even though the data from the sensors in a building would not necessarily be available to the data engineer after the project is done, mainly because most of the building developers do not fully understand, or embrace the possibilities with data collection. The data engineer would need to consult and convince developers of the possibilities with data collection, even if not applied at the moment to the process, but as a reservation of possible future use.

5.5 Smart cities

Electrical engineers and data engineers must become more informed of what is happening around the buildings in the area. Currently the only connections from a building is the utilities, water, sewage, electricity and broadband. In the future all systems, or even all things, will be connected to the outside via the Internet. With all buildings becoming more and more connected, they will develop into smart districts and smart cities, which in the case of IoT is very much similar in the philosophy of connecting systems to a even larger ecosystem to create more and better services.

As applications in smart cities grow, the issues around safety becomes more apparent. Especially when dealing with traffic control. With subpar traffic control systems, cars will crash or traffic jams become more common which in turn can lead to emergency services being delayed [65].

5.6 Markets

While most of the emphasis and attention of new IoT innovations are geared towards consumer products, mostly because of the broader market appeal and therefore larger media coverage, the potential economical impact of IoT is more likely to come from business to business (B2B) applications. Many of worksite applications will impact the manufacturing processes and their optimization, with no direct impact for the customers (except the obvious cost-benefit). While business to customer (B2C) applications will most certainly create value for the customer in terms of new experiences and possibilities, it will only marginally lower costs to the customer, the B2B applications will be used mostly for lowering production costs. In the beginning IoT will probably raise costs for the customer-products in short term when the technology is still new. [5]

Electrical engineers need to look into providing long term services for their customers. This can be done with integrating the said building data engineer with the customers' chief information officers (CIOs) and together decide and investigate how the data from building services could be used for better business decisions within the customer's company. Since IoT will become common in every industry, the expertise of the data engineer will mainly be in building services.

6. Conclusions

The confusion among the general public regarding the Internet of Things is significant. This is due to many companies and manufacturers using their own derivations of the phrase, like “Internet of Everything”, “Industrial Internet” whichever fits their agenda and describes their product line the best. Some companies are using IoT as a synonym for “smart devices”, which further confuses customers. Even though the term IoT have been around since 1999, companies and the media have not decided on a common phrase to use, and therefore many different organisations have started collaborations in order to create a common definition of what the Internet of Things is.

The world of interconnected things that make up the IoT universe, is still beyond imagination with many wild ideas floating around. The main goal is to enhance our current way of living or to enable completely new applications. The cross use and analysis of big data from many different sources and industries help business leaders make more informed decisions and more accurate predictions of the future. In building services, more systems will be interconnected and share data in order to have a more coherent understanding of the state of the premises at any given time, with predictive maintenance and automatic fault reporting. Buildings will become connected with other buildings and services, and together create smart cities and societies.

Many companies are working hard on making this dream a reality, and in the process have their share of the emerging market. One of the biggest prerequisites for IoT systems is low cost sensors and electronics. This trend with prices going down while performance rises, has given small companies and hobbyists the means to pursue the IoT market and create applications that earlier was only possible by large PLC manufacturers with huge R&D departments.

The lighting and building services industry will also have to adapt to this new technology. Current lighting control systems, for example DSI, DALI and KNX, will probably be replaced with IP addressable light sources. The simplicity of a ubiquitous IP based system far outweighs the benefits any of the current control systems currently enjoy. There are already some lighting systems on the market that can be classified as IoT, but since the amount of data from other sources is still lacking, a true IoT ecosystem is not yet still available.

Currently in building services design, electrical engineering has a clearly defined role and responsibilities stated in the TATE 12 description list. The current automation designers are more concentrated on HVAC automation, since this is their primary tasks in TATE 12. This is about to change since the emergence of IoT will bring automation design closer to electrical design as more and more electrical (or electrified due to IoT) devices start sending sensor information and become controllable. The emphasis for automation will switch from HVAC to “things”. It is thus advisable to consider the possibilities to hire automation engineers in electrical engineering firms to prepare for this shift in focus. In time, with sensors generating big data, the automation engineer

in electrical engineering firms can divide into classical automation engineers and create a whole new discipline, the data engineer. The data engineer would be responsible for collecting, handling and analysing the data generated by sensors and devices in the building.

One of the more important preparations for IoT is to build reliable partner networks. IoT has too broad a scope for it to be plausible that a single person or company can give IoT advice in all industries as an expert. This is comparable to the emergence of the Internet. Some people understood how the Internet worked and could very efficiently utilize the new tools that were available. After a while, when the Internet grew exponentially and became an everyday tool, experts in all industries replaced the Internet or ICT experts as they became obsolete. Even though the mind set in many companies that explore IoT opportunities seem to be that there should be IoT experts, this is not a sustainable long term strategy. Companies should instead offer their consultancy within their area of expertise and become IoT evangelists, and preach IoT to customers who will build and expand IoT systems and this way contribute to a even larger IoT ecosystem.

Big data will be the next valuable resource, since the intelligence of systems is dependent on massive amounts of data. The use of a data engineer in building design teams would promote the thought of data as a resource much in the same way as water or electricity. All data generated should be stored and analysed if possible to find new patterns. With the generated data, the user can produce knowledge. While knowledge is the most crucial outcome, the data should be stored for future use for discovering correlations with currently unimaginable data sources. Companies need to investigate what big data can be harvested from customers while keeping their privacy a top priority. The negligence of privacy and security can result in massive data breaches which will be considered much in the same way as electricity theft, and seriously harm to a company's image and brand. The impact of a such breach will be emphasized in the future and cause much more than a data breach will harm today.

Hand in hand with security comes openness. It is possible that in the future, engineers must consider what kind of API the building should have. If the building has services such as hairdressers, there might be a queue query; if the building has shops, the API can have a warehouse query. The APIs of adjacent buildings and city traffic control can also be queried by the building, for example informing its residents of traffic jams on their way to work or their favourite washing powder running low, but the local market doesn't have it in store, so you will have to take a detour etc.

There is no doubt that IoT will change the way we interact with devices, things or systems. There are no right answers or tried business models. There will definitely be a lot of mistakes and wrong decisions made, but the importance is to make informed decisions.

7. References

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