LAPIN AMK
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SMART HOUSE

Analysing benefits of Internet of Things to residential homes in Finland

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Älytalo tarkoittaa taloa, jossa on käytössä esineiden internet eli Internet of Things -tekniikkaa sisältäviä laitteita, jotka kommunikoivat keskenään langattomasti. Älytalo on tullut teknisesti mahdolliseksi kahdesta eri syystä, eli aina halventuvasta prosessorilaskentatehosta ja laajakaistaisten Internet-yhteyksien markkinaosuuksien kasvusta. Älytalossa voi olla monia hyviä ja käytännöllisiä sovelluksia kuten etäohjattava valaistus, etäohjattava äänentoistolaitteisto ja turvaominaisuuksia, esimerkiksi liiketunnistimia ja valvontakameroita.

Tämä tutkimus tutkii älytalojen laitemarkkinoita ja markkinoilla olevien yritysten tarjoamia erilaisia sovellutuksia. Tämän tutkimuksen päämääränä on määritellä, kuinka älytalo toimii ja kuinka älytalon eri laitteet kommunikoivat langattomasti keskenään. Tämä tutkimus perustuu älytalolaitteiden markkinatilanteeseen syksyllä 2015.

Tämä tutkimus tehtiin laadullista tutkimusmenetelmää käyttäen; suurin osa tiedosta kerättiin analysoimalla kriittisesti keskeisiä tieteellisiä lehtiartikkeleita ja muita luotettavia lähteitä. Luotettavista lähteistä kerätty tieto esitetään syntetisoimalla, ja tämä tutkimus sisältää myös tekijän omia näkemyksiä.

Tämä tutkimus vahvistaa sen, että älytalotekniikkaa on jo käytössä Suomessa. Kuitenkin tekniikka saattaa olla vielä liian kallista massamarkkinoille, ja eri valmistajien laitteiden kesken on myös olemassa yhteensopivuusongelmia. Tämä tutkimus myös osoittaa, että on olemassa joitakin tietoturvaongelmia, jotka pitää ratkaista ennen kuin älytalotekniikka laajenee massamarkkinoille Suomessa.

Avainsanat esineiden internet, älytalo, laitteet

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Abstract of thesis

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Smart house means a house equipped with Internet of Things enabled appliances that communicate with each other. Smart house has become technically possible because of two reasons. Firstly, by the ever decreasing price of processing power, and by the increasing penetration of broadband Internet connections in households. Smart house can have many good practical applications such as remotely controllable lighting, remotely controllable stereo systems and security features, for example motion detection and security cameras.

This study explores the smart house appliances market, and the different solutions that different corporations offer. The objective of this study is to define how smart house works, and what some of the most popular appliances used are in a smart house. The research specifically analyses the technical aspects of how different smart house appliances communicate wirelessly with each other. This research is written based on the status of the market situation of the smart house appliances in autumn 2015.

This study was conducted by using qualitative exploratory research methodology, and most information was gathered by critically analysing relevant journal articles and other reliable sources. The information gathered from the sources is presented by synthesizing, in addition to which this study includes personal contribution.

The results indicate that smart house technology is already in use in Finland. However, the technology might be too expensive for mass market currently, and there are some compatibility issues between devices made by different companies. This study also found out that there are some security risks that need to be dealt with to enable a wide use of smart house technology in Finland.

Key words Internet of Things, smart house, applications

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SYMBOLS AND ABBREVIATIONS

2G	Second generation mobile technology, including GSM
3G	Third generation mobile technology, including UMTS
4G	Fourth generation mobile technology, including LTE
ADSL	Asymmetric Digital Subscriber Line
App	Application
Bluetooth	Standard for communication between devices, originating from Viking Harald Blåtand
ESH	European Society of Hypertension
GSM	Global System for Mobile Communications
GPRS	General Packet Radio Service, an addition to GSM
GPS	Global Positioning System
HSPA	High-Speed Packet Access, an addition to UMTS
HVAC	Heating, ventilating, and Air Conditioning
IFTTT	If This Then That
IoT	Internet of Things
LTE	Long Term Evolution
NFC	Near Field Communication
RFID	Radio Frequency Identification
RF	Radio Frequency
UMTS	Universal Mobile Telecommunications System
Wi-Fi	Marketing term for IEEE 802.11 standard compliant devices and networks
ZigBee	Standard for communication between IoT devices
Z-Wave	Standard for communication between IoT devices

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1 INTRODUCTION

First background information including the main topic and motivation of the study are presented. Further, objectives are described, research questions and methodology is given, and lastly the structure of the thesis is given.

1.1 Background and motivation

This thesis researches the possibilities that Internet of Things (hereinafter IoT) can provide for residential homes in Finland. The motivation for this research is my own interest in IoT technology and its applications. Smart house was chosen as the focus of this research as all humans live in some sort of home. “The Internet of Things revolves around increased machine-to-machine communication; it’s built on cloud computing and networks of data-gathering sensors; it’s mobile, virtual, and instantaneous connection; and they say it’s going to make everything in our lives from streetlights to seaports ‘smart.’”. (Burrus 2014.)

Smart house means a house that has sensors and devices that provide additional comfort, security and convenience to its residents. Several possible features of a modern smart house can be centralized control of lights and other electrical appliances, HVAC (heating, ventilation and air conditioning) and security features for example motion detectors, cameras and locking all doors of the house with the push of a button on smartphone. The technology that makes all these devices and sensors work together is called Internet of Things. IoT means interconnecting identifiable devices with the existing Internet Infrastructure. As there is no one single IoT standard, IoT is an umbrella term for all different technologies connecting devices through the Internet.

IoT technology is arguably one of the hottest trends on IT today, i.e. in 2015. However, a question to answer is why is it only becoming reality now? The reason is that computer processors used to be as expensive as a small car, and therefore even in the 90’s the technology was still too expensive for consumer market. Today the reality is different, and as processing power is relatively

cheap, people can install processors on objects and appliances that people could not afford before, for example on a toothbrush or coffeemaker.

1.2 Scope and objectives

The scope of this research is narrowed down to investigate applications that smart house devices can provide to residents' use. This research also analyses how Internet of Things works in order to understand how smart house appliances work.

The objective of this study is to explore the smart house appliances market, and the different current and future applications, what IoT technology can give to people. An important aspect of this research is also the comparison of different solutions and how well they work together. An important stepping stone towards understanding connected home is knowing the ways which the solutions are integrated. The secondary objective of this research is to find out general information about IoT, and different applications that can take advantage of it. The target group of this research are companies and people working with IoT-technology.

1.3 Research questions

This study addresses three research questions, which are discussed below.

Research question number 1:

What are the main technologies used in smart house appliances and systems? How can smart house technology facilitate the lives of its residents?

This research question aims to discover knowledge concerning how smart house appliances and technologies work, and how different appliances com-

municate with each other. The second question related to the first questions aims to gain knowledge about how smart house technology can make the lives of its residents easier.

Research question number 2:

Which companies produce smart house appliances? Which of the different solutions offers the best compatibility and flexibility?

This research question aims to gain knowledge of different companies producing smart house appliances. Residents in mass-market generally want products that can be plugged in to use them. Therefore, analysing the different solutions is important.

Research question number 3:

What are the main technologies of IoT? How can societies benefit from IoT applications?

This research question aims to analyse the technologies of IoT; the second part of this question aims to gain knowledge of how societies can benefit from the increased technology in households.

1.4 Research methodology

This research is entirely theoretical, but the companies and products in examples are real. This research is a qualitative exploratory research including critical analysis of relevant journal articles and other acknowledged sources, synthesizing information from various sources. The qualitative method was chosen because the information on this research derived from a combination of analyses of various sources is qualitative, complemented by some personal contribution.

1.5 Thesis structure

This thesis is divided into 5 chapters. Introduction, background, motivation, scope, objectives, research questions and methodology are described in this chapter. Chapter 2 concentrates on IoT, and the definition of the concept. In chapter 3, the focus is on smart house. Chapter 4 discusses the benefits and challenges that societies face with the technological innovations discussed in previous chapters. Conclusions are provided in chapter 5.

2 INTERNET OF THINGS

The general idea of the IoT is discussed in this chapter including the technological aspects of IoT, most common programming languages used in IoT and the data infrastructure of IoT. In the technology subchapter, the most used wireless communication technologies of IoT are also discussed.

2.1 Concept of IoT

IoT means connecting various existing appliances to the worldwide Internet, thus expanding their ways of use. IoT has many good practical applications for example earthquake early warning system, automated electric and water meter reading, centralized control of lights and other appliances, security and HVAC. According to Ofcom (2015), the United Kingdom already has 40 million IoT devices in 2015. It is expected that the global number of IoT devices to be 50 billion in year 2020. (Barrie 2015.) According to Xavier (2014), the global market for IoT maybe $290 billion USD by 2017. Smart houses are based on IoT technology, and require constant network connectivity and electrical supply to function maximally.

According to Porter and Heppelman (2014), IoT devices have three core elements: physical components, smart components, and connectivity components. Physical components mean the traditional components that are required for the device to work at all. Smart components increase the capabilities of the physical components and provide additional functionality. Connectivity components increase the capabilities of smart components and make it possible to some of the features of the device to work outside of its physical location. (Porter & Heppelman 2014.)

According to Barrie (2015), one way IoT can provide benefits in the United Kingdom is Intelligent Transport Systems. British communication agency Ofcom has a vision of “a world where cars communicate with each other, making traveling from A to B smoother and safer.”(Ofcom 2015.) According to Ofcom

(2015), these systems could be used in the next 10-30 years. In the Intelligent Transport System cars and roads would be equipped with sensors. The sensors would monitor the amount of cars on the roads, send the information to the central traffic control system, and the system could automatically impose speed limits to decrease amount of accidents. Cars could also communicate with each other independently, and the cars could accelerate and brake in unison. (Ofcom 2015.) According to Ofcom (2015), “fragmented movement on motorways is a significant cause of congestion.” In the future, it might be possible for the driver to just sit back and relax while the car drives itself. (Ofcom 2015.)

2.2 Technology

IoT is based on existing technology. Perhaps the most important technology that IoT takes benefit is the Internet. It is possible to have local smart devices for example in a house, but for a house to be truly smart, it needs to have Internet connectivity. According to Slovick (2013), “Arguably the toughest hurdle” that designers of IoT devices are going to meet is the selection of technology to connect all the different devices. Smart Home appliances today use a manufacturer selected combinations of Bluetooth, Wi-Fi, cellular networks, ZigBee, Z-Wave, RFID and NFC. However, there is the question of which should be the standard, as all these built on one device increase the manufacturing costs. Mobile operators are in favour of their networks to become the backbone of the IoT, but even tough cellular modems are becoming increasingly cheaper, it is still easier and cheaper to use Bluetooth, WiFi or ZigBee at the local level instead of cellular networks. Slovick (2013) backs up his statement by the fact that “about one out of every eight Apple iPads sold has a built-in 3G or 4G cellular connection, but over time, very few (estimates suggest less than five percent) of those units result in permanent cellular subscriptions.” As an example of manufacturer; Greenpeak makes radio chips that “are designed for the new smart and connected home – a network of appliances, sensors and entertainment devices – all linked to the set top box and from there to smartphones, remote controls, tablets and mobile devices.” (Greenpeak Technologies 2015.)

2.3 Software

IoT is based on existing software languages. C++, Java, JavaScript and Python are all used while programming IoT devices. (Curtis 2015) Apart from the more advanced programming languages, C or Assembler code is still usually running at the lowest level of device, which is firmware. Apart from programming language, one important software aspect of smart house is operating system. Microsoft HomeOS is an operating system developed by Microsoft to be used on smart homes. According to Microsoft (2015), HomeOS is centralized, and it offers holistic control of devices in the home. Microsoft is planning to make the control interface of the HomeOS intuitive, to enable users an easy control of their home. HomeOS is going to be coupled with a HomeStore, where users can obtain applications that interact with the devices already present at their house, and users can also purchase additional new devices. The system also informs if certain devices could make some applications more useful, i.e. motion detector to be bought when the user already has security cameras and is running a security software. Apart from HomeOS, Microsoft has also created IoT version of Windows 10. (Microsoft 2015.)

Apple is also developing a system called HomeKit. HomeKit is not a complete smart house operating system similarly to that of Microsoft's HomeOS; it is a communication framework that allows the control of connected smart appliances that support it. It is heavily Apple-centric, and allows easy control from iPhones, iPads and Macbooks but it is not compatible with other operating systems. HomeKit is designed for a person who prefers Apple over Microsoft, and thus it is probably never going to as popular as Google's and Microsoft's solutions. Despite not being as popular as some other solutions, it offers great functionality, and for example Philips HUE lights can be controlled by talking to Siri, Apple's virtual assistant. (Apple 2015.)

2.4 Data infrastructure

Data infrastructure is an important aspect of a smart house, as it can have an own home server, or all data can be stored on remote servers in the cloud. Figure 1 shows the most common data infrastructure model of IoT (Neratec Solutions AG 2015.)

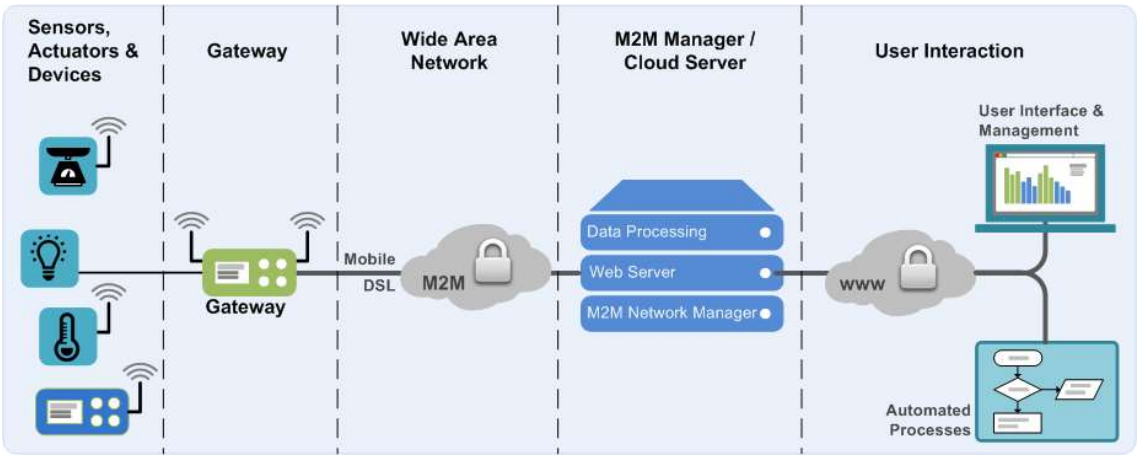


Figure 1. The data infrastructure model of IoT (Neratec Solutions AG 2015)

Figure 1 presents that the lowest level of data is sitting in the sensors, actuators & devices, and to get that data out of those devices a gateway is needed. Gateway can be a Zigbee or Z-Wave hub, or other similar device. The hub then connects to the Internet router by Wi-Fi or Ethernet. Internet router passes the information by along by connecting to landline or mobile based connections, usually fiber optic, ADSL, cable modem or 3G/4G, and the information travels by the Internet to a server somewhere. The server ‘cloud server’ does the data processing and offers user interface for the owner to control the devices. Cloud server can also act according to pre-set rules, i.e. keeping temperature at safe level, or alerting police if motion detected.

Belkin WeMo appliances and Philips HUE bulbs support IFTTT, an online service where users can connect several applications together, and users can create and share ‘recipes’ to be used. Recipe means an if-statement. For example; if SMS text message ‘lights off’ is received, then IFTTT sends command forward to Philips HUE system to turn off the lights. IFTTT is compatible with a wide

range of services and manufacturers including Facebook, Twitter, Instagram, Nest labs, Samsung SmartThings along with the Belkin and Philips already mentioned. IFTTT works by keeping connections to all users wanted accounts on their servers, and sending commands according to input signals coming from different services and devices. Therefore it is acting as a central server.

3 SMART HOUSE

House with IoT enabled appliances that bring additional value to living and make the managing of everyday life easier is called smart house. Examples of IoT enabled appliances include robot vacuum cleaner that automatically cleans the floors, lights that turn off when there is nobody in a room, and a fridge that "automatically order more milk" from the neighbourhood grocery store. (Hammersley 2013.)

Smart house features including lighting can be controlled from smartphone, and if wanted, the house can be connected to the Internet and thus making the management accessible even from other side of the world. Some smart house appliances for example motion detected lighting and robot vacuum cleaner can work independently, but a house becomes truly smart only when there is a computer controlling everything. The computer can be local or a server computer part of a system operated by a company far away. However, there needs to be one computer that manages the entire house, and where residents connect by their smartphones to control the house appliances.

On aspect of smart house is that it is allegedly eco-friendly. Lights that turn itself off when nobody is in the room can indeed offer power savings, but the increased amount of complicated electrical components in regular household items is not especially eco-friendly on my opinion. One way to increase the eco-friendliness of a smart house is to install solar panels. Electricity can be produced by solar panels, and solar panels will also offer some independence from the power grid.

3.1 Technologies of smart house

Smart house takes advantage of existing technologies including Internet connectivity and electricity. Another advantage are technologies that connect smart house appliances together. Traditional technologies including Wi-Fi and Blue-

tooth are widely used, but there are also developed technologies that work more efficiently among smart house appliances. For wired connections, Ethernet and USB are used.

3.1.1 ZigBee

ZigBee means IEEE 802.15.4-standard defined short range communications network. ZigBee is controlled by ZigBee alliance, with over 400 members including Intel, HP and Philips. The membership fee of ZigBee Alliance is 3500 US Dollars, and that gives a member the right to use the standard commercially. Therefore ZigBee is quite affordable for manufacturers compared to other technologies. ZigBee uses 868 Mhz and 2,4 Ghz frequencies in Europe, and 915 Mhz in United States. (Zigbee Alliance 2015.)

To this day the most popular use for ZigBee has been on smart light bulbs. Market leaders Philips and Belkin both use ZigBee on their smart light bulbs and Samsung also supports ZigBee within its SmartThings product line.

Zigbee is good on communication between devices that does not need to transfer a lot of data, as the transfer rate is quite low 20 kb/s at 868 MHz and 250 kb/s at 2,4 GHz . This low transfer rate is also a limitation as it is not suitable for transferring a lot of data. Another negative side of ZigBee is interoperability between devices made by different manufacturers. In theory, all devices should work together, but in reality they do not as sometimes there are differences with how different manufacturers implement certain features. This problem is caused by the same thing that makes ZigBee popular, the fact that the standard is not as tightly controlled as Z-Wave. (Zigbee Alliance 2015.)

3.1.2 Z-Wave

Z-Wave can be seen as a direct competitor to ZigBee as they both offer similar functionality. Z-Wave is also based on alliance, and it is supported by 325 companies, but to this day it has been clear that ZigBee is the more popular choice.

Most popular uses for Z-Wave include security solutions, i.e. door locks, and also smart lighting similarly to ZigBee. Biggest difference to ZigBee is that Z-Wave is expensive. Due to smaller demand than ZigBee, Z-Wave components are more expensive and the alliance also enforces expensive license fee. This research did not find accurate information about Z-Wave licensing fees, but some rumours say that the licence fee might be up to $30 USD per device sold. (Z-Wave Alliance 2015.)

Z-Wave operates at 900 MHz, and has real life transfer speed of 100kbit/s, 5 times the speed of ZigBee at 868 MHz, 20 kb/s. Despite Philips and Belkin not supporting Z-Wave, there are still some devices using Z-Wave including Samsung, Fibaro, Hauppage and Schlage's and Yale's Connected Touchscreen Deadbolt door locks. Despite ZigBee being the more popular choice, according to Kastrenakes (2014) Z-Wave offers superior compatibility across devices from different manufacturers due to tighter control of the standard by the alliance. (Z-Wave Alliance 2015.)

3.1.3 Bluetooth

Bluetooth is a communication protocol originally designed by Ericsson in 1994 for transferring data between mobile devices, but its uses have been expanded to a wide range of different use case scenarios. The licensing cost of Bluetooth is several thousand USD annually, and it varies by company size. Bluetooth operates at 2,4 GHz, and has transfer speed of 3,0 Mbps in 2.0 standard or even 24 Mbit/s with Wi-Fi interoperability. Bluetooth is perhaps the most widespread wireless connectivity technology on par with Wi-Fi, and wire variety of manufacturers use it, including Apple, Samsung, Sony and Bose. (Bluetooth SIG Inc. 2015.)

In smart houses Bluetooth can be used for example to send music from smartphone to stereo system, but in many cases Wi-Fi is better due to short range of Bluetooth and the limitation that one smartphone can be connected only to a couple of Bluetooth devices at the same time. Despite its huge suc-

cess, Bluetooth has no mesh support, and this limits its usage on smart houses severely. (Bluetooth SIG Inc. 2015.)

3.1.4 Wi-Fi

Wi-Fi is a marketing term for IEEE 802.11 standard compliant wireless networks. Wi-Fi is the universal wireless network connection standard, and it is hugely popular, used by all kinds of devices and solutions. IEEE 802.11 includes many different standards which differ mostly in in speed. The most important versions are: Original standard, 802.11, was released in 1997, and it supported a maximum speed of 2 Mbps. 802.11b standard increased the maximum speed to 11 Mbps in 1999. In 2003 802.11g was released, and it brought the maximum speed to a more modern standard of 54 Mbps. The most recent standard, 802.11n, was released in 2009, and it brought the theoretical maximum speed to 600 Mbit/s. These speeds can also been seen on table 1. (Wi-Fi Alliance 2015.)

Table 1. Comparison of most important Wi-Fi standards (Wi-Fi Alliance 2015)

Name of standard	Maximum speed	Release year
802.11	2 Mbps	1997
802.11b	11 Mbps	1999
802.11g	54 Mbps	2003
802.11n	600 Mbit/s	2009

The licencing cost of Wi-Fi is $0.15 per device, and Wi-Fi operates at 2,4 GHz and 5 GHz frequencies. One thing that makes Wi-Fi less suitable than ZigBee or Z-Wave to certain smart house applications is the fact that it has no mesh support on client level. Typical Wi-Fi access point can only cover a small house, therefore bigger houses need range extenders to cover the entire house. Range extenders are quite affordable at the price of 30 €, but ZigBee is more flexible because all devices in ZigBee network work as range extenders, thus making it flexible to increase the range of a ZigBee network. Despite no mesh support on client level, Wi-Fi still is usually the most important network in a smart house.

Smartphones connect to the network, laptops connect to the network, security cameras connect to the network and even ZigBee and Z-Wave hubs connect to the network. Smart house is not a smart house without Wi-Fi. (Wi-Fi Alliance 2015.)

3.1.5 Cellular networks

Cellular networks including GSM, UMTS and LTE are operated by national operators, and they offer direct wireless access to the Internet and telephone network. Usages for cellular networks include smartphones, electrical meters and important security solutions for example security cameras at remote places. Cellular components cannot be usually self-made by manufacturers of smart house appliances, but modems i.e. component that connects to the wireless network, can be purchased from reputable manufacturer for a price. That price is usually not cheap, at least not for recent technology for example LTE. Different cellular network standards in Finland are compared in table 2. (Afterdawn 2015 & UMTS World 2006.)

Table 2. Comparison of cellular network standards in Finland (Afterdawn 2015 & UMTS World 2006)

Generation	Name	Frequency	Speed	First network active
2G	GSM GPRS	900 MHz and 1800 MHz	171kbps	1991
3G	UMTS HSPA	2100 MHz and 900 MHz	21 Mbps	2002
4G	LTE	1800 MHz and 800 MHz	150 Mbit/s	2009

As can be observed from table 2, speed increases radically when upgrading from one generation to another. Speeds listed are of course theoretical maximum speeds, and when in a badly covered area, the speed obtained from 4G network can fall way beyond average 3G speeds. Cellular networks offer good

practical solutions in the IoT landscape, but it is not practical to install a separate modem to every single IoT device, therefore cellular networks are used as Internet backbones, or in remote areas for example in security cameras, but not in every single light bulb in a smart house.

3.1.6 RFID and NFC

RFID and NFC are standards mostly for identification purposes. RFID is mostly used in access cards and other government or other 'authority' issued cards, while NFC is the consumer version of the same technology. If the packaging of groceries would include RFID chips, fridges could know what is inside them. RFID technology is relatively cheap and works at 866 MHz. (Technovelgy LLC 2015.)

NFC is present in most smartphones costing more than 200 euros, and it offers faster way start data transfer. For example, if user 1 wants to send picture to user 2's phone, it can be done by tapping the phones backsides together. The phones share information about the event through NFC, but the actual data transfer is carried by Bluetooth due to higher transfer rate, and longer operational range. Reprogrammable NFC tags can also be bought at affordable prices, and for example in Oulu, if user taps their phone to sticker in a bus stop, the data on the sticker tells the phone to open the timetable for that particular bus stop from the Internet. The licensing cost of NFC is $0.49 USD per sold device, and NFC works at 13,56 MHz with the theoretical maximum speed of 424 kbit/s, although experienced real life speeds are around 100 kbit/s. The slow transfer speed limits NFCs usage to hyperlinks or other small texts, as it would take many minutes to transfer even a small video through NFC. In smart houses NFC tags can be used to automatize actions, for example touching one tag would turn off all lights in a house, and another could light up the lights in the morning, and turn on the coffee maker. (Faulkner 2015.)

3.2 Platforms

According to Chester (2015) “Technology heavyweights Apple, Google and Samsung are leading the charge to make your home smarter as analysts predict an explosion in app-controlled devices around the house”. Chester (2015) also states that “Gartner estimates connected household devices will skyrocket in number from fewer than 300 million this year to more than 1 billion by 2017.” To make all these devices work together, people need platforms. Apart from Google and Samsung mentioned by Chester (2015), plenty of different companies also offer different solutions for smart houses, but the compatibility of solutions made by different companies can vary a lot.

Belkin WeMo is a home automation network that has many different optional products that can be picked and combined according to user’s needs. WeMo Link ZigBee hub acts as a centre of WeMo. Devices connected to the WeMo Link ZigBee hub can be controlled by iOS or Android apps. (Belkin 2015.)

BuildTrack is India based home automation system manufacturer that makes a wide range of different smart home appliances that work together with each other. Some of the devices include touch switches with remote control, EzMonitor IP cameras, EzCurtain remote control for curtains, EzSense motion sensor controller lighting and EzCentral lighting control. (Buildtrack 2015.)

Sensorflare offers a centralized home control center platform. Sensorflare is compatible with Philips Hue lamps, Samsung SmartThings devices and Withings devices among others. (Sensorflare 2015.)

Nest Labs is the creator of the Nest Learning Thermostat, the Nest Protect smoke detector and the Nest Cam IP-camera. Google bought Nest Labs for $3.2 billion in 2014. (Whitney 2014.) Currently they do not offer platform similarly to Belkin, BuildTrack and Sensorflare do, but with the help of Google’s financial reserves it seems probable that they are going to expand to a lot of different smart house product categories in the future. (Nest Labs 2015.)

Samsung SmartThings is a portfolio of a platform and a lot of different devices that work together within it. The starter kit is called Home Monitoring Kit, and it includes a Hub, a remotely controllable outlet, one motion sensor and two multi usage sensors. Security camera is the first recommended addition, and they also offer plenty of different appliances. (Samsung 2015.)

3.3 Applications, devices and features

In this chapter this research goes through some of the most important applications, devices and features that are possible in a smart house. Pictures are used to show what the devices look aesthetically.

3.3.1 Centralized control of lights and electrical appliances

Controlling lights can provide cost savings when lights are turned off when not in use and lights can also be set to automatically to turn off when there are no people in a particular room. This can be detected by motion detection, the user's smartphone or by keychain and sensor that can detect keychains. Certain appliances can be automatically turned off when leaving the house, and thus saving energy. Picture 1 presents Belkin WeMo Insight Switch which is similar to Samsung SmartThings Outlet; both of them are small devices that come between device and wall socket, and they can be used as a remotely controllable socket. (Belkin 2015.)

Picture 1. Belkin WeMo Insight Switch (Belkin 2015)

Picture 1 presents Belkin WeMo Insight Switch, which is a simple device as it has only a place to plug in the users desired device, and a power button to turn the device on or off. The actual features it offers can be found from the user's smartphone screen; remotely and wirelessly turning the device on or off, or even creating a schedule about when the device should be turned on or off.

From the same manufacturer, Belkin, WeMo Keychain, which is present in picture 2, is a keychain that coupled with sensor at door can be used to automatize heating, or even firing up certain resident's favourite radio station as they get home. (Belkin 2015.)

Picture 2. Belkin WeMo Keychain (Belkin 2015)

As present in picture 2, the Belkin WeMo Keychain is a simple device. It looks similar to any other normal keychain, but the automation features offered can facilitate the owner's life.

Centralized control of lights is one of the first applications of IoT enabled smart house, and the systems come from many different manufacturers. Belkin WeMo Smart LED Bulb, Osram Lightify, and Philips HUE, which is present in picture 3, are among the leading smart IoT enabled lighting solutions. (Philips 2015.)

Picture 3. Philips HUE lightning system (Philips 2015)

Philips HUE present in picture 3 is a complete lighting system. The Hue Starter pack includes three GU10-socket HUE light bulbs, and ZigBee Hub. The lights connect wirelessly to the hub, and all lights do not need to be at the coverage area of the hub, as ZigBee supports ad-hoc.

Bose and Samsung offer smart speakers to be used in a home audio system, that allows different music to be playing at different rooms, and the whole system can be controlled from smartphone. Picture 4 presents Bose SoundTouch 20 III wireless music system unit. (Bose 2015.)

Picture 4. Bose SoundTouch 20 III wireless music system unit (Bose 2015)

Bose SoundTouch 20 III wireless music system unit, present in picture 4, is wireless speaker that can be used as a part of larger stereo system, but it also works as an only speaker. It connects to Wi-Fi, and allows streaming music from any smartphone located in the same Wi-Fi or through the Internet to the speaker.

Fishbit manufactures products that allow the home aquarium to become remotely controllable. Picture 5 presents the Fishbit aquarium system. (Fishbit 2015.)

Picture 5. Fishbit aquarium system (Fishbit 2015)

Fishbit aquarium system present in picture 5 looks like a regular extension cord, albeit with USA sockets in the picture, with a 6 way split at the end, but the real magic is hidden. It connects to Wi-Fi, and all of the sockets can be individually

managed from smartphone. Other than the ‘split-end extension cord’, it also includes sensor to be inserted inside the aquarium. This sensor measures water’s pH, saltiness and temperature. (Fishbit 2015.)

Amazon Echo is a learning voice command device designed by the Internet shopping giant Amazon that allows question answering, music playback and the controlling of smart devises by voice. Amazon Echo is present on picture 6. (Amazon 2015.)

Picture 6. Amazon Echo (Amazon 2015)

Amazon Echo present in picture 6 includes Wi-Fi and Bluetooth connectivity, and it can be activated by saying a defined ‘wake word’ or by pressing a button on top of it or on the additionally purchasable remote control. Echo offers news and weather, music from various services including Amazon Music, Pandora, Apple Music and Google Play Music, creation of shopping lists, looking up information from Wikipedia and also controlling IoT enabled home devices. Amazon Echo works with Philips HUE, Belkin WeMo, Samsung SmartThings and also IFTTT. (Amazon 2015.)

3.3.2 Children and elderly care and other home healthcare products

IoT enabled health devices offer solutions mainly for elders and children, but there are also some products for adults. Examples of elderly care products include Lively which is United States based company that offers smart service for

elderly people and their younger family members. The Lively system is present on picture 7. (Lively 2015.)

Picture 7. Lively system (Lively 2015)

As present on picture 7, elderly Lively users get smart watch type watch which works as a heart rate monitor, pedometer, push button emergency service and of course as a watch. The service is based on home central unit where the smart watch keeps a connection when needed. Other than the smart watch, the service also includes various sensors, and smart pillbox which keeps track of medication usage, and alerts family members if a user forgets to take his/her medication. (Lively 2015.)

For adults Withings SA offers various products for monitoring health status. Withings offers two scales, a little cheaper Wireless Scale and the more advanced smart body analyser. Picture 8 presents Withings WS-50 wireless smart body analyser. (Withings 2015.)

Picture 8. Withings WS-50 wireless smart body analyser and Apple iPhone with the application open (Withings 2015)

Withings Smart Body Analyser, connects to Wi-Fi and transmits data automatically to the company's servers for easy viewing from smartphone. It includes Health Mate app which visualizes trends and allows monitoring of health. (Withings 2015.)

Withings also offers Pulse Ox, a modern version of pedometer. The Pulse Ox can be used as a sports watch with a wristband, or it can be in the user's pocket. The Pulse Ox is present in picture 9. (Withings 2015.)

Picture 9. Withings Pulse Ox (Withings 2015)

Pulse Ox present in picture 9 transmits the collected data to the user's smartphone by Bluetooth. It allows tracking steps, calories, elevation and distance. It displays heart rate and blood oxygen level for easy monitoring during workout, and it also allows monitoring sleep cycles. (Withings 2015.)

Withings Aura is a connected alarm clock that wakes the user up with a light. It is present in picture 10. (Withings 2015.)

Picture 10. Withings Aura (Withings 2015)

Withings Aura can be set up to play Spotify playlist or Internet radio during alarm. It includes Wi-Fi and Bluetooth connectivity, and it also logs information about temperature, luminosity and sound levels, therefore it is possible to looks for sources of disturbance if resident's wake up during sleep regularly. (Withings 2015.)

Withings Smart Kid Scale is a smart scale that allows monitoring the growth of the kid by the same smartphone app as all the other Withings devices. It is present in picture 11. (Withings 2015.)

Picture 11. Withings Smart Kid Scale (Withings 2015)

Withings Smart Kid Scale connects to smartphone by Wi-Fi or Bluetooth. It allows monitoring the user's baby's weight, and displays the information on chart in the smartphone display for easy monitoring of growth. The information recorded can also be synced to the user's account on Withing's server. (Withings 2015.)

Withings Smart Baby Monitor allows parents to watch their baby through camera and listen to the baby through microphone. It is present in picture 12. (Withings 2015.)

Picture 12. Withings Smart Baby Monitor (Withings 2015)

Withings Smart Baby Monitor allows parents to talk to their baby through speaker to calm down the baby. When connected to Internet enabled Wi-Fi, the baby monitor can be watched where-ever the parent may be, even from other side of the world. (Withings 2015.)

Withings Wireless Blood Pressure Monitor is a blood pressure monitor that sends the measured data to smartphone by Bluetooth. It is present in picture 13. (Withings 2015.)

Picture 13. Withings Wireless Blood Pressure Monitor (Withings 2015)

Withings Wireless Blood Pressure Monitor allows easy monitoring of changes in heart rate from smartphone. It gives instant feedback based on ESH (European Society of Hypertension) recommendations.

3.3.3 Security

CCTV and motion sensors can make sure the house is safe from burglars when residents are out of the house. If the sensors are activated, and there is contract with security company, police/security can be automatically alarmed to the scene. IP cameras works as security cameras, and the footage can be stored to remote server. Security Cameras can be also used to monitor children. Security products are available from Belkin, Nest, Samsung, Schlage, Yale and Withings.

Belkin WeMo Keychain solution is tracking device primarily intended for children and pets. The systems tracks keychains that are in the house, and parents can receive alerts if children comes to home or leaves from home at obscure times. It can also be used to automatize functions by IFTTT. (Belkin 2015) Belkin WeMo Motion Kit is an intruder detector kit which uses infrared. It can ignore pets, and thus can be used even though the user has pet alone at home. It can also be used as a motion detected light switch.

Nest Labs offers Nest Cam security cameras and Nest Protect smart smoke detectors. Nest Cam security camera is present in picture 14. (Nest Labs 2015.)

Picture 14. Nest Cam (Nest Labs 2015)

Nest Cam, similarly to other products made by Nest Labs, uses Wi-Fi to connect to home network and the Internet. It allows 24/7 live streaming to smartphone, tablet and computer, and users can subscribe to Nest Aware for continuous recording. (Nest Labs 2015.)

Samsung offers SmartThings Motion Sensors and SmartThings Smartcam HD Pro security cameras that allows streaming live video to smartphone and can alert if unexpected motion is detected. Samsung SmartThings SmartSense motion sensor is present in picture 15. (Samsung 2015.)

Picture 15. Samsung SmartThings SmartSense motion sensor (Samsung 2015)

SmartSense motion sensor connects to Samsung SmartThings hub by ZigBee. It allows turning lights on automatically when someone enters a room, and it can also work as a traditional security minded motion detector. (Samsung 2015.)

Schlage Connect Touchscreen Deadbolt is a door lock with touchscreen and up to 30 different user codes that supports Z-Wave wireless communications specification. It is present in picture 16. (Cnet 2013.)

Picture 16. Schlage Camelot Touchscreen Deadbolt (Cnet 2013)

Schlage Camelot Touchscreen Deadbolt allows alerting owner or a security company if the door is forcibly entered. Its touchscreen is advertised to be durable, and it also includes ‘Anti-pick’ technology against tempering. (Schlage 2015) Yale Real Living Touchscreen Deadbolt offers the same functionality as Schalge, but it also supports ZigBee. Withings offers Home-branded security camera that can be used to make sure everything is alright at home by smartphone viewing, and it also offers recording functionality and monitors air quality by built in sensor. (Yale Security Inc 2015 & Withings 2015.)

3.3.4 Control of physical environment including heating, ventilation and air conditioning

One of the most important features of a smart house is the automatized management of the physical environment. This physical environment usually means temperature and air flow, but it can also include features that are leaning more towards security aspects, for example sensors that monitor leakages. For example Samsung SmartThings Water Leak Sensor can alert house owner in case of excess water detected. (Samsung 2015.)

Picture 17. Samsung SmartThings Water Leak Sensor (Samsung 2015)

Samsung SmartThings Water Leak Sensor uses ZigBee, and it is battery powered, thus making it easy to place it anywhere. It monitors also temperature.

Centralized control of heating, ventilating, and air conditioning (HVAC) can make sure that the physical environment of the house stays as residents want it. Important aspect of HVAC is smart thermostat. Smart thermostats are made by Ecobee, Honeywell, Zen, Tado, Ngenic and Nest Labs. They all offer pretty similar features, usually control of the temperature by the unit itself and also remotely by smartphone, but the way they work differ for each manufacturers. Zen is compabatible with ZigBee based home solutions, Ngenic has its own gateway and Ecobee, Nest Labs and Honeywell connect to the Wi-Fi including most universally compatible smart home devices. Ecobee also works with Apple Homekit, therefore it is possible to make all kinds of macros that work within the Apple ecosystem. Nest Learning Thermostat is present in picture 18. (Nest Labs 2015.)

Picture 18. Nest Learning Thermostat, 2nd Generation (Nest Labs 2015)

One of the selling points of all smart thermostat is the saved energy by automatical decreasing of temperature when the house can be a little colder, including when the residents are away. Nest Learning Thermostat tries to reduce energy bill by learning its user's schedule, and automatically decreases heating when it is acceptable. They claim that "Since 2011, the Nest Thermostat has saved over 4 billion kWh of energy in millions of homes worldwide." They also report

that “Independent studies showed that it saved people an average of 10-12% on heating bills and 15% on cooling bills.” (Nest Labs 2015.)

Water Hero allows controlling water system from smartphone and thus allowing cost savings and auto-shutoff if leaks are detected. It is present in picture 19. (Water Hero Inc 2015.)

Picture 19. Water Hero system (Water Hero Inc 2015)

Water Hero uses Wi-Fi to connect to home network. The inventor Dan Sterling financed it by Kickstarter campaign. It has received 372 backers with total worth of $64,024 USD, thus making over its goal of $54,000 USD. The first people who ordered it are expected to have their devices during 2016. (Kickstarter & Water Hero Inc 2015.)

3.3.5 Garden appliances

One part of smart house is making the life of its residents easier. Automatizing garden work that were previously done by hand can offer time savings. RoboMow is a robot lawnmower which can be controlled by Bluetooth from smartphone. It is present in picture 20. (RoboMow 2015.)

Picture 20. RoboMow (RoboMow 2015)

RoboMow will follow set up schedule, and it is suitable for all different kinds of lawns. It is programmed by smartphone application. (RoboMow 2015.)

Edyn manufactures Smart Garden System which includes solar powered and Wi-Fi connected water sensor that can be easily inserted into flowerbed. It is present in picture 21. (Edyn 2015.)

Picture 21. Edyn Smart Garden Sensor (Edyn 2015)

Edyn Smart Garden Sensor allows information about the soil to be displayed on smartphone. Equipped with Edyn Water Valve, the watering of the flowerbed can be totally automated. (Edyn 2015.)

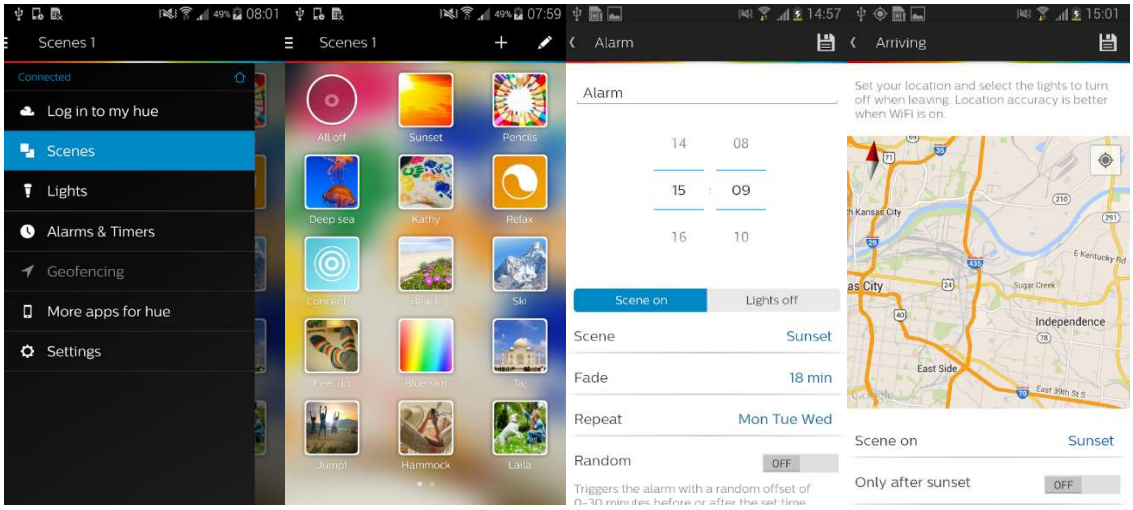
GreenIQ is another manufacturer which produces smart garden appliances. GreenIQ smart garden hub is present in picture 22. (GreenIQ 2015.)

Picture 22. GreenIQ smart garden hub (GreenIQ 2015)

GreenIQ smart garden hub allows easily controlling irrigation. It is compatible with IFTTT, and it can automatically keep the flowerbed moist.

3.3.6 Smartphone control of the house

Users can have an apps on their Android or iOS phones or tablets to control functions of the house. Currently users need multiple apps to control fully equipped smart house as all devices do not communicate with each other. Wi-Fi, ZigBee and Z-Wave devices can also be controlled from anywhere in the world through the Internet if the local hub in the house is connected to the Internet. Bluetooth devices are usually only controllable from within the house. Example of control interface, the Philips Hue control app, is present in picture 23. (Philips 2015.)



Picture 23. Options of Philips HUE application running on Android phone (Philips 2015)

The Philips HUE application can control Philips HUE products, and it has many relaxing pre-sets, including sunset, deep sea and blue rain. It also has useful features including time and GPS triggered actions. (Philips 2015.)

3.3.7 Earthquake Early Warning System

One of the most essential applications of IoT in some parts of the world is Earthquake Early Warning System. Seismic meter located on smart houses can provide accurate live data on even the lowest quakes, and this information can be used to issue a warning if quake is detected on one area, thus possibly saving human lives. According to Dietz (2015), earthquake early warning systems are in place at Japan, Mexico and Romania and the systems can give few seconds to couple of minutes warning. Example of functioning earthquake early warning system from Asia can be seen in figure 2. (NOAA 2005.)

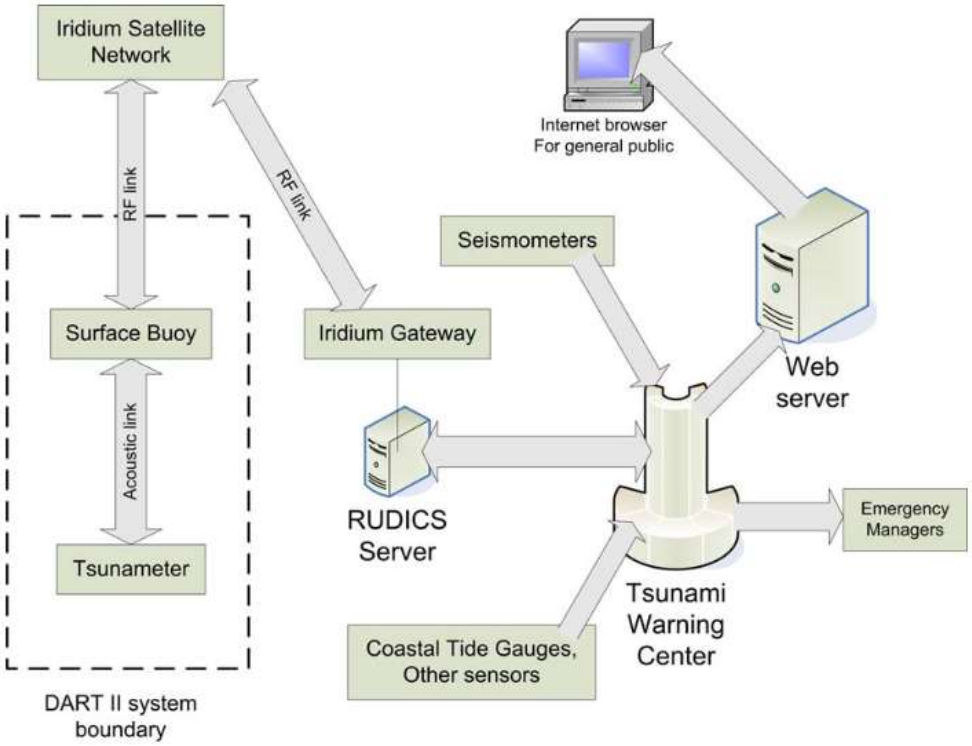


Figure 2. Data infrastructure of a tsunami warning system (NOAA 2005)

Underwater earthquakes can cause deathly tsunamis. For example the Indian ocean tsunami of 2004 killed around 250 000 people. (NOAA 2005.)

Figure 2 presents a possible data infrastructure of a tsunami warning system. It includes tsunameter's placed on seabed which share data to surface buoys by acoustic link. The surface buoys connect to Iridium satellites by RF-link. The satellite passes the signal to earth station, from where it becomes normal Internet traffic. Eventually RUDICS server receives the data, which is monitored at the tsunami warning centre. Based on the data received, combined with other data including seismological data, tsunami warning centres can then place tsunami warnings, which alert people to get to higher ground. (NOAA 2005.)

3.3.8 Automated electrical meter reading

Electrical companies can save money by using smart meters that send electricity usage data through the Internet. The information is usually not easily accessible to the customer, but nowadays more and more electrical companies are

offering hourly energy usage data easily viewable by smartphone application and on website. British Gas has offered this service for years, but it is nowadays also becoming available to users in Finland. For example Helen (former Helsingin Energia) offers this kind of service with the name Sävel Plus.

3.4 Possible future applications

One of the possible future features of a smart house is a fridge that can automatically order more milk from grocery store. This is technically possible even nowadays, but it have not been brought to reality yet. It would require cooperation from the milk manufacturers, shops and fridge manufacturers to make the whole process possible. Milk cartons would require to have ‘how much liquid is left?’-sensor, the fridge must be able to read that data and transmit it to the shop, and the shop would be required to act accordingly. Currently milk cartons do not include sensors similarly to that, fridges are not able to transmit the signal to the shop even if the cartons would contain the sensor, and except few exceptions, shops do not offer home deliveries unless the order is of great size.

4 BENEFITS AND CHALLENGES OF IOT

Societies can benefit from saved energy, i.e. turning off lights that are not needed, and increased security. Burrus (2014) uses a bridge collapse of 2007 in Minnesota, USA as an example of how IoT can offer benefits to societies in general. According to Burrus (2014) the bridge collapsed because the steel plates that were supposed to manage the load of the bridge were unable to do their job. However, when rebuilding bridges, it is possible to use smart cement, a cement “that alerts us to fix problems before they cause a catastrophe”. (Burrus 2014) Burrus (2014) also states that IoT is not just about saving money. According to him “This is a huge and fundamental shift. When we start making things intelligent, it’s going to be a major engine for creating new products and new services.” (Burrus 2014.)

The biggest challenge of smart appliances currently is that different manufacturers use protocols and standards that are not compatible with each other. The challenge is similar to Mac vs Windows, but for much more devices and manufacturers. According to Hill (2015), smart house technology is still not stable enough and error-proof for domestic use. One completely equipped smart house froze completely because of a faulty light bulb. The light bulb had burned out, and it was constantly sending information ‘I need attention’ to the hub, which caused the network to overload with information. Changing the bulb fixed the problem, but without the house’s smart owner the problem would have required outside assistance to be solved. That bulb was not the only problem in the same smart house, cleaning robots had fallen off the stairs into the cellar, and got stuck under the furniture. The robots also had problems following the schedule, as sometimes they would start cleaning at 3 am and woke up the owner. (Hill 2015.)

One aspect of how smart houses influence societies is security. Therefore, manufacturers have a huge responsibility for making wireless devices secure. If hackers acquire access to smart houses lightning system, music system and security cameras, smart houses can instantly turn into nasty place. Some online

pessimists have been pondering what it would result in if a virus infected the central computer of a smart house. One scenario would have lights flashing constantly, loud dubstep starting to play at 6am, and security camera taking a picture of resident getting out of shower naked and uploading it to Facebook. Such scenario is realistic is realistic scenario if security is not taken seriously. One of security faults that has already been noticed is the ‘shoddy’ authentication system that Philips used in its HUE lighting system. (Moon 2013) “That system uses the bridge's MAC address, which is easy to detect. As such it's also easy to hack the device and cause a blackout.” (Moon 2013.)

5 CONCLUSIONS

The objective of this research was to research IoT with a focus on smart house, and to gain knowledge of how smart house appliances work together as an integrated system. The main product categories were first recognized, and analysed. Lastly, competing products on offer at the market were compared from the point of view of technical specifications and the ease of use.

This research found out that smart house technology already is here, but it is not on every home because of two reasons. First, one reason is compatibility. Each manufacturer uses their chosen standards and their own applications; thus the devices are still largely incompatible with each other. Incompatibility confuses people, and makes people wait till the devices become more compatible with each other before investing a lot of money. The second reason is money. Smart house appliances are still expensive. For example Nest Labs Learning Thermostat costs $249 US dollars. If one resident needs two of them, that is already $500. That sum is a lot of money as a regular mechanic thermostat can be purchased at a price as low as 30 € in Finland. These both problems will probably will be solved as time passes, and this research did not find any obstacles that cannot be overcome on the way to all houses becoming smart. Increased manufacturing volume in the future will allow lower prices, and as manufacturing volumes increase, the techniques used by market leaders become the most popular solutions.

Based on the findings of this research, one aspect might be a problem. The possible problem is that smart house appliances are quite complicated to use and install, and it makes difficult for people without technical knowledge to operate smart house appliances. For those interested in the differences of wireless network technologies within smart houses, the most important ones were present in section 3.1 in this thesis.

This research may serve as a basic document for people interested in making their home smart. This thesis also provides good information about the market

reality of smart house appliances today. The scope of this research was influenced by the extent of Bachelor level thesis studies. Therefore, the scope was limited to include discussions of smart house and its appliances, and not conducting an in-depth researching on other aspects of IoT. However, the essentials of IoT are still described in this Thesis. This document is an opportunity for people not having good a knowledge of smart houses to learn to know the essence of IoT.

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