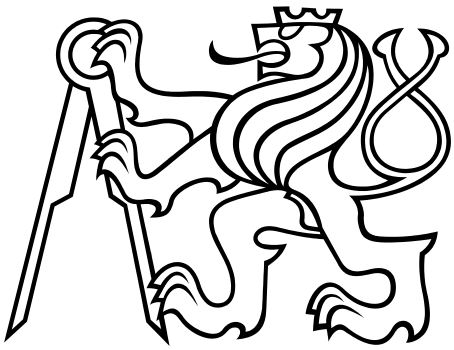

ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

Fakulta elektrotechnická

Katedra radioelektroniky

Průzkum trhu pro aplikace internetu věcí

Market Research for Internet of Things Applications

Bakalářská práce

Studijní program:	Komunikace, multimédia a elektronika
Studijní obor:	Multimediální technika
Vedoucí práce:	doc. Ing. Leoš Boháč, Ph.D.

Jakub Novák

Praha 2018

Declaration

I hereby declare that the presented thesis was created on my own and that I have cited every used source in compliance with methodical instructions about ethical principles for completing an academic thesis.

Prohlášení

“Prohlašuji, že jsem předloženou práci vypracoval samostatně a že jsem uvedl veškeré použité informační zdroje v souladu s Metodickým pokynem o dodržování etických principů při přípravě vysokoškolských závěrečných prací.“

V Praze dne ……. …….

Jakub Novák

ČVUT
ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

ZADÁNÍ BAKALÁŘSKÉ PRÁCE

I. OSOBNÍ A STUDIJNÍ ÚDAJE

Příjmení: **Novák** Jméno: **Jakub** Osobní číslo: **457125**

Fakulta/ústav: **Fakulta elektrotechnická**

Zadávající katedra/ústav: **Katedra radioelektroniky**

Studijní program: **Komunikace, multimédia a elektronika**

Studijní obor: **Multimediální technika**

II. ÚDAJE K BAKALÁŘSKÉ PRÁCI

Název bakalářské práce:

Průzkum trhu pro aplikace internetu věcí

Název bakalářské práce anglicky:

Market Research for Internet of Things Applications

Pokyny pro vypracování:

Proveďte metodický výzkum využitelnosti konceptu Internetu věcí pro reálné aplikace v praxi. Dle možností začleňte do tohoto výzkumu i potenciální zákazníky, jak z oblasti firem, tak i koncových osob. Dílčím výstupem práce by měl být souhrn klíčových IoT aplikací, které mají budoucí potenciál komerčního uplatnění. Z daného souboru aplikací si poté student vybere jednu, pro níž následně navrhne celou architekturu technického řešení a dle možností a rozsahu ji implementuje.

Seznam doporučené literatury:

[1] HANES, David. IOT fundamentals: networking technologies, protocols, and use cases for the internet of things. 3rd edition. Indianapolis, IN: Cisco Press, 2017. ISBN 978-1587144561.
[2] SLAMA, Dirk, Frank PUHLMANN, Jim MORRISH a Rishi M. BHATNAGAR. Enterprise IoT. Boston: O'Reilly, 2015. ISBN 978-1491924839.
[3] SHOVIC, John C. Raspberry Pi IoT projects: prototyping experiments for makers. New York: Apress, 2016. Technology in action series. ISBN 978-1484213780.

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doc. Ing. Leoš Boháč, Ph.D., katedra telekomunikační techniky FEL

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Datum zadání bakalářské práce: **14.02.2018** Termín odevzdání bakalářské práce: **25.05.2018**

Platnost zadání bakalářské práce: **30.09.2019**

doc. Ing. Leoš Boháč, Ph.D. podpis vedoucí(ho) práce	podpis vedoucí(ho) ústavu/katedry	prof. Ing. Pavel Ripka, CSc. podpis děkana(ky)

III. PŘEVZETÍ ZADÁNÍ

Student bere na vědomí, že je povinen vypracovat bakalářskou práci samostatně, bez cizí pomoci, s výjimkou poskytnutých konzultací. Seznam použité literatury, jiných pramenů a jmen konzultantů je třeba uvést v bakalářské práci.

. | Datum převzetí zadání

Podpis studenta

Acknowledgement

I'd like to thank my thesis supervisor doc. Ing. Leoš Boháč, Ph.D. for the many consultations given for the thesis and for an unusual type of assignment which helped me learn how to communicate and encouraged me to send out "cold" emails and carry out phone calls to high level professionals.

I also massively appreciate all the firms and experts that helped my information gathering process and invested more time into helping me than I expected:

doc. Ing. Leoš Boháč, Ph.D., Ing. Radek Janča, Ph.D., Ing. Marek Neruda PhD., Ing. Lukáš Kvarda, Doc. MUDr. David Kemlink, Ph.D., MUDr. Martin Pretl, CSc., MUDr. Jan Kordík, doc. MUDr. Jan Polák, Ph.D., MUDr. Eliška Vyskočilová, Ondřej Kalaš, Ing. Martin Víšek, Chipfox , Hardwario, Flea, MyMight , SimpleCell, Anonymous firm, Starnet, CTI Software, IoT-Billing

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Dále bych rád poděkoval všem firmám, odborníkům a zastupitelům, kteří mi věnovali svůj čas, který byl většinou nad rámec toho, co jsem očekával:

doc. Ing. Leoš Boháč, Ph.D., Ing. Radek Janča, Ph.D., Ing. Marek Neruda PhD., Ing. Lukáš Kvarda, Doc. MUDr. David Kemlink, Ph.D., MUDr. Martin Pretl, CSc., MUDr. Jan Kordík, doc. MUDr. Jan Polák, Ph.D., MUDr. Eliška Vyskočilová, Ondřej Kalaš, Ing. Martin Víšek, Chipfox , Hardwario, Flea, MyMight , SimpleCell, Anonymní firma, Starnet, CTI Software, IoT-Billing

Abstract

The goal of this work is to analyze the IoT market as a whole from the B2B (business) perspective as well as from the B2C (customer) perspective and identifying the parts of the market with the greatest potential as well as opportunities to develop these branches of IoT in the future. Secondarily it analyzes problems from the perspective of B2B businesses that have been in the market for several years, it also compares the situation in Czech Republic to some European countries.

Based on this information I came up with several concepts worth investing time in. Applications for hospitals came out to be quite complicated mostly because certification problems and a lack of a clear concept that would bring a significant improvement. RFID tags for inventory tracking were quite the opposite, they seem to be very promising and I managed to secure a possible internship working on this concept for a rental company in the next year. This thesis considers an initial architecture design and a proposal minimum initial stage investment.

In the last part of the thesis we tested a few potentially problematic cases for UHF RFID such as negative effects of PELI cases on the maximum read range and bending UHF tags with dipole antennas.

Keywords

IoT, Internet of Things, Market analysis, Polysomnography, RFID, UHF RFID, RFID rental, RFID warehouse, RFID inventory tracking

Abstrakt

Cílem této práce je analyzovat IoT trh jako celek jak z hlediska firem pracujících v tomto oboru, tak z hlediska koncových zákazníků, a na základě těchto informací identifikovat část trhu s největším možným potenciálem a také určení možných slibných odvětví do budoucnosti. Jako vedlejší cíl analyzuje problémy z B2B perspektivy pomocí příspěvků firem pohybujících se v oboru již několik let, také obsahuje krátké porovnání České republiky se zahraničím.

Na základě těchto informací jsem přišel s několika možnými koncepty, do kterých by se vyplatilo investovat čas a dvě z nich jsou zde prezentovány do detailu. Aplikace pro medicínu se ukázaly být dost komplikované z hlediska certifikace přístrojů a přesné vize finálního produktu, který by měl dostatečný přínos. UHF RFID značky pro sledování stavu zásob jsou pravým opakem a naskytla se možnost pracovat přímo s půjčovnou videotechniky na této aplikaci v praxi. V této práci se tedy dále nachází návrh minimální možné investice do této technologie pro zmíněnou firmu pro testování v budoucnu.

V závěrečné části je nastíněno několik možných problémů s touto aplikací a následné měření negativních efektů ohýbání RFID „značek“ a negativní vliv ochranných kufrů pro videotechniku na maximální možnou vzdálenost čtení.

Klíčová slova

IoT, Internet věcí, Průzkum trhu, Polysomnografie, RFID, UHF RFID, RFID půjčovna, RFID sklad, RFID kontrola inventáře

Table of Contents

Theoretical part

1 Introduction

Internet of Things is a term that was first used in 1999 [1] but it wasn't until about 2010 that this term has really caught on. Instead terms such as M2M were being used, however according to several professionals in the world of IoT that I have spoken to (at SigFox IoT Expo 2017) there is little to no difference between these names. They are merely a progression of one another rebranded so they sound more attractive. The differences are shown in fig. 1.

M2M	IoT
Point-to-point communication usually embedded within hardware at the customer site	Devices communicate using IP Networks, incorporating with varying communication protocols
Many devices use cellular or wired networks	Data delivery is relayed through a middle layer hosted in the cloud
Devices do not necessarily rely on an Internet connection	In the majority of cases, devices require an active Internet connection
Limited integration options, as devices must have corresponding communication standards	Unlimited integration options, but requires a solution that can manage all of the communications

fig. 1 – a comparison of M2M and IoT [2]

A recurrent definition of IoT given by marketing professionals to institution representatives that don't know much about the concept is: "installing 'relatively' cheap sensors on new networks into places where it was not previously possible". (When asked what "relatively" meant, it was "under 5000 CZK").

The primary goal of this thesis is to determine which applications have a real financial potential in this domain and then test this assumption with potential clients and decide if the abbreviation IoT is a mere buzzword used for marketing.

Secondary goals which I have not anticipated that would have to be addressed at the beginning of the research include: familiarity with the concept of the IoT, common problems in the B2B sector, smart cities and education of city representatives (smart cities.)

2 Web and literature based market research

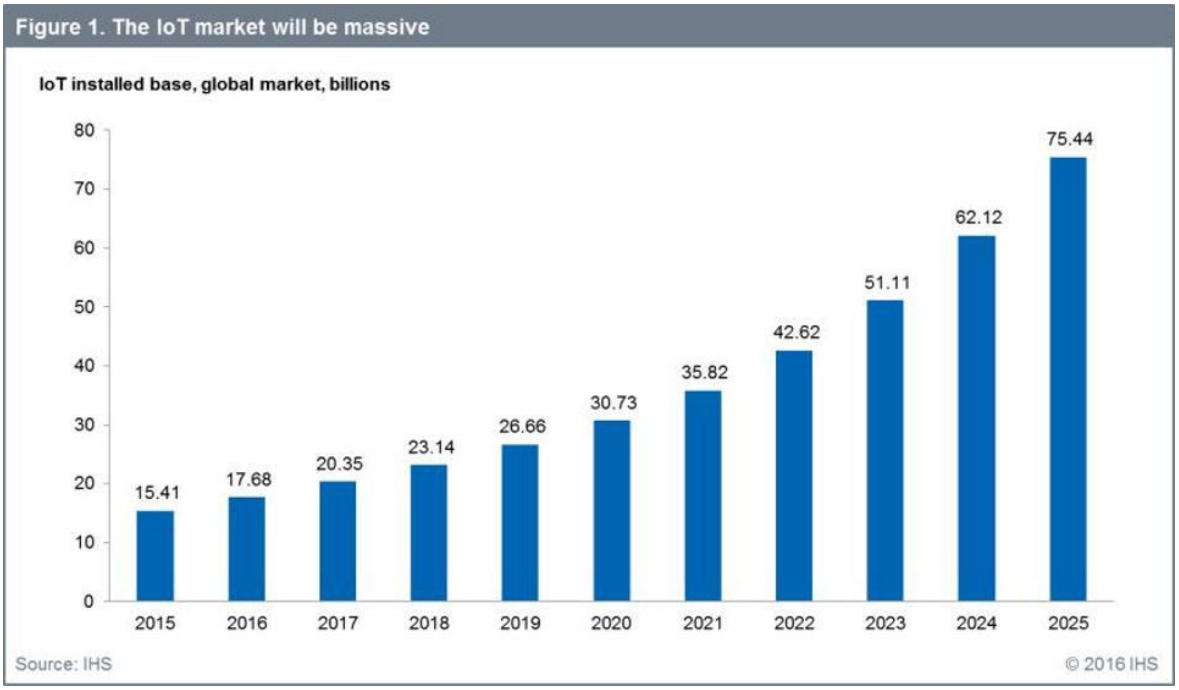

fig. 2 – a 10 year estimate of the growth of the IoT market [3]

These kinds of studies show that IoT has an enormous potential when it comes to projected global market value (fig. 2 is here to only illustrate the types of values - billions of USD). I strongly believe these numbers are so astronomical because of the loose definition of IoT and counting in everything that is used in it from HW, SW, implementation costs, connection providers, security etc. (as seen in fig. 3).

Studies do not necessarily show the same absolute numbers but they agree on an approximate 500% growth in a decade which should not be ignored. However the legitimacy of such studies should be taken with a grain of salt.

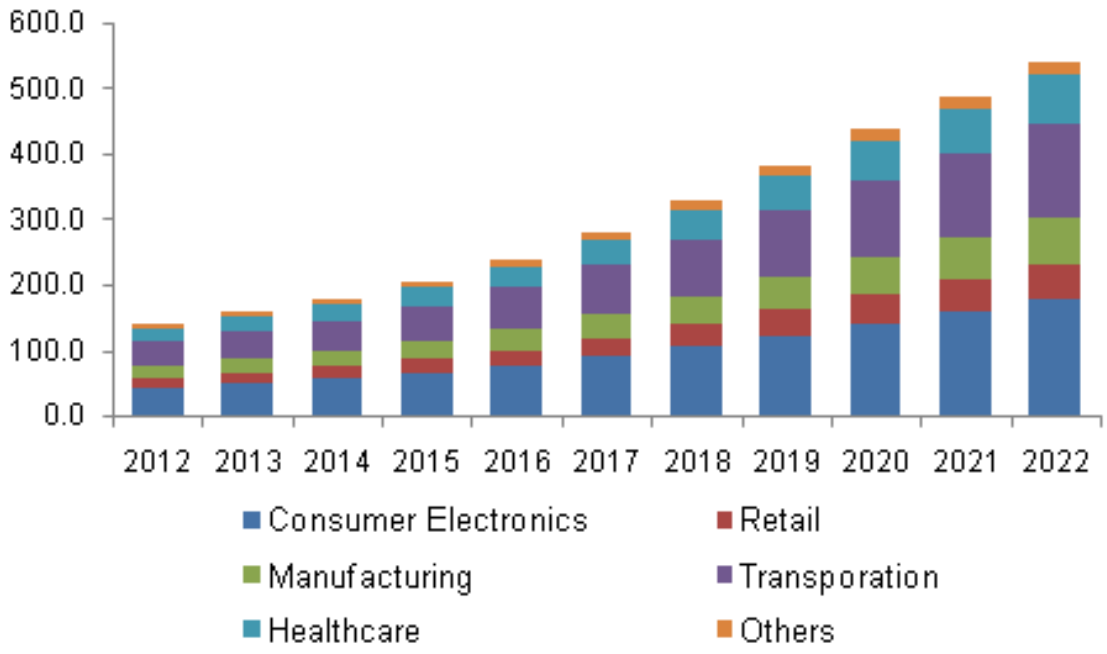

fig. 3 - North America IoT market revenue by application, 2012 - 2022 (USD Billion) [4]

When looking at a similar graph in fig. 3 - North America IoT market revenue by application, 2012 - 2022 (USD Billion) [4] it is obvious that consumer electronics cannot be ignored in the world of IoT. Wearables and smart watches such as FitBit have been experiencing enormous attention in the mainstream media such as Wired magazine [5].

Healthcare is considered a "sleeping giant" by technology blogs [6] and IoT healthcare will be worth approximately 152 Billion USD by 2022 which again doesn't precisely correspond with fig. 3 but the estimates are quite close to each other.

The two aforementioned areas are very close intertwined and have a lot of overlap such as sleep studies and specialized wearables for use at home such as a consumer oriented EEG device for tracking sleep called "Sleep Shepherd" [6].

From fig. 3 it might seem that consumer market might take up to 30% of the whole market share, however it differs from fig. 4 where industrial applications might show bigger potential because more companies concentrate on them instead of consumer electronics, that might change in the next couple of years as new startups might arise as it was the case of the Kickstarter campaign "Sleep Shepherd" or later mentioned "Gear Eye" also launched on the same platform.

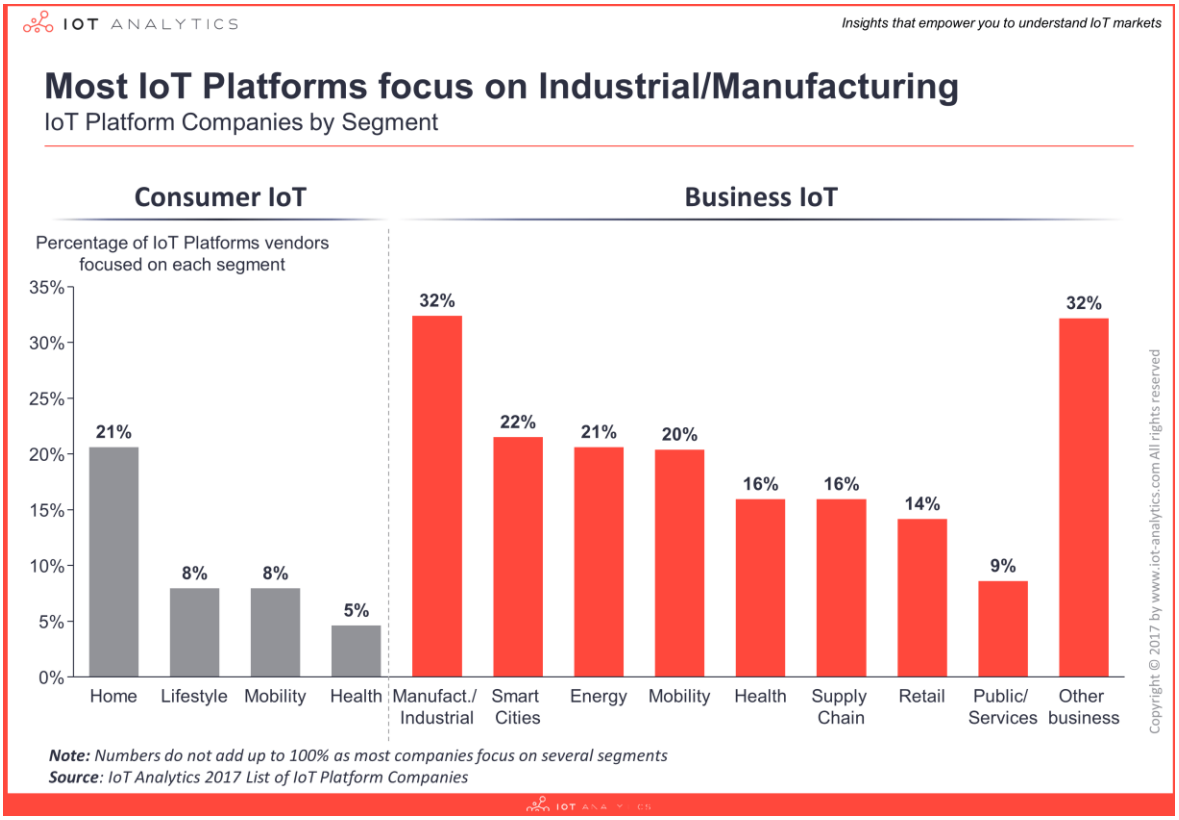

fig. 4 – "percentage of IoT Platforms vendors focused on each segment" (some of them focus on more areas thus the numbers do not add up to 100%) [7]

These two studies are shown here to prove a point that estimating the exact market share of each segment is a difficult task which among other things boils down to the definition of IoT itself. Such as what is healthcare and what is a consumer wearable device or what is mobility for the consumers – "smart" maps tracking each vehicle like Waze - and what is mobility for businesses/cities - parking apps like "Parkuj v klidu" in Prague [8] that show you where you are allowed to park. The city is paying for it but the end users are people who want to find a free legal parking space.

However we can see that some trends and approximate market shares can be extracted from this such as consumer IoT taking up to 40-50% of the whole market which is an important statistic for part 7 of this study – *7 Creating a business idea* – which looks into sleep tracking options for home use.

2.1 IoT market division

The IoT market can be broken down into the following categories.

- Personal (B2C)
    - Health/Wearables – glucometers, sleep tracking, fitness
    - Home – home automation, energy efficiency e.g. thermostats, lights, smart locks
    - Mobility – eBikes, connected cars
- Industrial (B2B)
    - Retail – smart price tags, warehouse applications such as RFID
    - Health – tracking patients in hospitals
    - Agriculture – water consumption
    - Asset tracking – from big containers with goods to envelopes
    - Product amount measurement – gas tanks etc.
    - Smart cities – lighting, energy consumption, water levels, traffic lights, parking, traffic measurement
    - Public Services and Schools
- Both
    - Energy consumption measurement
    - Autonomous vehicles
    - Data collection and evaluation – cloud based services
    - Microprocessor and semiconductor manufacturers
    - Antenna development
    - Connectivity providers
    - Sensor manufacturers
    - Billing
    - Lights

2.2 Familiarity of companies with IoT

Nearly 100% of companies that could benefit from IoT has already heard of the concept, most of them are looking to invest or have already invested in IoT. However for 60% of companies it is mostly a strategic decision to keep up with the competition as of 2016 [9].

fig. 5 - Global IoT Decision Maker Survey, IDC, 2016, Western European Sample, N = 202 [9]

IDC (the research company) also predicts over 80 billion devices in IoT around the year 2025 which will approximately generate over 180 zettabytes of data as of 2016 in comparison to a study from 2013 that predicted 44 zettabytes of data by 2020 [10].

Here are some of the findings of the 2016 IDC study summarized [9]:

- 80% of manufacturers know of the concept of IoT and almost 100% have heard about it.
- 70% consider IoT an extremely important topic.
- 30% manufacturers claim to be implementing IoT in different stages.
- 90% want to invest in it in the following 12-24 months.
- 59% consider it mainly a tactical decision to keep up with competition.

In comparison to a 2017 study (again - by IDC) [11] the companies still consider implementing IoT as a strategic move in 57% of cases. However in a year's difference almost 50% companies are in various stages of implementing IoT in comparison to 2016's 30%. About 10% have already launched one IoT application and are not planning on another one as of the date of the study.

2.3 Changes brought in with the concept

2.3.1 Data collection

Cisco expects 3x larger data flow on cloud services in 2020 (14.1ZB), in comparison to 2015 (2.9ZB) [12] (it does not correspond with the IDC study, but again here it is limited to cloud services only and the main point is that the data flow will rise dramatically.)

Forbes [13] and Wired [14] have repeatedly written about the lack of Big Data specialists in IoT and about the big financial potential for future experts in this field.

"At the edge" data processing helps lower the amount of data transferred [12].

There is also the importance of management that knows what to do with results of such data and how to react to them. As a result there is a new emerging role called CDO – chief data officer.

2.3.2 New business models and billing

Kärcher (a cleaning machine company) started selling clean area in square meters instead of their machines [15] such as vacuum cleaners etc. That brings new challenges to the marketing team which has to develop new techniques to sell such a product in comparison to selling technical parameters of a machine. These concepts are very close to the IoT applications (see *5.7 New billing opportunities*).

2.3.3 Build vs Buy

Companies underestimating the complexity of IoT and thinking they can do everything in-house and failing is a problem. More importantly when it come to the MVP's (Minimum Viable Product) - buy decision could be a 1 year process whereas developing a platform from ground up might take almost twice as long [16]. Additionally maintaining an IT service e.g. a cloud service and it's security for its whole lifespan demands deep expertise in this area as well as many man hours.

2.3.4 Building a reliable partner network

Maybe not as new concept in "tech" but equally important - IoT requires many different components that (as mentioned above) are usually not made in-house. Partner network is quite a factor as well – who supplies your suppliers is almost as important who your direct partners are. Ensuring that you do not base the solution on a proprietary system that will make changing providers of the service very difficult e.g. *5.8.6 Legacy systems*.

2.4 Differences between countries

"Western Europe has the lowest use and highest resistance to using an IoT Platform, with a purchasing decision occurring within the next 12–18 months." [11]

In the next 24 months (as of September 2017) Japan and Asia/Pacific are expected to overtake North America and Western Europe in IoT.

Launching GDPR in Europe in May 2018 could be quite transforming and might hinder future development. That is not to say data protection is not important as more data is collected every year.

"Companies could face fines of up to four percent of turnover for data breaches" [17] when GDPR takes place. Which means companies will have to be especially thorough in EU when it comes to security which could result in greater expenses. On the other hand greater security might be a big selling point for some products.

In GDPR the customer has a right to be forgotten thus companies will have to adopt strict rules of erasing data from the database. [17]

2.5 Findings of previous studies of the IoT market

These are some of the findings based on internet research that I will approve of or disapprove of in *6 Comparison to other studies.* I had these findings in mind when creating questions for companies in the IoT business.

- Mindset of target clients and companies must be actively changed by companies selling IoT because there is still reluctance to invest into IoT.
- IoT brings new ways to bill the client based on data collection and evaluation, the sales are no longer a one time event. [15]
- "Willingness to invest in IoT is not very high."[18]
- "There is a lack of IoT knowledge and skills." [18]
- Management needs to go through extra education or be changed to be able to utilize the concept IoT.
- "EU has strong IoT advantages." [18] "Questionable, because GDPR is happening" [18]
- "Partnerships are important, because one company usually can't deliver a complete solution" [18]
- There is a need of Big Data experts [19] and CDO's (Chief Data Officers).

Practical part

3 Creating questions

Questions were created so they were thought provoking and a slightly generalized so the respondent could feel free to expand on any of these questions, of course it was not always the case. The goal was to get each respondent to speak up about their "pet-peeve" in the world of IoT.

The complete set of questions (that were being sent by mail) can be found in *14 Appendix A – Questions sent via mail.*

The goal was to keep the questions as simple and easy to answer as possible, so they didn't look too overwhelming when received. [20]

The use of so called "aided recall" [21] to help respondents understand the goal of the question while simultaneously leaving free space for their own ideas that I have not thought of. In the following question I have mentioned specific protocols or batteries as a problem *10. Main technical concerns? (e.g. battery life, resilience of electronic components, security e.g. do you see problems in communication protocols for example the KNX secure protocol etc.)*

Using "informants" [21] meaning asking questions about the companies' partners e.g. comparing technology of some partners, their pros and cons, however this information is unluckily unpublishable for ethical reasons. However asking companies about how knowledgeable are the politicians concerning IoT has proven to be insightful.

Asking about "undesirable behavior" [21] such as asking about how these companies contribute to a unified IoT ecosystem and what is their approach to security. In case I asked them in a wrong way, the company representative could get defensive and not respond truthfully. I instead asked if they see these things as a problem or sometimes asked how could all the companies achieve this in a collective effort.

The questions are also largely based on *2.5 Findings of previous studies of the IoT market* to see if these arguments from 2014 are still valid. The verdict is presented in part *6 Comparison to other studies.*

4 Short introduction of each respondent

4.1 Chipfox

A daughter company of Carius Tech. Their product is a SigFox enabled asset tracker with GPS/GLONASS made primarily for the consumer market. Their partners include SigFox, SimpleCell and Ryston Electronics [22].The number of employees wasn't disclosed.

4.2 Hardwario

Their flagship product is called BigClown it is a HAT (Hardware Attached on Top) prototyping platform meant for quick solution design. As a HW and FW company they are also able to deliver completely custom solutions such as CO_2 level measurement for schools [23]. The firm has 12 employees.

4.3 Flea

Their main focus is energy consumption tracking and optimization as well as data collection. They focus on heat regulation and measurement [24]. They have 14 employees.

4.4 MyMight

This company focuses on interconnectivity of "smart" platforms and basically putting the "Internet" in IoT focusing on connecting different communication protocols into one platform. Their product that interconnects systems in "smart" houses is called "Myjordomus" [25]. They are a daughter company of Gordic (200-300 employees) and have 11 employees.

4.5 SimpleCell

They are the exclusive "SigFox operator" for Czech Republic as this LPWAN only has one exclusive provider of their service per country. They are in charge of coverage of CZE boasting 96% population already covered [26]. This company employs 10-15 people.

4.6 Starnet

Originally an internet connection provider (as well as TV services etc.) secondarily concentrating on LoRa coverage in CZE [27]. This is the biggest company that collaborated on the research with 170 employees + 14 daughter companies with 10-12 employees each.

4.7 CTI Software

In the 90s they started creating SW for call-centers and are now utilizing this knowledge in the world of IoT with automatic SMS and phone calls that react to data collected by sensors. They work on the following platforms: SigFox, LoRa, GPRS, NB-IoT (Vodaphone). They also develop they own HW in the form of sensors providing A to Z solutions [28]. They have 15 employees.

4.8 IoT-Billing

The only foreign company on this list coming from Australia, selling BSS (business support systems) software to Telcos (Telephone companies), applications for high number of transactions and billing [29]. In their words: "IoT generates lots of transactions of small economic value - we provide monetization capabilities and billing for these sorts of networks and applications." They are the "sales arm" of Select Software, this group has between 50-100 employees.

4.9 ČRA

Television, broadcasting and internet provider working on a wide range of telecommunication applications. In IoT they mainly focus on LoRa coverage in CZE as well as providing A to Z solutions to customers in collaboration with their partners. The representative was unable to provide me with an estimate of the number of employees.

4.10 The anonymous company

Provides parking sensor solutions.

5 Findings

Findings are based on 30-40 minute calls and/or e-mail exchanges that for Czech companies happened in Czech thus the responses here are mere paraphrases and might not be representative of what the company representatives truly meant to say.

Surprisingly larger companies (over 20 employees) were able to provide me with people who were willing to talk on the subject with great enthusiasm and at greater length in more cases than smaller companies were.

5.1 Familiarity with the concept of IoT

The general public seems to be uneducated when it comes to the complete concept of IoT, they are familiar with the concept of smart parking, smart benches or smart fridges which - at most - merely scratch the surface of IoT according to Starnet, Chipfox, Hardwario, Flea, SimpleCell representatives.

The main advantage of IoT is having sensors and data collection in places that were previously unavailable because of the absence of communication networks and/or power supply. – Chipfox

Companies that want to get on the wave of IoT early also struggle to grasp the concept and understand what kind of benefits they could really get from implementing IoT in their businesses. – Chipfox

Politicians seem to have about as good of an overview of the possible applications in IoT as the general public, not really seeing the real potential and thus slowing down the development i.e. investing in projects like "smart" benches (Starnet). This statement has been supported by a city representative saying that some of the people in the administration might not actually understand it on any level. Additionally: "State officials are not very well informed at all." – IoT Billing

The public does not completely understand the concept of interconnected devices, meaning they only understand the "Things" but not the "Internet". Isolated "island systems" are not intelligent or IoT. IoT is conceived as a set of separate technologies that could help improve a certain pain point but not as a complete ecosystem e.g. companies have "smart heating" that works based on a schedule but are unable to understand that it can also work together with their security solution to find out if there are people in the building when it's not on the scheduled (e.g. weekends). – MyMight

Not only there is a problem of not enough IoT specific professionals but general people in IT. The reason for that is the motivation that is given to kids in high schools and even in elementary schools, it is not sufficient. – MyMight

"Companies in the industries affected by IoT are becoming quite aware of the potential - but often lack an understanding of the commercial impact of the IoT and M2M. Telcos are affected greatly by this because IoT transactions have very small amount sod data and telcos are unlikely to make a profit from the base carriage of IoT networks." – IoT Billing

5.2 Comparison of Czech Republic to EU and the rest of the world

For instance the company representative MyMight found that in Germany (they had several projects in Frankfurt) people are quite familiar with the concept of IoT as a whole, understanding the ecosystem concept much more than in CZE.

In comparison to France there are way more companies that see the potential of IoT and that are already trying their hand in the business, however there is a problem of creating commercially viable solutions. – SimpleCell

According to Starnet: Czech Republic seems to be ahead of other countries when it comes to innovations and new applications since there is a long tradition of DIY electricians. The mentality of Czech engineers is also a bit more flexible in comparison to those in Germany or in Japan, from the interviewee's experience these countries are quite bound by strict rules and are not as flexible in trying new solutions that might be risky but also are quite likely to work. There also seems to be more people who are enthusiastic about engineering and do this partially as a hobby. German companies very often outsource product development to CZE.

IoT Billing was kind enough to provide the following quick comparison:

The US tends to be less price conscious - less afraid to spend money to gain benefit - but less rigorous with business cases, so more likely to fail in that sense. Also - despite the weather of technology coming out of the US - businesses are not at all that innovative in their use of technology - relatively speaking.

Europe tends to be more bureaucratic - more consensus oriented - more conservative with business cases - but more likely to succeed when the case is approved. Government is better informed in Europe because decisions are made by larger organizations - often at a national level. The US is organized at a county level - and often very small centers.

Australia, New Zealand, Canada, and South Africa are more flexible and innovative. They will do more with less because historically hardware and licensed software were more expensive - so they had to squeeze more out of their technology.

SE Asia - opportunities are beginning to flow in this market as well.

Middle East - this is a strange market - but some real investment is coming through this market now.

Africa - a developing market - with a real focus on low-cost solutions

5.3 The lack of professionals

There are enough professionals. – Chipfox

According to some there are not enough IT professionals in general, secondly technology companies are barely keeping up and do not have enough people to spare to innovate new technologies in the IoT world (Hardwario). SimpleCell agrees with the first point and adds that IoT specific engineers as well as experts for making a solution more scalable are in demand. Companies are quite often able to put out a working prototype or even a small number of devices however often they are not able to scale the project well and make it commercially viable. There seems to be a lack of properly

functioning back-office as well as sufficiently educated integrators, according to them it is not necessary for these people to have a university degree but a shorter specialized education perhaps in network management. Often the price of the device is significantly smaller in comparison to the payment for the integrators that install the device on site. – SimpleCell, Anonymous firm

The solution for some companies is to make a device that is as easy to install as possible, to be a "plug and play" solution especially because some partners who buy their application try to save money on integrators which might in turn cut the time that the device lasts due to improper installation (this company does parking sensors and traffic sensors which are put into asphalt.)

According to CTI there are not enough sufficiently educated people on site that would be able to effectively troubleshoot why a sensor isn't working that concerns HW, SW as well as specific knowledge of network connection principles in IoT.

Integrators also cannot be a "one size fits all" since there will be many applications in factories that might already have some systems in place but maybe not necessarily integrated in a greater system thus creating the need of industry specific specialists that know these legacy systems. – Starnet

As for missing integrators, internet connection providers could be the ones who could in the future potentially be able to provide this service since their employees are quite familiar with the inner workings of networks and with a some IoT specific education it might happen. - CTI

Starnet has encountered another problem and that is the lack of experts familiar with dashboards on platforms such as Grafana. They however do not see a problem with a lack of Big Data experts in comparison to some studies in the theoretical part of this study.

Lack of management that would be able to utilize the information collected from the IoT devices and react based on this information which confirms the need of a CDO function in firms. - Starnet

Explaining the concept to the target clients seems to be a bigger problem and this is where the professionals are missing, capable marketing personnel which understands the world IoT just enough to sell its full potential. – CTI

"There are plenty of experts. There are also plenty of snake oil sellers. The technology skills abound - new ideas abound - but commercialization is a distinct area of need." – IoT Billing

"Customers see the value of the proposition when it is articulated in their terms. Unfortunately - it is not often articulated in this way. Customer don't want IoT or M2M - they want lower prices or better service or more control." - IoT Billing.

"The business often doesn't see the value of IoT or M2M. The technology people can be quite enthusiastic about it - but unable to articulate a sound business case. Even key vendors in the market are confused and even blinded by their own interest to see the broader picture of business cases that require integrated efforts from multiple parties." – IoT Billing

5.4 IoT ecosystem

There are several ways to go about this:

1. Providing the system integrators with information to decode their data as well as API (Chipfox).
2. Compatibility with as many systems as possible to gain a competitive edge (Hardwario).
3. Solving this problem as a main business – interconnectivity of platforms – creating a communication protocol that unifies these platforms (MyMight).
4. Standardizing messages for every customer on the platform (e.g. when Starnet provides LoRa connection). That among other things brings advantages when upgrading to new systems in the future.

Starnet, one of LoRa connection providers in Czech Republic sees a great advantage in a system that is 1) open to modifications (in comparison to SigFox) and 2) can have more providers in one country which might in turn bring a way faster coverage in comparison to NB-IoT systems that have only one exclusive provider. Also there is an option of implementing a system like Roaming that was used in GSM to interconnect the whole Europe (or other continents) together.

When comparing connection providers and technologies the most important statistic – mostly because of the technologies being quite similar – is the price.

For example CTI - a company that provides A to Z solutions – works with several connection providing partners (SigFox, LoRa, Vodafone). Each of these technologies offer different advantages in each application.

This question can also be perceived differently that is as a centralized IoT network controlled by one single company. Of course there are problems with choosing one of the 20 available technologies as the "one size fits all" which is hardly applicable. Then there is the question of the right choice of a non-partisan company running the whole operation. This solution that has been adopted in early telephone and radio days doesn't really seem viable in the current market landscape and requirements. - IoT Billing

5.5 Which technology isn't ready for the idea of IoT

5.5.1 Battery life

1. It is not a problem with battery life expectancy of 2-5 years (Starnet).
2. The commonly advertised life expectancy of 2-10 years is over-hyped (CTI).
3. It is probably better than the life expectancy of electronics inside the device (Starnet, CTI).
4. Developing self-charging devices (solar, wind, thermoelectric effect) - Hardwario, MyMight

Ad 3: a device of an IP Code of 65 was tested and after 6 months there have been signs of water getting inside to the electronics, which was still working flawlessly, but it might cause problems in the future. - CTI

5.5.2 Security

It is one of the most discussed problems in the world of IoT, it was even recognized by some of the biggest blogs such as Wired [30].

It has been neglected as a thing that would be "solved later" which made sense when there was really no integration between systems and holes in one system would not compromise the security of other interconnected systems. However with rising integration of systems between each other these loopholes are starting to be a problem. According to a MyMight representative it is especially a problem in CZE. One of the reasons is KNX secure protocol which in his opinion is outdated and there are visible weak points for potential attacks from his cyber security experience.

Some companies do not worry about people hacking into certain systems such as smart lighting or other seemingly not threatening applications.

It is not worth it to steal this kind of data e.g. stealing data from a pressure sensor that measures the amount of water in a river. It is especially inconvenient because it takes an approximately 15 m long antenna in the case of SigFox to be able to read the sent data (CTI).

LPWA networks are not suitable for medical use because they are in the ISM band which is prone to interference and thus are not safe enough to take care of a patient's life (CRA).

5.6 Competition

The competition in CZE is next to none (as of spring 2018), especially when it comes to connectivity providers of LoRa and SigFox. The potential market seems to be too big for the few companies that exist here as of 2018. Starnet representative, who provide LoRa said that they do not really consider SimpleCell a competition and that most of the time they have not met during negotiations for a project (Starnet).

5.7 New billing opportunities

Usage-Based Insurance - where vehicles are monitored for the way in which they are driven - and insurance premiums adjusted - almost in real time - according to the load placed on the vehicle.

Preventative Maintenance - monitoring motors, conveyers, bearings, filling machines, etc. - to check for heat, vibration, power factor and so on - so failing components can be detected before they fail and replaced in controlled conditions rather than shutting the line in the middle of production.

These and other examples require a mix of IoT network and device management capabilities - and significant application software to use the data in the unique way each business needs - the premium calculations - or the maintenance scheduling software. In many instances the will to make all this work together is difficult to establish - but it is beginning to work. – IoT Billing

5.8 Cities

The city in question is Prague, Czech Republic. Other European cities (especially the Western ones) such as Munich, Germany are considered more advanced when it comes to IoT. One example would be their dynamic traffic system that starts measuring and controlling the traffic even before the cars get into the city thanks to a large number of cameras and traffic sensors.

The findings in this part are based on responses of a "Praha 2" representative.

5.8.1 Understanding IoT

From the tested sample of 1 administrative worker (who has worked in IT for years) it is hard to tell whether or not is this concept truly understood by the decision-making parts of the city council. It would definitely be an interesting subject to analyze but due to time constraints more reliable information cannot be provided here.

5.8.2 Preferred "smart" projects

At this time in Prague the preferred projects include "smart lamps", "smart benches", "smart lighting" etc. These applications usually include Wi-Fi, a USB port for charging mobile devices and a few sensors for measuring the heat and CO2. These projects are ridiculed among the companies involved in IoT and criticized for "not being really IoT". One reason might be the aforementioned lack of education of politicians in this field. The other reason might be that these projects are more visible to the population thus they serve as a marketing opportunity for the politicians involved.

5.8.3 Communication between districts

Another great problem is that in some cases each city district operates on their own, such as the parking and traffic measuring project in Karlín (a district in Prague). Though it is positive for companies involved that these projects are slowly appearing, the fact that they are not interconnected with other parts of Prague, that are not only missing this technology, but also might be considering a different supplier/company to carry out the project thus making an integrated system for the whole city might be a huge potential problem in the future. The representative suggested that in such cases the City Hall should dictate how these projects would be carried out and not give free will to all the districts to achieve maximum efficiency.

5.8.4 Noise measurement

Noise measurement projects (used during summer concerts in the city center namely in Náplavka/Výtoň) have been in development. For example Praha 5 has already launched their own in their district and Praha 2 is waiting to see the results of this project before deploying the same technology. However it seems to be quite a complicated task to carry out, because with the rise of mobile apps, citizens send their own screenshots from their "Noise measurement" apps (that for obvious reasons are not even close to the reality) and demand that the noise levels are above the limit to which the administrative would have to respond by sending "City health station" experts in the field which is costly and time consuming - this is one of the biggest selling points of potential use of automated sensors. There are concerns for the reliability of the device, because one of the requirements for the project is that the data are available on the website of the city district and if the device malfunctioned the expected amount of complaints flooding the administrative would be time

consuming and damaging to the reputation of the city district council.

5.8.5 Water level measurement

As for measuring water levels in the river of Vltava to prevent flooding of the city the there is some skepticism about relying purely on sensors. The human factor combined with years of experience is an added level of security. It is especially important to see what is floating in the water (for example how many and how big branches there are) as this has a great effect on how dangerous the situation is. Simply putting in web-cameras doesn't really solve the problem according to the representative. Another thing is the whole area of Prague is not as big as some other European capitals thus the distances that employees have to travel are negligible so the costs are not as high as they might seem.

5.8.6 Legacy systems

In the past there have been attempts to have a unified payment card for public transport, parking and many other possible applications. The name of the failed project was "Opencard". There were many reasons for the failure one of which might have been corruption. However later on the city representatives were able to salvage a part of the project by renaming it to "Lítačka" and including the public transport payment part as well as the city library pass under that name. One of the biggest problems with this project was that it was known to be flawed but the city could not get out of the commitment.

This is one of the examples of how the city council got trapped in a sub-optimal contract. Legacy systems seem to be a problem for example in the ways documents are handled in offices under the City Hall. Thanks to using these highly specialized legacy systems for years and changing would be very costly the City Hall is forced to renew their contracts with these companies which in turn dictate their prices. This might be one of the reasons why the city might be reluctant to invest into new ambitious IoT projects.

6 Comparison to other studies

- Mindset of target clients and companies must be actively changed by companies selling IoT because there is still reluctance to invest into IoT.
    - The will to invest into IoT seems to be quite high in CZE. Companies are very excited about the concept however not everyone really understands what kind of benefits it could bring such as interconnectivity between "smart" systems and the evaluation of data.
- IoT brings new ways to bill the client based on data collection and evaluation, the sales are no longer a one-time event. [15]
    - IoT-Billing is a good example of how unconventional billing could bring new business models with concepts such as dynamically changing car insurance pricing based on driving style.
- "Willingness to invest in IoT is not very high." [18]
    - As mentioned before for example cities like Prague are allocating big sums of money into these projects but do not necessarily choose "the right" projects with the biggest possible positive impact.
- "There is a lack of IoT knowledge and skills." [18]
    - It seems that there are enough people creating new IoT applications however there are not enough sufficiently educated people that would be able to 1. troubleshoot why a sensor isn't working, 2. make solutions scalable (just 2 examples.)
    - The general public doesn't understand the concept at all.
- Management needs to go through extra education or be changed out to be able to utilize the concept IoT, there is a need of CDO's (Chief Data Officers).
    - Some companies struggle to utilize the data collected. It however is still unclear how to go about this problem.
- "EU has strong IoT advantages." [18] "Questionable, because GDPR is happening" [18]
    - From the viewpoint of successfully finished projects the EU seems to have a higher rate. However it is harder to land such a business opportunity in the EU than in USA (according to IoT-Billing).
- "Partnerships are important, because one company usually can't deliver a complete solution" [18]
    - Most companies only provide a part of a solution and have many partners. There are only a few companies that ventured from originally creating SW to HW development (e.g. CTI Software).
- There is a need of Big Data experts [19].
    - Companies need experts that are comfortable with data evaluation programs such as Grafana.

7 Creating a business idea

7.1 Asset tracking for warehouses/equipment rentals

When I rented some video gear from one video equipment rental in Prague (they want to remain anonymous), I realized that I had not seen any "proper" item identification system nor any barcodes. At the same time asset tracking in the world of IoT seems to be gaining a lot of traction and RFID technology (in retail) has been around for well over 15 years.

Doing a quick market research, I have found that this application is already in use by some major companies such as Warner Bros., Paramount Pictures etc. [31]

I have contacted all the major video equipment rentals in Czech Republic. Not too surprisingly only two (out of 15) companies responded one of which was the one which inspired the idea.

This company has already looked into the RFID technology and hired a startup from California called "GearEye" [32] which was primarily focused on confirming the presence of items inside a backpack and not in a large storage facilities and multiple rooms. This company's product was also mainly B2C and at the time it was only a Kickstarter project. They were also reluctant to provide any API's to the rental company due to the nature of their business. Another problem that they ran into was the European ETSI standard. The bandwidth of this standard is quite different from the American FCC standard that has a frequency range of 902-928 MHz in comparison to the ETSI 865-868 MHz which brings several extra complications. Then there was also the inability to come see the storage facility in person due to being overseas. Lastly the power of the returned signal wasn't enough to pierce through an industry standard protective case called "PELI case" (copolymer polypropylene [33]).

This company was very excited about my proposition and might be willing to fund the whole project during the next year. They are currently awaiting my proposition for the architecture of the system.

7.2 Polysomnography for sleep tracking

7.2.1 Motivation

I've heard one of our long-time family friends talk about his problem with sleep apnea and the ways of measuring the severity of this sleep disfunction. In short the measurement is very uncomfortable thus the data collected is not really representative of the patient's regular sleep patterns. To confirm this I went to NÚDZ ("Národní ústav duševního zdraví" – which freely translates to national mental health institution) and participated in a sleep study that involved EEG. I can confirm that the cap used for EEG can get quite uncomfortable after the first hour of measurement, the discomfort could even prevent sleep.

One of the goals is getting rid of as many wires as possible and making all the communication and data transfer wireless while maintaining "acceptable" precision and size.

7.2.2 Based on conversations with professionals

I started with testing my assumption of PSG not being comfortable enough to provide fine measurement in an acceptable percentage of measurements asking doctors and professionals in the field of biological signal processing.

The idea was to make as many of the measurement devices as small as possible, preferably wireless, starting with one of the measurements that could then possibly be taken to other applications such as sport performance analytics as seen in fig. 6.

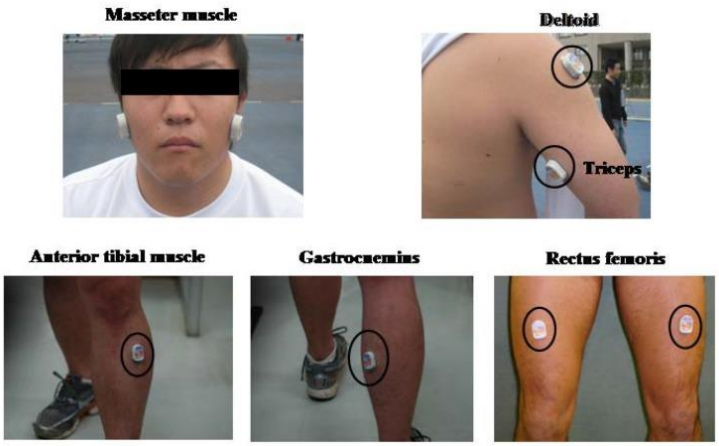

fig. 6 – an inspiration for portable sensing devices [34]

7.2.3 Doctors

With current technological options there is no need to try to advance in the realm of making every single sensor wireless, especially not trying to use Bluetooth (ISM bands) since hospitals are quite abundant in interference sources. To mention a few more problems that could occur in such technology

1. Time sync of each signal.
2. Bitrates might be too high especially if including an HD video of the sleeping patient
3. The battery consumption of such systems would call for a rigorous recharging workflow that might in turn make the whole system as slow as the original wired version.

There are several solutions already on the market including an oximeter that is a part of a PSG system called Nox T3 as seen in fig. 7 that uses a watch as a transmitter using BT connection. Experiences from practical use seem to be all over the place meaning one laboratory reported an approximate loss of data in under 5% of measurements due to the BT nature of the connection whereas another laboratory reported almost 20% - that might be due to the familiarity with the system. (Numbers are based on approximate estimates and are not based on proper research methods.)

fig. 7 - a wireless oximeter from "Nox medical" [35]

This brings us to the point of every doctor preferring a different system, mostly because of what the clinic provides them with. In USA where health insurance is not as common as in Europe the price comes into play where the patients are more cost conscious and to lower some of these costs they are often mailed the devices needed for LP of PSG. One of the contacted professionals with experience in measuring sleep disorders in several European countries that is one of the most respected in the field reported that her favorite by far is the aforementioned Nox T3 but not because it was that much superior in any way, but because she was familiar with the software and her workflow for evaluating the test results was in result considerably faster. Another favorite that came up several times (3 times) was "MiniScreen" from a German company called Löwenstein.

There is a much lower potential in developing an improvement for PSG than trying to improve LP which is also a much simpler system, especially because it doesn't contain EEG and few other measurements. LP has a much greater potential, because - as I was told by several doctors – approximately 80% of patients who come to sleep laboratories have a breathing disorder (e.g. sleep apnea) that can be diagnosed simply by using LP. As it doesn't contain that many measurement methods (professionals can put it on the patients in 10-15 minutes in comparison to 30-45 mins for PSG), they are able to put the device on the patient in the laboratory and send the patient to sleep at home, which dramatically improves their quality of sleep and the quality of the measurement. This is one of the main reasons why I have not chosen to try to make a solution for this because it goes against my initial assumption of the measurements not being comfortable enough.

There are of course risks to measurements at home such as a wire falling off during the night and rendering a part of the measurement unusable as well as unprofessional installation by the patient at home, this is of course highly dependent on each patient and on the quality of the professional instructions provided prior to the measurement. From practical experience the doctor's estimates have averaged around 5% of measurements that have had to be repeated because they didn't have sufficient data for them to be able to give a precise diagnosis. That is (according to some specialists) a very high precision and is in agreement with a 2017 study that compared measurements at home and in sleep laboratories which came to a conclusion of 96.4% agreement of measuring at home and in the laboratory [36].

As sleep laboratories get more attention in the media they are getting increasingly overbooked and a great portion of their year is taken up by repeated measurements of their previous patient. In one case a professional expressed a wish for more personnel as they had enough devices and rooms but not enough people to attend them.

Another place where it could be improved is the automatic evaluation system that again by averaging the estimates of professionals is about 50-80% accurate but it is highly dependent from patient to patient where for a perfectly healthy one it might be 90% accurate but for a patient with an irregular sleep pattern it might be much lower. The SW is there mainly for speeding up the workflow of the evaluating professional (for LP it might be around 20 mins in comparison to 2 hours without the SW).

Hospitals are reluctant to purchase single use devices like the EEG purely for PSG that requires less electrodes (around 10) than an EEG for epilepsy that has around 60 of them.

7.2.4 Technical professionals/engineers

Testing and licensing any new technology for hospitals is a problem in Czech Republic where testing a technology on yourself is borderline illegal. Finding an appropriate sample size of patients to test on is even more complicated and very expensive. Licensing a new technology in the realm of PSG might cost up to 1 mil. CZK.

On the other hand there is a possibility to try to improve these measurements by motion tracking patients with video input (either with standard motion tracking or with Kinect). The upside of this solution is that the laws are more forgiving and a question of top notch hygienic norms is almost eliminated.

Such applications could find a great use in epilepsy diagnosis and some of these ideas have already been tested at The Faculty of Electrical Engineering at CTU in Prague.

8 RFID - from client to solution

8.1 Contacting potential clients

After coming up with key concepts that might have some potential in the world of IoT it is equally as important to test such hypotheses.

PSG has been deemed very problematic due to several reasons mentioned in the previous chapter additionally it would be quite complicated to implement with a small team of people (mostly students) since it is such a complex problem.

Logically the other viable idea was RFID.

8.1.1 Retail alternative – dynamically changing price tags

When pitching the RFID tag idea to one of the largest photography gear retailers in Czech Republic (arguably the biggest one in Prague) I was told that they were rather looking for a solution of digital price tags that update from a centralized control unit with the option of dynamically reacting to prices of competitors. They had a proposal from a German company (Wincor Nixdorf) however for a three level store (about 1000 m^2) that is in a historical building the coverage with antennas would make the solution quite expensive (about 1M CZK) which would not pay off and the shop owners decided that hiring an intern is much cheaper and in the long run less of a headache.

8.1.2 The client

Because the company wants to remain anonymous so I can only provide so much information.

It is a video rental business that so far does not have a system that would be similar to RFID. They have postponed the decision of implementing bar codes but have tested QR codes. They have experienced a rapid growth in the past 4 years since the company was established. They are now the main competition in Prague for an international video rental company called Panavision with thousands of items in their inventory.

8.2 Client's needs

8.2.1 Primary needs

- Improving the reliability of the renting process over 95%
- Quick (under 5 minute) check of each order preferably with a handheld device
- A unique ID for multiple instances of the same item
- Interconnectivity with their existing online rental system
- 1-3 m read range, at least 1 m through a PELI case
- Tag cost around 1 USD as a maximum
- About 1000 "bigger" items of higher value such as cameras, lenses and light stands

8.2.2 Secondary needs

- Confirming that the client has left the building with all their gear
- Movement in and out of the building – direction of the movement of the RFID tags
- Adding about 3000 items of smaller size such as batteries
- In case of using the gateway solution the read speed needs to be around 100 pcs/s

Though they have a rigorous workflow and a very strict system for carrying out orders it is not a process that would approach a 95% success rate for larger orders. As a result some equipment gets lost at hectic times and even damaged and it is hard to track who damaged it since there is usually more than one piece of each item (especially when it comes to lenses that they have approx. 10-15 pieces each). Such events usually lead to unexpected unavailability of items and result in losses in revenue.

The client has expressed a will to invest in the initial development stages of the solution and has even outlined a possible overall budget for the finalized system.

The most important question of all is if a 95% reliability is an option at this point and time. The client said that if it wasn't possible right now but there was a future potential in this technology they would be still happy to invest in such a system.

It is also not a problem if it only worked for the big and expensive items such as cameras and lenses and not for smaller items e.g. batteries or memory cards. These items will be placed in cases as they already are rented so tracking cases should be sufficient.

Changing up workflow is not a problem e.g. segmenting the insides of PELI cases meticulously for smaller items.

There is also a desire for tracking the direction of items going in and out of the building if found as a viable option that would serve as an added layer of precision.

Different items will require different tags (size, IP Code, tags for metal) as they have various sizes and materials e.g. light stands will require much more resilient tags with a higher IP Code as well as special tags made for tracking metal items.

And last but not least interconnectivity with their website rental system that they have been externally developing for the last 3 years.

8.2.3 Challenges

There is a lot of metal in and on the walls, metal carts and metal shelves. The current workflow consists of putting parts or the whole order on an industry standardized metal cart (fig. 8) on which they'd like to scan the items just before handing them off to the clients.

fig. 8 – standardized metal cart that is used by the client

Size restrictions on lenses are also a problem as seen in fig. 9 there is usually quite a big size difference in “prime” and “zoom” lenses thus there are different size restrictions with each type of lens for the RFID tags. The smallest space that lenses provide is about 40mm x 5mm as seen in fig. 10.

fig. 9 - Two Canon „L series“ lens which are very common items at the client’s rental (about 10 pieces each) [37]

fig. 10 – a Carl Zeiss prime lens that has probably the least available space for an RFID tag (5mm on the top ring) [38]

There are various materials in camera body builds, from magnesium alloy to plastic, all these materials will have to be tested with several tags to find the optimal solution.

There is also a possibility of too great of a read distance and getting false positives, perhaps even because of all the metal in the room (see *9.5 Results*.)

A study about bending and folding octagonal chipless UWB RFID (ultra wide band - from 3.1 to 10 GHz) has proven that it has a dramatic negative effect on the read range [39]. Unfortunately I was unable to find a similar study made about more conventional UHF RFID tags with dipole antennas.

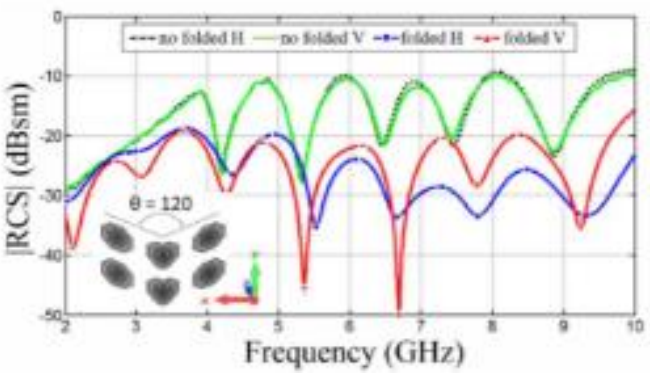

fig. 11 – Effect of different folding and bending of chip-less UWB RFID on RCS [39]

8.3 Minimum components needed

8.3.1 Tag choice for lenses and small items

The “AVERY DENNISON AD-160U7” as seen in fig. 12 is by far one of the smallest UHF labels available on the market with dimensions of 60 x 4 mm which should be possible to put on most lenses which are one of the most problematic items when it comes to size constraints. It also has a long enough range of 1.8 m that will of course be tested once delivered. Operating frequencies range from 860 to 960 MHz which conforms to the European ETSI standard. This tag also meets the price requirements with the cost of 0.72 USD per tag at 100 pieces or 0.299 USD at 1000 pieces bought.

fig. 12 - AVERY DENNISON AD-160U7 UHF RFID PAPER LABEL (NXP UCODE 7) [40]

8.3.2 Choosing a portable interrogator

The main requirement for interrogator is the range of 1-3m. The "ALIEN ALR-H450" has a range of 9.1 m with "Standard Tags" (of which I was unable to find a meaning) which is more than enough for our application, however skepticism should be in place. Circular polarization is also very important to speed up the process of scanning – while we sacrifice range in comparison to linear polarization, we need not to turn the scanner in different orientations (as much) to get a response from the tags. There are several aspects like IP Code of 64, a combined battery capacity of over 8400 mAh, weight and size that are not as important for indoor use where the interrogator will be docked in the charging station most of the time.

The most interesting aspect of this reader is that it runs on Android 4.4.2. (Kit Kat) thus Android studio in combination with a proprietary SDK (Alien SDK [41]) can be used to develop applications and modifications to the system which is hugely important to be able to interconnect with the current renting SW. Another great advantage of this is that I have previous experience with an Android mobile BLE Beacon application for tracking golf balls so the whole process might be faster.

fig. 13 – Alien ALR-H450 Handheld RFID reader [41]

8.3.3 Footnote

According to the client it is not a problem that these items would be shipped from the USA concerning VAT and shipping.

Unfortunately to this day I have still not have been provided with documentation of the SW used to

rent items.

8.4 Expanded solution

Once the initial testing is done there are several more possibilities to improve the whole architecture one of which being a gateway by the exit from the building.

8.4.1 Gateways

Range of approximately 2 m for the main doorway will be needed. Possible use of 2 antennas on each side of the door to assure perfect measurement of each item placed on the metal cart.

There is also an option of creating checkpoints at the exit of each storage room to help increase effectivity in case of losing track of an item which as written above is a source of significant losses for the company. With such architecture there would be a possibility of determining the last known location of an item and manually searching for it with portable interrogator that also has a function of sensing proximity on short ranges of around 1 m.

Gear passing through the main doorway – above/besides which the gateway would presumably be mounted – will be placed on the aforementioned standardized metal cart which might bring some problems:

1. Metal items blocking signal to other inventory pieces if the gateway is next to the doorway
2. The second level shelf of the cart would not be scanned if the gateway is ceiling mounted

Solution: use two gateways on each side of the door which in turn makes the application twice as expensive.

Some gateway solutions combine the possibility of having antennas and a reader in one device. These readers cost around 2000 to 3300 USD. Some of these readers have PoE capabilities making the installation much quicker.

Suggestion: “IMPINJ SPEEDWAY XPORTAL” is the cheapest of available gateways at 1945 USD and also the smallest (774.7 x 222.25 x 50.8 mm) which goes great with the limited space around the door.

Range (usually several meters - is undisclosed in the technical sheets), the beamwidth (elevation - 80°, azimuth – 60°) should be sufficient for our placement.

These gateways have Octane SDK which is different from the portable reader that runs on Android (Kit Kat) and has Alien SDK and that might cause minor complications.

8.4.2 Cables

Some of the cables rented out are expensive up to 5000 CZK. Zip-tie based tags seem to be the best possible option. The “PT-103” with the range of 3 m, IP 69 and dimensions of 10 mm x 5 mm (the wrap is 103 mm long) looks viable [42]. I am currently waiting for a price quote. These tags might be later tested with lenses.

fig. 14 - PT-103 UHF RFID Tie Wrap [42]

8.4.3 Metal/stands/grip

There is no size restriction however tags for metal surfaces are needed as well as a higher IP Code because light stands are not treated as carefully as cameras and lenses.

8.4.4 Batteries

Power supplies for cameras such as the Sony NEX-FS700 (fig. 15) are not a problem (this item is also very common in the client's inventory). There is enough space on each side of the pack as seen in fig. 15. The dimensions are 57.0 x 73.0 x 38.0 mm [43]. Question remains whether wet inlays will be possible to use or metal tags will be needed for this kind of item due to its internals (see *9.2 Batteries*). As a wet inlay I'd suggest the same one as we will be testing for the lenses so we can buy in bulk with extra discount. As for the choice of the hard tag I'd suggest the "MONZA R6-P" [44] with the dimensions of 55.0 x 12.5 x 1.1 mm and a tested range of 1 m for handheld readers.

fig. 15 – The battery placement in Sony NEX-FS700, the type is NP-F970 [45]

Batteries for DSLR's have a tight fit such as the LP-E6 as seen in fig. 16 the usable area is just 38 x 20 mm and fits very tightly into the camera and will not tolerate any labels of thickness over 1 mm.

The client said that it would not be a problem if these small items were tracked only by identifying the cases (fig. 17 and fig. 18) that they are placed in. This compromises the reliability of the system and also doesn't remove the "human factor" from the equation.

fig. 16 – The Canon LP-E6 battery, the possible location is the visible right wall of the battery [46]

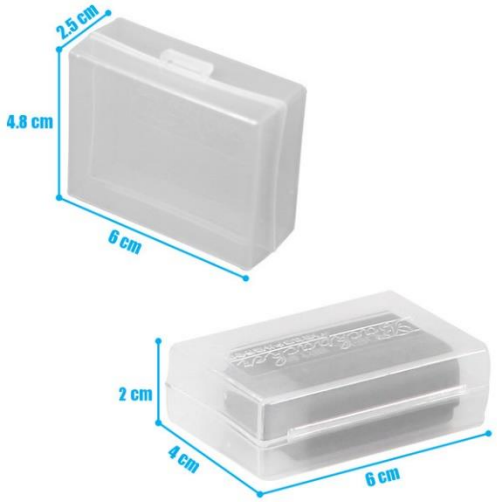

fig. 17 – (left) a battery case for LP-E6 Canon battery [47]

fig. 18 – (right) a textile pouch for batteries [48]

8.4.5 PELI cases

Tags will probably be the same high IP Code as for light-stands. The question is if the tags will be 1. inside (perhaps even behind the cushioning) or 2. on the outside. Also a lot of measurements for pieces inside those cases will have to be conducted to determine how much signal is lost in this copolymer polypropylene case.

fig. 19 – PELI Case 1510 [49]

8.4.6 Cameras

There is usually plenty of spare space on cameras (fig. 20) thus the main concern is for cameras like GoPro (fig. 21) that fit tightly into a housing. The question of whether to use a metal tag on these (usually plastic) bodies or a wet inlay remains the best option.

fig. 20 – The aforementioned Sony NEX-700 camera body offers more free space than e.g. batteries [50]

fig. 21 – GoPro Hero 6 – an action sports camera, dimensions 45 mm x 61 mm x 33 mm, client has more than 10 [51]

8.4.7 Lights

Professional Fresnel lights might cause quite a bit of problems mostly because of the metal body structure as seen in fig. 22. Metal tags will have to be used but it might not be a problem (when it comes to space and bending) in the end since this item is quite large.

fig. 22 – Arri Fresnel 2000 W light, 47.1 x 21.2 x 26 cm [52]

8.4.8 Light modifiers

Soft-boxes, bounce boards and different diffusion material might need a textile specific tag. That is not a problem to acquire since laundry businesses are already integrating RFID technology as well. Dimensions are usually not a problem for these items. Suggested tag: "INVENGO LINTRAK C" with a range of up to 3m is ideal, with the price of 0.9 USD for 100 pcs [53]. The only problem with these is that they will have to be (hand) sewed on the more rigid sides of the cloth which will be time consuming.

fig. 23 – A diffusion cloth used in film industry, notice the rigid sides made of high performance webbing [54]

8.5 Possible future improvements

Perhaps it would be possible to design custom UHF RFID tags that would have ideal dimensions for our application, especially when it comes to problematic items like lenses and batteries.

8.6 Firms in the RFID rental business

The fact that there are a lot of businesses in this specific area of RFID gives a great reassurance that it makes sense to invest time into this.

Besides the fact that this is just one very niche use case which can expand into all kinds of applications like retail and warehouse management.

Thanks to the items being so diverse in the video making business, this application will bring a wide range of items and materials to test the solution on which in turn will give us great experience for future projects.

8.6.1 Rental Works

With clients such as Warner Bros, Sony and Paramount [55] RFID tags in film making business seem to have a great potential.

This company diversified into vehicle management and parking optimization as well.

8.6.2 Rental tracker

Clients such as Disney and 20th Century Fox [31] give this company great credibility. They also provide services in garment rental for film making.

9 Measurement

The goal of this measurement is to determine whether the problems projected in the previous parts (*8.2.3*, *8.3.1*, *8.4.4* and *8.4.5*) will render the project impossible to carry out fully, cause complications or perhaps have no effect at all. This is important because if the client was not able to apply the solution to a sufficient portion of their inventory, investing in a partial solution would not pay off.

Additionally as mentioned in *8.2.3 Challenges* I have not found a study considering bending of dipole UHF antennas thus specific measurement had to be conducted.

The mentioned problems can be summarized in the following 3 questions:

1. Are metal tags necessary for batteries?
2. What is the effect on the maximum read range when bending a wet inlay?
3. How does the range change when the tag is enclosed into a PELI case?

9.1 Hardware and software used

The measurement was carried out at the power of 2 W ERP (according to ETSI EN 302-208 [56]) which is the maximum possible power that can be legally used in EU. The approximate calculation: by sending 28 dBm into the antenna with a loss of 2 dB in the cable and a gain of 7 dBi results in 33 dBm of ERP.

UHF reader - IMPINJ SPEEDWAY REVOLUTION R420, ETSI and FCC enabled, max receive sensitivity -84 dBm [57], transmit power 10-31.5 dBm

Antenna - Metra Blansko RFA01, 7 dBi, RHCP polarization [58] (one of the supervisors claimed that when he measured it, it was closer to an elliptical polarization).

Due to the antenna being static the measurement is not as representative when it comes to real application as the client demands a portable reader with which the employee can get closer as well as rotate the reader around to “change” the polarization of each tag’s antenna.

Cable - Unknown brand and type with an approximate 2 dB loss.

Software - Multireader for Speedway Gen2 RFID v6.6.13.240 (from Impinj)

Tag	Purpose	Size [mm]	Claimed range	Price/pcs
1. Alien Squig White Wet Inlay	Non-metal	47.5 x 13.4	> 3 m [59]	$52/100
2. Confidex Steelware Micro	Metal, hard-tag	13 x 38 x 3	up to 3,5 m [60]	€1.406,25/1500
3. Avery Dennison AD-550M5*	Non-metal	38 x 76	> 4.6 m [61]	discontinued
4. Confidex Ironside Micro	Metal, hard-tag	27 x 27 x 5.5	Up to 5 m [62]	$449/100

Table 1 – Tags used in the measurement; * - the supervisors were not sure of the tag type, it was a free sample

9.1 The setup

Despite limited resources, we managed to setup a measurement (fig. 24) that has brought some valuable insights. The room itself contained a lot of interference sources and reflective surfaces such as PCs, cables, measuring devices (oscilloscopes) and metal (mounting brackets for various devices like antennas) which corresponded with the setting in the client's storage facility also abundant with metal shelving, electronics and metal beams in their drywalls.

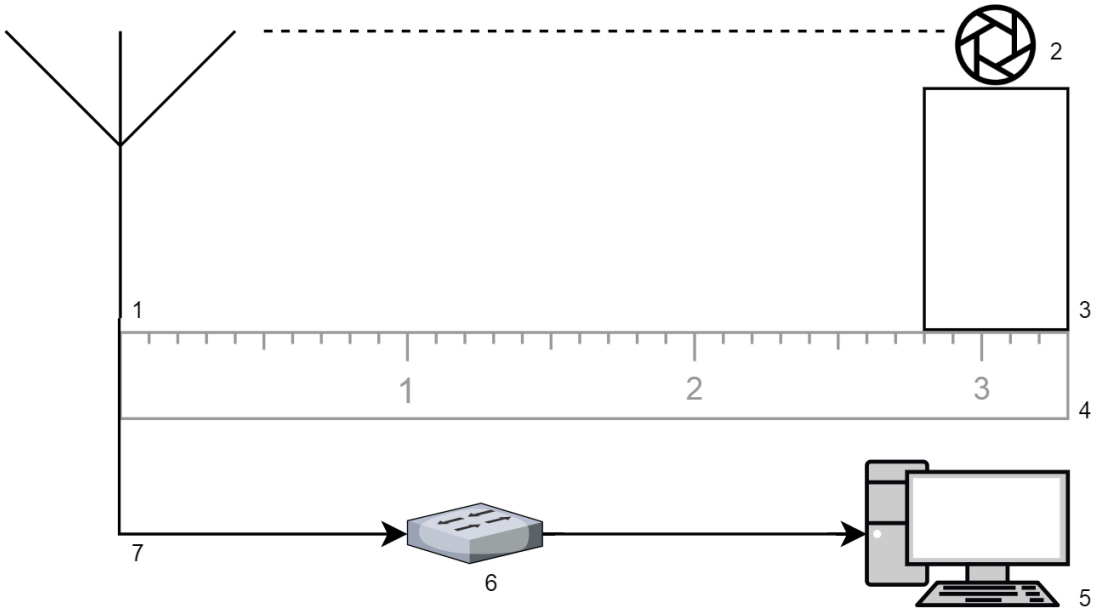

fig. 24 – the setup of the measurement – 1 – antenna; 2 – the item with an RFID tag; 3 – stand; 4 – measurement tape; 5 – PC running reading SW; 6 – UHF reader; 7 – cable; created with draw.io

9.2 Batteries

The battery tested was Sony's NP-F970 (see *8.4.4 Batteries*). The tags were stuck directly on them in the case of wet inlays or - for hard-tags - secured on the battery using a tape (PVC electrician's tape) as seen in fig. 25 and fig. 26.

fig. 25 – (left) – 3 Avery Dennison AD-550M5 tag stuck on the NP-F970 battery pack

fig. 26 – (right) – 4 Confidex Ironside Micro tag on NP-F970

There were two measurements conducted with the tag (in the X-Z plane of Cartesian coordinate system):

1. Facing the antenna
2. Facing away with the battery in between the line of sight of the tag and the antenna

It might be useful to point out that the positioning of the hard-tag had a major influence on the read distance (especially in the 2nd measurement) where it was significantly shorter when the tag was placed in the center of the battery wall than when placing it on the edge (fig. 26). The measurement was highly dependent on the rotation around the y-axis despite the RHPC antenna polarization.

Tag	**1. Range [m]**	**2. Range [m]**	**Claimed range [m]**
1	0.4	0	> 3
2	1.1	0.3	up to 3,5
3	> 2.1*	0.6	> 4.6
4	1.1	0.8	Up to 5

Table 2 – Measurement of the real range in an environment abundant in interference, reflected signal etc., * - limited space in the laboratory prevented us to go further

9.3 Bending wet inlays

This measurement was conducted with the tag facing the camera. The tags 1 and 3 were not designed for use on metal surfaces. Lens 1 was mostly made of metal whereas Lens 2 had plastic moving rings for zooming.

Tag	Lens 1 [m]	Lens 2 [m]
1*	0*	0.1
3	0	0.8**

Table 3 – the effect of bending of dipole UHF RFID tags on the read range; * - when on metal, but when put on a less convenient plastic part of the lens – it was 0.9 m; ** - when turned away from the antenna it was 0.4 m

fig. 27 – (left) - Lens 2 with tag 3 - Canon EF 16-35mm f/2.8L III USM; the radius is 41.5 mm

fig. 28 – (right) – Lens 1 with tag 1 - Panasonic Lumix G Vario 12-60mm f/3.5-5.6 ASPH; the radius is 29 mm

9.4 Losses through a PELI case

Unexpected technical difficulties have prevented us from measuring the precise difference in power of the backscattered signal when in and out of the PELI case. We decided that the best way to measure the effect would be to put each tag on an item at maximum read distance (at a certain polarization of the tag) and then mark the exact position. Then we placed the PELI case in a way that the item inside would be at the same approximate height and distance from the antenna and moved the stand with the case on it further and closer to the antenna.

We found that there was no difference in the maximum read distance in our setting.

The PELI case used was “B&W International Type 4000 black” (technically it is not a “PELI case” but a “protective case” but it is also made of polypropylene [63].)

9.5 Results

Coming back to questions raised in the beginning of the measurement:

1. Based on our results we cannot clearly state whether metal tags or wet inlays (for plastic) are the superior choice for batteries when it comes to the range. Though using a long-range wet inlay (tag 3) seems like the best choice from the standpoint of space restrictions around the battery since the range is limited from 2.1 m to 0.8 m which is nearly sufficient for our minimum read distance requirements.
2. The maximum distance was lowered almost to a third when bending the tag in a radius of 41.5 mm (comparing *Table 2* and *Table 3*). Additionally (and not too surprisingly) we cannot get away with using wet inlays (meant for plastic and glass) on metal. What was enough to remedy this problem was to place the tag on the plastic moving ring (used for zooming) as seen in fig. 27 (though highly inconvenient and practically unusable).
3. There turned out to be no measurable difference in the maximum read distance in or inside the case (with closed or opened lid) with our setup.

Other insights:

1. RHCP polarization does not mean that the tag's rotation (dipole polarization) does not have significant effect on the read distance
2. Measurements with the same tag on an item are highly dependent on how the item is placed on the stand, being very dependent on every small interference source (such as a human body standing nearby with a cell phone etc.)
3. False positives were a frequent phenomenon as the signal from the antenna "bounced" around the room and measured tags that were out of the measuring area in a different part of the room

10 Conclusion

Online research has proven that IoT has a real potential when it comes to availability finances and willingness to invest in IoT. The word is clearly not just a buzzword but undoubtedly plays a big role in selling certain applications such as “smart” city objects.

This industry has a real potential but a big part of that is that it contains almost every branch of the industry and the potential use cases and business opportunities are wide ranging.

B2B businesses are currently encountering some previously unexpected problems such as not enough professionals to install the devices on site as well as occasional insufficient education concerning the IoT for politicians and city representatives resulting in seemingly overpriced projects such as “smart lighting” and “smart benches” that do not use the concept of IoT to its full potential.

Medical applications were mentioned as the “sleeping giant” of the IoT business in the theoretical part. It however does not look that promising in CZE. It might be because of the strict and expensive certifying procedures as well as reluctance of clinics to invest in new technology if there is clearly not a significant improvement in measurement, incremental improvements are not enough.

RFID tag technology that has been around for well over 15 years (in this area, first patented in 1983 [64]) is just now experiencing mass application in rental businesses as well as warehouse inventory management. Based on this knowledge I designed a proposal to several potential clients and successfully managed to start working on a solution with one company willing to invest in this project. Due to time constraints only a basic proposition for initial stage development kit has been pitched to the client.

The measurement proved that the RFID technology can only be measured to a certain extent and that a lot of sample tags will have to be ordered and tested on each type of item if not on every individual piece. As for the expectation of PELI cases being a problem, that was deemed to be wrong. In our setting they had no measurable effect. Conversely bending wet inlays was proven to be highly problematic especially with dipole antennas.

11 Future development

Measurement of precision of the RFID tags and the suggested portable reader in different possible scenarios within the client’s shop on different items is much needed. At the current time we are trying to find ways to perhaps rent portable RFID readers before purchasing one. A sample pack will be ordered and tested. After a viable solution is found software interconnectivity will be next. Then there is a possibility of improving on the architecture with gateways and other possible HW to maximize the efficiency though there is a question of how good the ROI would be since a high performance portable reader costs around 2000 USD [65] which is around the same price of a gateway (with a built in reader [66]) that would serve as an additional checkpoint to the portable version. Lastly there is a possibility of designing application specific RFID tags in the future.

12 Abbreviations

IoT – Internet of Things

IP – "IP Code, International Protection Marking, classifies and rates the degree of protection provided against intrusion" [67]

SW – Software

HW – Hardware

GDPR - General Data Protection Regulation – as of 2018 a new regulation in the EU that is more strict than the one before

MVP – Minimum Viable Product – "A minimum viable product (MVP) is a development technique in which a new product or website is developed with sufficient features to satisfy early adopters." [68]

HAT - Hardware Attached on Top

LPWAN - Low-Power Wide-Area Network

ISM band - industrial, scientific and medical radio band

CZE – Czech Republic

B2B – business to business

B2C – business to customer

PSG – Polysomnography, it is a set of medical measurements containing EEG, EKG to determine sleep disorders

EEG – Electroencephalography measures patient's electric activity in patient's brain [69]

EKG/ECG – Electrocardiography records electrical activity of the heart [70]

BT – Bluetooth, wireless technology

LP – limited polygraph, in comparison to PSG it doesn't contain EEG and several other methods, it is a simpler method sufficient for sleep apnea diagnosis that

Sleep apnea – mostly overweight patients whose muscles around their breathing tract relax [71] and cause them to gasp for air during sleep, 80% of patients who come to sleep laboratories have a breathing problem, thus LP is the most used method.

RFID - Radio-frequency identification

DSLR – Digital Single Lens Reflex – the most common type of digital cameras

RCS – radar cross section – "measure of a target's ability to reflect radar signals in the direction of the radar receiver, i.e. it is a measure of the ratio of backscatter power per steradian" [72]

ERP - equivalent radiated power

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14 Appendix A – Questions sent via mail

Questions 1-5 are designed just as short warm-up questions, so short answers are welcome.

Questions 6-12 don't necessarily have to be answered all at length, there are rather here to find a "pet peeve" and having perhaps one to two great answers that might be thought provoking for my further research would be very helpful.

General

1. What is the main focus of your company?
2. What is the main focus of your company concerning IoT?
3. What divisions does the company have (HW, SW)?
4. How big is your company (preferably the approximate number of employees or other quantifiable statistic)? Is your company a daughter company or a part of a bigger group?
5. Are you B2B or B2C?
6. How familiar are companies/state officials with IoT nowadays and how willing are they to invest in it? Are they lacking knowledge about what advantages the IoT brings?
7. Are there enough experts in the world of IoT? If not, what skills are lacking?
8. A unified IoT ecosystem seems to be one of very discussed problems, do you see it as a problem? If so what do you think could help?
9. What value do they see in IoT to the customer/business?
10. Main technical concerns? (e.g. battery life, resilience of electronic components, security e.g. do you see problems in communication protocols for example the KNX secure protocol etc.)
11. Do you find there are differences in markets such as USA vs Europe? Is there perhaps a difference of thinking or knowledge of government officials or businesses in general?
12. What kind of questions would they find valuable answered by other companies?

Ending questions

1. Do you wish to remain anonymous as a company or not?
2. Do you wish to be sent the results of the study?

15 Appendix B – Example of an e-mail template used for research

Hi,

I have first come to contact with your company's representatives at SigFox IoT Expo 2017.

Your company has immediately caught my attention mostly because of how important of a role billing has in IoT as the whole concept is quite different from other business opportunities and this opens new doors for the better or for the worse.

I am a student of Czech Technical University in Prague (faculty of Electrical Engineering). I am conducting an IoT market research as a part of my thesis.

It would be very beneficial to my study if you were able to answer a few basic questions regarding the IoT market.

As a repayment I would sent my work to you with answers from mostly Czech and European companies.

A 5-15 minute phone call or only an email exchange would be much appreciated.

Best regards

Jakub Novák

[My phone number]