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THE ROLE OF TELECOMMUNICATION COMPANIES IN INTERNET OF THINGS

by

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Dissertation presented as partial requirement for obtaining the Master's degree in Information Management, with a specialization in Information Systems and Technologies Management

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ABSTRACT

Internet of Things is pervading the enterprise and consumer worlds. This technological concept is leading towards pervasive connectivity and encompasses everything connected to the Internet, being used for defining objects that 'talk' with one another. As stated by many reports, it is expected to generate a huge amount of added value through applications and the resulting services. Telecommunication companies with their central role, and their well established ability to connect millions of devices, are in a distinctive situation brought by the opportunity of new revenue streams and new challenges resulting from this revolution of connectivity. Their share of the added value market that is generated by the IoT is going to be dependent on the role they are going to play in the value chain.

The purpose of this work is to investigate the impact Internet of Things will have on the telecommunications industry and to identify and analyse the possible directions for telecommunication companies as they take their role in IoT. In addition the IoT value chain is examined, possible business models for telecommunication companies in IoT are identified, and technology and business related challanges are elaborated. Furthermore in this work, a case study on Makedonski Telekom AD is presented.

Telecommunication companies, being in the process of planning and/or implementing IoT have several business models to consider. The ones that will position themselves highly on the value chain, will have to play smart in order not to focus too heavily on industry specific solutions and balance in adding highly differentiated vertical offers where feasible on one hand, and facilitate third-party vertical solutions where differentiation is more difficult and the investment is too great on the other, so they do not underplay their hand in the connectivity and life cycle management layer.

KEYWORDS

Internet of Things; Telecommunication Companies; Telecommunications Industry; Value Chain; Business Models; Case Study; Challenges.

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LIST OF ABBREVIATIONS AND ACRONYMS

ADAS	Advanced Driver Assistance Systems
AEP	Application Enablement Platform
API	Application Program Interface
ARPC	Average Revenue per Connection
BaaS	Backend as a Service
CaaS	Communication as a Service
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expense
CMAS	Commercial Mobile Alert System
CMP	Connectivity Management Platform
CSP	Communications Service Provider
DM	Device Management
DoS	Denial of Service
E2E	Exchange to Exchange
ETS	Emergency Telecommunication Service
ETWS	Earthquake and Tsunami Warning System
GCC	Green Cloud Computing
GDC	Green Data Center
GM2M	Green Machine-to-machine Communication
GWSN	Green Wireless Sensor Networks
IaaS	Infrastructure as a Service
ICT	Information and Communication Technology
IoT	Internet of Things
KPAS	Korean Public Alert System
LAN	Local Area Network

LP-WAN	Low Power WAN
M2M	Machine to Machine
MIMO	Multiple Input and Multiple Output
MTC	Machine Type Communication
NFC	Near-field Communication
NFV	Network Function Virtualization
O&M	Operations and Maintenance
OPEX	Operating Expense
OTT	Over-the-top
PaaS	Platform as a Service
PAN	Personal Area Network
PWS	Public Warning System
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technologies
RFID	Radio Frequency Identification
SaaS	Software as a Service
TAC	Type Allocation Code
WAN	Wide Area Network
WAN	Wide Area Network
WPS	Wireless Priority Service

1. INTRODUCTION

1.1. CONTEXT

The developments in wireless and computer technologies, in recent decades, have led to processors and sensors being embedded into a lot of objects that are used in our daily lives. In order to be able to build and design a real smart environment, these advancements are supported by huge developments in many research and industrial areas, some of them being ubiquitous computing, wireless mobile communications, portable appliances and devices, machine learning-based decisionmaking and many more. A smart environment, that makes peoples' lives more comfortable, has sensor-enabled devices that work together, in order to build a small and connected world. Kevin Ashton has first introduced the Internet of Things concept where smart objects are connected with the Internet (Matin & Gad-Elrab Ahmed, 2019).

Internet of Things is popular and getting attention in a lot of fields nowadays, some of them being agriculture, transport, and healthcare. There are reports from Cisco that 50 billion devices and objects will be connected to the Internet by 2020, and in addition that the Internet of Things will contribute $117 billion to the Internet of Things based healthcare industry. And, according to Gartner and Forbes the Internet of Things will contribute $1.9 trillion to the global economy. Automotive News predict that the number of cars that are connected to the Internet in the world will increase from 23 million to 152 million in 2020, and according to Navigant Research's report the number of installed smart meters worldwide will grow to 1.1 billion by 2020.

Internet of Things based smart environments can be classified in several areas based on the application requirements. Those areas are smart cities, smart homes, smart buildings, smart transportation, smart grid, smart health, smart agriculture and smart industry.

From connected cars and smart homes to wearable devices and smart cities, the technological development is leading towards pervasive connectivity and transformation of traditionally "mute" devices into connected and data generating Internet of Things devices. The Internet of Things would change the way of human interaction with machines and will lead the way to a hi-tech machine-tomachine interaction. Almost all the devices around us would be connected to the Internet, and would be collecting and exchanging data with the other devices.

With the connected devices thriving on the market, there is a radical increase in the consumption of data. According to many business intelligence reports the Internet of Things has the potential to generate huge added value through applications and resulting services, and companies around the world are in constant battle to capture this share of added value. To keep in pace with this, telecommunication companies are fine-tuning their strategies and data services. In order to stay a step ahead of their competitors telecommunication companies are revisiting their infrastructure, as well as their partnerships and business models. The advent of the Internet of Things is changing the way telecommunication industry functions and would have an immense impact on it.

1.2. MOTIVATION

IoT leads to new business models and opens new opportunities on the market, and network providers who have until now excelled at connecting phones, PCs, tablets and other consumers' devices will have to develop new capabilities to be able to create and manage the IoT ecosystem. As these are still evolving areas and technologies, and telecommunication companies are in the process of setting their infrastructure, partnerships and business models for IoT, the research on this topic does not have a long history. There is a considering amount of research done on the IoT, and also on telecommunication companies throughout their existence, but there is a lack of research done that will consolidate that knowledge and will investigate the interconnection between the two. Further research is needed to correlate and deepen the knowledge in the influence the IoT will have on the communications industry and the possible directions in which telecommunication operators can consider to move. As so, a need has emerged to investigate this matter, which was the motivation for this Masters' thesis.

1.3. OBJECTIVES

The main goal of this work is to investigate the impact Internet of Things will have on the telecommunications industry, to identify and analyze the possible directions for telecommunication companies as they take their role in the Internet of Things and on this basis, to examine a real life example. Following are the main objectives of this work:

- To examine the IoT value chain and to identify the possible business models for telecommunication companies in IoT.
- To investigate the impact of IoT on the telecommunication industry and to understand the challenges for telecommunication companies in IoT.
- To identify a suitable case study concerning the telecommunication companies' role in IoT.
- To analyze the case study.

This work has the following structure:

In the introductory part the context is elaborated and the motivation, the main goal and objectives of this work are presented.

In the second part, the Internet of Things concept is introduced.

In the third part the role of the telecommunication companies in IoT is elaborated. The IoT value chain and possible business models for telecommunication companies are presented, the impact of IoT on

the telecommunication industry is investigated and also a strong accent is given on the challenges that the telecommunication companies are facing in IoT.

The methodology is explained in the fourth part of this work.

The fifth part is consisted of a case study, including an interview, and the following, sixth part, is the discussion.

And, in the seventh and final part the conclusion is given.

2. INTERNET OF THINGS

Internet of Things can be defined as a network that is interconnected and consists of things and objects that are able to interact and cooperate with each other and also with other things and objects using wireless and wired connections, in this way creating applications and services that are of benefit to the society. The benefits that the Internet of Things brings in this way are almost limitless and have the potential to radically change our lives with creating possibilities for growth and innovation and, by saving time and resources (Bahga & Madisetti, 2014).

The potential that the Internet of Things has is disruptive in almost all the application domains, and this is creating many challenges that need to be faced and considered when IoT-based solutions are implemented, such as prevailing over obstacles that are generated by the fragmentation of the Internet of Things, in terms of application domains and technologies too. Therefore, it is quite challenging to recognize all the potential that Internet of Things applications have, while having in mind the technology development and the requirements of the individuals, businesses and the society as a whole as well.

The Internet of Things as a huge network of sensors and smart devices and combined with advanced analytics and cloud services in order to make sense of all the data is promising to augment and disrupt products and services across industries. And expectations, which every day grow more spectacular are that within few years there will be up to 20 billion IoT devices, which will generate 5 trillion gigabytes of data every year, thus creating more than $300 billion in opportunities by 2020 (Chaouchi,2013).

Since Internet of Things will affect different industries, the executives in these industries will have to understand where in their industry the effect will happen and also where it comes from. Also it will be important for them to understand where their companies can enter and play and what are the capabilities that they will need to win. For many it is difficult to get a foothold and to develop a strategy, and many are investing significantly, but few have a clear roadmap, while complete solutions are still in their infancy.

The Internet of Things is not just one market, it is a set of overlapping markets and with strong connections to analytics and the data centre (Figure 2.1). And technology executives should consider this when forming their strategies. They need to understand which are the battlegrounds that are emerging, and how platform dynamics can shape the competition and the profitability. They also need to see what are the barriers that exist to adoption, such as security and interoperability, and this will help them in determining where to invest and what is required in order to win.

The IoT strategy will be dependent on the position of the company and the dynamics of the battleground. When designing their strategy, executives should consider some questions, for example:

- What segments should we prioritize?
- Where can we generate revenue and profits?
- What do our customers need?
- Who will we compete against, and how can we differentiate ourselves?

- What parts of a solution should we deliver on our own, and where will we need partners?
- What standards should we support?
- What capabilities will we need?
- Where should we invest?
- What are the risks of not acting? (Kamal, 2017)

If executives want to position their companies for leadership, it will be critical for them to answer these questions and to form a strategy in the Internet of Things battlegrounds context. As the Internet of Things is gaining traction and begining to influence most of the industries over the next three to five years, to mobilize now is essential.

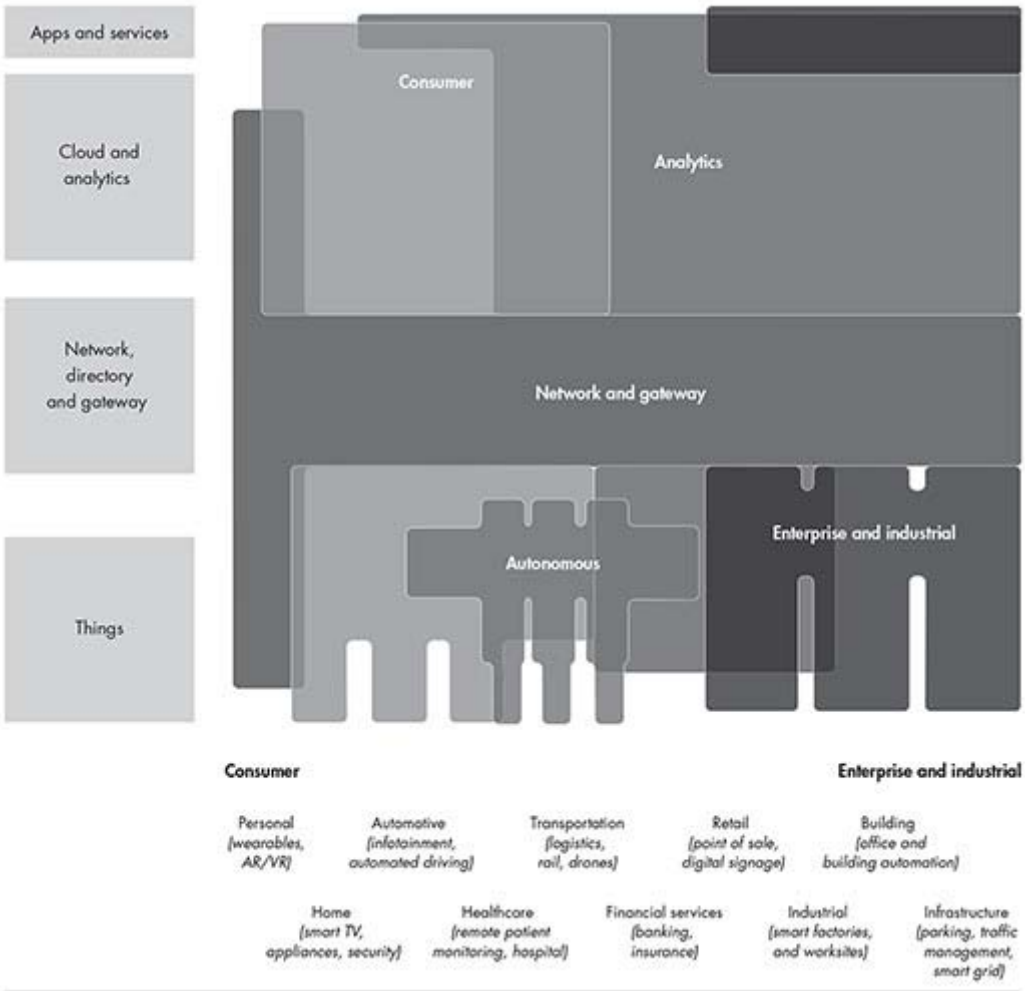

Figure 2.1 - The internet of things is not a single market but a collection of overlapping ecosystems

Source (Bosche, Crawford, Jackson, Schallehn, & Smith, 2016)

3. THE ROLE OF TELECOMMUNICATION COMPANIES IN THE DEVELOPMENT OF INTERNET OF THINGS

During the rise of the Internet, communication services treated their network providers as little more than 'dumb pipes', providing bandwidth. The Internet of Things revolution, requiring a dramatic increase in strong, secure communication links, offers providers an opportunity to not only play a larger role but to create new value.

The Internet of Things has become increasingly visible thanks to the rise of intelligent thermostats, interactive fitness trackers, and the promise of autonomous vehicles. Such technologies are compelling because they make the things around us smarter and more interactive. In the words of one commentator, we need no longer settle for dumb tools but can instead look forward to 'enchanted objects' (Buyya & Dastjerdi, 2016). The sensor technologies that make things 'smart' are only part of the Internet of Things, however, and connecting all of these devices is what makes isolated pockets of technology a network that generates and pools data in ways that lead to valuable insights.

Communications have a central role in many Internet of Things deployments, and thanks to this companies often create value as a function of the interaction between the sensor technologies and the network layer. When linking new and legacy sensors within an Internet of Things ecosystem companies that seek to realize value from the Internet of Things need to work closely with their CSPs (Communication Service Providers).

These advantages together provide a three-layered opportunity for telecommunication companies which they can use to develop unique and differentiated strategies for the Internet of Things. The three-layered opportunity is as follows:

- Connectivity which represents the network as it interconnects billion of devices with analytics engines and massive data warehouses. In this layer of opportunity also network services are included, some of them being quality-of-service guarantees and pricing plans, and also the ability of running analytics engines in the network, managing data flows more effectively and accelerating response time;

- Life cycle management represents the ability of managing the complex cycles of devices enablement, authentication, management, maintenance and replacement. And doing this ina way that will ensure security of the network, device directory maintenance, and also rights management. Management like this can often take place years after the devices are installed and also spans a universe of devices which is very larger than what other suppliers would typically manage.

- Vertical solutions represent the industry-specific offers. They deliver value to the enterprises and the consumers and telecommunication companies can participate directly or choose to facilitate through the other underlying layers, the vertical solutions that the others will provide (Tomlinson, 2000).

Only telecommunication companies have the experience and capabilities to deliver carrier-grade networks that meet compliance requirements and governance demands across a global range of

regulatory schemes. They are building software-defined, virtual networks that can offer flexibility in terms of service suites and various security and performance levels. This flexibility will be essential in allowing clients to automatically self-provision when necessary or enabling integration with thirdparty systems through appropriately monitored APIs.

Telecommunication companies have deep expertise in deploying, maintaining and decommissioning the millions of devices on their networks, and this is where the opportunity in life cycle management comes from. They have expertise in managing devices like mobile phones and tablets which have a SIM card and link directly to an individual account. Although most of the telecommunication companies' executives are aware of this, there is an even larger opportunity that comes from managing the billions of devices without SIM cards and laying behind gateways, for example, controllers on factory floors and thermostats in private homes.

The focus in the early days of the Internet of Things is on the developing and deploying the initial device infrastructure, and few are thinking about the scale of Internet of Things devices after deployment, and also the massive effort that will be needed to manage these billions of devices throughout their lives. Related to this, top-down estimates for commissioning, maintaining, upgrading and decommissioning these devices could be more than $28 billion globally by 2020 (Blum, Jackson, Sinha, & Smith, 2017). Another clear opportunity for telecommunication companies is that they can develop platforms which the other industrial and consumer companies can use in order to manage their devices. A life-cycle management platform with a telecommunication company's brand which is trusted could be a significant selling asset for industrial and commercial businesses that are selling vertical solutions. Telecommunication companies can also use their advantaged position in terms of connectivity and life cycle layers to assemble vast data lakes of information. Then, they can make that information available to providers of vertical market solutions. They could also furnish infrastructure embedded in the network where analytics engines reside, whether it is operated by the telecommunication companies or by others, allowing analytics to be performed at the edge. Faster response times, and better control of which information flows or does not flow into the network will be some of the benefits.

Telecommunication companies, if well executed have a very competent position to build powerful platforms that enable vertical market solutions, and they can deploy these solutions themselves or, which may happen more frequently, they can support third-party solutions on telecommunication companies-provided platforms. Some of the vertical markets and segments where it would be logical for the telecommunication companies to enter and compete are already becoming crowded, such as smart homes, which are also drawing investments from cable TV providers, home security firms, and other tech behemoths such as Amazon , Facebook, Google, and Microsoft.

When focusing on vertical solutions, it is important for telecommunication companies not to underplay their hand in the two large horizontal spaces where they have the right to compete and win. In terms of scale connectivity solutions that are in the centre of the Internet of Things, only the telecommunication companies have the experience needed and, second, in terms of managing extensive directories and the life cycles of millions of devices they are also the only players with experience. Developing and managing analytics at the edge of the network and across a range of uses and industries is also where telecommunication companies have a strong position. The strengths mentioned and combined with the trusted status that telecommunication companies enjoy, leaves them uniquely qualified to facilitate the Internet of Things solutions.

3.1. DISRUPTION IN THE TELECOMMUNICATION COMPANIES' REVENUE STREAMS

For the past three decades telecommunication companies have dominated the business in information and communication technologies industry, and the main reasons for this were based on the high demand for a communication medium, therefore, a mean to transport information from a source to a destination. Their revenue streams for the most part were based on provision of voice calls and SMS services (IoT-Ignite's Whitepaper, 2017).

In recent time, there was an emergence of smartphones as a form of mobile computation devices and an increase in the amounts of offered information and lifestyle and entertainment services delivered through smartphone applications. In order to diversify their revenue sources, telecommunication companies started offering data plans. A communication medium has become a commodity rather than a luxury in recent times. The provisioning of a communication medium is on what the business success of telecommunication companies can be owed to.

Also there are other factors that have caused the profits of telecommunication companies to drop. One of them being the work of telecommunication regulation agencies and various international agreements, that have resulted in for example, lower roaming or no roaming rates at all. An addition to that is that telecommunication companies are facing companies that deliver alternative communication services as competitors. Telecommunication companies have been put to test with the decrease of revenues from voice calls and SMS that was caused by the Over-the-top content services. In fact, in 2013, the number of exchanged OTT messages was larger than the number of exchanged SMS messages for the first time in history (IoT-Ignite's Whitepaper, 2017).

The way in which we communicate has been disrupted by the mentioned services and the predictions are that this trend will continue in the future. Regarding telecommunications, the choice for telecommunication companies in terms of terminal devices have become mobile devices, smartphones and tablets. This is owed not only to their ability to provide means of communication, but to their ability to act as delivery point of various digital services as well, and this is also the reason why mobile devices have also become an important part of the value creation in the digital disruption. For one to be able to fully understand the telecommunication companies' situation and the possible future directions, to look at the value chain and the distribution of revenue of modern services is very important. Traditional value chain of services directly or indirectly relating to telecommunication companies shows that much value was captured by infrastructure provisioning and device management links, directly affecting telecommunication companies' revenue streams.

In the times of digital disruption, where the value chain has also changed, telecommunication companies face a challenge in finding a way to capture the full potential and to monetize on these new digital services.

Although the situation is expected to change in the future, the majority of the connected devices today are mobile phones, tablets, and laptops, and the digital service as a part of the digital economy, whether it is consumer, medical, finance, agriculture or retail domains, is delivered to the end users through connected devices.

3.2. INTERNET OF THINGS VALUE CHAIN

Ericsson's research on the Internet of Things forecasts that by 2026, there will be 20 billion IoT connections worldwide, up from 7 billion in 2017. This 20 % compound annual growth rate (CAGR) means that connecting these devices and helping them communicate is streaming to be a considerable business. This research also predicts that telecom service providers will be looking at a $619 billion industry digitalization market by 2026, a 35 % bump compared to the revenue from their services today.

According to Porter, 1985, value chain is a business model that describes the full range of activities needed to create a product or service, and it can be conducted at the firm level, as internal value chain, or at an industry level, industry value chain. And at industry-level, an industry value chain consists of the various processes involved in producing the goods and services. The industry value chain is composed of all the value-creating activities within the industry, beginning with raw materials, and ending with the completed product/service delivered to the customer. For a vertically integrated business the internal and industry value chains can be almost the same. Same as with any other industry, there is a value chain that is associated with the Internet of Things when it comes to telecom services. The first level is all the connected devices. From industrial way of looking at it, these devices can be anything. From connected machinery in factories, to the sensors and cameras that make cities "smart", such as: cars, fitness watches, pet trackers etc.

The second level is related to the network and connectivity and it deals with how devices communicate and how they are connected. Also, where the device and network data is collected by service providers and uploaded to the cloud.

The third level relates to the software platforms that manage devices and applications and all the data in use. It includes all the expected features, such as: charging and billing, security, analytics etc.

And the final level in the value chain brings us closest to the end users, whether they are consumers or industry, and all the applications and services that they use to take advantage of the Internet of Things.

The market opportunity consists of everything, from network connectivity to software and applications. As the Internet of Things market matures, the higher a service provider is on the IoT value chain, the more potential for revenue growth it will have. The above mentioned Ericsson's research shows that 80 % of service providers in order to grow revenue were looking to move up the chain beyond networks and connectivity. It also shows that 70 % did not have a well - defined strategy to do it.

For telecom carriers to move up the value chain it may require for them to get out of their comfort zone and start diversifying existing offerings by providing IoT network integration services or even device lifecycle management to its enterprise customers. They can also take on new paths such as delivering IoT platform services and industry solutions. Whether taking a completely new path to embrace more sophisticated roles, or diversifying the existing offerings, developing new capabilities is essential for moving up in the IoT value chain.

3.3. BUSINESS MODELS

The IoT Barometer 2017-2018 from Vodafone shows that between 206 and 2017 the number has doubled of companies implementing large-scale Internet of Things networks with over 50 000 connected devices. Also, that in China, 20 % of cellular connections are Internet of Things connections and that the number of Internet of Things connections will account for most of the mobile connections by 2020, are the forecasts.

In how the leading operators are implementing Internet of Thing, the trend that is being witnessed is that during initial implementation they break into the upstream and downstream ends of the value chain with application services and devices and then, in order to tap value from ICT industry and to avoid pipefication, they extend from the two ends.

Typical model for operator IoT implementation is " 1+N+X" (Huawei, 2018), where

1 = IaaS + Connectivity management platform (CMP): infrastructure and connection management services, where operators have inherent expertise

N = Device management / Application enablement platform (DM/AEP): construction of enablement platforms with partners

X = SaaS: opening up capabilities and tapping value from ICT industry customers.

The basis of "1+N+X" are IaaS and CMP. PaaS capabilities enable the connection and management of devices and scenarios with high concurrency or high number of connections, which can be expanded to enablement platforms, SaaS applications and finally, industry solutions, and at each successive layer the value from the Internet of Things increases. A question we are looking at is how to reconstruct the business model, since traditional models, such as network construction or selling data traffic, do not apply to developing Internet of Things services.

3.3.1. Possible Business Models for Telecommunication Companies in Internet of Things

Opportunities for big data applications are created by industry data that is generated by high numbers of connections, and also about 60 % of the industry chain are smart devices and upperlevel-applications, while value of connections and platforms yields just 20% (Huawei, 2019). The result is, all ecosystem players wish to occupy leading positions in the value chain by using their existing strengths to move into upstream and downstream sectors.

Following are connectivity based business models, with more services provided and more value obtained from each successive model (Huawei, 2019):

IaaS

Traditional M2M market, very simple approach, uses a data package sales model. Operators sell SIM cards and provide only general network guarantees and billing functionality. They do not know where or in what scenarios they are used.

PaaS

Providing SIM card management services and offering customer - facing services like self - service allowance queries and top ups, and volume activation/shutdown, the operator constructs CMP for the Internet of Things market. The operator at this stage can also adopt a message - based billing method as well as the traditional one based on data usage. CMP provides a link to industry customers, so operators can package cloud services on top of connectivity services and also move into the module market.

PaaS+

A model that includes building an Application Enablement Platform (AEP), letting operators to integrate Communication as a Service (CaaS) capabilities such as voice and video calls, SMS or data storage, with third party capabilities such as voice semantic identification, maps and image recognition. In addition to a billing model based on data usage or messages, customers can be build according to the API invocations or functions packages, since these capabilities can be open to developers and industry customers through cloud APIs.

SaaS

The operator builds general purpose industry suites by refining solutions for common industry requirements and then the customer just needs to do a small amount of development and customization to meet their specific needs for different scenarios such as: smart homes, smart metering or warehouse management, and the billing model can be based either on the number of connected devices or on the industry suite.

SaaS+

The carrier provides connectivity as well as device and upper - layer application platforms. This way realizing E2E integration of upstream and downstream ends of the chain. Through service provision, it participates in industry back end O&M, and by generating value for industry customers, the operator can acquire even higher returns and participate in value distribution through revenue sharing. This is a suitable model for new application scenarios in small-scale industries that are easier to enter but offer high value.

BaaS

This is the most advanced form of industry application, where the operator obtains a business license, and operates in a cross-sector manner.

Looking at how leading operators around the world have implemented IoT services, Huawei, 2019, recommends the following three classic business models:

- **Connection expert -** this model has connectivity and cloud at the core, and is suitable for operators which are new to the Internet of Things, have a strong network foundation, but they lack the IT service capabilities and experience. The operator provides bundled basic cloud services, meeting industry cloud service requirements, increasing service stickiness, avoiding price wars, and increasing average revenue per connection (ARPC).

- **Platform provider -** this model offers rapid integration and TTM and also cross-selling od products like carrier cloud and big data, and is a popular choice with operators with ecosystem capabilities. Provides open APIs and creates an Internet of Things ecosystem with development tools for industry developers, operating environments, device management, data aggregation, data processing, business analysis, and smart decision making.

- **Solution integrator -** this model focuses on service integration, SaaS and devices, and value sharing with industry players, and the operator must have high capabilities in multiple areas, also a strong network and IT capabilities, and deep understanding of the target industry, in order to be able to offer customers package solutions including terminals, software apps and integrated services.

3.3.2. IoT Development

For operators to develop IoT services, typically, the steps are the following:

- providing connectivity services for verticals and then quickly scaling up;

- providing platform services to companies that want to build IT capabilities, then enabling industry players step by step on the IoT platform;

- providing E2E solutions for three to five vertical industries; refining, optimizing, and finally standardizing the solutions to replicate them at scale.

The operators are strongest in the area of connectivity, so platforms are the key for them to achieve future success in Internet of Things. The first to provide cloud - based platforms, low-cost IaaS, open access management, and extensive pre-integration capabilities, will be the one that has a head start in building IoT ecosystem.

3.4. THE IMPACT OF INTERNET OF THINGS ON THE TELECOMMUNICATION INDUSTRY

When it comes to providing tailored consumer applications, telecom industries can be seen capitalizing on their infrastructure, and in order to deliver impeccable network, platform and solution

functionalities, faster adoption of the cloud technologies would be seen. As there is a wide variety of IoT use cases, one-size-fits-all approach will not be applicable in the technologically advanced world to come.

3.4.1. Technological Aspects

Network providers will have to deliver the highest-quality functionalities for the network to connect machines to machines uninterruptedly, as new IoT applications are rolled out every now and then. They will have to ensure that they have a robust infrastructure that is also flexible and agile to acclimatize to the scalability and development of the new applications. Operators will have to provide uninterrupted network facilities, without any drops, at the right time and at the right speed as the need of the application dictates.

On the data side, adopting the cloud technologies is critical. And as a consistent service across different devices would be the key to success in the connected world, the telecommunication companies will have to invest more resources into providing the highest quality of network. The telecommunication industry will be spending more resources in delivering data network as per demand per different use cases. Faster data will be required for connecting cars and other things, and a low bandwidth data will work just fine in the use case of smart metering. Low-power WAN networks aka LP-WAN are being rolled out by some of the leading mobile operators to ensure smooth working of the smart devices and applications that require low power consumption and can work perfectly in low bandwidth.

3.4.2. Business Aspects

IoT is changing consumers' data and connectivity demands, and because of that telecommunication companies will need to define a strategy that supports and enhances the next generation of smart devices. Strategies to increase data monetization and boosting profitability will be required. Telecommunication companies will have to offer novel value propositions and innovative pricing models that will meet the preferences of the consumers and increase the benefits to the customers. Where markets are mature, telecommunication companies will have to adopt data-centric plans and develop unique features that support the use of new smart devices, in order to be able to differentiate their offerings and obtain a competitive advantage in the market.

Another aspect to be considered is developing strategic partnerships. Telecommunication companies will have to develop strategic partnerships that will allow them to tap into new and lucrative markets and also increase brand loyalty. IoT would drive telecommunication companies to partner up with platform providers in order to get tailored platforms for their needs. In this way, companies will leverage their current capabilities and encourage the use of new devices that ultimately can increase data consumption.

Also, hiring best cloud software talent for platform management may pose several challenges like lack of experience in cloud platform operations or cloud development. Keeping these challenges in mind while needing to offer platform solutions impacting the telecom industry and more telecommunication companies would be seen partnering with platform providers instead of finding their own platform solutions (Mattison, 2005).

In a nutshell, the impact of the Internet of Things on the telecom industry will be huge. We will see telecommunication companies adapting to the changing network usage and providing services that would benefit the customers. Monetization of data, better cloud infrastructure, an adaptable data network for the different use case, and developing strategic partnerships will be some of the changes that will be visible in the telecommunications industry in the coming years.

3.5. 5G

Internet of Things resides on the idea that everyday devices are connected, and these interactions between large numbers of heterogeneous devices increase a substantial demand on providing highconnectivity, extremely high data rates, low latency, designing special applications to serve the IoT and many other communication requirements. Thus, the promising 5G cellular networks can be considered as the key enabler for IoT technology (Alsulami & Akkari, 2018).

Today, 4G cellular networks are being deployed and the world is getting ready to embrace the fifth generation (5G). 5G systems are expected to provide an enhanced mobile broadband targeting peak data rate of 20 Gbps, extend 4G's Internet of Things capability, and enable mission - critical applications that require ultra - high reliability and low latency.

A cellular network or mobile network is a wireless network that is spread over the land through a web of cell sites and each of this sites or cell towers is comprised of a transceiver (transmitter, receiver) for communications with mobile devices. Mobile devices rely on die hard cellular towers for communications and this cell sites or cell towers are designed to keep a hexagonal shape in mind. The use of hexagonal cells was invented by Bell Laboratories in the 1970s and this shape was selected over other geometrical shapes since. By using it the cells can be laid next to each other with no overlap, thus providing coverage theoretically to the entire service area without any gaps.

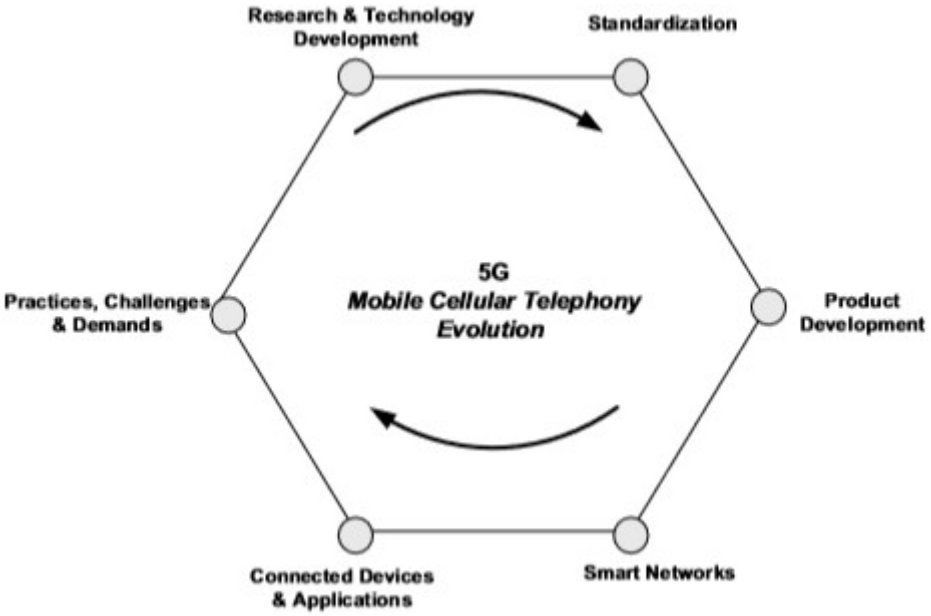

Figure 3.1 - Key steps in mobile cellular telephony

Source (Asif,2019)

If we look at it from an end - to - end perspective, the key phases of the mobile cellular telephony can nicely fit on the six corners of the hexagon shape (Figure 3.1). These generic six phases are research and technology development, standardization, product development, network development, device and application development, and the sector's practices and challenges (Asif, 2019).

Research and technological development is the first step that leads into standardization followed by product development. Once telecom products are ready, they get deployed in the cellular networks. Device development usually lags behind network equipment production, and once networks are up and running and users are connected to networks through their devices, applications start to pour in. From there, the sectors begin to see the good or not-so-good practices, bottle necks and challenges, and new business demands, which then leads back to the first step to start all over again.

3.5.1. Market Drivers and Use Cases

3G and 4G technologies have mainly focused on mobile broadbend use cases, providing enhanced system capacity and offering higher data rates, and this focus will clearly continue with 5G. But, the future will be more than just enhancements to the conventional mobile broadband use case and future wireless networks will be expected to offer wireless access to anyone and anything. Wireless access goes beyond humans and is expanded to serving any entity that may benefit from being connected. 5G is about enabling new services and devices, connecting new industries and empowering new user experiences, with other words, connecting people and things across a diverse set of scenarios.

By 2020, a wide variety of cellular-enabled IoT applications will prevail. From smart utility grids to earthquake or tsunami detection sensors that worn the public, applications can and are beginning to get deployed even on today's cellular networks. Yet, IoT applications are predicted to grow at a much faster pace than what existing networks and technologies can optimally handle. To be able to support this predicted numbers of billions of IoT devices, a wireless network infrastructure is needed which is not only highly scalable in terms of its capacity, but can also optimally handle differing service needs of various IoT verticals, such as requirements for mobility, latency, network reliability and resiliency.

Today's societies depend on a wide array of critical infrastructure to function properly and malfunction or damage to this infrastructure could result in huge financial impact, degradation of the quality of living and even loss of life. For example, to detect a fault in a high-voltage transmission line and be able to take corrective action, the required communication latency is beyond what current wireless networks can achieve. With 5G this will be overcame, as it is expected to support reliable low-latency communications among densely deployed devices that are subject to power constraints and wide-ranging data-rate requirements.

An ongoing trend around the world is massive urbanization, and Smart Cities initiatives aim at improving cost, resource and process efficiency, while maintaining a high living quality for their rising populations. Smart Transportation, Smart Building and Smart Homes are only three potential use cases of 5G-enabled Smart City.

Also, in the field of medicine, the increasing use of diagnostic tools such as 3D and 4D ultrasounds, CAT scans and MRIs, the miniaturization of the equipment to a portable, hand-held form factor, leads to even higher demands being placed on wireless networks. Bio-connectivity, continuous and automatic medical telemetry collection via wearable sensors is another strong emerging trend that will have its requirements.

No need to mention the automotive industry - the Advanced Driver Assistance Systems (ADAS) and Autonomous Vehicles as emerging trends, and 5G wireless technologies supporting high-speed, low-latency, vehicle-to-vehicle and vehicle-to-infrastructure communications as key enablers.

From this use cases mentioned above, some general trends in the industry can be identified (4G Americas, 2015):

- The number of devices using cellular networks is expected to increase significantly, and a large part of this increase will be coming from M2M services;
- Some of the future services will require much higher data rates compared to what is typically achievable today.

In order to be able to support all this and many other use cases, future wireless networks must provide robust, highly reliable, resilient, and low-latency communication infrastructure.

3.5.2. Requirements for 5G

Requirements for 5G can be subdivided in the following two categories (4G Americas, 2015):

- User-driven requirements in terms of quality of experience, user satisfaction, reliability and speed of the connection;

- Network-driven requirements in terms of network operation and management.

3.5.2.1. User-driven requirements

Battery Life

Several of the IoT applications involve battery operated sensor networks that are out in the field and transmit data only occasionally, therefore wide-scale deployment of 5G based sensor networks would be possible only if much longer battery life and reduced energy consumption by such devices guarantees their unattended operation over a duration of years.

Per-user data rate and latency

This attributes define the typical data rate and round-trip delay that users experience, so the values of these attributes determine the types of applications that can be supported on a network. Applications in the future such as augmented reality, 3D gaming and “tactile internet” will require a 100x increase in achievable data rate compared to today and a corresponding 5x to 10x reduction in latency.

Robustness and resiliency

5G networks will increasingly be used as the primary source of communication. They will also support emergency communications and public safety, therefore a key requirement is for the network to be robust, reliable and resilient, and to ensure the ability to defend against security attacks such as DoS (Denial of Service) for mission-critical applications like public safety, smart grids and natural gas and water distribution networks.

Mobility

5G systems are expected to support very high mobility scenarios, but also scenarios with low to no mobility for end devices, therefore should be able to cope efficiently with such extreme situations by providing mobility on demand based on unique needs and capabilities, to cover extreme cases from no mobility to future high-speed trains or even aircrafts.

Seamless user experience

Current cellular systems provide very high peak quality, such as very high peak data rates, nevertheless quality often varies substantially over the coverage area of interest. The achievable data rates can be substantially lower for devices far from the base station site or in indoor locations. So, achievable quality should be defined as the quality experienced with perhaps 95% probability, rather than peak data rates.

5G should deliver a much more consistent user experience, irrespective to the user's location. It will likely comprise a collection of layers, technologies and frequency bands that should seamlessly interwork when moving across networks, layers or frequencies.

Context-aware network

It becomes increasingly important for the network to provide the correct resources to meet the unique needs of each application and device. This becomes possible if the network is context-aware and can dynamically adapt to meet these needs, meaning that for example:

- Full mobility need not be provided to MTC devices that are stationary;
- 3GPP mobility management and paging need not be provided for services that require only device-initiated communication;
- Resources that are configured to support long battery life, high reliability, low latency, low cost, secure communications and global roaming is truly needed.

Optimizing resource allocation in this manner makes possible for only the necessary resources to be used, and also enables a better end user/device experience. Context includes network awareness, application and device awareness with associated service requirements, subscription context and subscriber analytics. Awareness of these attributes makes it possible for the network to dynamically adapt to the needs of devices and applications, rather than the applications adapting to today's onesize-fits-all set of access characteristics.

3.5.2.2. Network-driven requirements

Scalability

The key to the success of 5G networks will be the support for IoT use cases. 10x-100x increase in the number of devices is expected, and primarily because of M2M services, that will require network elements that can scale up gracefully to handle this growth. This comprises both the user plane and the control plane, for example: the 5G network should be able to scale well to handle signalling traffic, such as for authentication and authorization for larger numbers of IoT devices, and the user plane must be able to scale well to handle (in)frequent and small data transmissions from large number of devices.

The term 'scalability' has an additional dimension when it comes to supporting a mix of traffic from IoT applications and more traditional services like voice and video. 5G networks should be able to support both:

- High-data-rate/low-latency conventional services
- M2M applications that require much lower bandwidths and each M2M vertical will likely have its own unique traffic pattern.

Example: Traffic pattern and transmission requirements (data rate, latency) from earthquake or tsunami warning sensors will be quite different than for traffic from a vending machine.

Network capacity

The expected rise in traffic over the next decade is 1000x - 5000x (IWPC's MoGIG, 2014). Therefore, a key requirement for 5G networks will be to increase traffic-handling capacity. Traffic-handling capacity is defined as the total traffic that the network can handle while still maintaining QoS.

Cost efficiency

The next generation of mobile networks should be able to provide a significant cost benefit over the current one. This cost benefit should be at least as good, or possibly even better than the one that was experienced in going from 3G to 4G. In this context cost refers to both the OPEX and CAPEX of delivering a byte of data to the subscriber.

Automated system management and configuration

The network density in 5G deployments is expected to significantly increase for number of reasons that include higher data volume density and the use of higher frequency spectrum. A key requirement to better manage OPEX and CAPEX of running a network with a much higher number of network nodes will be the ability of 5G networks to self-configure as much as possible.

Network flexibility

5G network should allow the RAN and the core network to evolve and scale independently of each other, and changes/enhancements to one, should not mandate changes/enhancements to the other. To achieve this, the RAN and the packet core should avoid mutual dependencies, and also 5G networks must support multi-RAT connectivity efficiently and effectively. This includes the ability to provide an access-agnostic packet core across multiple radio technologies (for example: cellular, WiFi) to support uniform authentication, session continuity and security, and provide plug-and-play capability where a new access technology may be attached to the packet core without any modifications.

Energy efficiency

Network functions should not convey excessive energy, both radiated and consumed by the network infrastructure. Energy consumption could be adapted to the current traffic conditions to achieve significant energy savings in off-peak situations.

Coverage

5G will take special care in improving coverage for IoT-related applications to make 5G viable for this emerging market. Although it is clear that coverage largely depends on the frequency of operation and density of deployment sites, special actions can be taken to ensure optimal coverage for specific such as IoT, public safety and other critical systems.

Security

Applications such as smart grids, telemedicine, industrial control, public safety and automotive, that can be categorized as mission-critical, have strict security requirements to ensure uninterrupted

operations and to defend against intrusions. Therefore, 5G should address the following security objectives:

- Integrity - to ensure that information is not tampered in any way, either accidentally or deliberately during transit; this includes the ability to authenticate the source of the received information and to authenticate the recipient.

- Confidentiality - to keep sensitive information away from unauthorized sources; includes proper user authentication, data protection through encryption, etc.

Diverse spectrum operation

5G is expected to operate in a diverse set of spectrum bands, including traditional sub-6 GHz cellular bands for coverage and low-power operation, to above-6 GHz bands including millimetre spectrum for ultra-high data rates. 5G systems will need to accommodate the requirements in radio access, network architecture, protocol, and modem design considerations, as the characteristics and hardware implications of these bands are expected to be substantially different.

Unified system framework

If we look at the following example: sensor applications generally require low data rates and can tolerate high latencies, while evolving applications such as telemedicine require high data rates and low latencies, we can conclude that IoT use cases can have very diverse and sometimes, even conflicting requirements. Therefore, 5G systems should be as flexible and extensible as possible to support the existing and the future requirements, hence avoiding the need to introduce a dedicated system for each emerging use case.

3.6. CHALLENGES FOR TELECOMMUNICATION COMPANIES IN INTERNET OF THINGS

Telecommunication companies will face many challenges in the battle to capture Internet of Things value. The diversity of these challenges lies in their nature. Challenges awaiting telecommunication companies are of technical nature relating to the changing connectivity requirements (availability, reliability, security and privacy, scalability, precision, interoperability, compatibility, big IoT data and mobility) and business challenges that are relating to the investment, avoiding pipefication, fragmented scenarios, monetizing the value of IoT, and regulatory and environmental considerations.

3.6.1. Technology-related Challenges

Technical challenges that telecommunication companies face are originated at the changing connectivity requirements for Internet of Things devices. Surely, speed and reliability requirements have been anticipated and addressed with the roll-out of 4th generation wireless mobile

telecommunication networks, however, these networks have been designed on the licensed spectrum and primarily target high-quality mobile voice and data services. Internet of Things devices of the future will be able to make use of 4th and future 5th generation networks in the applications such as traffic and safety control, industrial control applications, smart grid, remote healthcare and remote manufacturing where reliability, low latency and large spectrum availability is of critical importance. On the other hand, massively rolled out Internet of Things devices such as smart metering, smart agriculture, logistics, fleet management, retail, smart building and smart homes have different connectivity requirements such as low cost of connectivity modules and data transmission, low energy consumption, wide area coverage, efficient scalability and diversity.

These challenges can be met to a certain extent with the aid of a variety of wireless and wired connectivity options. Such are: radio frequency identification (RFID), near-field communication (NFC), Bluetooth and Wi-Fi, etc. Considering their geographical area coverage they are categorized in three broad types: personal area network (PAN), local area network (LAN) and wide area network (WAN).

Figure 3.2 - IoT Communication technologies

Source (IoT Technology Guidebook. (2019). Retrieved from https://www.postscapes.com/internet-of-thingstechnologies/.)

Existing Wi-Fi networks should be modified in order to attain wider coverage and to be able to support mesh networks. The confirmation on communication pathway of IoT is very important to understand the information exchange within IoT, as it uses various standards, techniques, and protocols to disseminate information.

Following, common major technical challenges of Internet of Things will be described. These challenges are:

Availability

As Internet of Things is used to facilitate information and data anywhere, at any time and for any person, based on his request, availability is a highly critical issue. IoT network requires high availability guarantee of physical devices as well as IoT applications in order to achieve high availability. A feasible solution to this would be using redundant maintenance of programs and hardware devices, so the program or redundant device can be used to perform load balancing when the failure happens (Matin & Gad-Elrab Ahmed, 2019).

Reliability

In all aspects of software and hardware of IoT, reliability requires to be guaranteed and reliability is not just sending reliable information, but being able to adapt to changing environmental conditions, be resistant to long-term usability and security problems.

Security and privacy

In IoT memory cards of a device have a limited storage capacity and some of the data will be remotely stored on other sites. Since security and privacy are an essential requirement of most applications, for these remote data users do not want to disclose their information with others, so new technology is required to give users the ability to verify whether the company satisfies their service level agreement or not. Ruivo, Santos, and Oliveira, 2014, state that accordingly ICTs experts, data protection is the main piece of privacy and therefore is everyone's responsibility, however is a process that services and support teams much embed in their roles. Their daily actions greatly impact on their firm's trustworthiness and reputation.

Scalability

The increase in the number of smart devices, and the advances of embedded technologies have increased the devices-to-person ratio. The requirements from applications by client increase over the time so the scalability of IoT, which is the ability to add more devices and services to IoT, without degrading the Quality of service, must be considered.

Precision

In many smart IoT environments such as transportation, healthcare and unmanned aerial vehicular networks, where devices and systems are connected globally, precision is one of the most important challenges. Available bandwidth and network latency are the key factors that can affect the precision of distributed IoT deley-sensitive and mission-critical environments, so when deploying IoT in smart environment these parameters need to be considered.

Interoperability

Since various types of devices are connected to each other via IoT, IoT should facilitate services to all these devices regardless of the type. This can be achieved to a certain level at the network and application levels by adhering to standardized protocols. Achieving interoperability is challenging because of the ambiguous interpretations of the same protocol. By avoiding such ambiguities interoperability of IoT would become more realistic.

Compatibility

Most of the products are unable to connect with each other and this makes compatibility another challenge in the IoT based smart environment, where various products need to be connected with each other. A collaboration between leading companies is required to obtain the infrastructure information of each product and design a universal coding language accordingly by developers. In order to ensure the success of IoT, a solution to compatibility issues is demanded.

Big IoT Data

IoT is one of the largest sources of data. As the performance of most IoT applications is based on data management services, managing the big IoT data in terms of processing, access, and storage requires highly scalable computing platforms that do not affect the performance of the application.

Mobility

Since in IoT most of the devices are mobile devices, IoT applications need to deliver services by considering the mobility factor as well. There are standard management protocols that are available, Mobile IPv6 (network layer) and TCP migrate (transport layer) to facilitate mobility issues in IoT. Nevertheless, these standards are too complex to be used in IoT nodes. For constrained devices in IoT, some approaches and mechanisms have been proposed and in this context, the leader machine does mobility management for the group of machines that are grouped according to mobility patterns.

3.6.2. Business-related Challenges

When discussing the challenges that telecommunication companies are facing, some of them have business and strategic nature, and these challenges are discussed in the following part.

Carriers must shift their focus from connecting people to connecting things. To open up new revenue sources they need to access the industry vertical market through Internet of Things.

Aside from market competition from other telecommunication companies, they face many other challenges. These challenges include how to avoid devolving into a mere pipe provider - pipefication, incubating high-value customers and applications across fragmented industries, building Internet of Things platforms and monetizing value, greening Internet of Things and also regulatory challenges.

Investment

For industries, there is a difficulty in adopting these technologies where things are not open and interoperable in terms of hardware and software. Open and interoperable hardware and software based IoT solutions should be built for deployment in industries. Also, instead of replacing these deployments with new systems, the solutions should be flexible enough to adapt to their changes. Expertise and also investment are required for generating innovation within existing hardware and software architectures.

Under-the-top disruption/Pipefication

The term Under-the-Top is used for innovative technologies and initiatives that are hitting the core business of telecommunication companies - connectivity, through the whole connectivity value chain.

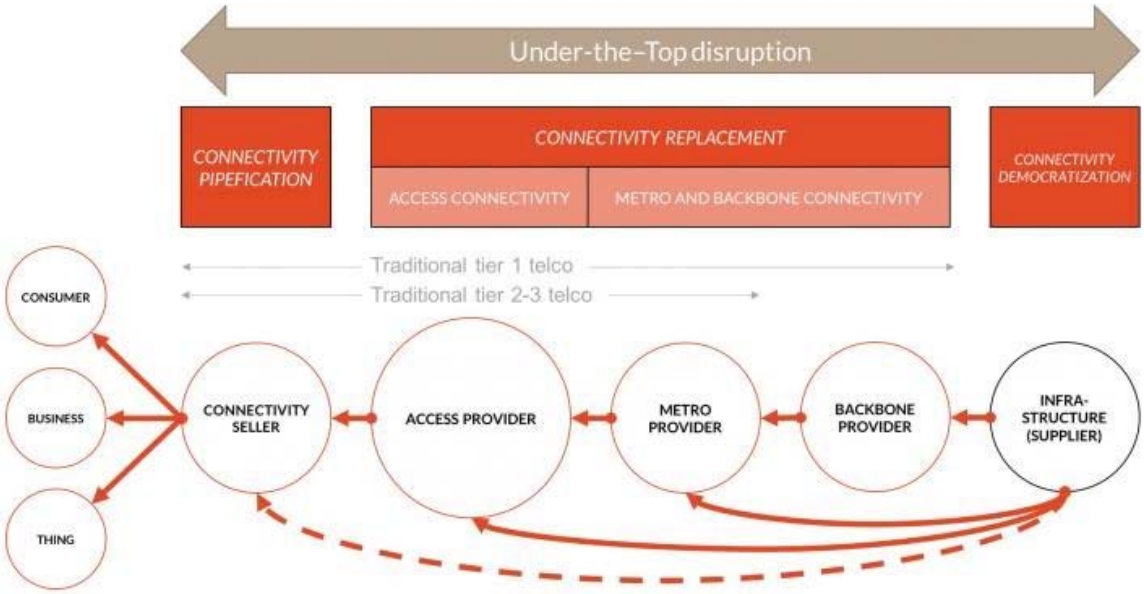

Figure 3.3 - Under-the-Top disruption

Source (Joonas & Wei, 2017)

Connectivity pipefication (Joonas & Wei, 2017) refers to initiatives that weaken or break the relationship between telecommunication companies and end users.

Connectivity replacement

- **Access connectivity** refers to initiatives changing how businesses, consumers or things get connected;
- **Metro and backbone connectivity** refers to initiatives impacting how and by whom metro and backbone networks are built and operated.

Connectivity democratization refers to initiatives that lower the industry barrier, enable new players to enter the connectivity business easier and intensify the competition.

Industry customers are still regarding operators as mere pipe providers and providers of SIM cards. In the competition for industry customers, operators need to beat competitors that provide unlicensed spectrum-based connection technologies and solutions. Also, as operators offer undifferentiated pipe services, they need to deal with the fierce price competition.

Fragmented scenarios

The Internet of Things industry is extremely fragmented. If carriers want to become trusted enablers, they will need expertise in and also expert personnel from many verticals. But, before they can decide and develop large - scale industry applications, operators should resolve one of the trickiest questions - what industries to choose and how to generalize common industry requirements based on individual requirements.

Prioritizing vertical opportunities

Successful deployment at the connectivity and life cycle layers supports success further up the stack, in the vertical solutions developed for clients in specific industries. But as with any broad new opportunity, telecommunication companies need to thoughtfully choose where they participate directly and where they facilitate the success of other vertical market-solutions providers. Telecommunication companies that choose to build up their capabilities in only a few industries stand a better chance of succeeding than those that enter too many verticals at the same time (Mattison, 1999).

Executive teams can start this decision process by assessing their unique assets and mapping them to specific opportunities. With a clear understanding of their relative strengths, telecommunication companies should be able to determine which opportunities most closely align with their capabilities. By resisting the temptation to over-extend and instead investing in three or four of the most promising possibilities - telecommunication companies can materially increase the likelihood of success while improving industry credibility and trust.

Even after identifying their competitive advantages, telecommunication companies need to reinvent some capabilities to become competitive with their industry offers. In some cases, telecommunication companies will need to partner with or acquire other companies to obtain the industry expertise and capabilities needed to succeed.

First-mover advantage

Even as they partner to gain capabilities for vertical solutions, telecommunication companies' executives should focus on taking full advantage of their core network assets and capabilities. Leaders in the field are already building Internet of Things-enabled platforms at the connectivity and life cycle management layers to head off third-party service providers from working directly with their customers. In this way, these telecommunication companies can either selectively add highly differentiated vertical offers or facilitate third-party vertical offers where differentiation is more difficult or the investment needed is too great.

Rebalancing toward Internet of Things-enablement services, and away from excessive enthusiasm over vertical solutions, should provide significantly more success for telecommunication companies around the world.

Connectivity and life cycle management are inherently platform plays in the Internet of Things, and only a limited number of telecommunication companies will see their platforms widely adopted. Those that are first to market will also capture deep knowledge about how to plan future network architectures and will develop the new skills and capabilities necessary to win as the market evolves. The need to move quickly is imperative.

Monetizing the value of Internet of Things

While operators hope to become the key enablers of connected devices through Internet of Things platforms and complete the transition from M2M to IoT, they face two problems.

The first one, many industry players indicate that they've built their own end-to-end applications and only need operators to provide pipes. So, here the question rises, do industry players need operators' IoT platforms?

And second, if strong demand exists for Internet of Things platforms, how should operators determine what to and what not to offer, and thus truly act as enablers.

Green Internet of Things

Green IoT is something that telecommunication companies will have to consider while taking their roles in the IoT value chain. The awareness of environmental issues all over the world is increasing and IoT is not an exception of its impact. As people are getting concerned about the impact of IoT in context of mountains of obsolete devices and no way to dispose of them, the concept of greening IoT takes its place.

Greening IoT refers to the technologies that make the IoT environment healthier in a friendly way by making use of facilities and storages that enable subscribers to gather, store, access and manage various information. With the growing application of ICT (Information and Communication Technologies) much more energy has been consumed, and ICTs can cause climate change in the world. The consideration for sustainability of ICTs has concentrated on data centers optimization through techniques of sharing infrastructure. This leads to increasing the energy efficiency, reducing CO2 emissions and e-waste of material disposals. Technologies for green IoT are enabled by greening ICT and this technologies include green wireless sensor networks (GWSNs), green machine-tomachine communication (GM2M), green RFID, green data center (GDC), green Internet, and green communication network. Green ICT technologies play an essential role in green IoT and provide many benefits to the society such as decreasing the energy used for designing, manufacturing, and distributing ICT devices and equipment (Gad-Elrab Ahmed, 2019).

Green IoT (Alsamhi, Ma, Ansari, & Meng, 2018) is also defined as the study and practice of designing, using, manufacturing, and disposing of servers, computers, and associated subsystems such as monitors, storage devices, printers, and communication network systems efficiently and effectively with minimal or no impact on the environment.

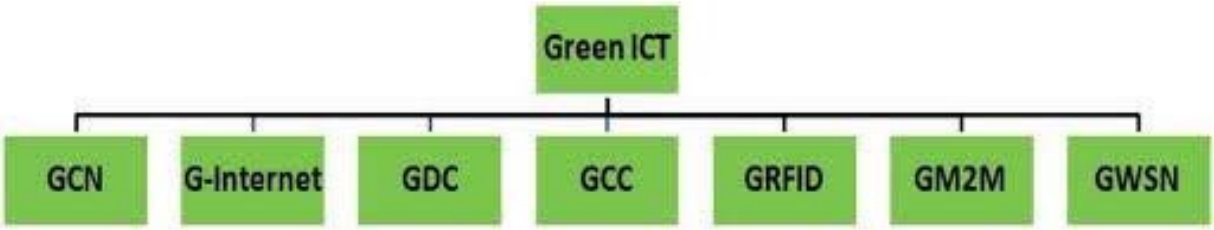

Figure 3.4 - Green ICT technologies

Source (Gad-Elrab Ahmed, 2019)

Significant changes in our environments have occurred, and others are yet to come with the developments in IoT, and the cost of this developments is potentially significant due to the increases in e-waste, hazardous emissions, and energy usage. The estimations for green IoT is to make substantial changes to our future lives and that would lead to a green environment. Green IoT benefits IoT in exploring different energy sources, eco-friendly and minimize the harm of IoT done to the

environment, and not only green IoT is helping other industries reduce the greenhouse effect but is also reducing the impact of IoT itself on the environment.

Regulatory considerations

One thing that cannot be overlooked as the new technologies are implemented is the regulatory environment. Telecommunication companies are used to manage many millions of devices and connections, but yet, none of them is big enough to avoid standards and regulations. Regulatory obstacles to the development of IoT vary from uncertainty over how rules apply to IoT, which means that rules that are primarily designed for human communications are being applied, to a fragmented application of rules across Member States in Europe, which hinders the ability to operate seamlessly across the single market (Vodafone's Whitepaper, 2019). These obstacles are distorting investment choices and hinder the ability to keep up with competitors where regulations are more effective.

3.7. FUTURE PERSPECTIVE OF TELECOMMUNICATION COMPANIES

The numerous and diverse applications of the Internet of Things have the potential to change all areas of daily life of individuals, businesses, and society as a whole. The vision of a pervasive Internet of Things spans a wide range of application domains and addresses the enabling technologies needed to meet the performance requirements of various IoT applications.

A deep and comprehensive understanding of the scope and classification of Internet of Things applications is an essential precondition for determining their performance requirements with the overall goal of defining the enabling technologies towards fifth generation (5G) networks, while avoiding over-specification and high costs.

Telecommunication companies now have the opportunity to seize a share of the value that is generated by internet implementation. The size of this share will depend on telecommunication companies' role in the value chain that ranges from being a traditional provider of communication infrastructure to being an end-to-end solution provider. In order to monetize Internet of Things, telecommunication companies will have to address many challenges which can be summarized as follows (IoT-Ignite's Whitepaper, 2017):

- strategic challenges, relating to decisions on future directions - as telecoms are increasingly viewed as an enabler of the digital transformation, by actively articulating new value propositions to enterprises and governments at all levels, telecoms can position themselves to lead the emergence of new ecosystems and play their full role in transforming industries and society.
- business challenges relating to successful management, investment, partnerships - telecommunication companies will have to adopt data-centric plans and develop unique features that support the use of new smart devices, in order to be able to differentiate their offerings and obtain a competitive advantage in the market; also, they will have to develop strategic partnerships that will allow them to tap into new and lucrative markets and also increase brand loyalty;

- technical challenges relating to changing connectivity and performance requirements - since connectivity and performance requirements of IoT objects (things) cannot be fulfilled using existing cellular networks that limit numerous IoT applications, to overcome issues associated with the current cellular networks, new types of technologies are introduced (leading towards 5G network).

4. METHODOLOGY

In the literature there are mainly three types of researches: quantitative, qualitative and mixed. Often the distinction between qualitative research and quantitative research is framed in terms of using words in qualitative, rather than numbers in quantitative. Using closed-ended questions (quantitative hypotheses) as opposed to open-ended questions (qualitative interview questions) is another distinction. As Creswell, 2013, suggests, a more complete way to view the gradations of differences between them is in the basic philosophical assumptions researchers bring to the study, the types of research strategies used in the research (e.g. quantitative experiments or qualitative case studies), and the specific methods employed in conducting these strategies (e.g. collecting data quantitatively on instruments versus collecting qualitative data through observing a setting). (Creswell, 2013)

According to Creswell, 2013, if a concept or phenomenon needs to be explored and understood because little research has been done on it, then it merits a qualitative approach. Since Internet of Things is rather new and currently happening topic, and the role that the telecommunication companies will play in the Internet of Things is something that the telecommunication companies are actively working on and is yet to be seen, a qualitative research approach was chosen.

4.1. CASE STUDY METHODOLOGY

Qualitative case studies provide researchers with opportunity to explore or describe a phenomenon in context using a variety of data sources, therefore to explore individuals or organizations, simple to complex interventions, relationships, communities, or programs, and supports the deconstruction and the subsequent reconstruction of various phenomena. According to Yin, 2003 a case study approach should be used when the focus of the study is to answer ‘how’ and ‘why’ questions, when you cannot manipulate the behaviour of those involved in the study, when you want to cover contextual conditions because you believe they are relevant to the phenomenon under study, or when the boundaries are not clear between the phenomenon and context.

When determining the case, the unit, of the analysis the following type of questions can be of help:
a) do I want to ‘analyse’ the individual? b) do I want to ‘analyse’ a program? c) do I want to ‘analyse’ the process? d) do I want to analyse the difference between organizations? When it is determined what the case will be, it is important to determine what the case will not be, therefore to bind the case and place boundaries, for example by time and place or definition and context. Binding the case ensures that the case study remains reasonable in scope (Baxter & Jack, 2008). The selection of a specific type of case study is guided by the overall study purpose and following are presented types and definitions of case studies.

Case Study Type	Definition
Explanatory	This type of case study would be used if you were seeking to answer a question that sought to explain the presumed causal links in real-life interventions that are too complex for the survey or experimental strategies. In evaluation language, the explanations would link program implementation with program effects (Yin, 2003).
Exploratory	This type of case study is used to explore those situations in which the intervention being evaluated has no clear, single set of outcomes (Yin, 2003).
Descriptive	This type of case study is used to describe an intervention or phenomenon and the real-life context in which it occurred (Yin, 2003).
Multiple-case studies	A multiple case study enables the researcher to explore differences within and between cases. The goal is to replicate findings across cases. Because comparisons will be drawn, it is imperative that the cases are chosen carefully so that the researcher can predict similar results across cases, or predict contrasting results based on a theory (Yin, 2003).
Intrinsic	Stake (1995) uses the term intrinsic and suggests that researchers who have a genuine interest in the case should use this approach when the intent is to better understand the case. It is not undertaken primarily because the case represents other cases or because it illustrates a particular trait or problem, but because in all its particularity and ordinariness, the case itself is of interest. The purpose is NOT to come to understand some abstract construct or generic phenomenon. Thepurpose is NOT to build theory (although that is an option) (Stake, 1995).
Instrumental	Is used to accomplish something other than understanding a particular situation. It provides insight into an issue or helps to refine a theory. The case is of secondary interest; it plays a supportive role, facilitating our understanding of something else. The case is often looked at in depth, its contexts scrutinized, its ordinary activities detailed, and because it helps the researcher pursue the external interest. The case may or may not be seen as typical of other cases (Stake, 1995).
Collective	Collective case studies are similar in nature and description to multiple case studies (Yin, 2003)

Figure 4.1 Types and Definitions of Case Studies

Source (Baxter & Jack, 2008)

Potential data sources for a case study include, but are not limited to documentation, archival records, interviews, direct observations etc. The data collection and analysis happen concurrently, and the type of analysis depends on the type of case study. Yin mentions pattern matching, linking data to propositions, explanation building, time-series analysis, logical models, and cross-case synthesis. And Stake describes categorical aggregation and direct interpretation as types of analysis. When it comes to reporting the case study, a researchers responsibility is to convert a complex phenomenon into a format that is readily understood by the reader. There is no correct way to report a case study, but some suggested ways are by telling the reader a story, whether it is comparative, linear, chronological, theory building, suspense or unsequenced (Baxter & Jack, 2008).

4.2. CASE STUDY METHODOLOGY IN THIS WORK

As the goal of this work is to be able on the basis of the knowledge gained on the matter and the examination of a real life example to be able to give an overall conclusion on the telecommunication companies' standing and role in IoT, in this work a descriptive case study methodology is chosen, as accordnig to Yin, 2003, this type of case study is used to describe an intervention or phenomenon and the real-life context in which it occured.

A telecommunication company will be investigated, and the real-life context is binded by the time as the stage of early implementation of Internet of Things Y2019, and by place due to the environmental and regulatory considerations to telecommunication companies operating in a single country, in Europe. The case is further binded by the context to telecommunication companies operating in a single country as part of an international telecommunication company group.

As telecoms are working "multinational" and international telecom groups like Deutsche Telekom, Vodafone and Telefonica are well known in the global telecom space, but they produce and operate networks and services as an accumulation of national business (Günther K. & Hischke S., n.d.) the previously identified context of the case study and the unit are considered suitable as representative of national telecommunication service providers that are commonly part of international telecom groups.

According to Stake's, 1995 classification it can be classified as an instrumental case study, that is defined as a case study used to accomplish something other than understanding a particular situation, it provides insight into an issue or helps to refine a theory, the case is of secondary interest as it plays a supportive role, facilitating our understanding of something else, and the case may or may not be seen as typical of other cases.

5. CASE STUDY - MAKEDONSKI TELEKOM AD

Figure 5.1 - Makedonski Telekom AD

Source (Makedonski Telekom, Head Office, Skopje, Part of the International Deutsche Telekom Group. (n.d.). Retrieved from https://www.stmgconsultancy.com/project/makedonski-telekom-head-office-skopjemacedonia-part-of-the-international-deutsche-telekom-group/.)

5.1. COMPANY BACKGROUND

Makedonski Telekom, as the leading national telco operator, offers voice and data services provided via fixed and mobile network, within many years of experience and leadership on the market. Makedonski Telekom is part of Magyar Telekom Group which is fully-consolidated subsidiary of international Deutsche Telekom Group. Founded in 1997, Makedonski Telekom AD is based in Skopje, the Republic of North Macedonia.

The corporate strategy of Makedonski Telekom is in accordance with Deutsche Telekom's strategy - to become leading telecommunications company in Europe.

The company has been technology leader in the country and the region for many years and according to the opinion of the customers, Makedonski Telekom is the best network in the Republic of North Macedonia.

As mentioned on Makedonski Telekom's web site following are some of its highlights:

- The first company in Europe and in Deutsche Telekom Group with an ALL IP - based network;
- Makedonski Telekom was first in the country to introduce the 4G network, and as a result of continuous investment in infrastructure, at the end of 2016 the 4G network coverage reached

60% coverage of the territory of the Republic of North Macedonia and 80% coverage of the population;

- Most of the people in the Republic of North Macedonia consider the mobile network of Makedonski Telekom the best network in the country and that it meets their expectations, according to 'BRIMA' agency customer survey;

- The Telekom Point of Sale in GTC in Skopje was selected as the best trade facility for 2016 in the service segment for the 'Computer, audio video and telecommunications equipment' category, and the award was granted based on the results obtained in the survey conducted by SWOT Research, in cooperation with the Department for Local Economic Development of the City of Skopje;

- Makedonski Telekom won the prestigious award for the Smart City Project, in 2016, presented by the World Information Technology and Services Alliance - WITSA. By means of the Smart City Project, a modern integrated automatic vehicle location (AVL) and automatic fare collection (AFC) system has been implemented in the public city transport.

The company constantly introduces international know-how, innovative solutions and cutting edge technological trends.

It offers a portfolio for residential and business customers, provided from a single source and focuses on Cloud and ICT solutions in order to provide the best customer experience.

Makedonski Telekom is continuously focused on the modern-day needs and demands of the customers.

In September 2018, Makedonski Telekom performed the first 5G Demo in the Republic of North Macedonia, where a mobile network speed which is over four times higher than the data transfer speed of the 4G network, was measured for the first time in the region. As it is stated in Makedonski Telekom's press release, 'The fifth generation network will not only bring enormous data transfer speeds over internet and real-time communication, but it will completely change the way our societie works: Internet of Things will become reality (drones, robots), we will live in smart homes and smart cities, we will drive smart cars and we will also have benefits in the medicine, education, business.'

Also in May 2019, on the occasion of 17 May - World Telecommunication Day, Makedonski Telekom and FEEIT announced their partnership for testing the 5G technology. As stated, Makedonski Telekom will install 5G equipment and testing devices that will enable the students and professors to be the first to work on the functionalities of this new technology standard and the obtained results will be used for scientific purposes and improvement of services that will be available for the customers in the future. The tests will be made on the new equipment of Makedonski Telekom and in the new '5G Evolution Laboratory' within the Wireless and Mobile Networks Laboratory within the Telecommunications Institute of FEEIT.

As of March, 2019, Smart Home Solutions of Makedonski Telekom have been introduced to the public. Makedonski Telekom's Smart Home for Modern Living represents a new solution that with just few devices can save electricity, coordinate the devices that are already used and adjust them to follow the customers' pace of life.

Smart sensors alert when the window or the door on which they are installed opens, they can be used to turn the light on or off and with one click all the smart devices in the home can be controlled.

The smart LED lights, in addition to saving energy, are adjusted to the customer's preferences in terms of the color and the intensity of the light, and they are turned on and off via a mobile application.

The security camera is considered one of the most used smart devices in the home because it provides 24-hours surveillance, maximum security and control.

These devices are available in the offer of Makedonski Telekom in Magenta 1 M.

5.2. CREATING THE INTERVIEW GUIDE

In order to get more insights on the role of Makedonski Telekom in the Internet of Things, and its standings and positioning on this subject, an interview with Makedonski Telekom was conducted. The interview questions were created prior to the interview, and it consisted of eleven open-ended questions, which were sent to Makedonski Telekom through email. The interview was conducted in August, Y2019.

The first question is a 'warm-up question'. Although the topic was previously known to the respondent, the question's aim was to give a general idea about the topic at hand. Also, as a result, to be able to have a broad idea of Makedonski Telekom's standing on the matter. Thus the first question is:

Q1: As part of the Deutsche Telekom Group, what is Makedonski Telekom's stand on the new industrial revolution including the Internet of Things?

As discussed in section *3.1 Disruption in the Telecommunication Companies' Revenue Streams,* telecommunication companies have dominated the business in the information and communication technology for the past three decades, but in the era of digital disruption the value chain is also changing, and over-the-top services are an example of such disruption. Internet of Things offers new ways for telecoms to capture value and the second question is about understanding what new revenue streams Makedonski Telekom thinks IoT will create.

Q2: Over - the - top (OTT) content services have caused decrease of revenues from voice calls and SMS, two main services that used to be revenue corner stones of telecommunication companies. What new revenue streams do you think IoT will create for Makedonski Telekom?

Whether telecoms will choose to provide only the connectivity, or will choose to provide life-cycle management and provide industry specific vertical solutions is what will determine their role in the IoT. In section *3 The Role of Telecommunication Companies in the development of Internet of things*, three layered opportunity for telecommunication companies is discussed. One layer is connectivity, another one is life-cycle management, and the third is vertical solutions (the industry specific offers that deliver value to enterprises and consumers). The third question is designed to understand whether Makedonski Telekom is thinking in the direction of providing end-to-end solutions.

Q3: Telecommunication companies have an advantage thanks to the central role of communications in many Internet of Things deployments. Considering the three-layered opportunity they can use to develop unique, differentiated strategies for the Internet of Things, in terms of connectivity, life cycle management, and vertical solutions, what is the positioning of Makedonski Telekom on this, to participate directly or facilitate, through the underlying layers, vertical solutions that others provide?

Following the previously discussed question, on what role the telecoms will play, and whether they will position as merely connectivity providers or end-to-end solutions providers, and all the possibilities in between, in section *3.3.1 Possible Business Models for Telecommunication Companies in Internet of Things*, six connectivity based business models are discussed, with more services provided and more value obtained from each successive model. As addition three classic business models are discussed that Huawei, 2019, recommends from looking at how leading operators around the world have implemented IoT services. The objective of the fourth question is to understand which business model Makedonski Telekom is adopting.

Q4: In one of its publications - Six IoT models: Which should telcos choose? - Huawei refers to Deutsche Telekom as an operator that has adopted the solution integrator model. Is Makedonski Telekom also adopting this model to position itself on the value chain?

Leaders in the field are already building Internet of Things-enabled platforms at the connectivity and life cycle management layers to head off third-party service providers from working directly with their customers. In this way, these telecommunication companies can either selectively add highly differentiated vertical offers or facilitate third-party vertical offers where differentiation is more difficult or the investment needed is too great. This being discussed in *3.6.2 Business-related Challenges* section *First-mover advantage,* it is important for telecoms to know which are the sectors, industries and the early adopters of IoT, so they can understand where the opportunities lie, who are the competitors and with whom they can partner up with.

Q5: Which according to you will be the sectors/verticals that will be the early adopters of IoT, worldwide and in Macedonia?

IoT applications are predicted to grow at a much faster pace than what existing networks and technologies can optimally handle. To be able to support this predicted numbers of billions of IoT devices 5G plays a crucial role. As investment is one of the challenges that come with 5G, the following question is directly about understanding how big of an investment 5G actually is for Makedonski Telekom.

Q6: How big of an investment is moving to 5G, for Makedonski Telekom?

And, as 5G network has demanding requirements which are discussed in details in section *3.5.2 Requirements for 5G*, the following question is about understanding how ready is the 5G network and how reliable it is in terms of its requirements.

Q7: How ready and reliable is the 5G technology in terms of the user-driven and network-driven requirements, like coverage, latency, robustness and resiliency?

Furthermore, the next question is about understanding when 5G is expected to have a commercial roll-out.

Q8: By when do you hope to see commercial roll-out of 5G in Macedonia?

The value that IoT can bring is well recognized, and leading telecom operators have made it clear that they want to play their part in this digital transformation. But, if the policies and regulations are not adequately adapted for a world of M2M communications and data, this could represent a major challenge, as discussed in section *3.6.2 Business-related Challenges*, section *Regulatory considerations*. Therefore, the following question is designed to understand Makedonski Telekom's experience on the matter and whether the regulatory climate represents a significant challenge for them.

Q9: One thing that cannot be overlooked as the new technologies are implemented is the regulatory environment. And there is already an opinion that the current policies and regulations are not adequately adapted for a world of machine-to-machine (M2M) communications and data. What is the regulatory climate like in Macedonia? And does the regulatory framework represent a significant challenge for Makedonski Telekom, in this context?

Going through this work, the concept 'pipefication' is mentioned several times, and explained in detail in *3.6.2 Business-related Challenges,* section *Under-the-top disruption/Pipefication*. This term relates to the weakening or breaking the relationship between telecommunication companies and end-users. Since there have been some examples in the past for this, like OTT, hence the following question.

Q10: When we talk about challenges, one of the most spread, considering telecoms and IoT is pipefication. Do you think that telecoms are going to be able to avoid pipefication and enjoy the benefits of massive growth in IoT?

And last, but not least, is the environmental factor that concerns every aspect of our lives, and IoT is not the exception. As discussed in *3.6.2 Business-related Challenges,* section *Green Internet of Things*, significant changes in our environments have occurred, and others are yet to come with the developments in IoT, hence the need to understand whether the object of this case study, Makedonski Telekom, is considering this matter, and using or planning to use any of the green ICT technologies.

Q11: A new concept that takes place is Greening IoT. There is a concern about the impact of IoT in context of mountains of obsolete devices and no way to dispose of them, but not only green IoT is helping other industries reduce the greenhouse effect but it is also reducing the impact of IoT itself on the environment. Does Makedonski Telekom use or is planning to implement some of the Green ICT technologies?

5.3. RESPONSES OBTAINED FROM MAKEDONSKI TELEKOM AD

Following the responses that were received from Makedonski Telekom to the interview questions are provided.

1. As part of the Deutsche Telekom Group, what is Makedonski Telekom's stand on the new industrial revolution including the Internet of Things?

a. Makedonski Telekom as part of the Deutsche Telekom Group and technological leader in the region always drives the pace towards the next level. Considering the widely distributed Internet network and availability all over the world, Makedonski Telekom has recognized the opportunities for new commercial models to support mass global deployments. The Internet of Things reflects on the next wave of life-enhancing services across several fundamental sectors of the economy. As a premium service provider, Makedonski Telekom grows the idea of providing "smarter" solutions which will ease the customers' life, provide added-value services and strengthen operators' commercial models.

2. Over - the - top (OTT) content services have caused decrease of revenues from voice calls and SMS, two main services that used to be revenue corner stones of telecommunication companies. What new revenue streams do you think IoT will create for Makedonski Telekom?

a. At the beginning, when the OTT services have appeared on the market, the very first statement was more than correct. OTT services had huge negative impact on the telcos, especially incumbents, on the direct revenues of the core services, which provided them the chance to grab some part of the shares on the market. However, fortunately, this has not lasted long. The main reason was that on one hand the OTT service providers needed stability and availability of the pipes and Internet service. On the other hand, the service providers needed to enter joint venture with the OTT operators and stabilize the revenues by opening themselves to different services that would be provided to the end customers.

b. New revenues streams for Makedonski Telekom from IoT as a new technology are already visible on the market. Makedonski Telekom has launched smart services, such as SmartHome which provides higher customer home security that includes various devices which can be installed at the customer premises and make customers' life easier for higher number of everyday standard activites in the home. Additionally, Makedonski Telekom has started several projects which will make the cities in Macedonia and its areas smarter, called Smart City which includes Smart Lightning, Smart Metering (Water & Electricity), Connected Cars, etc.

3. Telecommunication companies have an advantage thanks to the central role of communications in many Internet of Things deployments. Considering the three-layered opportunity they can use to develop unique, differentiated strategies for the Internet of Things, in terms of connectivity, life cycle management, and vertical solutions, what is the positioning of Makedonski Telekom on this, to participate directly or facilitate, through the underlying layers, vertical solutions that others provide?

a. Easier setup, effective provisioning and faster penetration on the market for Makedonski Telekom as telco provider would be definitely to take the approach of using the cloud based solutions, where the partnering company has already established IoT platform in the cloud. This case definitely lowers the time-to-market and eases the G2M plans of the new products.

b. Other approach (more telco one) is to have the IoT platform installed on the Makedonski Telekom VPS platform, and provide the added-value services towards the customers using the cloud of the telco provider.

4. In one of its publications - Six IoT models: Which should telcos choose? - Huawei refers to Deutsche Telekom as an operator that has adopted the *solution integrator* model. Is Makedonski Telekom also adopting this model to position itself on the value chain?

a. As mentioned in the previous answer, in order to be more concurrent on the market and develop provisioning process which results into faster G2M plan, then it is more than obvious that Makedonski Telekom as a telecommunications leader and premium service provider should also follow the solution integrator model. As this takes effect, the collaborating with different IoT partners becomes stronger and stronger.

On the other hand, Deutsche Telekom developed Multi-IoT Service Platform with open interfaces, providing other IoT providers easy integration for faster provisioning process.

5. Which according to you will be the sectors/verticals that will be the early adopters of IoT, worldwide and in Macedonia?

a. Service provides, for sure, will be the first ones. The main thing that might appear on the market is at least two different group of IoT service operators. The first group is fulfilled of ones that use the re-sale model, where the customer communicates directly to the cloud-based IoT operator. This group of operators is not providing support to the endcustomers for the service that is implemented. The other group includes ones that develop complete IoT solution, using the solution integrators role, while having the strong partnership with the IoT partners, provide full support to the end customers. The latter group of operators is definitely, where Makedonski Telekom is included.

Additionally, Makedonski Telekom seeks for implementing new access technologies, such as NB-IOT, with which will easier provide the new services to the end customer, as they seem to appear more and more essential for them.

6. How big of an investment is moving to 5G, for Makedonski Telekom?

a. The project teams in Makedonski Telekom are in a phase of planning for the implementation of 5G access network all over in Macedonia. Investing in the 5G network shall happen as a project for expanding and improvement of the 4G (LTE) network, especially in the rural areas, along with building the 5G infrastructure.

7. How ready and reliable is the 5G technology in terms of the user-driven and network-driven requirements, like coverage, latency, robustness and resiliency?

a. Reliability is one of the key elements of the 5G technology. As 5G spectrum waves cannot travel great distances or pass through objects, booster antennas will have to be positioned an average of every 150 meters. Exact coverage must be provided when implementing the 5G technology in order to achieve the stability of the new access technology and the

reason for which it is being developed – higher speeds, lower power and extremely low latency.

On the other hand, as the mobile operators deploy the network, the manufacturers of terminal equipment must take the pace with the mobile operators and spread the availability of the end-customer devices that will support 5G access technology.

8. By when do you hope to see commercial roll-out of 5G in Macedonia?

a. At the moment, the initial predictions and plans show that by end of Y2023, Makedonski Telekom should implement 5G connectivity on a national level all over the country. The percentage of 5G penetration per areas shall depend on the openness of the market and necessity of the services, which will be supported by the new access technology. Addition to this is also the progress of the terminal equipment on the market.

9. One thing that cannot be overlooked as the new technologies are implemented is the regulatory environment. And there is already an opinion that the current policies and regulations are not adequately adapted for a world of machine-to-machine (M2M) communications and data. What is the regulatory climate like in Macedonia? And does the regulatory framework represent a significant challenge for Makedonski Telekom, in this context?

a. Makedonski Telekom has always been harmonized with the regulatory body in Macedonia for each product implementation. Some of the greater innovative implementations require to be done jointly between the operators and the regulatory body, which has proved to be the case in the past. As the society has technologically evolved and the world has started using the M2M communication services, both regulatory bodies, and the telecom operators must work closely together to have even higher progress. Simply said, we must keep the rhythm with the technological expansion and provide the best for the society and our customers.

10. When we talk about challenges, one of the most spread, considering telecoms and IoT is pipefication. Do you think that telecoms are going to be able to avoid pipefication and enjoy the benefits of massive growth in IoT?

a. Telecoms, as they own the major pipes all over the national networks, they always see the main benefits and stability of the business in the core services. Especially for massmarket products, there is still the sense that telecoms appear to be the main players on the market.

As mentioned before, the telecoms learned through the years that they need to start playing with the partners, smaller/bigger on the market that have developed IoT platforms and could easily provide the IoT cloud-based service to the end customer. The joint venture will be win-win situation for all…

11. A new concept that takes place is Greening IoT. There is a concern about the impact of IoT in context of mountains of obsolete devices and no way to dispose of them, but not only green IoT is helping other industries reduce the greenhouse effect but it is also reducing the impact of IoT itself

on the environment. Does Makedonski Telekom use or is planning to implement some of the Green ICT technologies?

a. Definitely yes. As we are in the planning process of implementing IoT and using the benefits of it, the IoT providers already patted the road for the best practices of IoT implementation. Greening is something that Makedonski Telekom as socially responsible company added to its postulates.

   At the moment Makedonski Telekom is mostly in the "Green Design" approach, but also considers the other ones as relationship with the partners is increased.

5.4. INTERPRETATION

From Makedonski Telekom's response on Q1, we can take out that they recognize the opportunities for new commercial models to support mass global deployments, and as a premium service provider they grow the idea of providing 'smarter' solutions which will ease the customers' lives, provide added-value services and strengthen operators' commercial models.

For the past three decades, telecommunication companies have dominated the business in information and communication technology, but the value chain is also changing in the digital disruption. Such example are over-the-top services that have caused the decrease of revenues from voice calls and SMS, which have been two main services that used to be revenue corner stones for telecommunication companies. From Makedonski Telekom's response we can take out that although this was correct, it has not lasted long, and the main reason for that is that on one hand the OTT service providers needed stability and availability of the pipes and Internet service, and on the other hand the service providers needed to enter joint venture with the OTT operators and stabilyze the revenues by opening themselves to different services that would be provided to the end customers. In their opinion new revenue streams from IoT as a new technology are already visible on the market, as they have already launched smart services, such as SmartHome and started several projects which will make the cities in the Republic of North Macedonia and its areas smarter, called Smart City which includes Smart Lightning, Smart Metering (water and electricity), Connected Cars, etc.

For Makedonski Telekom as telco provider, taking the approach of using the cloud based solutions, where partnering company has already established IoT platform in the cloud would assure easier setup, effective provisioning and faster penetration on the market, and as can be taken from their response to Q3, this case definitely lowers the time-to-market and eases the G2M plans of the new products. Other approach they mention, a more telco one, would be to have the IoT platform installed on the Makedonski Telekom VPS platform, and provide the added-value services towards the customers using the cloud of the telco provider.

IoT still being in its early days, telecommunication providers can explore multiple approaches towards IoT. In the previous sections of this work *3.3.1 Possible Business Models for Telecommunication Companies in Internet of Things,* six business models for telecoms in IoT were discussed and three classic business models followed that Huawei, 2019, recommends from looking at how leading

operators around the world have implemented IoT services, them being: connection expert, platform provider and solution integrator. Makedonski Telekom, same as the international Deutsche Telekom Group, which they are part of, follows the solution integrator model, and as this takes effect the collaborating with different IoT partners becomes stronger and stronger. They add that Deutsche Telekom developed Multi-IoT Service Platform with open interfaces, providing other IoT providers easy integration for faster provisioning process.

In terms of early adopters of IoT, taken from their response on Q5, Makedonski Telekom identifies the service providers. They identify two groups that might appear on the market. The first group uses the re-sale model, where the customer communicates directly to the cloud-based IoT operator and this group of operators is not providing support to the end customers for the service that is implemented. The other group are the ones that develop complete IoT solution, using the solution integrators role, while having the strong partnership with the IoT partners and provide support to the end customers. Makedonski Telekom categorizes themselves in the second group. They seek for implementing new access technologies, such as NB-IOT, which will easier provide the new services to the end customer, as they seem to appear more and more essential for them.

While discussing technologies, from the interview we understand that the project teams in Makedonski Telekom are in a phase of planning for the implementation of 5G access network all over in Macedonia and investing in the 5G network shall happen as a project for expanding and improvement of the 4G (LTE) network, especially in the rural areas, along with building the 5G infrastructure. And, in terms of the user and network driven requirements for 5G that are discussed more in detail in section *3.5.2 Requirements for 5G*, what we can take from Makedonski Telekom's response is that they also recognize reliability as one of the key elements of the 5G technology, and add that as 5G spectrum waves cannot travel great distances or pass through objects, booster antennas will have to be positioned an average of every 150 meters. Exact coverage must be provided when implementing the 5G technology in order to achieve the stability of the new access technology and the reason for which it is being developed - higher speeds, lower power and extremely low latency. Also, they note that as the mobile operators deploy the network, the manufacturers of terminal equipment must take the pace with the mobile operators and spread the availability of the end-customer devices that will support 5G access technology. Considering the commercial roll-out of 5G in the Republic of North Macedonia, at the moment of the interview, the initial predictions and plans show that by end of Y2023, Makedonski Telekom should implement 5G connectivity on a national level all over the country, and as they add, the percentage of 5G penetration per areas shall depend on the openness of the market and the necessity of the services that will be supported by the new access technology, and also the progress of the terminal equipment on the market.

In section 3.6 *Challenges for Telecommunication Companies in Internet of Things,* the challenges that telecommunication companies face when it comes to IoT were identified. When implementing new technologies, if the regulatory environment is not adequate, it can represent a significant challenge. As can be seen from their response on Q9, Makedonski Telekom has always been harmonized with the regulatory body in the Republic of North Macedonia for each product implementation. They recognize that some of the greater innovative implementations require to be done jointly between the operators and the regulatory body, which has proved to be the case in the past, and that as the society has technologically evolved and the world has started using the M2M communication services, both regulatory bodies, and the telecoms must work closely together to have even higher progress. Another challenge that is highly associated with telecoms and IoT being pipefication, Makedonski Telekom's

stand is that telecoms learned through the years that they need to start playing with their partners, smaller/bigger on the market that developed IoT platforms and could easily provide the IoT cloud-based service to the end customer, and joint venture will be a win-win situation for all. And as the awareness of environmental issues all over the world is increasing, Makedonski Telekom, as socially responsible company, has added greening to its postulates, being presently in the 'Green Design' approach, but also considering other ones as relationship with the partners is increasing.

Considering the above, what can be concluded is that Makedonski Telekom is in the process of planning the implementation of IoT and using the benefits from it. They are already aware of the potential impact that IoT can have on the telecommunication industry and also in the consumers' lives. In their planning they take into consideration the challenges and the best practices from the providers that are already patting the road of IoT implementation. They follow the solution integrators model which is highly advanced in terms that in order to be able to offer customers package solutions including terminals, software apps, and integrated services, the operator must have high capabilities in multiple areas and a deep understanding of the target industry. If this is the direction they will follow, this will place them highly on the value chain as the Internet of Things market matures, and the higher they are on the value chain, the more potential for revenue growth they will have.

6. DISCUSSION

As discussed throughout this work, Internet of Things has the potential to radically change our daily lives, bringing almost limitless benefits by saving time and resources, while creating possibilities for growth and innovation (Bahga & Madisetti, 2014). The opportunities for new comercial models and the idea of providing 'smarter' solutions in IoT is recognized by the telecommunication companies. And the knowledge that is gained from the case study combined with the theoretical part of this work can be used by national telecommunication service proveders in Europe, that commonly are part of a bigger international groupation. In this chapter the main takeaways are presented.

In the days of early implementation of Internet of Things, telecommunication companies face many challanges. They need to overcome the technical challanges, while having a well established strategy and choosing the most suitable business model that will place them most favorably on the value chain.

When discussing technologies, what we can take from this case study is that the technical and business driven requirements of the new technologies must be considered, and reliability is one of the key elements. Exact coverage must be provided when implementing the 5G technology in order to achieve the stability of the new access technology and the reason for which it is being developed - higher speeds, lower power and extremely low latency. Telecommunication companies need to consider the openness of the market and the necessity of the services that will be supported by the new access technology in different areas. They also should consider if the manufacturers of terminal equipment are at pace with them.

When implementing new technologies, if the regulatory environment is not adequate, it can represent a significant challenge. An advantage that telecommunication companies operating in a single country as part of an international group can have is that they can benefit from the regulatory standards that

are pre met by the group, while also by being a national operator in the country they probably have already developed collaboration with the local regulatory body.

Telecommunication companies will have to provide 'smarter' solutions and added value services in order to strengthen their models. When considering the new revenue streams from IoT, telecoms will also have to consider other players on the market in order to avoid pipefication. And as the awareness of environmental issues all over the world is increasing, it is telecommunication companies role to implement IoT prudently to show that not only green IoT is helping other industries reduce the greenhouse effect but is also reducing the impact of IoT itself on the environment.

Telecommunication companies that operate in a single country but are part of an international telecommunication company group enjoy the advantage that they can use the know-how and the support of the groupation to implement IoT, in terms of the strategy and the business model to follow. IoT still being in its early days, telecommunication providers can explore multiple approaches towards IoT. In the previous sections of this work *3.3.1 Possible Business Models for Telecommunication Companies in Internet of Things,* six business models for telecoms in IoT were discussed and three classic business models followed that Huawei, 2019, recommends from looking at how leading operators around the world have implemented IoT services, them being: connection expert, platform provider and solution integrator. The most advanced and favorable is the solution integrator model, which is highly advanced in terms that in order to be able to offer customers package solutions including terminals, software apps, and integrated services, the operator must have high capabilities in multiple areas and a deep understanding of the target industry. Being part of a leading international group can certainly help in adopting this model, and as the effects take place the collaboration with different IoT partners will become stronger. For telecommunication companies that will follow this direction, it will place them highly on the value chain as the Internet of Things market matures, and the higher they are on the value chain, the more potential for revenue growth they will have. In this case, there is a need to be careful not to focus too heavily on industry specific solutions and balance in adding highly differentiated vertical offers where feasible on one hand and facilitate third-party vertical solutions where differentiation is more difficult and the investment is too great on the other, so they do not underplay their hand in the connectivity and life cycle management layer.

7. CONCLUSION

This master thesis main goal was to investigate the impact Internet of Things will have on the telecommunications industry, to identify and analyze the possible directions for telecommunication companies as they take their role in the Internet of Things, and on this basis, to examine a real life example. The work's objectives that were set are completed.

The first one, being to examine the IoT value chain and to identify the possible business models for telecommunication companies in IoT, is completed in the theoretical part of this work. It is identified that there is a value chain that is associated with the IoT when it comes to telecom services and it escalates from first level that includes all the connected devices, to the second level that is related to the network and connectivity, the third level is related to the software platforms that manage devices and applications and all the data in use, to the final level that brings us closest to the end users and all the applications and services that they use. Also, six possible connectivity business models for telecommunication companies in IoT are identified: IaaS, PaaS, PaaS+, SaaS, SaaS+, and BaaS, followed with three classic business models: connection expert, platform provider, and solution integrator (Huawei, 2019).

The next objective of investigating the impact of IoT on the telecommunication industry and to understand the challenges for telecommunication companies in IoT is also completed in the theoretical part. The technological and business impacts of IoT on the telecommunications industry are presented and technology-related and business-related challenges are identified and elaborated.

The objective of identifying a suitable case study concerning the telecommunication companies' role in IoT is completed in the practical part of this work. A case study is elaborated, where the company's background is provided, the company being Makedonski Telekom AD, along with information on their current engagement in this field. Furthermore, on the basis of the acquired knowledge in the theoretical part interview guide is created, and the responses are presented.

Analyzing the case study, the following objective, is completed in the practical part of this work too, in the Discussions part, where the stage at which Makedonski Telekom is in implementing IoT is identified, as being in the process of planning the implementation of IoT, same as the direction that they will follow in terms of business models and positioning on the IoT value chain. In terms of business models they follow the solution integrators model which is highly advanced and if done right, will place them highly on the value chain, opening up the potential for revenue growth as the Internet of Things market matures.

And finally to summarize the work done, an overall conclusion on the telecommunication companies standing and role in IoT on the basis of the knowledge gained on the matter and the examination of a real life example follows. After studying the field of IoT, examining the IoT value chain and identifying the possible business models, identifying the impact of IoT on telecommunications industry and understanding the challenges and investigating a real life example through the case study, it can be

concluded that the knowledge that was gained through the theoretical part of this thesis is relevant and is applicable in real life, as there were not significant differences or contradictions noticed of this knowledge when a real life example was examined. Telecommunication companies can consider the context, value chain, business models, and challenges identified and elaborated in this work when implementing IoT, to assist them in being able to choose the right model for their unique situation and position themselves in the value chain in a way that will be most feasible for them.

8. LIMITATIONS AND RECOMMENDATIONS FOR FUTURE WORKS

This work presents several limitations, which hopefully will encourage future work on this matter. Implementation of IoT being in the early stage and the whole concept being still rather new, there is a limitation in finding relevant research and studies conducted that investigate the interconnection and impact of IoT on the telecommunications industry. Also, as telecommunication operators are presently in the process of planning or implementing IoT, there is limitation in finding relevant studies on the approaches that telecommunication companies can undertake in this process. Another limitation on the approaches is that considering this is still an evolving area, there is lack of evaluation performed on the suggested approaches and their appropriateness. In this context, there is a need of future work that will deepen the knowledge on the mutual impact of IoT and telecommunications industry, and the interconnection between the two. Additionally, the evolution of the present approaches for telecommunication companies in implementing IoT can be studied, and also the additional ones that might appear. Furthermore, when the results from implementing IoT for telecommunication companies are mature enough to be studied, performing an evaluation of the approaches will be essential.

Another limitation of this work is that there is a single case study performed. And this limits the findings of the case study to the context and setting of that one company. In future work, it is recommended to investigate more than one case study, and if possible different settings should be considered, such as the stage of development of the country (countries) where the company operates, whether the company in question is a key player in the industry or not, etc. In this way, a comparative analysis can be performed, and also the appropriateness of different approaches for different settings can be studied.

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10. APPENDIX

Appendix 1

An interview with Makedonski Telekom, as part of a case study included in a master thesis dissertation that will be presented as partial requirement for obtaining the Master's degree in Statistics and Information Management at NOVA IMS Information Management School.

1. As part of the Deutsche Telekom Group, what is Makedonski Telekom's stand on the new industrial revolution including the Internet of Things?
2. Over - the - top (OTT) content services have caused decrease of revenues from voice calls and SMS, two main services that used to be revenue corner stones of telecommunication companies. What new revenue streams do you think IoT will create for Makedonski Telekom?

3. Telecommunication companies have an advantage thanks to the central role of communications in many Internet of Things deployments. Considering the three-layered opportunity they can use to develop unique, differentiated strategies for the Internet of Things, in terms of connectivity, life cycle management, and vertical solutions, what is the positioning of Makedonski Telekom on this, to participate directly or facilitate, through the underlying layers, vertical solutions that others provide?
4. In one of its publications - Six IoT models: Which should telcos choose? - Huawei refers to Deutsche Telekom as an operator that has adopted the *solution integrator* model. Is Makedonski Telekom also adopting this model to position itself on the value chain?
5. Which according to you will be the sectors/verticals that will be the early adopters of IoT, worldwide and in Macedonia?
6. How big of an investment is moving to 5G, for Makedonski Telekom?
7. How ready and reliable is the 5G technology in terms of the user-driven and network-driven requirements, like coverage, latency, robustness and resilency?
8. By when do you hope to see commercial roll-out of 5G in Macedonia?
9. One thing that cannot be overlooked as the new technologies are implemented is the regulatory environment. And there is already an opinion that the current policies and regulations are not adequately adapted for a world of machine-to-machine (M2M) communications and data. What is the regulatory climate like in Macedonia? And does the regulatory framework represent a significant challenge for Makedonski Telekom, in this context?
10. When we talk about challenges, one of the most spread, considering telecoms and IoT is pipefication. Do you think that telecoms are going to be able to avoid pipefication and enjoy the benefits of massive growth in IoT?
11. A new concept that takes place is Greening IoT. There is a concern about the impact of IoT in context of mountains of obsolete devices and no way to dispose of them, but not only green IoT is helping other industries reduce the greenhouse effect but it is also reducing the impact of IoT itself on the environment. Does Makedonski Telekom use or is planning to implement some of the Green ICT technologies?