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DOCTORAL THESIS
- SUMMARY -

CONTRIBUTIONS TO THE IMPROVEMENT OF THE QUALITY AND SECURITY OF IP BASED SERVICES IN INTELLIGENT TELECOMMUNICATIONS NETWORKS

CONTRIBUŢII LA ÎMBUNĂTĂŢIREA CALITĂŢII ŞI SECURITĂŢII SERVICIILOR BAZATE PE IP ÎN REȚELE INTELIGENTE DE TELECOMUNICAȚII

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Chapter 1: **Introduction**

In chapter 1 is presented an overview of the steps taken in order to develop this thesis: from explaining the motivation behind it, the steps that accompany the determined objectives, to the importance, the novelty and the way this subject relates to international concerns.

Nowadays, it is more and more the case that information is seen as a decisive ontological factor that together with matter and energy forms the basis of our knowledge of the universe.

1.1 The motivation behind the choice of topic

This study defines the technology known as „Internet of Things" as an active area of research with the goal of bringing intelligent objects closer to reality.

What it brought me motivation in order to develop these distinct applications and to present them in this thesis was my own objective of bringing improvements with regards to the security of „intelligent" object that we use on a daily basis, by preventing any unpleasantness caused by various cybernetic terrorism attacks, thus ensuring that all types of users have a better life quality – this concept often being referred to as „well-being".

1.2 The importance and the novelty of the topic

From the point of view of the study, the suggested topic has a major importance, considering its contribution that it will bring to the progress within the telecommunications domain.

The need to process large volumes of data has led to an evolution of the digital technologies and to the emergence of modern mechanisms, such as: „Internet of Things", 5G technology, cloud computing services, data analysis and processing including on an artificial intelligence level etc. All these technologies have the predecessor role to inform the change in the way various products and associated services are designed, developed and commercialized, as well as the way one can benefit from them.

The innovative characteristic of this thesis is supported by implementing a practical application respecting ideologies from the 5G standard, more specifically, a software product that applies the concepts developed in the 5G standard, as well as ideas from the „Internet of Things" technology, that will be spread in all the domains around us.

1.3 The structure and the objectives of the thesis

This thesis is structured in two parts.

The first part contains an introduction section made of the first two chapters, where the first one is the introduction, and the second presents concisely concepts regarding communication

networks and technologies relying on the Information Protocol, as well as the main characteristics of the various mobile telephony generations.

In the second part, including chapters from 3 to 6, it is being presented the research I have done, my personal contributions, the details on the implementation, the analysis I performed, followed by the obtained results. Validation of the scientific results of the doctoral thesis by the development and publishing of summative articles that outline the original contributions can also be found in chapter 7, as well as conclusions and future perspectives of my actual work.

Through this thesis, I aimed to perform a critical analysis of all the stages that have led to the development of mobile telephony technologies, highlighting each method or operating principle, the focal point being the exploration and implementation of the forerunner steps to the 5G technology.

The fundamental goal of this thesis is to propose solutions for programming a virtual environment in which various common place electrical devices can interact with each other in order to provide better maintenance and accident prevention (including cybernetic terrorism), as well as providing easier and faster ways to interact with these devices.

1.4 The topic in relation to international concerns

While globally, the role and usefulness of things is changing substantially, by studying and actively integrating in our daily routines the new technology „Internet of Things", one can say with conviction that the new telecommunications 5G standard and the Artificial Intelligence domain will make it much easier to interact with these „things", more generally known as „devices".

Chapter 2: A critical analysis of the evolution of telephone networks

Chapter 2 is a rendering, in the most concise form, of the knowledge gained in the field of telecommunications networks, through the theoretical study of the research carried out, as well as of the professional activity carried out during the academic study and doctoral internship.

This chapter is an essential one and represents the foundation on which the following chapters of the thesis were built, in which the practical contributions made to improve the quality and security of IP-based services in intelligent telecommunications networks will be presented. Summarized, from a diachronic perspective, it is presented the evolution of mobile networks, from the appearance of analogue telephone switchboard to the digital ones that are existing also today.

Before the modern Internet was designed, people were investigating alternatives to the traditional telephone system for voice transport. ARPANET[6] was originally a project used in the U.S. military, which provided three very well-developed services for those early times: telnet (remote connection), ftp (file transfer) and remote printing (the verbatim translation would be printing a remote document). In other words, this project began in 1968[7] and is considered the ancestor of today's Internet. It has been observed over time that telephony via the Internet Protocol[21] has the advantage of lower call costs, as the distance between the participants in the discussion was no longer a problem. In this case, the quality did not depend in any way on the distance, but on the request to which that communication channel was subjected. The development and diversification of networks and telephone stations has made it possible to connect between remote users, where the transmission was having a high level of confidentiality and security in comparison with the previous times.

Preliminary conclusions: by the 20th century and the beginning of the 21st century represent a period of time of „overwhelming" importance in the progress of mankind through the dynamism and creativity of telecommunications specialists, who had as „allies" or as inspirations, as well, the demands and desires expressed by the users of communications based on telegraph, telephone and later, voice, data, video via the Internet and mobile telephony.

2.1 Mobile telephony generations – specific architectures and features

In this sub-chapter, the stages on the evolution of mobile communications systems have been studied by presenting the generations" predecessor to the 5G generation. We have described each generation by comparison, respectively chronologically, with the most important peculiarities and contributions, but also the limitations found for each generation. The aim of this analysis is to prepare the foundation for strengthening the new 5G generation.

The purpose of this doctoral work is not to explain the functionality of each block within each generation of standards, but to mention what each of them brought new and to make comparisons between standards, in terms of the design of architecture through the components, as well as technological specifications, advantages or disadvantages – *notions also found in the article where I was the first author „Interactive mobile telecommunications systems"[148]*.

For the foreseeable future, all devices and equipment integrated into the daily lives of users, i.e. the inclusion of medical equipment, cinema equipment, telecommunications and automobiles, etc., are expected to be completely switched to IP. To support these increases, both sales service providers and network operators have turned their attention to streamlining and simplifying processes within mobile networks.

I consider that the new generation will develop using and including specific elements from Artificial Intelligence domain, nanotechnology and radio-cognitive technology and the main protocol that will underlie these technologies will be the well-known Internet Protocol.

Chapter 3: **Evaluation of Quality of Service in voice-based technologies**

In this chapter, I brought my personal contribution through a comparative study upon the analysis and classification of two factors, respectively parameters that influence the evaluation of the quality of the voice.

a. Mean Opinion Score, known by the standardized abbreviation „MOS“[69], is a numerical measure of the quality of an event or experience. Being applied very often and also in the context of different types of networks based on Internet Protocol, it is highly used also today.
b. The transmitted Quality R-factor[71] is the evolution of MOS and aims to provide a more detailed measure of voice quality, and it varies on a scale from 0 to 100, as exemplified in the table below:

Satisfaction of the user	**R-factor**
Very satisfied	90-100
Satisfied	80-89
Few users unsatisfied	70-79
Many users unsatisfied	60-69
Almost all of the users are unsatisfied	50-59

Tab. 1 Voice quality based on Quality R-factor[69],[71]

The loss of packets, the delay with its variations, creates, even today, deficiencies on the quality of the voice initially perceived. Thus, the Quality R-factor can be defined as having a value derived from the delay, i.e. the variation of the delay, to which it is being added the packets loss.

In conclusion, the result obtained by measuring these factors is the scalar assessment of the transmitted performance (through the method described in ITU standard G.107.1[70]).

From the study of factors that have an influence on the quality of voice, I realized that the most important one is the delay. And together with the variation of the delay in the network, which is influenced by the time that voice/data packets spend in the waiting-queues, it determines the actual level of „load” of the network.

I studied, as well, the parameters that influence the Quality of Service and they are the following: loss of packets, bandwidth and echo.

Future trends: using and improving QoS parameters in order to have more reliable, interactive and a value-for-money networks accessible to all categories of users[79] are

necessary. Each telephone operator will regularly analyze these parameters and the manner in which calls occur within technologies, such as VoIP or VoLTE.

Chapter 4: **Next Generation Networks: 5G and the Internet of Things.**

This chapter aims to address a description of the Next Generation Network, 5G, by focusing on a new type of technology called the „Internet of Things“, by giving the currently shortcomings regarding the fourth generation of mobile communications systems, and as well as the considerations that the generation of the future, 5G, aims to meet.

I have shown the three levels of communication between the user and smart devices, the fundamental requirements for the construction of the technology called the „Internet of Things”, together with the aspects regarding the implementation, the current level and future trends for this technology.

An ineluctable aspect when talking about „the generation of the future”, it consists of the concepts regarding the assurance of services based on IP related to the aspects of Quality of Service and security.

Inside this chapter, there are identified and experimented, through a contribution the influence that has „throughput“ parameter on the Quality of Service in a mobile communications network. And the second contribution consists of the implementation of a software product entitled „Safe House” which addresses detailed notions regarding the digitalized interaction and also the assurance of „well-being” between persons and „smart” objects registered therein.

From the study of research on the characteristics of a future network, I identified the requirements, for the implementation of the 5G standard and its offered capabilities[86], that can be dealt from the perspective of two fundamental points of view, namely:

a) Perspective No.1 – It is also called „hyper-connectivity”

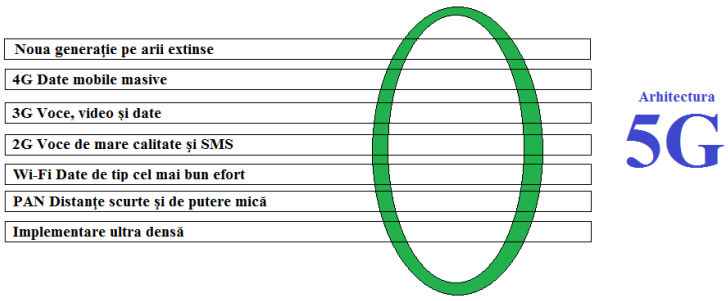

Fig. 4.1 Symbiosis of mobile communications technologies: current and future

b) Perspective No.2 – It is also called the „future generation of radio access technology“

These two points of view described above are regularly taken as a single set and therefore both requirements can be easily grouped together – in addition, are also described in Scientific Report No.3/2015.

At the same time, the cellular technology named „5G-NewRadio“[160] represents the evolution of the Internet itself.

In heterogeneous wireless networks, the new concept is similar to that of Genetic Algorithms[90], i.e. „always the best connected“ (always associated with the best quality).

4.1 Fast development: increasing the transfer rate

Objects have the capability to adapt to the ability of taking decisions using scheduled data combinations, as well as the ease of learning. They also have the ability and power to do almost everything on their own (i.e. without the need for human intervention). Thus, all this is the result of research in the field to transform current things into „smart“ objects.

Researchers estimate that in 2022 more than 220 billion devices worldwide will be connected[159], ranging from washing machines, espresso machines, conditioning machines, bicycles or even cars. Every day, more and more „objects“ become an integral part of human life, through the way in which each of them can adopt the ability to detect the user's needs, the ability to interact or communicate with him - these types of abilities or „attributes“ of the qualitative type is called, in the specialized literature, „usability” (term defined by the Danish researcher Jakob Nielsen).

Regarding the QoS in IoT it can be stated that, it is one of the critical factors, which requires research and stabilization processes for the implementation, management and optimization of the parameter's characteristic of „smart“ objects.

Thus, with an increase in the number of devices that will be interconnected and thus their facilities, there will be a need to improve a number of parameters such as: energy efficiency, bandwidth, storage optimization, coverage[93],[106], and the accuracy of sending and receiving data.

4.2 The obligation to implement the Quality of Service in the Internet of Things

Quality of Service seen as a non-functional component is the „ability to provide satisfactory services“ by different service providers and systems. Studying the issue of service quality in the „Internet of Things“ technology[106],[110], we found that this area obviously needs further improvement, as this concept is on the rise due to scalability areas and widespread applications, as well as in their application.

There are also devices that are real-world data detectors with or without any feature of „intelligence“ and are capable of detecting information for a given, specific purpose: sensors, actuators and other objects accessed directly or indirectly[105]. They can provide data that comes from fields, which are located in the heart of the smart environment by activating a software application designed to perform actions similar to those belonging to the real world.

Due to the fact that most devices need secure and reliable Internet connectivity, whether the selected application is interactive or not, the QoS plays a very important role and should continue to be treated as a priority at both provider and at user level[87],[106].

4.2.1 Parameters

The parameters, implementation schemes and algorithms applied to obtain the quality of services depend on the technology in question[108],[109].

The parameters from network level are the following[110],[127]:

a) Throughput - is, in fact, the current bandwidth measured at a certain time and at the same time, the sum of data packets' speed transmitted to all the mobile terminals in a network.

$$\text{throughput} = \frac{\sum \text{transmitted data packets } (bits)}{\text{time in which data packets are received (s)}} (4.1)$$

b) delay or latency

$$\text{latency} = \frac{\text{length of data packets (bits)}}{\text{throughput of the network (bit/s)}} \quad (4.2)$$

c) packet loss rate

$$\text{packet loss rate} = \frac{\text{sent data packets} - \text{received data packets}}{\text{received data packets}} \; x \; 100\% \quad (4.3)$$

d) interference

$$\text{interference} = \frac{\sum \text{variation of delayed data packets}}{\sum \text{received data packets}} (\text{s}) \; (4.4)$$

e) reliability - represents the probability of a network or a component of that network that, under precise working or environmental conditions, to function properly within a defined time interval. At the same time, being a probability, its value will be between 0 and 1.

During the research period, I studied and reproduced in the thesis the parameters at the application level, respectively at the perception level. I mention that all these listed factors, which affect the quality of services in a mobile communications network, should be periodically "trained" to improve the Quality of Service.

4.3 The impact brought by the evolution of the Next Generation Networks

Following the intensive, non-exhaustive study of the existing materials in this domain, as well as on the behavior of the subjects that are part of each field mentioned below, three essential areas[111] were identified and presented below:

a) the impact on user privacy
b) the health impact
c) impact on day-by-day activity

It will be tried to express the opinion that the most present in our lives, captivating and controversial aspect is the impact on health - it cannot be denied or hidden the effects that both equipment and the application of standards have on each of us ... so that „we can say that the future has arrived, we are contemporaries with it, and from now on it will arrive so fast that it will always be the present.“[111]

4.4 The Application „Safe House”

Based on the study, my own research and the experience gained in the field of activity that I practice, I proceeded to implement a contribution with practical applicability to the standard knocking on the door, namely 5G.

According to the specifications of this standard, everything will migrate to a permanent Internet connectivity[87],[88] - from telephony to everyday appliances, such as: household appliances, city-level utilities and also cars.

The software product that I developed, implemented and tested it is an essential contribution to overcoming the vision threshold in the ongoing technology, called „Internet of Things“, in order to provide access and, respectively, to monitor the devices owned, mentioned above, in order to protect against theft, destruction or even a malfunction of the device itself. At the same time, it is a method of prevention and control over electronic equipment. The purpose of the design of this software product, namely to provide end-users with visibility and permanent security on the „smart“ goods inside a house, by sending warnings of their behavior, following research and experiments, has shown that, these (visibility and safety) can be improved by the recognition by the „mounted“ sensors, the different activities that occur at the level of those „tested“ objects.

The following conclusions are being taken: smart homes are, more and more often, perceived as a valuable category, but also a target of attacks (cyber or classic, human in nature). These are mentioned not only in the literature, but also in various articles that direct attention in the direction of the present technology, that of the „Internet of Things“.

All these interconnections between man and machine, respectively machine-to-machine make the present as oriented as possible on the user's satisfaction, the difference consisting in the tastes, respectively the preferences of the latter, through the different ways of personalization and interaction with the respective „smart things" around the user. User satisfaction, together with efficiency and effectiveness are the three main components of usability specified in ISO 9241-11: 1994 - *aspects also mentioned in the article in which I was the first author „Mobile interactive telecommunications systems"[148]*.

Chapter 5: **The importance of information security in everyday life**

This chapter aims to address notions related to the security of the computer system. The need for information security in the technology of the present, the „Internet of Things", as well as the cohesion that is necessary to create between the „Internet of Things" and security, will be presented.

Information is the source of knowledge, but also of prosperity. If we interpret this metaphor, we realize that all that surrounds us is information, and therefore it is of vital importance not only to the user itself, but also to the devices or communities surrounding him.

The constant topicality of the three elements, recalled below, and which constitute the basic characteristics of information security through their applicability and implementation, are considered the true „foundation" against current cyber-attacks[118],[120]: availability, confidentiality and integrity. Some of the above aspects were also dealt in detail in the Scientific Report No.5/2016.

As the recent threats of connected devices on the Internet of Things have evolved considerably, solutions and implementations are presented to ensure high security for devices with „smart" features.

In the case of IT security, the most common standard is that of Information Security Management: ISO/IEC Standard 27001:2005[116].

5.1 Need for information security in „Internet of Things"

The ability to connect and manage all electronic devices remotely is becoming an increasingly present situation in our lives via the Internet. The easier the process of accessing information becomes, the more opportunities for risk arise for which new methods of control and protection need to be developed.

Assessing the nature of incidents that may affect the normal functioning of the network and its component devices is one of the constraints raised by cyber-security[115],[117]. Each

connected device creates opportunities for attackers. On the list of risks it is included: data transfer, access to the device, faulty and always connected devices that can be seen immediately by unauthorized users, as opposed to devices with intermittent connection (only for the strictly necessarily times).

As a partial conclusion, the evolution of security, of the methods of protection in the Intelligent Internet of Things, must continue with the same accelerated rhythm with which it develops itself. *This idea was also presented in the article published as co-author „Interoperability and security management of complex systems"[149]*.

Each smart device can be viewed as unique[85] in terms of configuration and competence. Protecting it from cyber-terrorism, physical wear or external factors independent of the user's daily activity leads to the ability to operate within optimal parameters, to the level of the requirements imposed by any type of user.

The improvement of security methods it is not only about data encryption, but it should be able to ensure also the implementation and security configuration of the entire system. *As well as I mentioned in the article „Cyberterrorism"[150], as the first author, once the vulnerabilities of a system are understood, it will be much easier to implement and optimize the necessary security methods.*

It is also recommended that the security session to be regularly updated for an extended life and without major, destructive hazards. Some of the above issues were also dealt before inside the Scientific Report No.1/2014 and Scientific Report No.5/2016.

5.1.1 International Standards in the „Internet of Things"

Today, almost all electronic devices constantly interact with the physical world through sensors that collect various information, while actuators can act on different entities. A growing concern today is to create efficient systems or standards of security in order to eliminate as much as possible risks involved and to guarantee the security or reliability of the things that can bring comfort it is needed for any kind of user.

As for a conclusion of those specified in this chapter, in accordance with the definition of security found inside the Explanatory Dictionary of the Romanian Language, it can be stated that: „security may constitute the sense of calm that an individual has in the absence of danger".

Chapter 6: **Next Generation Networks Optimization Techniques (5G)**

Based on the practical contributions described in Chapter 4, i.e. the theoretical ones in Chapter 5, I reshaped, in detail, this time by analyzing different new techniques for optimizing

a test network. The practical contribution that I have made this time represents a new concept, namely that of „optimization“ of telecommunications networks using the characteristics of Genetic Algorithms – a concept that has been studied since the years of The License, during the period of specialization – but which has been addressed in detail inside this chapter.

I would like to share with you that I think of optimization as being similar to the exploration and ascent of a virtual mountain.

6.1 Impact of the applicability of Genetic Algorithms in Next Generation Mobile Communications Networks

6.1.1 Case study : Smart Home

In the previous chapter, it was presented a personalized way of interacting with „smart“ devices, within a home, with the user through the alerts sent by these devices. These alerts were also received on the user’s mobile phone by selecting the preferences of notifications of categories of objects that were designated to be found under „surveillance“.

Through the practice of different activities done by the user and his interaction with intelligent „monitored“ things, he will feel a state of “well-being”, of safety.

Activities such as entering or leaving the house, sleeping, different ways of relaxing, eating, watching TV are included in the list of those that can be easily monitored and optimized. Through the detection of activities, it is possible to further analyze and determine a so-called „template-behavior“.

The given object under the analysis of this contribution is each window, with the characteristic of being intelligent, inside a smart home. I analyzed the activity of objects through the help of the sensors. The main feature that I have given to these „mounted“ sensors inside this „smart“ house was non-invasion. The reason is simple: so that users and smart devices don’t feel the desire to change something in their usual behavior. The given names for the sensors are original, they were chosen and customized by the author of this Doctoral Thesis.

The scope of this simulation is to analyze and to track the activity of intelligent objects, using sensors in the smart home, aiming to provide to end-users a continuous visibility and security on their goods. The purpose of this experiment has been achieved. One of the benefits of this contribution is that algorithms can detect a behavioral change across the usual states, which could indicate a problem, therefore it can be a sign in order to alert the emergency services.

6.2 Human interaction – machine: benefits and apparent negative considerations

As a result of the observations presented in the previous sub-chapter and the application (simulation of a smart home) developed in Chapter 4, one of the most important topics, namely human-machine interaction, will be dealt with here, at a theoretical level.

The dialogue between man and machine has become much easier, by including Artificial Intelligence both in telecommunications networks and by „enlivening“ the devices that surround us to make our lives easier, more animated and safer (just the recognition of human activities presented in this chapter).

The purpose of this subject is not done in order to convince the reader to surround himself only with „smart“ things, but to be presented with current aspects (most likely, for many of us, they are considered reflexes already) and also the advantages of current technology.

Whether it is the diagnostic doctor, a student who writes his Doctoral paper, the pharmacist who checks the stock of medicines or their contraindications, the pilot of an airplane, the teacher who set out to present in a more interactive way the lesson or even you who are reading this paper now... we all need the easiest and reliable interaction formed between „devices“ and therefore, us, the humans, in order to carry out the proposed work.

6.3 Inclusion of Genetic Algorithms: Potential Solution to Next Generation Mobile Communications Networks

The specialized literature in which Genetic Algorithms are presented is an extensive one. Through the existing notions, respectively the roles that Genetic Algorithms acquire , in the following lines, an introductory analysis will be presented inside this sub-chapter in order to design and optimize the Next Generation Networks.

The analysis of a Genetic Algorithm is of a scientific type, where its optimization must be taken into account from the initialization phase of the algorithm and its tracking throughout evolution. In order to design a prototype for a new Next Generation Network, I updated, respectively adapted, the diagram in which the „standardized” stages of an evolutionary type algorithm are presented, being exposed in the figure 6.1 that can be found inside this Doctoral Thesis. The purpose of including Genetic Algorithms in the process of improving mobile communications networks is to have as a final result a Next Generation Network with visibly much better performance.

6.4 The effects of constant monitoring of objects by users

The latest technology, in the field of automation related to cities, respectively „smart“ houses has the responsibility to offer the user, regardless of where he is, the feeling of security, safety

and comfortable life. That is why, in the technological era in full development in which we are at the moment, it is necessary that the technology of digitalization of the home to be available to every individual.

The possibility to constantly improve and control the things around us makes the digitalization of houses, respectively of households to be made much more accessible and much safer. Both control and status monitoring (open / closed / damaged / corrupt of a device) were implemented using distinct modes, such as: Internet connection and graphical user interface, but also keeping the traditional mode: the electrical switch.

6.5 „iCare4U": optimization contributions regarding security solutions for a smart house tied to evaluating the sensor parameters

Nowadays, the user spends a lot of time for activities outside the house, so that monitoring the state of things inside the house, as well as providing a reference frame to each, is very useful.

In this thesis, it have been shown that through the established „communication" between the sensors of each „smart" appliance, together with a monitoring application for the „smart" house, the user is able to receive timely information regarding the proper or faulty operation of appliances and what led to the change in the expected behavior. In other words, monitoring brings two significant advantages, namely: the lifetime extension and improved reliability for various appliances, as well as their security against attacks regardless of nature of the attack, be it human or virtual.

The method through which neural network concepts are included within a mobile communication network is the next step in the improvement and the further development of the interaction between humans and the things around us (human-to-machine). By applying the principles and steps of genetic algorithms, as well as adjusting them to a sensors micro-network from a smart house – the result of the aforementioned study, I have continued the research in this direction and I have further developed the existing concepts.

The added contribution, due to its practical applicability, has as purpose the detailed evaluation of the sensor parameters within a „smart" house in order to improve the security solutions afferent to the objects therein. *This simulation will also be presented in the article currently undergoing publication, with me as first-author, „Procedures to keep the voice of „intelligent objects" alive"[151].*

At the same time, this contribution follows two quality standards, „ISO / IEC 30141" and „ISO 24767-1 : 2008". Both standards rely on a common principle, that is the development and implementation of solutions and systems with the purpose of ensuring security against any type of cybernetic terrorism, such as: the failure to comply with data privacy, attacks using computer

viruses within a local network (the standard name being „LAN" - „Local Area Network"), account „break-ins" - *aspects which have also been presented in articles I have authored „Wireless LAN Security Issues (I). Types of Attacks"[152], respective „Wireless LAN Security Issues (II). Types of Attacks"[153]*, or even the modification of functional parameters from the sensors present in a smart house (please kindly see the B-Annex for more details, as well as regulatory references regarding these two standards).

As an additional personal input, I have proceeded to show the configuration and the display of the sensors within the „Safe House" application, as well as the „Event Generator".

6.6 Conclusions

Optimizing a network is an essential process within a technology used to improve the performance of the network, as well as an important process for the efficient management of the systems that form the network.

There are several advantages for optimizing a network periodically, such as: faster data transfers, faster data recovery (whatever that data may be) in the case of natural disaster or cybernetic attack, improvement in the processing and reaction time for application used by devices that interact with humans etc.

Chapter 7: **General conclusions**

7.1 Original contributions

The main focus of this thesis consists of revealing and implementing of personal innovative methods in order to enhance the quality and security of services in Next Generation Networks.

In order to put the spotlight of my personal contributions in a nutshell, accordingly to the order of the chapters presented in the thesis, may be summarized as follows:

1. In **Chapter 2**, I analyzed in a diachronically manner and I made a comparison study towards the evolution of telephony services, Internet as well as the effects of the interaction between them.
2. I provided a synthesis and I presented the main three technologies based on the Information Protocol: VoIP, VoLTE and IPTV with their characteristics, capabilities, but also with their shortcomings – all these influencing the transmitted data to the users.
3. I displayed the chronological display of each mobile generation technology from 0G to 4G, in which I summed-up the most important features and contributions, but also the shortcomings, weaknesses found for each generation. The purpose of this analysis was to prepare the foundation in order to bring strength to the new 5G generation.

4. I brought my contribution in **Chapter 3** through the performed study on the analysis and classification of the factors and parameters that influence the evaluation of the received and transmitted voice quality through digital circuits.

   On this matter, I presented two indicators for evaluating the voice quality, called „Mean Opinion Score" and „Quality R-factor".
5. In table no.3, called „Factors that affect the Quality R-factor", I synthetized the main elements that can influence the voice quality, the reference intervals of each parameter in order to rate a voice – either as good or as a bad one. Being dependent of these network parameters, the variation of R-factor implies also a variation of the Mean Opinion Score.
6. In the introduction of **Chapter 4**, I merged the actual information related to Internet of Things, by organizing it in the form of a diagram – revealed in Figure 4.1 (the present technology „Internet of Things" – representation of the three levels of communication in relation to human perception). This representation was done in order to render as concisely as possible, but also explicitly, the essential three levels of interaction with the user, in the following way: perception, transfer and application.

   Note[1]*
7. In section 4.2, I rendered into a graphical way, as can be seen in the Figure 4.2, the symbiosis of the current and of the future mobile communications technologies. By displaying the defining features of each technology, I anticipated some of the elements that formed the basis of „5G – New Radio" technology[160].
8. In the section 4.7., entitled „Outlining a new type of technology – the Smart Internet of Things", I analyzed by starting from the definition of usability and by describing the latest concepts, the impact and the level of satisfaction has the technology consisting of the so-called „smart things" on the user side.
9. Some of the concepts I implemented and even validated them as test-ideas, so I started to create a very useful software product (it is compatible with mobile phones that have Android as an operating system). Therefore, I decided to show its functionality and roles inside Chapter 4. I gave to it the name of „Safe House".
10. Within the implementation of the new technology „Internet of Things", I defined a set of factors, also of values for the implementation, management and optimization of these parameters regarding the Quality of Service. Inside the section 4.8.3., I brought to light the parameter called „throughput", that also has become the main subject of one of the most

[1] Chapter 4 was in my mind's eye three years ago as a reflection of my own ideas and contributions. In this chapter, the reader is able to detect concepts, that at that time were my own views, regarding the future of mobile communication standards, but at the current moment, when I present this thesis, the ideas are integrated parts of the development of the current mobile communication standards.

relevant case studies with practical applicability. By modifying different variables of this parameter, this case study had as subject of the analysis, under different conditions, the behavior and impact brought to the performances of the network.

11. The experiment took place in Berlin, Germany, and also different measurements were made in various locations, under various conditions and several time intervals.
12. Following the conclusions developed after the exposure of this case study, I made up also a set of recommendations, in the light of the comments already existing, and I wrote some future proposals.
13. I outlined aspects regarding:
    - the protection of fundamental rights and freedoms, in particular the one for private life, for confidentiality and protection of personal data in the area of users of „smart" electronic devices and beyond this, ensuring the free flow of transmitted/received data in different domains of activity;
    - Health protection, through the evaluation of the frequency spectrum, while identifying some health risks that users are being exposed to. These risks were already brought into discussion since the time of the previous network generations, but they are still under observation of the researchers.
14. In **Chapter 5**, I studied the standards in terms of protection and security assurance of objects and data with „smart" features, by specifying the security requirements that may come from inside or in the proximity of a house „populated" with devices that have those „smart" features.
15. For my own contribution which I developed, implemented and presented in **Chapter 6**, as a result of the researches that I made and of my practical experience that I have so far, I included basic notions from the actual topics related to Security International Standards, and in order to be more rigorous, from ISO/IEC 30141 and ISO/IEC 24767-1:2008, in addition to the well-known ISO Standard 27001 with its two versions already published (years: 2005 and 2013).
16. I analyzed by comparing these two mentioned standards from above, ISO/IEC 30141 and ISO/IEC 24767-1:2008, because I consider that they clearly specify the security requirements that may come from as well within, as well exterior of a house „equipped" with „smart things".
17. The earned observations I translated them into recommendations, namely the dedicated session to security of these objects to be updated periodically for an extended lifetime and without major dangers or even destructive, such as „cyberterrorism".

18. As a result of observations drawn from the application (simulating a smart house) developed in Chapter 4, I treated one of the most important topical issues, namely: human-to-machine interaction, by showing my own reflections that I gained from the whole research that "guided" me to prepare this Thesis.
19. Since the Bachelor years, during the specialization period of 18 months, I studied the concept of „Genetic Algorithms". Some relevant ideas of this concept I included, detailed and used in Chapter 6 with the role of bringing to life an optimization method in matter of improved security for actual telecommunication networks.
20. Activities such as entering/leaving the house, sleeping, eating, various ways to relax or even watching TV are on the list of those activities that can be easily monitored and optimized. Through this detection of activities, I approached the possible further analysis and I determined a so-called „pattern behavior".
21. Inside this PhD thesis, I simulated the digitization of activities inside a house, through objects with „smart" features. I examined also the Quality of the User Experience by implementing methods for a higher security and reliability of those objects.
22. I have updated configuration and I printed the new sensors including inside the "Safe House" Application and inside the Event Generator. If a problem with high priority is detected that is a consequence of an occurrence, including critical, resulting in endangerment user that house, I proceeded to implement the possibility of alerting the international emergency number "112" straight through "Safe House" application.
23. Thus, in this contribution brought to the thesis, as an innovative factor, I implemented the actual simulation of different activities, as well the inclusion of prevention and alerting methods given to the objects that are inside or in the proximity of a Smart Home.

In conclusion, all these contributions were synthesized and shown as reflection of my own studies, research or simulations for the entire time as a PhD student.

Many of these contributions are already being revealed, exposed and published in articles, symposiums and conferences in various areas of the IT environment.

The practical approaches of Case Study researches

The contributions mentioned previously together with the studied theoretical aspects are the foundation in order to materialize the scientific progress by the implementation of three digital innovations. Their purpose was to contribute at the improving of the satisfaction of users" lives, respectively of the objects that surrounds the user, through the expansion of the sector dedicated to Quality of Service or to the Security at a top level.

In this section, there are presented as well, the results achieved because of the experiments, which took place during the doctoral stage and that are described more in detail inside the thesis.

Chapter 4

A. QoS in IoT is one of the critical factors, which requires a continuous process of research and stabilization for the implementation, management and optimization of the parameter's characteristic to the objects with „intelligent" features.

In the following, I will detail one of the most relevant case studies, with practical applicability, having as subject the analysis, under different conditions, of the most important parameters of service quality and the impact, by modifying them, on network performance.

The implementation of that study was the first of its kind made, at that moment, in Europe and it took place during the years 2017-2019, the time period that matches with the second stage of my doctoral studies.

In the chosen location, the first Node Element „under study" was implemented with characteristics specific to the forerunner of the standard 5G that is 4G-Advanced with 5 carrier aggregation (in the technical literature, this is known as „5CC", where is „CC" stands for „ Component Carrier"). In this study, I performed an analysis of the factors that could affect the parameters of quality of service (the quality of the network installed, congestion, topology and location equipment forming the network „under study", weather conditions or time of the day) by analyzing at the same time the impact brought on the performances of current mobile communication network.

For the performed measurements in the chosen locations (globally named: „indoor" and „outdoor"), it was used as a device for performing the measurements a Huawei 4G+ smartphone, which was having Android as operating system and which was supporting technologies useful for the experiment. Related to storage and processing accuracy of the results of the two locations, especially later for the ones in the laboratory, I needed to set up a Server.

For the present study, the parameter called „throughput" was designated - to which different conditions will be applied in order to observe not only the changes of its values, but also the variation of the values of the quality of services. These conditions consisted in:

a. minimizing congestion in the 5-6 hour range of the morning. By performing measurements at different time intervals, I have noticed that this is the least crowded interval in terms of transmission and reception of voice packets, respectively data - thus, I considered it favorable to the study;

b. increasing the number of MIMO antennas (space streams): 4x4 and using more reflected signals. Of the two locations, I observed a concentration of these signals in the "indoor" location through different antenna positions - I obtained similar effects to the so-called "Fresnel zone" [135]) - so I consider the "indoor" location favorable to the study.

c. downlink frequency aggregation: the extension of the frequency spectrum, respectively of the transmission power. In other words, the proliferation of frequency aggregation, in the direction of the signal between the smartphone and the node found "under study", I consider the essential factor in increasing the network capacity (at the level of "bandwidth", respectively "coverage"). I noticed, thus, that I obtained an extension of the network coverage by up to 5%.

In each of these three cases, the value of the gained "throughput" was very good. I also plotted, in the thesis, other values obtained as a result of the "massive" aggregation of frequencies, the limit of the study included 5CC. I also addressed other conditions nevertheless.

Following the study, respectively the diversity of measurements made, I could notice that among the factors that could affect the parameters of QoS, respectively their performance, are: the quality of the installed network, the level of congestion present in the network, the network topology and location coordinates of a networks (which in some cases turn out to be improperly chosen), weather or time of the day conditions.

In my opinion, the present study has achieved its fundamental objective, namely to improve the QoS by determining the factors that may change one of the parameters, in this case – the "throughput".

B. The software product, which I developed, implemented and tested, is an essential contribution to exceeding the vision threshold in the technology in full blast, called IoT. Its purpose is to provide access and, respectively, to monitor electronic devices such as household appliances, utilities at city level and also cars in order to protect against theft, destruction or even a failure of the device itself. At the same time, it is a method of prevention and control over electronic equipment. The ultimate goal assigned to this software product was to give to users a permanent visibility and security over their goods by interacting with different types of „smart" objects connected to sensors.

I chose the name „Safe House" based on four fundamental characteristics that I considered that an application must meet. These properties, or characteristics, are: (S) - Security, (A) - Automation, (F) - Faithfulness and (E) – Economy saver (of resources, energy, etc.).

The entire application is able to process the amount of data received through the major components that make up the connection to a server - server that has the role of storing the data obtained and that will send these data in real time to an Android application and also, by creating a simulator for different devices to connect and to send events (as if they are sent by real devices) to that server and it also fulfills multiple and various roles, namely: viewing, recognizing notifications, interacting with the user in order to make predefined decisions and, respectively, displaying personalized statistics.

The Android application receives the alarms, that I have configured them so that there is the possibility to rank them according to priority, they may be displayed on the notification bar of the mobile phone and through a personalized notification sound, they are sent as warnings. Once the connection between the Event Generator and the Server is established, the Android device it has been configured to display an alarm notification, which can be viewed instantly. When opening notifications referring to alarms, it is noted what is most relevant to that alarm. The rest of the notifications have been configured to provide just an overview of the devices and sensor statistics. All this information will be recorded in a database, and for a clear record, I realized the possibility to view different statistics. If for various reasons the Internet connection is lost, the alarms are set to reappear as soon as the application reconnects.

Starting from the purpose of designing this software product, namely to provide end users with visibility and permanent security on the „smart“ goods inside a house, by sending warnings based on their behavior, following research and experiments, I brought a big contribution to improve the security by the recognition of the „mounted“ sensors of distinct activities that can occur at the level of those „tested“ objects.

Therefore, the purpose of these experiments was reached.

Chapter 6

C. In the experiment from Chapter 4, called “Safe House”, it has been presented a personalized way of interacting „smart“ devices, inside a house, with a user through the user’s mobile phone, which performs the exchange of notifications (I generically called them “alerts”) between these entities (“smart” things and the user). There is a possibility to select the preferences of the notifications individually assigned to the things under “surveillance”. Through this experiment, the activity of smart objects is monitored with the “help” of sensors inside a smart home, with the aim of providing end users with permanent visibility and security.

In Chapter 6, I expanded extensively research on the security of smart homes and by extrapolating the activity of monitoring individual objects to all activities carried out within it. This goal was achieved by making two contributions and applying the principles and stages of Genetic Algorithms, by adapting them as well to a micro-network of sensors inside a smart home. I mention that I programmed and simulated the steps similar to the concept of G.A. by using the functionalities of the academic product so-called MATLAB.

In the first contribution, the monitoring was extended at the windows level. The object under the analysis of this contribution was represented by each window, with the characteristic of being intelligent, inside a smart house. In this study, I highlighted for the simulation of monitoring, the presentation of a single, maximum of two activities that are part of the daily

register. Thus, the detection of these activities was simulated by using three so-called sensors, each having two states. All sensors were connected to a single machine-machine interaction device, so-called "server". They were able to easily communicate with the device, transmitting and receiving volumes of data in a fast and secure way. As a result, certain aspects of security can be improved by implementing sensors and the recognition of activities by sensors.

In the second contribution, I developed the software by adding three indispensable components in any smart home: an alarm system, a power supply and an Internet connection. The test location was chosen was from the real environment - namely, my own apartment located in Bucharest.

I implemented a number of 11 steps explained in detail in the Doctoral Thesis, with the appropriate graphical representation, and at each step, I included the relevant code sequence.

The principle of a G.A., adapted to be used in this simulation, was represented by the successive steps, as follows: it all started with a random "population" consisting of "s" individuals (here - sensors), where the selection took place, respectively their crossing in order to obtain the best individuals, and a so-called “mutation” was randomly applied on a part of that population. At the end, the "set of solutions" was being presented.

If in the first contribution, three sensors were included (two with “motion” features and one with infrared capability), in the second contribution, I included another pair – this one I chose to locate it at the entrance door of the apartment - and together with the alarm device having mode "activate", I designed for the user the possibility to receive an instant diagnosis on the state of the smart things that are being monitored inside his own house, managing, in addition, to detect a foreign existence. In the end, I updated the configuration and showed the display of the new sensors, included inside the "Safe House" Application, but also inside the Event Generator. The purpose of these contributions regarding the user's interaction with the "monitored" smart things has been achieved, therefore the user might feel a state of comfort, security - in general, the feeling of "well-being".

The initiative brought, through the implementation of the software products presented above, is a major innovation in improving the security of the smart home and implicitly, the goods inside of the designated smart home.

I can relate that this time of my research was a prolific, which has influenced my professional horizon, enriching my experience in different fields, such as computational intelligence concepts (artificial intelligence field), concepts and types for software products, Nano Electronics (sensors), but also in the security area of current and future mobile communication systems.

7.2 List of original works

Personal contributions include as well the following publications (as lead-author or co-author) previously performed, but mainly during the doctoral stage – having similar theme to the thesis objectives. These publications are respecting the principles of academic ethics. By publishing these articles in various journals (ISI / IEEE / BDI indexed), as well as presenting at conferences in this field ("Electronics, Computers and Artificial Intelligence"; "International Conference on Quality and Dependability"; "Advanced Topics in Optoelectronics, Microelectronics and Nanotechnologies"), they all had the role of marking the main stages of my own evolution in the research topics that I proposed for conceiving this Doctoral Thesis.

7.2.1 Scientific Articles in ISI indexed publications

[A1] (accepted article, to be published soon) C. Gherghina, A. Bacivarov, I. C. Bacivarov, P. Şchiopu, Procedures to keep the voice of "intelligent objects" alive, Advanced Topics în Optoelectronics, Microelectronics and Nanotechnologies, Constanța (Romania), 2020

[A2] C. Gherghina, A. Bacivarov, I. C. Bacivarov, G. Petrică, E-learning platform for automated testing of electronic circuits using signature analysis method, Proc. SPIE 10010, Advanced Topics în Optoelectronics, Microelectronics, and Nanotechnologies VIII, 1001030, Constanța (Romania), Dec. 2016, DOI: 10.1117/12.2246109 ; WOS:000391359600108

[A3] I. C. Bacivarov, A. Bacivarov, C. Gherghina, A New Approach în the Development of Quality Management Systems for (Micro)Electronics, Proc. SPIE 10010, Advanced Topics în Optoelectronics, Microelectronics, and Nanotechnologies VIII, 1001030, Constanța (Romania), Dec. 2016, DOI: 10.1117/12.2246030 ; WOS:000391359600104

[2] **Excellent Award**

[A4] S. Potlog, C. Gherghina, A. Vintea, Containerized Modular Data Centers Powered by Wind Farms, ECAI (Electronics, Computers and Artificial Intelligence) International Conference, Vol. 7, No. 3, 2015, ISBN 978-1-4673-6646-5,
DOI: 10.1109/ECAI.2015.7301264, pp.117-120 ; WOS:000370971100129

7.2.2 Scientific Articles in IEEE indexed publications

[B1] S. Potlog, C. Gherghina, A. Vintea, Containerized Modular Data Centers Powered by Wind Farms, ECAI (Electronics, Computers and Artificial Intelligence) International Conference, Vol.7, No.3, Bucharest (Romania), 2015, ISBN 978-1-4673-6646-5, DOI:

[2] Award of Excellence at the 8th edition of the International Conference - ISI indexed - "Advanced Topics in Optoelectronics, Microelectronics and Nanotechnologies" ATOM-N 25 - 28 August 2016, Constanța, Romania, list of scientific communications that were included in Proc. SPIE 10010, Advanced Topics in Optoelectronics, Microelectronics, and Nanotechnologies VIII (as lead-author and as SD-ETTI PhD student)

10.1109/ECAI.2015.7301264, pp. 117-120
(http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=7301264)

7.2.3 Scientific Articles in BDI indexed publications

[C1] C. Gherghina, Cyberterrorism, IJISC (International Journal of Information Security and Cyber-crime), Vol.1, Issue 2, December 2012, pages 33-39, ISSN 2285-9225
[C2] C. Gherghina, A. Bacivarov, Identification des défauts par la méthode de l'analyse de la signature, Asigurarea Calităţii – Quality Assurance, ISSN 1224–5410, Vol. XIX, Issue 76, October-December 2013, pages 14 - 23
[C3] C. Gherghina, G. Petrică,Wireless LAN Security Issues (I). Types of Attacks, IJISC (International Journal of Information Security and Cybercrime), Vol. II, Issue 2, 2013, ISSN 2285-9225, pp. 61-68
[C4] C. Gherghina, G. Petrică, Wireless LAN Security Issues (II). Security Assurance, IJISC (International Journal of Information Security and Cybercrime), Vol. III, Issue 1, 2014, ISSN 2285-9225, pp. 37-46
[C5] C. Gherghina, A. Bacivarov, Interactive Mobile Telecommunications Systems, Proceedings of the 14th International Conference on Quality and Dependability, 2014, pp. 259-268, ISSN 1842-3566
[C6] C. Ciuchi, C. Gherghina, G. Petrică, Interoperability and security management for complex systems, Proceedings of the 14th International Conference on Quality and Dependability, 2014, pp. 269-277, ISSN 1842-3566
[C7] C. Gherghina, A. Bacivarov, VoIP – Nowadays Gateway for a Better Unified Communications, Proceedings of the 15th International Conference on Quality and Dependability, September 14-16 2016, pp. 233-236, ISSN 1842-3566

7.2.4 Other received distinctions / completed projects

[3] **Certificate of Appreciation in quality as a Member**


Certificate of Participation

This certificate is proudly presented to

Cătălina Gherghina

for participating in the

Evolved Packet Core World Forum

26th October 2016

London

St Pancras Renaissance Hotel

We are very pleased to thank you for attending the Evolved Packet Core World Forum event which took place in London on 26th October 2016.

I would like to acknowledge your extraordinary contribution to this very important gathering for the telecommunication industry.

We hope you will honour us in the future by coming to the next important Informa events and sharing your wide knowledge with our audience.

3

[4] **Europe's first 5CC technology event**

7.2.5 Scientific Reports developed during the Doctoral Stage

(including also during the "Knowledge" Project Scholarship)

[D1] Report nr.1/2014 : „Aspects related to security in Wireless Networks"

[D2] Report nr.2/2014 : „Telecommunication Networks. Classification. Architectures."

[D3] Report nr.3/2015 : „New Generation Network – a change of perspective"

[D4] Report nr.4/2015 : Communications and multimedia via VoIP protocol"

[D5] Report nr.5/2016 : „Solutions to avoid insecurity in the Internet of Things"

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[87]https://www.dbresearch.com/PROD/RPS_EN-PROD/PROD0000000000496473/How_5G_will_change_your_life.pdf

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[109] http://www.zf.ro/business-hi-tech/cererea-pentru-soluțiile-bazate-pe-tehnologia-iot-vine-din-zona-logistica-14876008

[4] the first event launched in Europe of a Node Element "under study" (located in Berlin) with specific characteristics of the 4G-Advanced standard with 5 aggregated frequency channels (in the literature, this name is known as having the standard abbreviation "5CC ")

[110]https://www.agtinternațional.com/wp-content/uploads/2014/10/Academic-Paper_Enabling-QoS-in-the-IoT.pdf

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[148] *C. Gherghina, A. Bacivarov, Interactive Mobile Telecommunications Systems, Proceedings of the 14th International Conference on Quality and Dependability, 2014, pp. 259-268, ISSN 1842-3566*

[149] C. Ciuchi, C. Gherghina, G. Petrică, Interoperability and security management for complex systems, Proceedings of the 14th International Conference on Quality and Dependability, 2014, pp. 269-277, ISSN 1842-3566

[150] C. Gherghina, Cyberterrorism, IJISC (International Journal of Information Security and Cyber-crime), Vol.1, Issue 2, December 2012, pages 33-39, ISSN 2285-9225

[151] C. Gherghina, A. Bacivarov, I. C. Bacivarov, P. Şchiopu, Procedures to keep the voice of "intelligent objects" alive, Advanced Topics în Optoelectronics, Microelectronics and Nanotechnologies, Constanța (Romania), 2020 – with the actual status : accepted, to be published soon -

[152] C. Gherghina, G. Petrică, Wireless LAN Security Issues (I). Types of Attacks, IJISC (International Journal of Information Security and Cybercrime), Vol. II, Issue 2, 2013, ISSN 2285-9225, pp. 61-68

[153] C. Gherghina, G. Petrică, Wireless LAN Security Issues (II). Security Assurance, IJISC (International Journal of Information Security and Cybercrime), Vol. III, Issue 1, 2014, ISSN 2285-9225, pp. 37-46

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