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OPTIMIZATION AND SECURITY OF E-BUSINESS SYSTEMS

PhD. Thesis Summary

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Abstract

The accelerated process of innovation and development of information technologies and communications, the trend of economic globalization and macroeconomic effect of this process requires remodeling the lifestyle of modern society and of economic environment. Today's digital economy is based on the Internet, mobile networks, smart devices, digital information and not long ago this structure started to integrate the concept of IoT, making possible the interconnectivity between individuals and organizations. Technological progress is obvious in these circumstances and most users are tempted to believe that a logical outcome would be an extremely reduced number of threats targeting information security traded in this environment.

However, statistical figures show another reality. There is an increase in the rate of occurrence of vulnerabilities and risks that target information security, therefore requiring a continuous process of ensuring confidentiality, integrity and availability of digital information (mainly economic) that passes through available networks of communications.Given these events, research in this field should continue by optimizing existing techniques and by developing new methods and models to ensure the security of digital information.

The idea at the center of the research for this thesis was to develop a solution for confidential and private communications between traditional computer users and mobile platform users. To achieve this, I approached two widely used techniques for securing digital information namely: *cryptography* and *steganography*.

Cryptography changes the shape of information in such a way that it becomes indecipherable for unauthorized users. *Steganography* allows creating a communication channel in an undetectable manner without drawing the suspicion to the very existence of data transaction. Used together these techniques provide multiple levels of security, ensuring a robust solution for confidential communications.

These techniques are discussed in the literature in terms of their performances on traditional platforms. This is why in this research I propose to evaluate the efficiency of these techniques on mobile platforms in terms of: interoperability, security, capacity of embedding, computational speed, robustness against steganalysis and resource consumption.

Key words: *steganography, cryptography, mobile platforms, SmartSteg, Android, Windows, interoperability.*

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ACRONYMS

ABM	-	Automated Banking Machine
API	-	Application Programming Interface
ATM	-	Automated Teller Machine, Automatic Teller Machine, cash machine, cashpoint, cashline, minibank, bankomat
BMP	-	Bitmap Image File
BPaaS	-	Business Process as a Service
CERT-RO	-	Centrul Național de Răspuns la Incidente de Securitate Cibernetică
CSPRNG	-	Cryptographically Secure Pseudorandom Number Generators
DIB	-	DeviceIndependentBitmap
DoS	-	Denial – of – service
DSSS	-	Direct Sequence Spread Spectrum
DTC	-	Discrete Cosine Transform
FBI	-	Federal Bureau of Investigation
FTP	-	File Transfer Protocol
GIF	-	Graphics Interchange Format
HTTPS	-	Hyper Text Transfer Protocol Secure
IaaS	-	Infrastructure as a Service
ICT	-	Information and Communications Technology
IDE	-	Integrated Development Environment
IoT	-	Internet of Things
IP	-	Internet Protocol
IT	-	Information Technology
JEPG, JPG	-	Joint Photographic Experts Group
LSB	-	Least Significant Bit
LZW	-	Lempe-Ziv and Welsh
M2M	-	Mobile to Mobile
MMS	-	Multimedia Messaging Service
MSE	-	Mean Squared Error
NFC	-	Near Field Communication
OSI	-	Open Systems Interconnection
PaaS	-	Platform as a Service
POS	-	Point of Sale
PRNG	-	Pseudorandom Number Generators
PSNR	-	Peak Signal-to-Noise Ratio
QR	-	Quick Response
RAM	-	Random Access Memory
RGB	-	Red, Green, Blue

SaaS	-	Software as a Service
SDK	-	Software Development Kit
SMS	-	Short Message Service
SSL	-	Secure Sockets Layer
SUA	-	United States of America
TCP	-	Transmission Control Protocol
TIFF	-	Tagged Image File Format
TLS	-	Transport Layer Security
TRNG	-	True Number Generator
WAP	-	Wireless Application Protocol
Web, WEB, www	-	World Wide Web

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Research general overview and motivation

The twentieth century marked the emergence, improvement and spreading of the radio and television, telephone networks, satellite for communications, personal computers and Internet; *connectivity* being a keyword (Tanenbaum, și alții, 2011).

Fifty years ago, Moore's [1] Law set an exponential growing rate for innovation and development of digital technology, which led to the creation of a cheap and easy to use infrastructure based on computers, mobile devices, network connections with wide broadband and platforms for advanced applications (Fichman, și alții, 2014). These technologies converge in the XXI century and they impose reshaping of contemporary society lifestyle and of economic environment. It became imperative for modern society individuals to have knowledge of ICT and of innovation in digital technologies.

We are witnessing a process of interaction and interconnectivity between people and *smart* devices or between *smart* devices and *smart* devices. Today we see a process of changing the way users access the digital world from traditional human interaction with digital information via computer, to the human interaction with digital information via smart devices (Ferscha, 2006).

The physical world is merging with the digital world and this process leads the new economy, the political, social, administrative and cultural levels, transforming reality into a new form of virtual perception, which led to the emergence of new concepts such as: *Digital Economy, Mobility, Internet of Things*[2]*, Smart Devices, Big Data , Cloud Computing, Social Networks*. They enable wide access to connectivity, define the way we work and learn, enhancing the possibility of economic globalization having a major economic and social impact. The new economy changes the conditions in which people live and enables the leap over barriers of traditional economic development (Nițchi, 1999).

Computer networks are part of the ordinary landscape. The Internet has become a universal presence. At home, at work, at the coffee shop and even on the street, the internet is ubiquitous. We send emails, we read news, we visit websites, we buy online, and we make online payments and sign contracts online.

The process of globalization is leading to an increasing competition, but also to a better quality of life through access to information in electronic format, regardless of geographic location and to new opportunities in a business environment characterized by reduced economic cycles. As a society, we are becoming increasingly dependent on rapid access to

[1] Gordon Moore – co-founder and chairman emeritus of Intel Corporation, made a prediction in 1965, which set the pace for the development of the digital revolution. Moore predicted that computing power will increase at an exponential pace, inversely proportional to the cost of acquisition thereof. This is still true today.

[2] Internet of Things (IoT) - all products that can be equipped with wireless mechanisms.

information. As this request grows, more information is stored and transmitted electronically, leading to changes in how companies approach business.

E-business systems are no longer in their infancy, they are constantly expanding and developing to mobile-business area, together defining the Digital Economy. Mobility enables enterprises to increase the efficiency of business processes by using mobile communications through wireless systems (Tomai, și alții, 2012).

The definition of a company's heritage extends from its physical and tangible assets, to the information to which it has access. The company's physical assets (buildings, land, fixed assets, and inventory) are the means by which they carry out activities of production, purchasing, sales, services. Access to information for a company opens up new opportunities, increases competitive advantages, develops new opportunities for innovation, and leads to economic benefits.

The importance of information and communication systems for society and the global economy intensify with the value and quantity of information transacted and stored in the social and economic environment. The information floated today cannot be classified as exclusively military, political or other nature; it always has economic consequences. For many organizations, information and technologies that make it possible are the most valuable assets of the organization. Information, products provided by information, the costs and benefits of information are becoming increasingly transnational.

E-business and mobile-business systems are based on the Internet, the Web architecture, WiFi and telecommunications, which gives them reliability, high scalability and flexibility. At the same time, there are great concerns about security of transactions in this new business environment (Tomai, și alții, 2012).

As personal and non-commercial activities migrate to digital, so it is with the activities of cybercriminals. Their large-scale attacks are becoming more frequent and more costly for companies. Attackers are better organized representing true criminal organizations and sometimes even states, having by default financial and material funds that overcome company's capabilities. Given the tendency of companies and government institutions to adopt increasingly more cloud, mobile and IT infrastructure, the security of digital data is becoming an evermore difficult and expensive process (Ieşeanu, 2012).

In any system of security, the weakest link is the most vulnerable. It may be considered that an attacker either inside the company or outside would use any possible means of penetration. It will not necessarily be the most sophisticated, or those against which the most robust security measures were taken. Thus, the specialists in information security must seriously treat equally all available ways of attack (Bucerzan, 2005). An attacker of a computing system will use the simplest way; however, all aspects of a computing system security must be considered.

The security of digital information traded through today available infrastructures for communication, embedded in a complex and wide range of devices in constant transformation and development is ensured by guaranteeing the following characteristics of digital information: confidentiality, integrity, availability, authenticity and non-repudiation.

Among the solutions proposed in the literature for optimizing information security systems is the combination of cryptographic and steganographic techniques. By disguising and converting data so that they become incomprehensible to an outside observer the value of an interception and the possibility of a change becomes almost null.

Cryptography and Steganography are two sciences that have the same goal - to keep the communications confidential and secure. Cryptography ensures message confidentiality through encryption. Steganography serves to hide messages through regular data, so as the existence of a secret message is not suspected. In some cases sending a coded message may cast doubt, however, when a message is *invisible* it can pass unnoticed.

Combining the two techniques can optimize the confidentiality and security of digital messages. When steganography fails and the secret message can be detected, encryption ensures confidentiality. Encryption can be used to ensure data integrity because encryption can determine whether the data reached by the recipient is the same as the one that was sent.

Both methods are developed around the principle defined by Kerckhoff: the quality of a cryptographic - steganographic system must depend on the lowest extent possible on the data that make up the system, the secret key must be defining in the process of encoding and decoding the message.

The importance of managing the transfer of information in this context led me to approach this topic in my research. Another reason that determined me to study methods and techniques to ensure the security of data transactions in the new digital era was that the society, in particular the Romanian one is not ready for this transformation.

Some events presented by Mazurczyk which led me to approach mobile platforms steganography in this doctoral thesis (Mazurczyk, și alții, 2015): in 2008-2010, the Justice Department of the United States of America (USA) registered the use of steganography for spying by Russian spies; in 2011, the virus Duque traded numerous stolen data through internet using as cover digital images without attracting any suspicion.

Such premises together with the advantages of mobile technology, allows the development of steganography techniques in new environments with optimized and more sophisticated algorithms (Mazurczyk, și alții, 2015).

Objectives of the thesis

The main objective of this thesis is to study encryption techniques combined with steganography techniques for digital images to optimize security, privacy and interoperability of confidential data communications in e-Business systems (both between different devices and between different operating systems).

To achieve these goals I have set the following secondary objectives of this thesis:

- to provide an overview of the digital economy environment in which confidential, secret and private information is traded and of the procedures to ensure the availability of this information;
- to study, identify and provide a picture of the main threats that aim confidential and secret data in the digital economy and of the main vulnerabilities of the systems that ensures today the security of data;
- to study and to compare the main techniques used today to facilitate safe deployment of data transactions from the digital economy;
- to study the enhancements of data security achieved by combining different techniques used to ensure information security; implement such solutions with multiple levels of security on today's mobile platforms for communication; study the interoperability of such solutions.

In the thesis titled *OPTIMIZATION AND SECURITY OF E-BUSINESS* we conducted a research on vulnerabilities and threats aiming information traded in the digital economy and the techniques used today to provide security to sensitive information in order to improve existing security solutions and to develop new security architecture using cryptography and steganography.

We achieved a new, robust, fast and reliable solution, to ensure the confidentiality and security of information traded in the digital economy, enabling interoperability between different operating systems and between mobile devices and smart traditional computers.

Personal contributions in this area are reflected in the implementation and assessment of the proposed security architecture entitled *SmartSteg*. *SmartSteg* is a package of applications for mobile devices (smartphone, tablet, and laptop) and traditional computers, offering a solution for ensuring the confidentiality and security of digital information.

Currently, *SmartSteg* has two versions: *SmartSteg Windows* and *SmartSteg Android* that performs interconnectivity between traditional devices (personal computer) and smart mobile devices running different operating systems. *SmartSteg* allows the disguise of any type of file in a digital image. The proposed solution combines digital steganography and cryptography with a pseudo random selection function of the bits that will carry the secret information.

Thesis structure and organization

This thesis is divided into six chapters (see Figure 1).

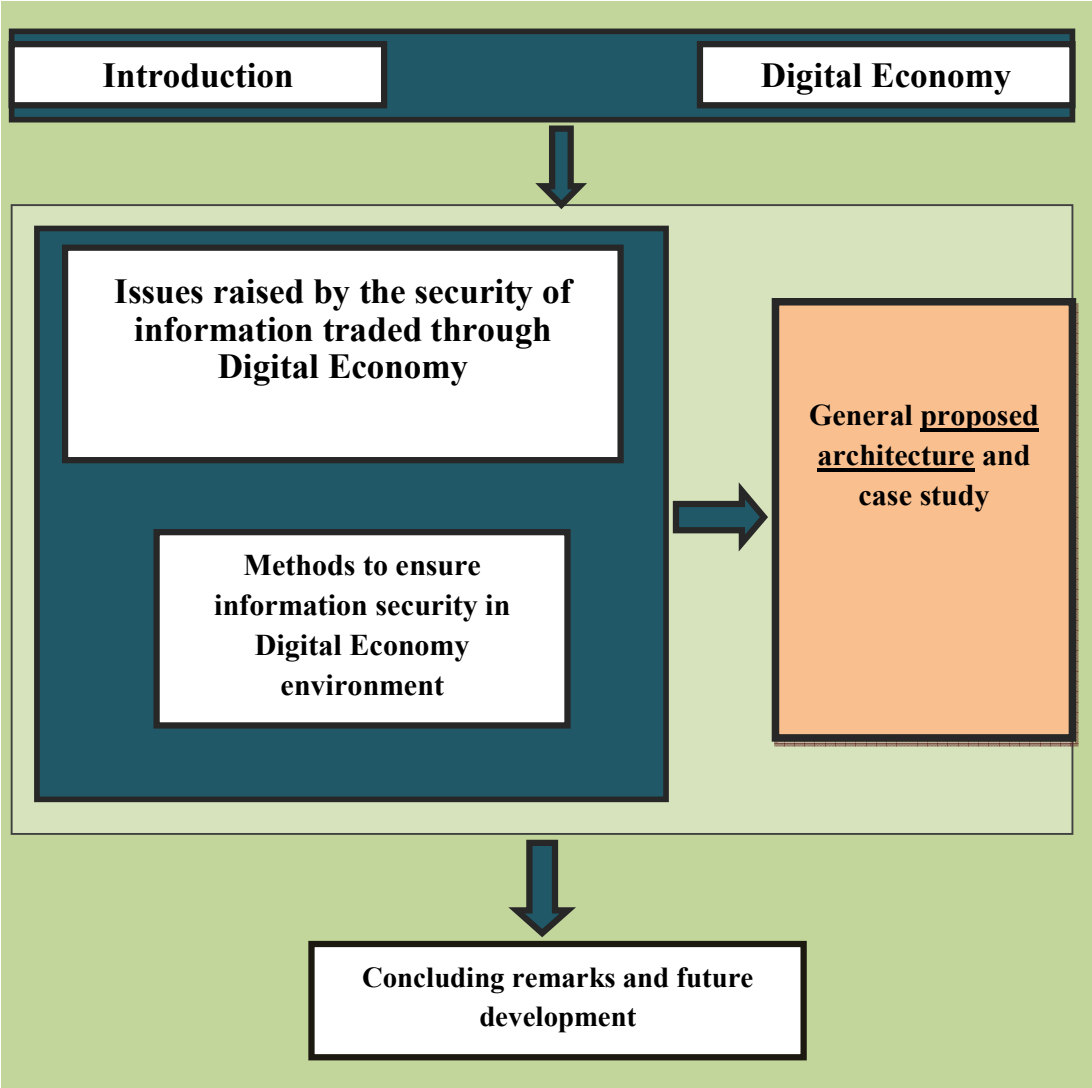

Fig.1– Organization of PhD Thesis

The first chapter, *Introduction*, presents a brief description of this thesis, research motivation, goals and purpose. It also presents the organizing of the PhD Thesis.

Chapter two, *Digital Economy,* presents an overview research of how Digital Economy emerged and evolved; we identified and analyzed both the positive and negative aspects imposed by social and economic changes emerged from the new economy and the new digital era. Information society lives a complex process of change and evolution of social and economic lifestyle.

Economic and social life is interwoven with technological advances creating new knowledge and information needs and also new threats. The open environment in which communication takes place today requires new security and confidentiality measures for the digital information that has become part of everyday life. Following the analysis that we performed in this chapter we have identified the main problems and threats to digital information.

These issues are detailed in chapter three entitled *Issues raised by the security of information traded through Digital Economy*. In this chapter we made a summary analysis to identify the main threats aiming at jeopardizing the security of electronic transactions carried out within the digital economy. I have identified and analyzed the evolution of the main risks *(malware*, *identities theft*, *privacy* and *financial incidents*) which threaten the transactions of digital economic information.

The main objective was to render the true image of the real life economic actors. Although today we benefit of high technology, information security threats and acts of cyber crime can not be eradicated, on the contrary their number has an increasing trend. A step towards reducing the problems raised in this research lies in their awareness by users and also the awareness of the threats they have to face in the digital environment. Regarding the companies, they should update their security policies based on the emerging risks and threats. Also, they should instruct their staff regularly in this regard.

Chapter four entitled, *Methods to ensure information security in Digital Economy,* presents the result of the research I have made on the main techniques used today to secure the operations taking place in the digital economy, namely:

- *Cryptography* (solutions, techniques, literature review, methods of evaluation cryptographic systems, attacks / cryptanalysis);
- *Watermarking* (solutions, techniques, literature review, methods of evaluation watermarking systems, attacks);
- *Steganography* (solutions, techniques, literature review, Steganography and Cryptography, Watermarking and Steganography, Steganography and information security, methods of evaluation steganographic systems, attacks / Steganalysis).

Today we live in the information age, information being a strategic resource, both for individuals and for organizations. Ensuring information security plays an important role regarding national security and social stability. Regarding this aspect, the literature includes a wide range of methods and techniques dedicated to digital information security.

Taking these considerations into account, in this chapter I made an analysys that identifies and discusses the main methods recommended by experts to ensure the characteristics of digital information, namely: confidentiality, integrity, availability, authenticity and non-repudiation.

From the ratio of these techniques and methods that threaten the security of digital information, contained in chapter three of this thesis, we may say that the techniques used for digital information security are not sufficient and must be improved continuously.

In chapter five, *General proposed architecture and case study*, I have detailed, personal contributions regarding development of SmartSteg security architecture proposed in this thesis, the peculiarities of implementation of the proposed solutions, evaluation and comparison of the proposed solution performances with those of other similar solutions presented in literature.

SmartSteg offers the opportunity for confidential communications, through Internet and communications networks available today using mobile devices and traditional computers that run Android and Windows.

The main objectives that we wanted to achieve in this thesis by SmartSteg architecture design and implementation, are:

- an algorithm that codes and hides a large amount of data in a digital image using mobile devices;
- an algorithm that consumes minimal hardware resources and time;
- a data embedding algorithm that minimizes the problems of steganalysis detection methods;
- a Steganography solution that provides interoperability between mobile devices and traditional computers;
- a solution that provides interoperability regardless of the operating system run - Android or Windows ;
- easy implementation;
- high security;
- high processing speed;
- a fast pseudo-random number generator;
- reducing or even making impossible to deduct from the resulting image with secret information embedded, the original form of the information;
- to create confusion and diffusion as much as possible;
- using minimal time and hardware resources.

In this chapter I developed extensively the motivation of the theme chosen to be studied in this thesis, I set the objectives of this research and the requirements of the proposed solution, I described in detail the proposed algorithms, I presented the test made for the proposed solution and the results obtained and I made a comparison between the performance of the proposed solution and the performance of other similar systems present in literature.

During the research, we have developed a robust and reliable solution that provides privacy and information security traded in the digital economy.

In Table 42 I presented a comparison of the steganographic systems approached in this thesis.

Table 42 – Comparison between steganographic solutions tested

	Security	Capacity	Secret data	Speed	Steganalysis	Interoperability
4-LSB	AES Criptography + Steganography	<300 kb	text,images	No data	Irelevant	No
Android-Stego	Public key Criptografie + Steganography	<300 kb	text	No data	Irelevant	No
MoBiSiS	Steganography	<300 kb	text	No data	Irelevant	No
MobiStego	Steganography	No data	text	No data	Irelevant	No
SmartSteg	Symetric stream cipher Criptography + Steganography	≤ 2 MB	Any file type	See 5.5.3	High	Yes

The proposed solution offers multiple levels of security through: data encryption using symmetric cryptography; steganography optimised with a pseudo-random function selection of the bits that will carry the secret information and hiding the length of the secret information.

Compared to other similar systems presented in the literature, SmartSteg sets itself apart by:

- interoperability between mobile platforms and traditional computers;
- interoperability between different operating systems: namely Android and Windows;
- wide range of data types that can be embedded in the cover image;
- computational time;
- robustness against visual and steganalysis attacks;
- high security;
- processing large secret files, up to 2 MB.

In chapter six, we presented the general conclusions and perspectives of the research conducted in this thesis.

Conclusions

The environment in which digital information is traded recorded a significant increase in vulnerabilities in recent years, fast attacks, blocked files to be ransomed, malicious codes and theft of information. Due to economic and competitive damages they can create, these threats and risks have attracted the attention of organizations. Today, organizations must find solutions that ensure security to sensitive data that pass through the vulnerable medium of communication.

The main goal of the research conducted in this thesis is to give to the digital economy comunity members a solution for digital communications via the Internet and mobile networks that ensures the confidentiality, integrity and availability of traded data.

To achieve this, the following have been made:

- A thorough search of the digital economy environment that resulted in identifying and highlighting the main issues that the activity of organizations and legislation requires. The research analyzes and summarizes how the digital economy emerged and evolved, both the positive and negative perspectives, imposed by social and economic changes of the new digital era. Economic and social life intertwines with technological advances creating new knowledge and information needs but also new threats. The open environment in which communication takes place today, imposes new security measures for digital information propagated in all fields of society;
- An analysis of the methods of communication in the digital economy through which the main risks and dangers for the security of electronic data transactions have been identified. We have identified and analyzed the evolution of the main risks that threaten digital transactions. I aimed to restore the true image of the actual digital economy environment in which companies and individuals conduct their activity;
- An analysis by which we identified and discussed the main techniques recommended in the literature for quality assurance of digital information, namely: confidentiality, integrity, availability, authenticity and non-repudiation. The ratio of these techniques and methods that threaten the security of digital information shows that the techniques used to guarantee the security of digital information are not sufficient and must be continuously improved;
- I designed and developed a robust and reliable solution that offers privacy to information traded using the Internet and mobile communication networks in digital economy environment. The proposed solution has been implemented by project *SmartSteg*. It provides two levels of security: data encryption using symmetric cryptography and embedding of data using LSB steganography optimized with a pseudo random selection function of the bits that will carry the

secret information. *SmartSteg* offers the opportunity for confidential communications via the Internet and communications networks available today, using mobile devices and traditional computers running Android and Windows.

The personal contributions in this thesis are summarized in the following lines:

- I have designed an algorithm that encodes and encloses a large amount of data in a digital image, using mobile devices, which certifies that steganography on mobile devices today is real;
- I have developed an algorithm that consumes minimal hardware and time resources, confirmed by tests of functionality and speed, made through this research and presented in the thesis; this makes it suitable for use in business transactions;
- I have developed a robust algorithm for embedding secret data, that ensures high security by combining cryptography and steganography, providing multiple levels of security and minimizing detection issues by using steganalysis;
- I have developed a steganography solution that provides interoperability between mobile devices and traditional computers running any operating system - Android or Windows.

Personal contributions and the originality of the research conducted in this thesis are sustained by performance analysis of the proposed solution and the list of scientific papers published.

As future research directions - I want to complete the analysis carried out vis-a-vis the new technologies by:

- Expanding the functionality of the proposed solution to iOS operating systems, so that SmartSteg interoperability will include all major operating systems used worldwide;
- Diversifying the cover file types to reduce the likelihood that a particular file type is suspected of being the bearer of steganographic content;
- The possibility of implementing public key cryptographic technologies to eliminate secret key exchange between sender and recipient through another channel of communication;
- For ensuring the integrity of the secret information, the possibility of implementing a hash function to the proposed architecture.

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