Multimedia Encryption and Authentication Techniques and Applications

Editors-in-Chief and Authors
Borko Furht
Darko Kirovski

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Preface

Recent advances in digital communications and storage technologies have brought major changes for consumers. High-capacity hard disks and DVDs can store large amounts of audiovisual data. In addition, faster Internet connection speeds and the emerging high bitrate DSL connections provide sufficient bandwidth for entertainment networks. These improvements in computers and communication networks are radically changing the economics of intellectual property reproduction and distribution. Intellectual property owners must exploit new ways of reproducing, distributing, and marketing their intellectual property. However, a major problem with current digital distribution and storage technologies is the great threat of piracy.

This book is carefully edited — authors are worldwide experts in the field of multimedia encryption and authentication. Our goal is to cover all current and future trends in designing modern systems for multimedia encryption and authentication.

The technical level of the book is between an intermediate and high level. The book is primarily intended for researchers and practitioners in the field. However, some chapters are less technical than others and can be beneficial to those readers who need a broad understanding of multimedia security. The key points of the book can be summarized as follows:

- The book describes and evaluates the current state-of-the-art in multimedia encryption and authentication techniques and related technologies, architectures, standards, and applications.
- The book also presents future trends and developments in this area.
- Advanced topics, such as chaotic video encryption techniques and streaming media encryption, are also covered.
- Contributors to the book are the leading researchers from academia and practitioners from industry.

With the dramatic growth of *digital entertainment* and *Internet applications*, this book can be the definitive resource for persons working in this field as researchers, scientists, programmers, and engineers. This book can also be beneficial for business managers, entrepreneurs, and investors.

We would like to thank the authors, who are world experts in the field, for their contributions of individual chapters. Without their expertise and effort, this book would never have come to fruition. The Auerbach Publications editors and staff also deserve our sincere recognition for their support throughout the project.

Borko Furht and Darko Kirovski

Editors-in-Chief and Authors

Borko Furht is a professor and chairman of the Department of Computer Science and Engineering at Florida Atlantic University (FAU) in Boca Raton, Florida. Before joining FAU, he was a vice president of research and a senior director of development at Modcomp (Ft. Lauderdale), a computer company of Daimler Benz, Germany, and a professor at the University of Miami in Coral Gables, Florida. Professor Furht received Ph.D. degrees in electrical and computer engineering from the University of Belgrade. His current research is in multimedia systems, video coding and compression, video databases, wireless multimedia, and Internet computing. He is currently Principal Investigator and Co-PI of two multiyear, multimillion dollar projects — on Coastline Security Technologies, funded by the Department of Navy, and One Pass to Production, funded by Motorola. He is the author of numerous books and articles in the areas of multimedia, computer architecture, real-time computing, and operating systems. He is a founder and editor-in-chief of *The Journal of Multimedia Tools and Applications* (Kluwer Academic Publishers). He has received several technical and publishing awards, and has consulted for many high-tech companies, including IBM, Hewlett-Packard,

Xerox, General Electric, JPL, NASA, Honeywell and RCA. He has also served as a consultant to various colleges and universities. He has given many invited talks, keynote lectures, seminars, and tutorials.

Darko Kirovski received his Ph.D. degree in computer science from the University of California, Los Angeles, in 2001. Since April 2000, he has been a researcher at Microsoft Research. His research interests include certificates of authenticity, system security, multimedia processing, biometric identity authentication, and embedded system design and debugging. He received the 1999 Microsoft Graduate Research Fellowship, the 2000 ACM/IEEE Design Automation Conference Graduate Scholarship, the 2001 ACM Outstanding Ph.D. Dissertation Award in Electronic Design Automation, and the Best Paper Award at ACM Multimedia 2002.

List of Contributors

Rolf Blom, Ericsson Research, Communications Security Laboratory, Ericsson AB, Sweden

Elisabetta Carrara, Ericsson Research, Communications Security Laboratory, Ericsson AB, Sweden

Shih-Fu Chang, Department of Electrical Engineering, Columbia University, New York, New York

Guanrong Chen, Department of Electronic Engineering, City University of Hong Kong, Hong Kong SAR, China

Mohamed Daoudi, MIIRE Group, LIFL/INT ENIC-Telecom Lille1, Cité Scientifique, Villeneuve d'Ascq, France

Edward J. Delp, Video and Image Processing Laboratory (*VIPER*), School of Electrical and Computer Engineering, Purdue University, West Lafayette, Indiana

Chabane Djeraba, MIIRE Group, LIFL/INT ENIC-Telecom Lille1, Cité Scientifique, Villeneuve d'Ascq, France

Sabu Emmanuel, Nanyang Technological University, Singapore

Ahmet M. Eskicioglu, Department of Computer and Information Science, Brooklyn College, The City University of New York, Brooklyn, New York

Borko Furht, Department of Computer Science and Engineering, Florida Atlantic University, Boca Raton, Florida

Mohan S. Kankanhalli, National University of Singapore, Singapore

Deepa Kundur, Texas A&M University, Department of Electrical Engineering, College Station, Texas

Shujun Li, Department of Electronic Engineering, City University of Hong Kong, Hong Kong SAR, China

Fredrik Lindholm, Ericsson Research, Communications Security Laboratory, Ericsson AB, Sweden

Jeffrey Lotspiech, Henderson, Nevada

William Luh, Texas A&M University, Department of Electrical Engineering, College Station, Texas

Mohamed F. Mansour, Texas Instruments Inc., Dallas, Texas

Mats Näslund, Ericsson Research, Communications Security Laboratory, Ericsson AB, Sweden

Karl Norrman, Ericsson Research, Communications Security Laboratory, Ericsson AB, Sweden

Dimitrios Skraparlis, Toshiba Research Europe Limited, Telecommunications Research Laboratory, Bristol, United Kingdom

Daniel Socek, Department of Computer Science and Engineering, Florida Atlantic University, Boca Raton, Florida

Qibin Sun, Institute for Infocomm Research, Singapore 119613

Ahmed H. Tewfik, Department of Electrical and Computer Engineering, University of Minnesota, Minneapolis, Minnesota

Christophe Tombelle, MIIRE Group, LIFL/INT ENIC-Telecom Lille1, Cité Scientifique, Villeneuve d'Ascq, France

Heather Yu, Panasonic Digital Networking Laboratory, Princeton, New Jersey

Huicheng Zheng, MIIRE Group, LIFL/INT ENIC-Telecom Lille1, Cité Scientifique, Villeneuve d'Ascq, France

Xuan Zheng, Department of Electrical and Computer Engineering, University of Virginia, Charlottesville, Virginia

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Ahmet M. Eskicioglu and Edward J. Delp

INTRODUCTION

In recent years, advances in digital technologies have created significant changes in the way we reproduce, distribute, and market intellectual property (IP). Digital media can now be exploited by IP owners to develop new and innovative business models for their products and services. The lowered cost of reproduction, storage, and distribution, however, also invites much motivation for large-scale commercial infringement. In a world where piracy is a growing potential threat, the rights of the IP owners can be protected using three complementary weapons: technology, legislation, and business models. Because of the diversity of IP (ranging from e-books to songs and movies) created by copyright

industries, no single solution is applicable to the protection of multimedia products in distribution networks.

Intellectual property is created as a result of intellectual activities in the industrial, scientific, literary, and artistic fields [1]. It is divided into two general categories:

1. *Industrial property*. This includes inventions (patents), trademarks, industrial designs, and geographic indications of source. A *patent* is an exclusive right granted for an invention, which is a product or a process that provides either a new way of doing something or a new technical solution to a problem. A *trademark* is a distinctive sign that identifies certain goods or services as those produced or provided by a specific person or enterprise. It provides protection to the owner by ensuring the exclusive right to use it to identify goods or services or to authorize another to use it in return for payment. An *industrial design* is the ornamental or aesthetic aspect of an article. The design may consist of three-dimensional features (such as the shape or surface of an article) or of two-dimensional features (such as patterns, lines, or color). A *geographical indication* is a sign used on goods that have a specific geographical origin and possess qualities or a reputation that are due to that place of origin. In general, a geographical indication is associated with the name of the place of origin of the goods. Typically, agricultural products have qualities that derive from their place of production identified by specific local factors such as climate and soil.
2. *Copyright*. This includes literary and artistic works such as novels, poems and plays, films, musical works, artistic works such as drawings, paintings, photographs, and sculptures, and architectural designs. As many creative works protected by copyright require mass distribution, communication, and financial investment for their dissemination (e.g., publications, sound recordings, and films), creators usually sell the rights to their works to individuals or companies with a potential to market the works in return for payment. Copyright and its related rights are essential to human creativity, providing creators incentives in the form of recognition and fair economic rewards and assurance that their works can be disseminated without fear of unauthorized copying or piracy.

To understand the increasing importance of copyrighted content protection, we should apprehend the essential difference between old and new technologies for distribution and storage. Prior to the development of digital technologies, content was created, distributed, stored, and displayed by analog means. The popular video cassette

recorders (VCRs) of the 1980s introduced a revolutionary way of viewing audiovisual (A/V) content but, ironically, allowed unauthorized copying, risking the investments made in IP. The inherent characteristics of analog recording, however, prevented piracy efforts from reaching alarming proportions. If taped content is copied on a VCR, the visual quality of the new (i.e., the first generation) copy is relatively reduced. Further generational copies result in noticeably reduced quality, decreasing the commercial value of the content. Today, reasonably efficient analog copy protection methods exist and have recently been made mandatory in consumer electronics devices to further discourage illegal analog copying.

With the advent of digital technologies, new tools have emerged for making perfect copies of the original content. We will briefly review digital representation of data to reveal why generational copies do not lose their quality. A text, an image, or a video is represented as a stream of bits (0s and 1s) that can be conveniently stored on magnetic or optical media. Because digital recording is a process whereby each bit in the source stream is read and copied to the new medium, an exact replica of the content is obtained. Such a capability becomes even more threatening with the ever-increasing availability of the Internet, an immense and boundless digital distribution mechanism. Protection of digital multimedia content therefore appears to be a crucial problem for which immediate solutions are needed.

Recent inventions in digital communications and storage technologies have resulted in a number of major changes in the distribution of multimedia content to consumers:

- Magnetic and optical storage capacity is much higher today. Even the basic configuration of personal computers comes with 40 GB of magnetic hard disk storage. Although a DVD (digital versatile disk) is the same physical size as a CD, it has a much higher optical storage capacity for audiovisual data. Depending on the type of DVD, the capacity ranges between 4 and 17 GB (2 to 8 h of video).
- The speed of the Internet connection has grown rapidly in recent years. Currently, cable modems and Asymmetric Digital Subscriber Line (ADSL) are the two technologies that dominate the industry. The emerging VDSL (very high bitrate DSL) connection with speeds up to 52 Mbps will provide sufficient bandwidth for entertainment networks.

End-to-end security is the most critical requirement for the creation of new digital markets where copyrighted content is a major product. In this chapter, we present an overview of copyright and copyright

industries and examine how the technological, legal, and business solutions help maintain the incentive to supply the lifeblood of the markets.

WHAT IS COPYRIGHT?

To guide the discussion into the proper context, we will begin with the definition of ''copyright'' and summarize the important aspects of copyright law. Copyright is a *form of protection provided by the laws of the United States (Title 17, U.S. Code) to the authors of ''original works of authorship,'' including literary, dramatic, musical, artistic, and certain other intellectual works* [2]. Although copyright literally means ''right to copy,'' the term is now used to cover a number of exclusive rights granted to the authors for the protection of their work. According to Section 106 of the 1976 Copyright Act [3], the owner of copyright is given the exclusive right to do, and to authorize others to do, any of the following:

- To *reproduce the copyrighted work* in copies or phonorecords
- To prepare *derivative works* based on the copyrighted work
- To *distribute copies or phonorecords* of the copyrighted work to the public by sale or other transfer of ownership, or by rental, lease, or lending
- To *perform the copyrighted work publicly*, in the case of literary, musical, dramatic, and choreographic works, pantomimes, and motion pictures and other audiovisual works
- To *display the copyrighted work publicly*, in the case of literary, musical, dramatic, and choreographic works, pantomimes, and pictorial, graphic, or sculptural works, including the individual images of a motion picture or other audiovisual work
- To *perform the copyrighted work publicly* by means of a digital audio transmission, in the case of sound recordings

It is illegal to violate the rights provided by the copyright law to the owner of the copyright. There are, however, limitations on these rights as established in several sections of the 1976 Copyright Act. One important limitation, the doctrine of ''fair use,'' has been the subject of a major discussion on content protection. Section 107 states that the use of a copyrighted work by reproduction in copies or phonorecords or by any other means specified by the law, for purposes such as criticism, comment, news reporting, teaching (including multiple copies for classroom use), scholarship, or research, is not an infringement of copyright. In any particular case, the following criteria, among others, may be considered in determining whether fair use

applies or not:

1. The purpose and character of the use, including whether such use is of a commercial nature or is for nonprofit educational purposes
2. The nature of the copyrighted work
3. The amount and substantiality of the portion used in relation to the copyrighted work as a whole
4. The effect of the use upon the potential market for, or value of, the copyrighted work

For copyright protection, the original work of authorship should be fixed in a tangible medium of expression from which it can be perceived, reproduced, or otherwise communicated, either directly or with the aid of a machine or device. This language incorporates three fundamental concepts [4] of the law: fixation, originality, and expression. *Fixation* (i.e., the act of rendering a creation in some tangible form) may be achieved in a number of ways, depending on the category of the work. *Originality* is a necessary (but not a sufficient) condition for a work produced by the human mind to be copyrightable. Scientific discoveries, for example, are not copyrightable, as they are regarded as the common property of all people (however, an inventor can apply for a patent, which is another form of protection). Finally, it is the *expression* of an idea, and not idea itself, that is copyrightable. Ideas, like facts, are in the public domain without a need for protection. Nevertheless, the separation of an idea from an expression is not always clear and can only be studied on a case-by-case basis. When the three basic requirements of fixation, originality, and expression are met, the law provides for highly broad protection. Table 1.1 summarizes the range of copyrightable works.

It is interesting to note that copyright is secured as soon as the work is created by the author in some fixed form. No action, including publication and registration, is needed in the Copyright Office. *Publication* is the distribution of copies or phonorecords of a work to the public by sale or other transfer of ownership or by rental, lease, or lending. *Registration* is a legal process to create a public record of the basic facts of a particular copyright. Although neither publication nor registration is a requirement for protection, they provide certain advantages to the copyright owner.

The copyright law has different clauses for the protection of published and unpublished works. All unpublished works are subject to protection, regardless of the nationality or domicile of the author. The published works are protected if certain conditions are met regarding the type of work, citizenship, residency, and publication date and place.

TABLE 1.1. Main Categories of Copyrightable and Not Copyrightable Items

Copyrightable	Not Copyrightable
Literary works	Works that have not been fixed in a tangible form of expression
Musical works (including any accompanying words)	Titles, names, short phrases, and slogans; familiar symbols or designs; mere variations of typographic ornamentation, lettering, or coloring; mere listings of ingredients or contents
Dramatic works (including any accompanying music)	Ideas, procedures, methods, systems, processes, concepts, principles, discoveries, or devices, as distinguished from a description, explanation, or illustration
Pantomimes and choreographic works	Works consisting entirely of information that is common property and containing no original authorship
Pictorial, graphic, and sculptural works	
Motion pictures and other audiovisual works	
Sound recordings	
Architectural works	

International copyright laws do not exist for the protection of works throughout the entire world. The national laws of individual countries may include different measures to prevent unauthorized use of copyrighted works. Fortunately, many countries offer protection to foreign works under certain conditions through membership in international treaties and conventions. Two important international conventions are the Berne Convention and the Universal Copyright Convention [3].

A work created on or after January 1, 1978, is given copyright protection that endures 70 years after the author's death. If more than one author is involved in the creation, the term ends 70 years after the last surviving author's death. For works predating January 1, 1978, the duration of copyright depends on whether the work was published or registered by that date.

A law enacted by the U.S. Congress in 1870 centralized the copyright system in the Library of Congress. Today, the U.S. Copyright Office is a major service unit of the Library, providing services to the Congress and other institutions in the United States and abroad. It administers the copyright law, creates and maintains public records, and serves as a resource to the domestic and international copyright communities. Table 1.2 lists some of the copyright milestones in the United States for the past two centuries [5–7].

TABLE 1.2. Notable Dates in the U.S. History of Copyright

Date	Event
May 31, 1790	First copyright law, derived from the English copyright law (Statute of Anne) and common law, enacted under the new constitution
April 29, 1802	Prints added to protected works
February 3, 1831	First general revision of the copyright law
August 18, 1856	Dramatic compositions added to protected works
March 3, 1865	Photographs added to protected works
July 8, 1870	Second general revision of the copyright law
January 6, 1897	Music protected against unauthorized public performance
July 1, 1909	Third general revision of the copyright law
August 24, 1912	Motion pictures, previously registered as photographs, added to classes of protected works
July 30, 1947	Copyright law codified as Title 17 of the U.S. Code
October 19, 1976	Fourth general revision of the copyright law
December 12, 1980	Copyright law amended regarding computer programs
March 1, 1989	United States joined the Berne Convention
December 1, 1990	Copyright protection extended to architectural works
October 28, 1992	Digital Audio Home Recording Act required serial copy management systems in digital audio recorders
October 28, 1998	The Digital Millennium Copyright Act (DMCA) signed into law

U.S. COPYRIGHT INDUSTRIES

The primary domestic source of marketable content is the U.S. copyright industries [8], which produce and distribute materials protected by national and international copyright laws. The products include the following categories:

1. All types of computer software (including business applications and entertainment software)
2. Motion pictures, TV programs, home videocassettes, and DVDs
3. Music, records, audio cassettes, audio DVDs and CDs
4. Textbooks, tradebooks, and other publications (both in print and electronic media)

Depending on the type of activity, U.S. copyright industries can be studied in two groups: ''core'' and ''total.'' The core industries are those that create copyrighted works as their primary product. The total copyright industries include the core industries and portions of many other industries that create, distribute, or depend on copyrighted

works. Examples are retail trade (with sales of video, audio, books, and software) and the toy industry.

The International Intellectual Property Alliance (IIPA) [8] is a private-sector coalition that represents U.S. copyright-based industries in bilateral and multilateral efforts to improve international protection of copyrighted materials. Formed in 1984, the IIPA is comprised of six trade associations, each representing a different section of the U.S. copyright industry. The member associations are:

Association of American Publishers (AAP): the principal trade association of the book publishing industry

American Film Marketing Association (AFMA): a trade association whose members produce, distribute, and license the international rights to independent English language films, TV programs, and home videos

Business Software Alliance (BSA): an international organization representing leading commercial software industry and its hardware partners

Entertainment Software Association (ESA): the U.S. association of the companies publishing interactive games for video game consoles, handheld devices, personal computers, and the Internet

Motion Picture Association of America (MPAA): the MPAA, along with its international counterpart, the Motion Picture Association (MPA), serve as the voice and advocate of seven of the largest producers and distributors of filmed entertainment

Recording Industry Association of America (RIAA): a trade association that represents companies that create, manufacture, and/or distribute approximately 90% of all legitimate sound recordings in the United States.

"Copyright Industries in the U.S. Economy: The 2002 Report," which updates eight prior studies, details the importance of the copyright industries to the U.S. economy based on three economic indicators: value added to GDP, share of national employment, and revenues generated from foreign sales and exports. This report gives an indication of the significance of the copyright industries to the U.S. economy:

- In 2001, the U.S. core copyright industries accounted for 5.24% ($535.1 billion) of the U.S. Gross Domestic Product (GDP). Between 1977 and 2001, their share of the GDP grew more than twice as fast as the remainder of the U.S. economy (7% vs. 3%).
- Between 1977 and 2001, employment in the U.S. core copyright industries grew from 1.6% (1.5 million workers) to 3.5% (4.7 million workers) of the U.S. workforce. Average annual employment growth

was more than three times as fast as the remainder of the U.S. economy (5% vs. 1.5%).

- In 2001, the U.S. core copyright industries estimated foreign sales and exports was $88.97 billion, leading all major industry sectors (chemical and allied products; motor vehicles, equipment and parts; aircraft and aircraft parts; electronic components and accessories; computers and peripherals).

Special 301, an annual review, requires the U.S. Trade Representative (USTR) to identify those countries that deny adequate and effective protection for intellectual property rights or deny fair and equitable market access for persons who rely on intellectual property protection. It was created by the U.S. Congress when it passed the Omnibus Trade and Competitive Act of 1988, which amended the Trade Act of 1974. According to IIPA's 2003 Special 301 Report on Global Copyright Protection and Enforcement, the U.S. copyright industries suffered estimated trade losses due to piracy of nearly $9.2 billion in 2002 as a result of the deficiencies in the copyright regimes of 56 countries. The losses for the five copyright-based industry sectors are given in Table 1.3. In USTR 2003 "Special 301" Decisions on Intellectual Property, this data is updated for 49 countries to be almost $9.8 billion. The annual losses due to piracy of U.S. copyrighted materials around the world are estimated to be $20 to 22 billion (not including Internet piracy) [8].

A major study titled "The Digital Dilemma — Intellectual Property in the Information Age" [9] was initiated by the Computer Science and Telecommunications Board (CSTB) to assess issues related to the nature, evolution, and use of the Internet and other networks and to the generation, distribution, and protection of content accessed through networks. The study committee convened by the CSTB included experts from industry, academia, and the library and information science community. The work was carried out through the expert deliberations of the committee and by soliciting input and discussion from a wide range

TABLE 1.3. Estimated Trade Losses due to Copyright Piracy in 56 Selected Countries in 2002 (in millions of U.S. dollars)

Industry	Estimated Losses
Motion pictures	1322.3
Records and music	2142.3
Business software applications	3539.0
Entertainment software	1690.0
Books	514.5
Total	**9208.1**