

TKK Dissertations 257  
Espoo 2010

**POST-PAYMENT COPYRIGHT SERVICE FOR DIGITAL  
MUSIC: A MULTIDISCIPLINARY STUDY**

Doctoral Dissertation

**Heikki Kokkinen**



**Aalto University**  
**School of Science and Technology**  
**Faculty of Information and Natural Sciences**  
**Department of Computer Science and Engineering**



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# **POST-PAYMENT COPYRIGHT SERVICE FOR DIGITAL MUSIC: A MULTIDISCIPLINARY STUDY**

Doctoral Dissertation

**Heikki Kokkinen**

Doctoral dissertation for the degree of Doctor of Science in Technology to be presented with due permission of the Faculty of Information and Natural Sciences for public examination and debate in Auditorium T2 at the Aalto University School of Science and Technology (Espoo, Finland) on the 17th of December 2010 at 12 noon.

**Aalto University  
School of Science and Technology  
Faculty of Information and Natural Sciences  
Department of Computer Science and Engineering**

**Aalto-yliopisto  
Teknillinen korkeakoulu  
Informaatio- ja luonnontieteiden tiedekunta  
Tietotekniikan laitos**

Distribution:  
Aalto University  
School of Science and Technology  
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ISBN 978-952-60-3492-8  
ISBN 978-952-60-3493-5 (PDF)  
ISSN 1795-2239  
ISSN 1795-4584 (PDF)  
URL: <http://lib.tkk.fi/Diss/2010/isbn9789526034935/>

TKK-DISS-2850

Picaset Oy  
Helsinki 2010

ABSTRACT OF DOCTORAL DISSERTATION		AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY P.O. BOX 11000, FI-00076 AALTO <a href="http://www.aalto.fi">http://www.aalto.fi</a>	
Author Heikki Kokkinen			
Name of the dissertation Post-payment copyright service for digital music: a multi-disciplinary study			
Manuscript submitted 2.6.2010		Manuscript revised 22.11.2010	
Date of the defence 17.12.2010			
<input type="checkbox"/> Monograph		<input checked="" type="checkbox"/> Article dissertation (summary + original articles)	
Faculty	Information and Natural Sciences		
Department	Computer Science and Engineering		
Field of research	Data Communications Software		
Opponent(s)	Professor Harry Bouwman		
Supervisor	Professor Antti Ylä-Jääski		
Instructor	D.Sc. (Tech.) Sakari Luukkainen		
Abstract			
<p>This dissertation describes a post-payment copyright service for digital music. A challenge in the digital music industry is illegal copying, which is often called piracy. It decreases the revenue in the music industry and increases illegal digital music files on user devices. The post-payment service helps the users to legalize their illegally copied files by allowing the users to pay the copyright fees to the rights holders. This dissertation studies the post-payment from a technical, legal, business, and social perspective. The goal is to understand its impact on the rights holders' revenue and the amount of illegal files in the users' possession.</p> <p>The research is conducted in a multidisciplinary way that is typical for service research. The applied methods include prototyping the service, evaluating user interest with a questionnaire, forensics analysis on how to recognize the illegal files on the user device, positioning the service in the Finnish copyright legislation, techno-economic and privacy comparison with the existing systems, and the mathematical modeling of the number of illegal files and the amount of rights holder revenue.</p> <p>The prototype phase confirms the technical viability of the post-payment concept. In the questionnaire study, the users express their interest in the post-payment service. The forensics research supports the prototype by discussing the method used to recognize the illegal files on the user device. The legal analysis shows that the current legal framework is flexible enough to allow this service to be implemented. The techno-economic comparison with the online store states that the post-payment system is a competitive business compared with existing online stores, but the most viable business of all is to provide a bundle of both services. Technical methods must be applied to protect privacy, and they have to be clearly communicated to the users. The mathematical analysis reveals that the post-payment boosts the impact of the rights holders' anti-piracy actions by decreasing the number of illegal files and increasing the revenue of the rights holders.</p> <p>The post-payment copyright system is one of the new business proposals in the digital music industry. Its unique characteristics are that it brings revenue from the content that is otherwise outside the business – content that has been copied in the past, and it helps the rights holders in their anti-piracy actions to use a positive approach.</p>			
Keywords Piracy, copyright, post-payment, peer-to-peer, Internet service, digital music, multidisciplinary			
ISBN (printed)	978-952-60-3492-8	ISSN (printed)	1795-2239
ISBN (pdf)	978-952-60-3493-5	ISSN (pdf)	1795-4584
Language	English	Number of pages	69 p. + appendices 69 p.
Publisher	Department of Computer Science and Engineering, Aalto University School of Science and Technology		
<input checked="" type="checkbox"/> The dissertation can be read at <a href="http://lib.tkk.fi/Diss/2010/isbn9789526034935/">http://lib.tkk.fi/Diss/2010/isbn9789526034935/</a>			



VÄITÖSKIRJAN TIIVISTELMÄ		AALTO-YLIOPISTO TEKNILLINEN KORKEAKOULU PL 11000, 00076 AALTO <a href="http://www.aalto.fi">http://www.aalto.fi</a>	
Tekijä Heikki Kokkinen			
Väitöskirjan nimi Tekijänoikeudellinen jälkimaksujärjestelmä digitaaliselle musiikille: monitieteellinen tutkielma			
Käsikirjoituksen päivämäärä 2.6.2010		Korjatun käsikirjoituksen päivämäärä 22.11.2010	
Väitöstilaisuuden ajankohta 17.12.2010			
<input type="checkbox"/> Monografia		<input checked="" type="checkbox"/> Yhdistelmäväitöskirja (yhteenveto + erillisartikkelit)	
Tiedekunta	Informaatio- ja luonnontieteet		
Laitos	Tietotekniikka		
Tutkimusala	Tietoliikenneohjelmistot		
Vastaväittäjä(t)	Professori Harry Bouwman		
Työn valvoja	Professori Antti Ylä-Jääski		
Työn ohjaaja	TkT Sakari Luukkainen		
<p><b>Tiivistelmä</b></p> <p>Tämä väitöskirja esittelee tekijänoikeudellisen jälkimaksujärjestelmän, jota käytetään laittomasti kopioidun digitaalisen musiikin laillistamiseen. Laiton kopioiminen on haaste digitaalisen musiikin teollisuudessa. Se vähentää musiikkiteollisuuden liikevaihtoa ja lisää laittomien musiikkitiedostojen määrää käyttäjien laitteilla. Palvelu auttaa käyttäjiä maksamaan tekijänoikeuskorvaukset oikeuden omistajille ja laillistamaan päätelaitteillaan olevat laittomat musiikkitiedostot. Tässä väitöskirjassa tutkitaan jälkimaksujärjestelmää tekniseltä, lailliselta, taloudelliselta ja sosiaaliselta kannalta. Tavoitteena on ymmärtää sen vaikutus teollisuuden liikevaihtoon ja käyttäjien laittomien tiedostojen määrään.</p> <p>Tutkimus on toteutettu monitieteellisesti, mikä on tyypillistä palvelututkimukselle. Sovelletut menetelmät käsittävät palveluprototyypin, käyttäjien kiinnostuksen arvioimisen kyselytutkimuksella, rikosteknisen menetelmäkehityksen siitä, kuinka tunnistaa laittomat tiedostot kuluttajan päätelaitteella, palvelun aseman suomalaisessa tekijänoikeuslainsäädännössä, teknistaloudellisen ja yksityisyydensuojan vertailun olemassa oleviin järjestelmiin ja matemaattisen mallin laittomista tiedostoista ja oikeudenomistajien liikevaihdosta.</p> <p>Prototyypivaihe osoittaa jälkimaksujärjestelmän teknisen soveltuvuuden. Kyselytutkimuksen perusteella käyttäjät ovat kiinnostuneita palvelusta. Rikostekninen tutkimus selvittää menetelmiä, joilla voidaan tunnistaa laittomat musiikkitiedostot käyttäjän päätelaitteella. Teknistaloudellinen vertailu musiikkiverkkokauppaan osoittaa, että jälkimaksujärjestelmä on kilpailukykyinen liiketoimintamalli. Lisäksi verkkokaupan ja jälkimaksun yhdistäminen vahvistaa molempia liiketoimia. Järjestelmässä on käytettävä teknisiä keinoja yksityisyyden suojaamiseksi ja ne on viestittävä selkeästi käyttäjille. Matemaattisen analyysin perusteella jälkimaksujärjestelmä vahvistaa oikeudenomistajien piratismiin vastatoimia vähentämällä laittomien kappaleiden määrää ja lisäämällä oikeudenomistajien liikevaihtoa.</p> <p>Jälkimaksujärjestelmä on eräs uusista liiketoimintamalleista digitaalisen musiikin teollisuudessa. Ainutlaatuisina ominaisuuksina se voi luoda liiketoimintaa jo aiemmin kopioiduista tiedostoista ja auttaa oikeudenomistajia piratismiin vastatoimissa myönteisellä tavalla.</p>			
Asiasanat	Piratismi, tekijänoikeus, jälkimaksujärjestelmä, vertaisverkko, internet palvelu, digitaalinen musiikki, monitieteellisyys		
ISBN (painettu)	978-952-60-3492-8	ISSN (painettu)	1795-2239
ISBN (pdf)	978-952-60-3493-5	ISSN (pdf)	1795-4584
Kieli	englanti	Sivumäärä	69 s. + liitteet 69 s.
Julkaisija	Tietotekniikan laitos, Aalto-yliopiston teknillinen korkeakoulu		
<input checked="" type="checkbox"/> Luettavissa verkossa osoitteessa <a href="http://lib.tkk.fi/Diss/2010/isbn9789526034935/">http://lib.tkk.fi/Diss/2010/isbn9789526034935/</a>			





## Preface

The work reported in this dissertation was carried out at the Nokia Research Center (NRC), Helsinki in 2006-2010. The work was financially supported by the Finnish Funding Agency for Technology and Innovation (Tekes).

I am grateful to my supervisors, Professor Antti Ylä-Jääski and Dr. Sakari Luukkainen at the Aalto University School of Science and Technology, for supporting and encouraging me during the work. They have been flexible as well as receptive to the ideas of my multidisciplinary research the whole time.

I thank my previous team leader Klaus Hugel and the former head of NRC Helsinki, Petteri Alinikula, for fostering the post-payment research and giving me the opportunity to also continue to write the dissertation after the project was terminated at NRC.

I would also like to express my gratitude to the following people: my colleagues Jan-Erik Ekberg and Janne Nöyränen from NRC for developing the catalogue matching server, the client application, supporting the forensics research, and their other contributions since the beginning of the work; researchers Herkko Hietanen (Helsinki Institute of Information Technology, HIIT) for sharing his strong insights on copyright legislation in the media world; Anniina Huttunen (Helsinki University) for her hard work on the questionnaire and legal studies; Mikko Heikkinen from Aalto University for his invaluable contribution on the techno-economic modeling; and finally Markus Miettinen from NRC for support in privacy analysis and forensic data mining.

The service implementation team brought the research alive. I am grateful to Ben Mellin of SecuryCast for the negotiations with the rights holders and allowing the project to work with the SecuryCast music backend system; to Iiro Karesniemi for the system integration; Hanno Nevanlinna and Tuomas Syrjänen (Futurice Ltd) for their patience and sharing their knowledge in consumer Internet services throughout the project; to

Harri Hälikkää and Juha Pesonen for developing the web front-end for the post-payment prototype; and to Visa Noronen (HIIT) and Kimmo Kärkkäinen (Live Helsinki) for their contribution to the post-payment consumer message.

I would like to thank Marko Huiskonen for the legal help in Nokia Corporation, Toni Kopra from Nokia Music for the visibility in Nokia Services management; Jari Muikku and Markku Kivistö (Teosto), Lauri Rechartt (IFPI Finland), and Antti Kotilainen from the Copyright Information and Antipiracy Center (CIAPC) for sharing the rights holders' views about the service.

Finally, I wish to thank my mother Anja, my spouse Pauliina, and my sons Topias and Tiitus for their love, encouragement, and understanding.

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## List of Publications

This dissertation consists of an overview of the following publications, which are referred to in the text by their Roman numerals.

- I Kokkinen, H. & Ekberg, J.-E. (2008). Post-payment copyright for digital content. Paper presented at IEEE Consumer Communications & Networking Conference CCNC 2008. Las Vegas, NV, USA.
- II Hietanen, H., Huttunen, A., & Kokkinen H. (2008). Criminal friends of entertainment: Analyzing results from recent peer-to-peer surveys. *SCRIPT-ed*, 5(1), 31-49.
- III Kokkinen, H., & Nöyränen, J. (2009). Forensics for detecting P2P network originated MP3 files on the user device. In M. Sorell (Ed.), *Forensics in telecommunications, information and multimedia* (pp. 10-18). Berlin, Heidelberg: Springer.
- IV Hietanen, H., Huttunen, A., & Kokkinen, H. (2009). Post-payment, a filesharing indulgence service. *NIR – Nordic Intellectual Property Law Review*, 78(2), 175-180.
- V Kokkinen, H., Heikkinen, M. V., & Miettinen, M. (2009). Post-payment copyright system versus online music shop: Business model and privacy. *International Journal on Advances in Security*, 2(2), 112-128.
- VI Kokkinen, H. (2010). *Post-payment boosts the impact of the anti-piracy actions* (TKK Technical Reports in Computer Science and Engineering, TKK-CSE-B9). Espoo, Finland: Aalto University, School of Science and Technology.

## **Author's contribution**

The post-payment project was carried out at the Nokia Research Center (NRC) in 2006-2009, and it was continued as an independent research study at Aalto University in 2009-2010. The author was the inventor of the post-payment service idea. He was the project manager of the post-payment project. He was also the main contributor of the post-payment research study at Aalto University.

Article I describes the post-payment Internet service for the first time. The post-payment business model allows the rights holders to create revenue from the files that have been illegally copied in the past. In Article I, the author was the primary author. He wrote 90 % of the text.

Article II discusses consumer behavior related to the users' attitudes towards peer-to-peer, illegal copying, and knowledge of the copyright law. In Article II, the author was one of the authors. He initiated and steered the research. His contribution consisted of the sections related to the post-payment service: Section 4, Legal Web Stores and Willingness to pay in the P2P Environment, including Figure 10, and the related parts in the Abstract, Introduction, Conclusions, and Discussion.

Article III includes an analysis of the methods of detecting illegal MP3 files on a user hard disk. In Article III, the author was the primary author. He initiated and steered the research. He wrote 90 % of the text.

Article IV concludes the legal framework of the post-payment Internet copyright service and recommends the terms for the contract coverage. In Article IV, the author was one of the authors. He initiated and steered the research. He wrote 33 % of the text, especially in Section 1.2, Post-payment system and law, including the Table, "type of immunity covered and type of immunity not covered".

Article V elaborates the techno-economic model of the post-payment copyright system. The post-payment enhances the competitiveness of the existing online music stores. In Article V, the author was the primary author. He initiated and steered the research. He wrote 50 % of the text. His contribution was a half of I Introduction, II Post-payment copyright system, III Qualitative business modeling, a half of III C Privacy threat analysis, a half of IV Scenarios, a half of V Results and, finally, VI Discussion.

Article VI includes a new replicator equation and the Markov chain based mathematical models for the post-payment. The post-payment decreases the amount of illegal files and increases the rights holder revenue. In Article VI, the author was the sole author. He wrote 100% of the text.

# 1 Introduction

This dissertation describes the research process of a novel post-payment Internet service. With the post-payment service, the customers are able to legalize illegally copied music files in their possession by paying the copyright fees to the rights holders.

Illegal copying is a major challenge in the music industry. Although opinions to the contrary exist, it is generally acknowledged that illegal copying decreases rights holder revenues as illegal copies may decrease the users' interest in purchasing the legitimate products. The falling rights holders' revenues impact negatively on publishing professionally produced music and on creative outcomes in society. Societies and countries that allow illegal copying mostly end up damaging professional creativity in their own culture as the artists typically have the largest market in their own country and culture.

The rights holders and their industry associations or representatives, however, have fought back against illegal copying. Among other things, the tools used to limit illegal copying have been communication about copyright issues, price reduction, making illegal copying irrelevant with streaming solutions, and maintaining a considerable risk level for illegal copying by utilizing compensation requests and litigations. The post-payment service is an additional new tool to help the music industry to resist illegal copying.

This communication has taken several forms: it has been aggressive by its emphasis on the potential legal consequences of copying; the artists have also explained how illegal copying decreases their opportunities to continue in their creative professions; it has been informative by explaining what the copyright legislation really means; and it has used individuals who have been sentenced in court as warning examples. The tendency in the communication is to approach the customers of the music industry in a positive manner rather than by raising unnecessary feelings of guilt.

The new business models for music are a constructive way of handling illegal copying. Spotify, Nokia Comes With Music, and similar fixed payment models decrease the benefits of making illegal copies. If a person has access to all music at any time whatever, there is little need to make copies.

Illegal copying has a similar impact on the music pricing as an increase in competition. The illegal copy is often considered as a replacement for the original. In most studies, the value of the copy is lower than that of the original and the cost of copying is less than the price of the original. The copying leads to efforts to make the product value higher, for example by adding music videos to the CD sales package, and at the same time, it forces the rights holders to decrease the price of the originals in order to stay competitive compared with the illegal copies.

Illegal copying has been reported to have had positive impacts on the rights holders' business as well. The software products benefit from network externalities. The value of the product for the user depends on the number of other users. Often files processed with the software are viewed, edited and shared by other users. A popular piece of software that uses a specific file type may become a de facto standard, as most users have to support the file type. The network externalities are not strong in music, but sampling is typical for music content. Before purchasing, the consumer has most likely sampled the music content. Illegal copies operate as a form of sampling. There are various legal ways of sampling as well: FM radio channels, most advertising based services like YouTube, streaming services like Spotify, and listening features in the online music stores. The challenges of using illegal copying as sampling are that it is difficult for the rights holders to control and that allowing copying in one situation and prohibiting it in another can give a confusing message to the consumers.

The post-payment as defined in this dissertation is an Internet service. The service is implemented and studied in the dissertation. The service consists of a user client running on a personal computer, a service website, Internet servers for catalogue matching, and payments. The dissertation is a multi-disciplinary research work



approaching the service from the perspectives of technical, business, legal, and consumer behavior.

The research problem is: “What impact does the availability of the post-payment copyright service have on the amount of illegal music on user devices, and how does it contribute to the rights holder revenue?”

## **1.1 Research approach**

This dissertation addresses the research problem about the feasibility of a post-payment solution for the growing amount of illegal content and copyright revenue losses. At the dissertation level, I use a multidisciplinary approach of service science and induction leading to the mathematical model of the post-payment. Together the articles in the dissertation contribute to the study of the research problem.

Article I discusses what kind of system could implement the post-payment. It introduces the service and the concept. We use a proof of concept method to show that the post-payment service can be implemented.

Article II explores how consumer behavior in Peer-To-Peer (P2P) file sharing networks leads to illegal content on the user devices. It queries the users’ understanding of copyright law, perception of the risk related to copyright violation, and interest in new music services. It deploys a survey method to verify that the users have large amounts of illegal MP3 files. The results show that the users have an interest in paying for and using the post-payment.

The method of how to recognize illegal Motion Picture Expert Group Layer 3 (MP3) files on user devices is presented in Article III. We carry out a laboratory experiment to study the sensitivity and specificity of the album, directory, and file indicator methods for recognizing illegal MP3 files.

Article IV studies the position of the post-payment service in Finnish copyright legislation. We apply problem-oriented jurisprudence. We study how a post-payment copyright service could impact on MP3 file sharing activities, and what is the legal framework of the service.

The research on how the business of the post-payment copyright system compares with an online store and with the privacy analysis of the system can be found in Article V. The impact of the post-payment copyright service on the rights holders' revenue is studied by applying quantitative techno-economic and qualitative Service Technology Organization Finance (STOF) methods. In the same article, the privacy concerns of the users are analyzed by using an attack-tree method.

Article VI answers the research problem with a mathematical model of the system. A mathematical modeling method based on the replicator equation of evolutionary dynamics and the Markov chain is used to estimate the impact of the post-payment on the illegal files and on rights holder revenue. The conclusion of the results is that the post-payment decreases the amount of illegal files and increases rights holder revenue.

## **1.2 Contributions**

The main contribution of this dissertation is the new Internet digital music service – the post-payment. The multidisciplinary approach of this dissertation, to describe and research a novel Internet service, can be used in the future to study other Internet services. The disciplines included in this dissertation are service science, which binds the disciplines together, data communications software, consumer behavior, computer forensics, law and technology, network business, privacy, and mathematical modeling. The main contribution of the results is the theoretical answer to the research problem in the dissertation: the mathematical forecast about the impact of the post-payment on the number of illegal files and on rights holder revenue.

Article I describes the post-payment Internet service for the first time. The system architecture of the post-payment service is composed of a client software, service front-end, service backend, catalogue matching server, and payment system. The enabled business model allows the rights holders to create revenue from the files that have been illegally copied in the past. That revenue stream is otherwise outside the rights holders' control. The business model is favorable for the users as it does not force the users to any actions, and it does not limit the users' freedom of choice in the selection of the source of the content, distribution of the content, or the end user equipment of the user.

Article II increases the understanding of the users' attitudes towards peer-to-peer, illegal copying, and knowledge of the copyright law. It describes the users' preferences for new Internet music services, including the post-payment.

Article III introduces the method of detecting illegal MP3 files on a user hard disk. It consists of file, directory and album indicators. The performance analysis of the proposed indicators results in recommendations for their applicability.

Article IV elaborates the legal framework of the post-payment Internet copyright service. It concludes that the current Finnish legislation allows the operation of the service, but that the service terms must be described in the contracts between the end user, service provider, and the rights holder. Article IV recommends the terms for the contract coverage.

Article V defines the techno-economic model of the post-payment copyright system. The comparison between the post-payment, the online music store, and download post-payment services shows that the post-payment is a competitive enhancement to existing online music stores. The STOF model and the analysis of the post-payment copyright system deepen the understanding of the business model and the organizations in the service. The attack tree-based privacy model formalizes the sensitivity of the post-payment to privacy threats.

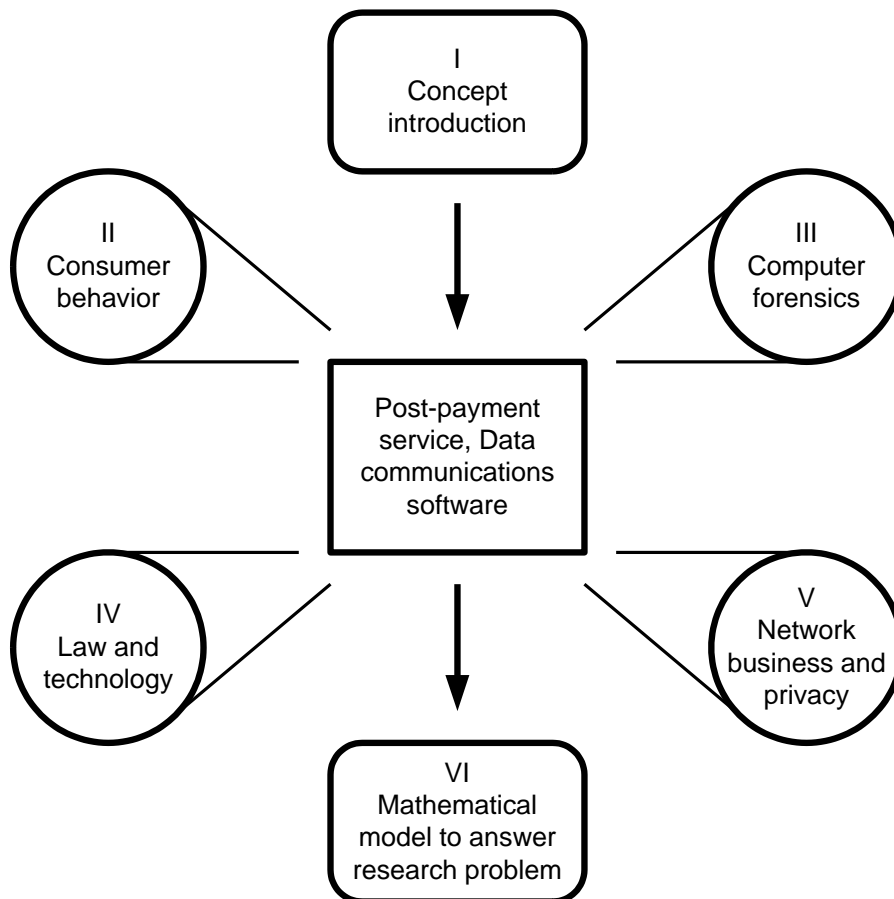
Article VI introduces a new way to apply evolutionary dynamics to a decision process. It includes a new replicator equation and Markov chain based mathematical models for the post-payment. The application of the models answers the research problem in this dissertation. The post-payment decreases the amount of illegal files and increases the rights holder revenue.

### **1.3 Structure of dissertation**

The first part of the dissertation describes the research problem, how I answer the research problem, and the contribution of the dissertation to scientific knowledge in Chapter 1. Chapter 2 discusses the state of the art both in scientific literature and in the industry generally. The research methods are presented in Chapter 3. In Chapter 4, the technical description of the post-payment service is featured in greater detail than what was possible in the articles of the second part of the dissertation. Chapter 5 summarizes the results of the articles. Finally, Chapter 6 discusses how the research results can be utilized in practice, describes the applicability of the research results, and recommends topics for future research.

The second part of the dissertation consists of six articles. The dissertation studies the service from four different perspectives: consumer behavior, computer forensics, law and technology, network business, and privacy. The post-payment service and this dissertation combine the post-payment research into a study of data communication software. The technical architecture of the system can especially be found in Articles I and V, and a more detailed description is given in the first part of this dissertation. The research process of the post-payment begins by introducing the post-payment copyright service in Article I. It is the first publication of the post-payment copyright service. In Article II, user preferences and attitudes towards peer-to-peer file sharing are studied using a questionnaire. One of the most interesting features of the service, the method of differentiating the illegal and legal files on the user device is described in Article III. Article IV sets the framework of the post-payment service in a legal context. In Article

V, the possible revenue alternatives of the rights holders and the service provider are evaluated with quantitative and qualitative analysis, and the privacy challenges and solutions in the service are presented. It shows the potential and challenges of running a business based on the post-payment. The post-payment research is completed by developing a mathematical model with the main objective of finding an answer to the research problem: “What impact does the availability of the post-payment copyright service have on the amount of illegal music on user devices?” The relationship of the articles in the dissertation can be found in Figure 1.



**Figure 1. The relationship of the articles in the dissertation**

## 2 Background

Since the 1990s, the music industry has experienced radical changes in their business. The fact that the industry faces the current change is due to digitalization of the media content from analog to digital formats in Compact Discs (CDs) and MP3, broadband Internet connections over Asymmetric Subscriber Lines (ADSL), cable modems and high-speed cellular data modems, and in the increased use of computers and software applications for copying and consuming the media content. It is constructive to look for new sources of revenue in the areas that are forcing the industry to change. Frost (2007) has listed various new business models that have appeared on the market such as ArtistShare, Pandora, LastFM, and Calabash Music. IFPI (2009) classifies the new digital music business models as music access, music download (Casey et. al. 2008), music social network (Douglis 2010), public performances (Schultz 2009), games (Beck and Wade 2004), branding (Beverland et. al. 2006), and merchandising (David 2010). The structural change forces the music industry to move from recorded music sales, primarily CD discs, towards new revenue sources. The new sources include increased concert business (Schultz 2009), advertising (Bhattacharjee 2009), merchandise (David 2010), sponsoring (Rowley and Williams 2008), and digital music sales (Zentner 2008) as a new form of recorded music. The digital music sales of online music stores have been growing steadily, but they have not compensated for the decrease of the CD sales value. In the digital domain, the industry is looking for new revenue streams. The Spotify streaming service has a flat rate and advertisement based funding. YouTube has also become a strong advertising based service in the music business. In Nokia's "Comes with Music", the music price is embedded in the device price, and the Napster music file sharing service has a flat rate. It is expected that Internet Service Providers generally will bundle the music and other content services into the access offerings.

In the early days of the online music stores, the major labels approved only Digital Rights Management (DRM) based music online services, but currently DRM-free online music is increasingly available. The new revenue streams are very important,

because it is not expected that a single digital music revenue model would acquire as dominating a position as the CD sales once had.

## 2.1 Piracy

Another catalyser of music industry change has been piracy, meaning producing, distributing, and consuming copies of copyrighted work without permission from the rights holder. Here, I recognize two classes of piracy: piracy of physical goods and online piracy. Online piracy is a much later phenomenon, and thus it has recently had a larger relative change in the music industry than physical goods piracy. The impact of physical goods piracy is generally high in the developing countries, Russia, China, India, and in Latin America. In the developed western countries and in Japan, online piracy is the main concern. Online piracy can be divided into server distribution and peer-to-peer distribution based copyright infringements. The evidence against server based copyright violations is straight forward to collect and to help identify the owner of the server. The actions towards such violations vary from requesting the removal of the copyright material from the server to monetary compensation in litigations. This dissertation focuses on the online piracy only. In some cases, like YouTube, the copyright holders have negotiated a license rather than removed the content (Hiatt and Serpick 2007). Such deals are close to the philosophy of the post-payment copyright service. After recognizing that the copyright violation has taken place, the copyright holders do not try to punish, but rather to benefit from it. Chen et. al. (2008) suggest that a reason for the success of illegal copying of music is that it is fashionable. Ingram and Hinduja (2008) discuss the university campus as an environment, which may value group norms higher than legal norms. Altschuller and Benbunan-Fich (2009) and Wingrove et. al. (2010) report high inconsistencies in university students replies as to whether illegal copying is acceptable and what the students themselves do. Al-Rafee and Rouibah (2010) study piracy in a developing Arab and Middle Eastern country. According to Bhattacharjee et. al. (2003) the price of music and available bandwidth have a significant effect on piracy. Gopal et. al. (2004) and Chiou et. al. (2005) develop

a behavioral model for music piracy. Bellemare and Holmberg (2009) note that factors that decrease probability of an individual copying illegally are willingness to pay, risk of lawsuit, and high moral standards.

The users share a lot of content illegally; IFPI (2009) estimates 40 billion unauthorized music downloads in 2008. It represents 95 % of all music downloads within a group of 15 studied countries. Copyright holders lose revenues due to illegal copying, and users store great amounts of illegal content on their devices. The Institute for Policy Innovation (Siwek 2007) evaluates the value of loss to be USD 5.3 billion in the US in 2007. There have been studies on how to convert popular file sharing into a legal activity in the literature with a legal version of Napster (DeVoss and Porter 2006), viral marketing (Pousttchi and Wiedemann 2007), and an amnesty program (Harmon 2003) as suggestions. There is also a file replacement service available (Beckham 2005). Scientific research on a service where users can pay for their illegal content has not been available earlier.

A trend in piracy is that it is becoming political. The Swedish Piratpartiet won one seat in the European Union Parliament in the 2009 election and got another one later (JHR and WTE 2009).

## **2.2 Anti-piracy**

The anti-piracy actions contain preventive actions such as DRM, watermarking, and an increased security level in the media production and distribution chain. For post-payment, the most relevant anti-piracy actions take place after the copyright infringement. Those include communication about the sanctions, closing piracy sites, requests to remove content from the services, compensation requests, and, as a final ultimatum, litigation. One of the key issues for post-payment service success is how consumers feel about the risk of getting caught for copyright infringement. The copyright organizations try to emphasize the legal consequences by communication,



warnings, compensation requests, and as a final act, by carrying out legal actions against individual file-sharing users. Copyright infringement cases are given publicity as warning examples. The published examples work positively for the motivation to use the post-payment service. The copyright and anti-piracy organizations do their best to maintain the threat as real. In Table 1 below, I collected a few selected litigations in which an individual person has faced legal consequences for illegal file sharing. The empirical study of Morton and Koufteros (2008) shows that females feel that the consequences of illegal copying are severe, but neither females nor males consider them probable. Sinha et. al. (2010) show in an empirical study that DRM free music has a potential to convert pirates into paying consumers. Chiu et. al. (2008) suggest using a value-added product, low-price, legal action, and technological strategies as anti-piracy tools. Seay (2009) supports the rights holders' efforts to work together with ISPs against piracy rather than proceed with suing individuals. Von Lohmann (2004) proposes voluntary collective licenses for the music industry. Malin and Fowers (2009) suggest that piracy prevention efforts should be targeted at high school age children and increasing self-control.

The copyright organizations have sent systematic claims to individuals who have been recognized as downloading illegal content from the Internet. In Germany, 25 000 people were targeted for illegal downloading in Jan-May 2007 (Spahr 2007). The District court of Hamburg (2007) has set the compensation level of illegal file sharing of a private person at 600 € per track, when there are more than 10 tracks identified. The first ten tracks are more expensive: 6000 € for the first, 3000 € from the 2nd to the 5<sup>th</sup> per track, and 1500 € from the 6th to the 10<sup>th</sup> per track. In the US, the music industry is changing from mass lawsuits to collaboration with Internet Service Providers (ISP) - see McBride and Smith (2008). The Finnish rights holder representatives are pushing for legislative changes to allow closer collaboration with the ISPs, as well.

**Table 1. Selected copyright infringement verdicts and settlements of consumers**

<b>Date</b>	<b>Location</b>	<b>Charge</b>	<b>Consequence</b>
29.8.2007	District court of Tampere, Finland	Uploading ca. 1000 music tracks and videos, and ca. 80 movies and TV episodes using DirectConnect.	550 € fine. and compensation payable of ca. 4500 €. (Tampereen käräjäoikeus 2007)
15.5.2007	District court of Rauma, Finland	Uploading of ca. 4000 music tracks and ca. 70 movies using DirectConnect	40 day fines making 800 €, and compensation of ca. 7000 €. (Rauman käräjäoikeus 2007)
21.3.2007	District court of Oulu, Finland	Uploading of movies, TV series and game console games using Finreactor bittorrent tracker.	40 day fines and a compensation of ca. 5000 €. (Oulun käräjäoikeus 2007)
14.9.2006	District court of Vantaa, Finland	File sharing of thousands of music files, and tens of movies and TV episodes.	Fines and a compensation of ca. 6000 €. (Vantaan käräjäoikeus 2006)
31.7.2009	Federal jury of Boston, USA.	Downloading and sharing 30 music tracks using Kazaa.	A compensation of USD 675 000. (Sony BMG v. Tenenbaum 2009)
18.6.2009	Federal jury of Minneapolis, USA.	Downloading and sharing 24 music tracks using Kazaa.	A compensation of USD 1 920 000. (Capitol v. Thomas 2009)

## 2.3 Future scenarios

Among others, the three following future scenarios have been proposed for music copyrights. The first is a world of free music, see (Anderson 2008, Netanel 2003, and Fisher 2004). The suggestion is analog to creative results produced by scientific research, which are then freely available for others. Open source software is another example of the trend. Software has traditionally been written commercially and, at the moment at least, part of the commercial software is created without direct compensation in open source software community activities.

The second option is a world, where illegal copying becomes irrelevant - please refer to (Larsson and Magne 2009, Wiechmann 2009, and Burnett et. al. 2010). Traditionally, music is consumed from local copies of the content. Listening to the music as a service, for example with Spotify, may become the dominant behavior compared to making local copies of the music. In centralized music services, copyright issues can be controlled and file-sharing related copyright violations become irrelevant. The music and other content may be bundled in other services, like ISPs may bundle music streaming in the access service.

The third option is that the copyright owners tighten their control over copyright violations. So far, the legal actions of the copyright holders have been primarily targeted at the piracy of physical goods, server hosting which enables copyright violations, and individual persons who have put files on the Internet for others to download. Stronger actions against individual downloaders would raise the threat of getting caught for copyright violation, which would then increase the potential of the post-payment copyright service. At the moment, all given scenarios are possible. There are signs of each of them, and it is possible that all three scenarios will co-exist. At the time of this project, scenario two has strengthened most. The prevailing scenario may depend on the time, place, content matter, and many other variables, e.g. (Henslee 2009 and Leung 2008). The post-payment provides benefits in option three.

## **2.4 Business and legal drivers for service**

The business and legal requirements for the post-payment at the beginning of the project were: novelty, peer-to-peer technology, illegal copying subject to control, no major changes in the content distribution, DRM free content, and use of commercial content. Matching the DRM based content distribution requirements of the rights holders, and the DRM free content distribution requirements of the users was a major challenge. When the project first began, DRM free online content distribution had not yet been approved by the rights holders as it later was by the end of the project. The content access was commonly performed by encrypting the content with DRM. A challenge with DRM is that even the most common DRM systems from Microsoft or Apple are not supported nearly as widely as the respective DRM free content formats like MP3.

Internet services live or die with their content. Although user created content services like Facebook and YouTube have been in the spotlight during this research, commercial content services like Spotify, TV Kaista or BBC iPlayer have received their share of public interest as well. In the commercial content services, the most important issue for success is to obtain content for the service. It has been argued that one of the reasons for

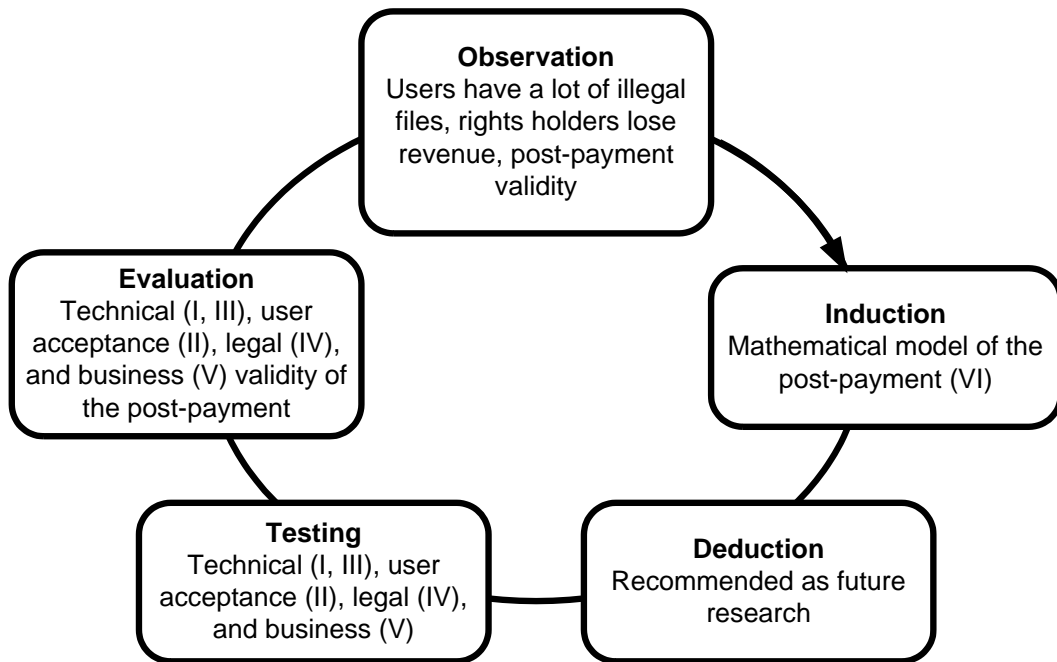
the peer-to-peer success is that it has a larger catalogue of content than what commercial online stores are able to provide. This is especially true with the video content. In music, the difference between the selection of the titles in online music stores and peer-to-peer networks is not that large, anymore. Two common legal approaches for having commercial content in the service are to sign contracts with all rights holders, or to create a service in a way that it does not require contracts from the rights holders. In the latter case, the service provider takes known legal risks, challenges the current copyrights legislation, and is ready to face litigations. The history of peer-to-peer downloading includes several media followed litigations including Napster (Pike 2007), Grokster (Högberg 2006), Kazaa (Ginsburg 2006), and Pirate Bay (Andersson 2009). From this perspective, it was natural to carry out research on the legal aspects of the post-payment service in Article IV. The results of the study indicated that the post-payment service could form an integral part of the group of services, which require contracts with the rights holders. With the required contracts, therefore, the service can be legally implemented.

From these simplified requirements, we can develop the post-payment copyright system. It is expected to be user friendly as there is no DRM. It is legal. It works with any peer-to-peer application and network, and does not force the user to take any actions. The rights holders will also be pleased with the system, because it creates revenue from earlier illegally downloaded content that is not accessible by other means. The system does not involve any new copies, nor does it transfer any unprotected files.

### 3 Research methods

At the dissertation level, the used research methods are induction, experimental computer science, and the multidisciplinary approaches of service science and piracy research. The induction method begins with the observations made especially in the questionnaire study in Article II and with the business evaluation in Article V. It leads to a mathematical model expressing the theory of post-payment in Article VI.

Holland et. al. (1986) describe the process of inductive reasoning leading to scientific theories. Fisher (1955) discusses common errors made in scientific induction. De Groot's (1969) empirical cycle has five phases, which follow each other, and after the last phase, the cycle begins again. The phases are observation, induction, deduction, testing, and evaluation. Please see Figure 2. The success of new technical innovations consists of three components: technology, user acceptance, and the business model. These areas are tested and evaluated in Articles I and III, II, and IV, respectively. Due to the nature of the service, the legal aspect is strongly present, and it is analyzed in Article IV. In the media area generally, copyrights and the related contracts play a growing role in successful business introductions. Evaluations form the basis of the observations: users have a lot of illegal content, rights holders lose revenue, and post-payment is a valid business proposition from the technology, consumer behavior, business and legal points of view. Following the observations, the mathematical model describing the theory of the post-payment is developed in Article VI.



**Figure 2. The empirical cycle as the dissertation level research method, and the Articles in the different phases (de Groot 1969)**

Dodig-Crnkovic (2002) states that experimental computer science is most effective in problems that require complex software solutions. Zelkovitz and Wallace (1998) describe four approaches to experimentation: scientific, engineering, empirical, and analytical. In the scientific method, a hypothesis based on theory is tested by experimentation. The engineering method continuously improves a solution for the hypothesis. In the empirical method, a statistical method with experiment data is used to validate a hypothesis, which may not have a formal model or theory. The analytical method develops a formal theory and its results are compared with observations in the experiment. Experimental data collection methods are classified as observational, historical, or controlled.

The validation of the computer science experiments is critically discussed. In many cases, the validation is missing. There is only an informal form of validation in the papers, very few validation methods are used, and the terminology in the experiments is variable. Computer science experimental validation methods are grouped into 12 areas: project monitoring, case study, assertion, field study, literature search, legacy data,

lessons learned, static analysis, replicated experiment, synthetic, dynamic analysis, and simulation. Expelid et. al. (2008) develop a proof of concept to show the vulnerability of a Norwegian bank Internet system. Eggelstone et. al. (2009) use the proof of concept method to improve amusement park rides with wearable bio-sensors. Jackson et. al. (2009) show how to protect browsers from DNS rebinding attacks by utilizing the proof of concept method. Yin et. al. (2009) experiment with a forensics service platform for Internet videos. Frattolillo and Landolfi (2009) experiment with a new DRM scheme. Fetshcerin (2004) analyzes movie piracy on Kazaa by using simulation.

Service science is a scientific discipline, which studies services. Service science addresses the service sector as a whole. It finds ways to improve innovation in the services, to increase value from service knowledge, to research, develop, and deliver new information services and business services (Spohrer and Riecken 2006). The nature of the science is multidisciplinary, and it is emphasized in the often used terminology as SSME, Service Science, Management, and Engineering (Chesbrough and Spohrer 2006). The multidisciplinary areas that are most commonly mentioned in the service science context include: technology, management, and social sciences, which together cover information technology, business, and law. Some examples of multidisciplinary service research papers are a study of Internet shopping using a multidisciplinary approach by Cheung and Lee (2006), a multidisciplinary framework for modeling services by Nakamura and Ikawa (2009) and, finally, a description of the multidisciplinary Internet research project “S-Cube” by Nitto et. al. (2009). This last mentioned paper is a good example of how a multidisciplinary approach using the methodology of computer science, networking business, law, and consumer behavior, can result in an aggregate service view. An overview of the whole service science field is presented by Pinhanez and Kontogiorgis (2008), who have suggested the classification of service science research. A sub-section of the service science, Internet service research is sometimes called e-services (Rust and Kannan 2003).

Piracy research as such is not a scientific discipline of its own, but digital piracy has been researched in several areas of science, including computer science, economy, law,

and behavioral sciences. They are the same disciplines that are present in this dissertation: computer science in Article I, III, and the privacy section in V, economy in Articles V and VI, law in Article IV, and behavioral science in Article II. This research would benefit from a supporting field trial to verify the theoretical results. The thesis contains all the technical components needed in a trial. Unfortunately, the planned trial was cancelled due to a copyright regulator request.

Hoffman (2009) writes an overview of content protection methods. Technical solutions to prevent piracy include e.g. software watermarks (Nagra and Thomborson, 2004), and hardware protection of piracy (Yang et.al. 2003). Oberholzer-Gee and Strumpf (2010) write that the impact of piracy on music sales is not as dramatic as many other papers suggest. Sinha and Mandel (2008) compare the impact of law enforcement and incentives to make legal purchases in piracy. Cummings (2009) provides a historic view of piracy and its impact on the music industry. Hoffman (2010) analyzes the impact of content hashing in the enforcement of copyright law. Glick (2010) develops a model to assess the actions of the policy makers. In a book review about the history of intellectual property rights, Gollin (2010) describes how pirating has transformed science publication, drug development, and software. Malin and Fowers (2009) suggest that more self-control should be exercised by individuals of high school age. Al-Rafee and Rouibah (2010) find that religion and awareness impact on behavior effectively, but that legal sanctions have no significance for behavior. Wingrove et. al. (2010) study why, in the area of digital piracy, so many people do not obey the law.

The post-payment copyright research begins by stating the research problem in Article I: what kind of service could benefit both rights holders, with strict requirements for the distribution, and consumers who are used to free sharing of the music? The idea of the post-payment copyright could serve both of these camps. We implement a proof of concept of the system to this end. The proof of concept is used to concretize the idea and to get more tangible feedback both from the rights holders and from the users. As the research problem of Article I includes a complex new software solution consisting of a sequence of different servers and actions by the user, the selection of the proof of



concept implementation as the research method is a natural choice. The proof of concept method includes definition of the user interface and the process of using the service. The software and service have been presented to colleagues, peers, and selected members of the rights holders to get feedback about the service.

Saunders et.al. (2007) show how questionnaires can be used to find out how respondents feel about something, or what they think or believe is true or false. It is possible to record users' concrete experiences, and to collect responder characteristics. According to van Kleef et.al. (2005), consumer research can be applied in all major phases of the new product development. It has four phases: opportunity identification, development, testing, and launch. Most commonly, consumer research is applied during the last three phases, but it is recognized that consumer research can improve the quality of the opportunity identification stage. The primary target of the new product development is to create a product that offers superior consumer value, so that consumer needs are satisfied. This leads to two separate stages of the research problem: what is the consumer need, and how well can a product satisfy the consumer need. 10 consumer research methods for opportunity identification are listed: category appraisal, conjoint analysis, emphatic design, focus group, free elicitation, information acceleration, Kelly repertory grid, laddering, lead user technique, and Zaltman metaphor elicitation technique.

Article II describes a web questionnaire survey about Finnish peer-to-peer file sharing. The research problem in the survey is what kind of demographics Finnish peer-to-peer users have, and what kind of behavior and opinions they have about copyrights infringements. The survey was available to Finnish users for two weeks. It was advertised on several popular Finnish technology related Finnish websites. The target was to reveal consumer needs without exposing them to specific products. The questionnaire had characteristics of a conjoint analysis. The user was given hypothetical options. We analyzed the forum discussions, and we led the user group. The survey was available through technical websites that have technically advanced readers. The users

described online how much illegal content they had, and so the lead users with the largest amounts of illegal content were identified.

Computer or digital forensics is a recent and fragmented scientific discipline (Rogers and Seigfred 2004). As an example of the segmentation, Internet forensics discipline is discussed in (Berghel 2003). Computer forensic methods include tools for tracing and locating computer hardware, recovering hidden data from storage media, identifying and recovering hidden data (for example, watermarks), decrypting files, decompressing data, cracking passwords, and bypassing the normal security controls and permissions of an operating system. Being a combination of two separate fields of science: computer science and law, computer forensics is multidisciplinary (Yasinac et. al. 2003). A legal precedent for the acceptance of scientific evidence is set by the US Supreme Court in the Daubert vs Merrell decision: the theory or technique has been tested, it has been peer reviewed and published, its known or potential error rate is subject to control, and it has acceptance within a relevant scientific community (Sanders et. al. 2002). Sensitivity and specificity analysis have widely been used in medical science to estimate indicators of illnesses, e.g. (Kulasingham et. al. 2002), Reith et.al. (2002) with a study of four digital forensic models, Mandia and Prosis (2001), the Department of Justice (Mukasey et. al. 2008), and the Digital Forensics Research Workshop (Palmer 2001), and Farmer. They built a new model based on the earlier ones including the following 9 steps: identification, preparation, approach strategy, preservation, collection, examination, analysis, presentation, and returning evidence. In each step, case-specific scientific methods can be applied.

The research problem in Article III is: "How can we separate illegal and legal MP3 files on a user hard disk?" We built a hypothesis of three different groups of indicators: file specific, directory related and album indicators. These indicators, totally 23, are implemented in a user client. A small number of examinees are chosen and they run the software on their hard disks. After the computed analysis, the users are requested to mark which files are from an illegal source. In the paper, we carry out a data analysis for the sensitivity and specificity values of the different indicators. The method

described in the article III, can be applied to the identification, examination, and analysis phases of the forensic analysis. Additionally, it could be used to set the value of the settlement compensation.

A characteristic of problem oriented jurisprudence is that it connects legal rules and their societal functions. The study is carried out by determining the valid law on the basis of the theory of the sources of the law (Teubner 2001). The other theory applicable to the method is the problem solving theory of social science case studies (Cox 1981).

The purpose of the study, in Article IV, is to analyze the relevant functions of Finnish law with reference to the implementation of the post-payment copyright system. It defines the legal research problem, and solving it leads to the research method of problem-oriented jurisprudence, which is also called constructive jurisprudence (Pettersen 2006). However, here the problem is solved by studying the existing legislation, and then applying relevant laws to the context of the post-payment copyright system rather than collecting statistical data as is typically the case with studies. Due to the type of the stated research problem, constructive jurisprudence is selected instead of other jurisprudence types like comparative, analytical, or teleological jurisprudence (Isaacs 1918).

The techno-economical method has been used to analyze the potential of new communication systems, for example WiMax in (Smura 2005). Usage data collection and statistics (Kivi 2009), consumer surveys (Anckar and D’Incau 2002), techno-economic and business case modeling (Smura et. al. 2007), service adoption and diffusion (Ali-Vehmas and Luukkainen 2005), and functional and mathematical modeling (Kilki 2007) all belong to the quantitative methods of the network business area. Only recently, has mixing quantitative and qualitative methods become popular (Morgan 2007). STOF is one of the first common frameworks for service design and designing business models, see Bouwman et. al. (2008). In addition to constructive tools, it also incorporates methods for service and business model analysis. Other qualitative network business methods include industry scenario construction (Heikkinen

and Hämmäinen 2007), business simulation with games (Faria 1998), and expert interviews (Dorussen et.al. 2005). Attack trees are a strategic, goal-oriented approach to analyze security threats. Sweeney (2002) studies privacy protection with quasi-identifiers. They are used to find out possibilities of linking two data sources together and to reveal privacy information through them. Agrawal and Srikant (2000) discuss privacy metrics. Liu et. al. (2003) apply the strategic social actors method for trust and role-role based pattern analysis. It includes attacker analysis, dependency vulnerability analysis, countermeasure analysis, and access control analysis. Hui et. al. (2008) derive indifference curves for their piracy model. The stratified node topology, an improvement to the attack tree, is proposed by Daley et. al. (2002).

In Article V, we study three different research problems. The quantitative business analysis was used to answer what the expected profit difference is compared to the online store business model. We research what the business eco-system for the post-payment copyright system looks like, and we ask what are the privacy threats in the system. We evaluate the post-payment business proposition with quantitative Monte-Carlo simulation and qualitative STOF methods. The profit of the post-payment system compared to online music shop is studied with techno-economic modeling method. The privacy analysis uses attack tree.

Conner and Rumelt (1991) calculate the optimal profit and price by finding the interior maximum as a function of the copy protection, when network effects are taken into account. Givon et. al (1995) build a diffusion model to estimate the number of the legal and pirate users of software. Rob and Waldfogel (2006) estimate piracy influenced sales displacement using Ordinary Least Squares (OLS) and instrumental variables. Bae and Choi (2006) evaluate piracy effects with the monopolist's optimal pricing strategy. Haruvy et. al. (2004) apply evolutionary dynamics to evaluate the effect of piracy on the market penetration of subscription software. Zentner (2005) estimates the effect of online music piracy on music sales using two different databases and empirical approaches. The mathematical modelling of piracy has been carried out by Belleflamme and Picard, (2007), Faugère and Tayi (2007), Oberholzer and Strumpf (2007), Gayer

and Shy (2003), Hui's and Png's (2003), Sundararajan (2004), Peitz and Waelbroeck (2006), Rob and Waldfogel (2006), Bae and Choi (2006), and Zentner (2006). Article VI contains a concise summary of their results.

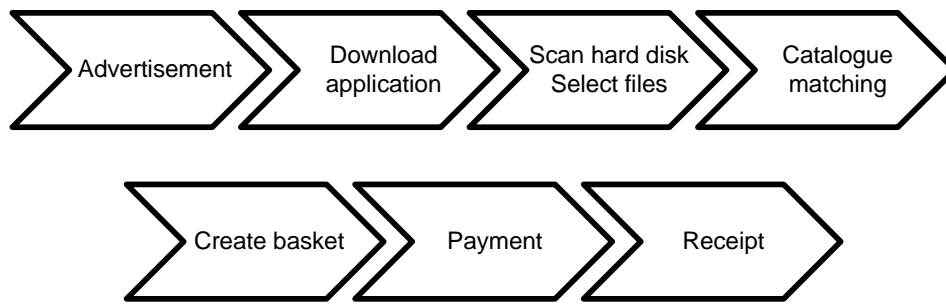
In Article VI, I calculate the post-payment impact on the piracy influenced market. I use evolutionary dynamics and Markov chains. Already small parts of the business potential create such high revenue that understanding even small movements is important. The deterministic game theory describes well the logical decisions of the players. In the post-payment, I am interested to see how the post-payment survives in a large population, where the individuals do not always act rationally. For that purpose evolutionary dynamics offer good support.

## **4 Post-payment service**

The post-payment service and system are described in this chapter. The technical description begins with an introduction of the network architecture, and it continues with the discussion on the client application, catalogue matching server, and protocols.

### **4.1 Service description**

The post-payment service provides the user with an opportunity to pay the copyright fees of the illegally copied music files to the rights holders. The web front-end gives information about the service and allows the user to download the user client. With the user client, the user scans for music files on the hard disk. The application separates the illegal and legal files. The user selects which files he would like to legalize with the post-payment service. The application knows only the tag information from the metadata of the file. In order to match the file information with the service catalogue, containing the information about the titles that are available in the service, the file information is sent to the catalogue matching server. The catalogue matching server returns the possible available titles and their price information. When the user decides to purchase the rights of the selected songs, a web front-end shopping basket is opened in a browser window. The user gives his email address. A click on the purchase button takes the user to an online bank payment page or to the credit card information page of the post-payment backend. After the successful payment, the user is shown a link to the receipt webpage, and he also receives the receipt link by email, see Figure 3. The consumer trust in Internet payments varies from country to country. Also, the popularity of the payment systems changes continuously. It is important to localize the system, including the content selection and the payment system for each market area.

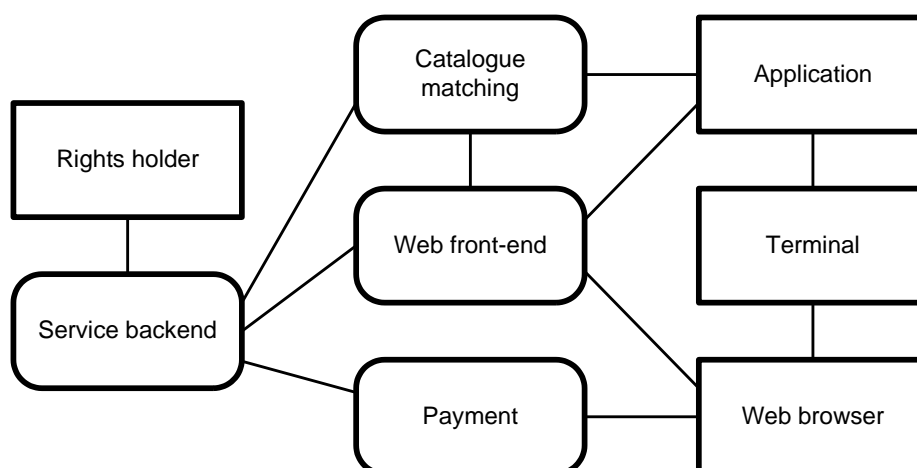


**Figure 3. The user process in the post-payment service**

The service has a similar price mechanism as the online stores. Individual tracks or albums have a price per title. The price is composed of the wholesale price of the record company, other rights holder fees, payment transaction, system operator's share of revenue, and the value added tax. The largest price component is the price to be paid for the record company. The price is set in negotiations, but the record companies may prefer to keep the price the same as in the online stores due to the possible substitution effect. The other price components have a smaller impact, and their variation is already visible in the current online stores: for example the price of the same music track may vary from 0.89 € to 1.19 € in online stores.

## 4.2 System architecture

The architecture of the post-payment system is influenced by two issues: privacy, and a commercial online music store. Privacy is a key concern for the user of the post-payment system. The information the user is giving to the network is related to the user's illegal activities in the past. It is crucial for the user to understand what information is collected, where it is stored, transferred, and who has access to that information. The system is designed so that as little as possible of the user information is transferred to the network. The sensitive nature of the data in the system is also a challenge for the service provider. The service provider does not want to get hold of the information which may have legal consequences for its customers. Additionally, there are several organizations involved in the system operation. Each party wants to limit its responsibility for storing the sensitive user data in its system.



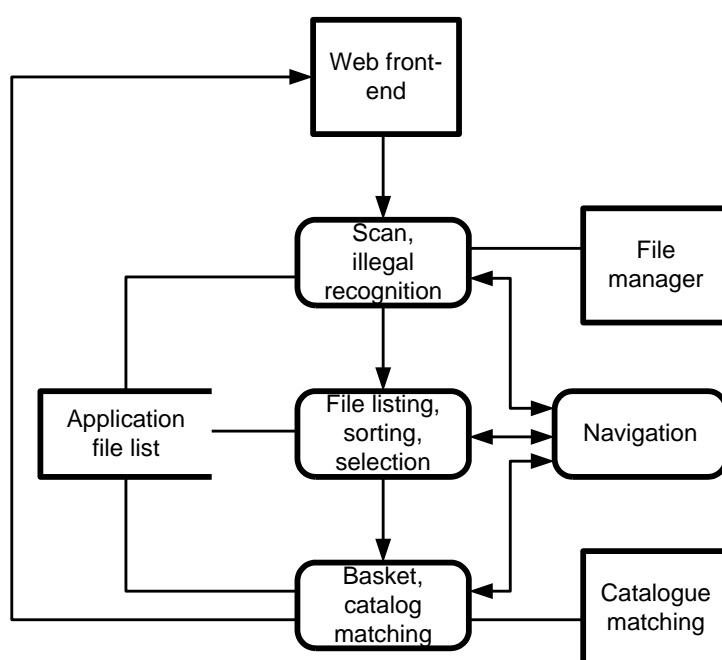
**Figure 4. The post-payment system architecture in Article IV**

As recommended in the results of the STOF analysis in Article V, we design the system so that it can easily be integrated with an online music store backend system. The commercial online stores are often divided in the payment, front-end and backend. The post-payment server system has additionally a catalogue matching server. The commercial backend system provider has an excellent opportunity to contract the rights holders and to make a wide music catalogue available for the users. With the commercial online store provider, we also get technical systems for rights clearance, catalogue updates from the rights holders, a payment system, and a feedback system. The final system architecture consists of the user client, catalogue matching server, web front-end, system backend, and protocols connecting these architectural elements to each other, see Figure 4.

### **4.3 Application**

The post-payment service is available for the user through a combination of a web browser and a post-payment application. The post-payment application is implemented with Java webstart technology. Java webstart implementation is a compromise between a native application and web browser approaches. The native application allows a full access to the operating system and processing environment of the user device, but it requires installation, which may turn away a few users from the service.





**Figure 5. The Ganes-Sarson data flow model diagram of the application**

The web browser is the most versatile solution over different terminal platforms, but the browser environment does not allow the service access to all resources like scanning the files in the user terminal. Web runtimes like Asynchronous JavaScript and XML (AJAX) and scripting help, but they still have limitations compared to a native application development. Flash and Silverlight are possible options for the webstart technology. The main challenges during implementation with the Java webstart are related to availability and maintenance of the available libraries, and the support for the required Java runtime version in different operating systems. The data flow structure of the application can be found in Figure 5.

The client application use begins by downloading it from the web front-end with Java webstart. The user is given an option to scan the whole computer or just selected directories. The whole computer scan proceeds through the internal and external hard disks, but not network drives. It scans all directory levels under directories with a word Music in them. It scans the Windows' My Documents directory fully. As far as the rest of the directories are concerned, it will only scan for two directory levels below the main directory. When the user chooses the scan of selected directories, a file manager

window of the operating system is opened. While scanning, the client carries out the recognition of illegal material according to Article III. The algorithm for combining the results of the different indicators is enhanced with an a priori algorithm association rules study. The association rules help to select individual indicators and indicator groups that raise the flag, "Possibly from an illegal source". The scan and recognition of users' files produce a file list view in the application. The results are sorted so that the illegal files are on the top. The intention is to sort the files further so that the most recently listened files would be higher, but at the time of implementation there is no support from the Java libraries for this. In the file list view, the user sorts the files according the illegal status, artist name, track name, album name, and duration of the track. It is also possible to use the search function within the file list view. The user selects songs for the shopping basket either per track or per album, and proceeds to the shopping basket either through the navigation tabs or by clicking the shopping basket button. Figure 6 shows the file list view of the application. The shopping basket view gives the user an opportunity to check the content that the user is purchasing. Possible operations are removing items from the list and carrying out the catalogue matching again. The user can change the metadata information sent to the catalogue matching server. This way, it is possible to compensate for the spelling mistakes or spelling differences between the user file metadata and the music catalog. The shopping basket view can be found in Figure 7.

**Laila**  
Laila Ohje

Haku  
Kappaleet  
Ostoskori

Ostoskoriin	Tila	Artisti	Biisi	Albumi	Kesto
		Usher	Yeah	MP3	4:08
		Eminem	Mockingbird	MP3	4:11
		Jay-Z	Crazy In Love	MP3	4:12
		Willy De Ville	Hey Joe	MP3	4:14
		Hurriganes	Roadrunner	MP3	4:16
		Bloodhound Gang	Uhn tiss Uhn tiss Uhn tiss	MP3	4:19
		Aventura	Obsesion (No Es Amor)	MP3	4:23
		Eminem	Ass Like That	MP3	4:24
		Ludacris Ft. Field Mob	Georgia	MP3	4:24
		Eminem feat. Nate Dogg	Shake that	MP3	4:33
		Eminem	Boulevard Of Broken Songs (Oas	MP3	4:34
		Brenda Fassie	Nakupenda	MP3	4:37
		Werner	Werner , Das Muss Kesseln	MP3	4:37
		Kraftwerk	Das Boot	MP3	4:39
		HIP HOP_RAP_Eminem & Shaggy	Eye Of The Tiger (DJ Defcon Re	MP3	4:55
		Cocobau Twins	Heaven or Las Vegas	MP3	4:56
		Xavier Naidoo	Ich Kenne Nichts	MP3	4:58
		Lil John Ft. Youngbloodz & Da	Damn!	MP3	5:00
		Lynard Skynard	Sweet Home Alabama	MP3	5:00
		Bomfunk MC's	Freestyler	In Stereo	5:06
		Ella Fitzgerald	Luck Be a Lady (with Frank Sin	MP3	5:16
		Eminem	Lose Yourself	MP3	5:31
		Denigrate	Mombasa	MP3	5:32
		U2	The Joshua Tree	MP3	5:39
		Danzel	Pump It Up	MP3	5:51
		Crazy Town	Butterfly	MP3	6:12
		Flvik nreslev	A Little Less Conversation (T	MP3	6:23

Musiikkikokoelman arvioitu arvo: 155,40 €

Ostoskoriin

Vimeisin biisien haku: 02.07.2009 | Biisien määrä: 148

Figure 6. The file list view of the application

**Laila**  
Laila Ohje

Haku  
Kappaleet  
Ostoskori

Ostoskorin sisältö:

Tiedosto	Valittu tuote	Poista ostoskorista
<b>Tahdet kertovat</b> Lapinlahden Linnut - Sedät jaksaa heilua [2:41] Lapinlahden Linnut - Älä viskaa mua pihalle [3:19] Lapinlahden Linnut - Karvaisen kiitoksen metsästäjä [3:09] Lapinlahden Linnut - Ojasta noustaan II [2:34] Lapinlahden Linnut - Arvon rauha [3:21] Lapinlahden Linnut - Hellä Ulla [2:54] Lapinlahden Linnut - Ilman sinua [1:35] Lapinlahden Linnut - Otto ja pano [2:24] Lapinlahden Linnut - Ruma [2:43] Lapinlahden Linnut - Aimon virsi [3:23] Lapinlahden Linnut - Vhtaasi on kustu [3:25] Lapinlahden Linnut - Ota se ja juokse [1:34] Lapinlahden Linnut - Fantastista [3:41] Lapinlahden Linnut - Paskaaks tässä [1:48]	<b>Tahdet Kertovat</b> Lapinlahden Linnut - SEDÄT JAKSAA HEILUA [2:42] Lapinlahden Linnut - ÄLÄ VISKAA MUA PIHALLE [3:20] Lapinlahden Linnut - KARVAISEN KIITOKSEN METSÄSTÄJÄ [3:10] Lapinlahden Linnut - OJASTA NOUSTAAN II [2:35] Lapinlahden Linnut - ARVON RAUHA [3:22] Lapinlahden Linnut - HELLÄ ULLA [2:54] Lapinlahden Linnut - ILMAN SINUA [1:35] Lapinlahden Linnut - OTTO JA PANO [2:25] Lapinlahden Linnut - RUMA [2:43]	9,15 € Poista
<b>Bomfunk MC's - Freestyler [5:06]</b> In Stereo	<b>Bomfunk MC's - Freestyler [5:06]</b> In Stereo	1,05 € Poista
<b>Kraftwerk - Computer Liebe [3:38]</b> MP3	<b>Ei löytynyt osumaa</b> Koeta muuttaa biisin tietoja ja suorita uusi haku	Poista

2. Siirry osto sivulle. ->

Osta

Vimeisin biisien haku: 02.07.2009 | Biisien määrä: 148

Figure 7. The shopping basket view of the application

## 4.4 Catalogue matching server

The catalogue matching server links the user MP3 file identification (ID) tag information with the music catalogue. The music catalogue is a database or, in a simplest form, a list of music tracks with metadata. The metadata includes artist, album, duration, record label, and the duration of the track. The catalogue matching runs in a mysql database server. The music catalogue is pre-processed at the time of updates. The pre-processing is carried out as inverse indexing (Lee et. al. 1996). The occurrences of a word in the catalogue items are listed per word (Brin and Page 1998). Figure 8 shows the flow chart of the catalogue matching algorithm. The search term, e.g. track name of the song, is broken into search words. The words are processed in order of rarity, the rarest words first. The catalogue items that match the word are stored, and the search continues until there is a unique catalogue match per item or a reasonably short list of matches.

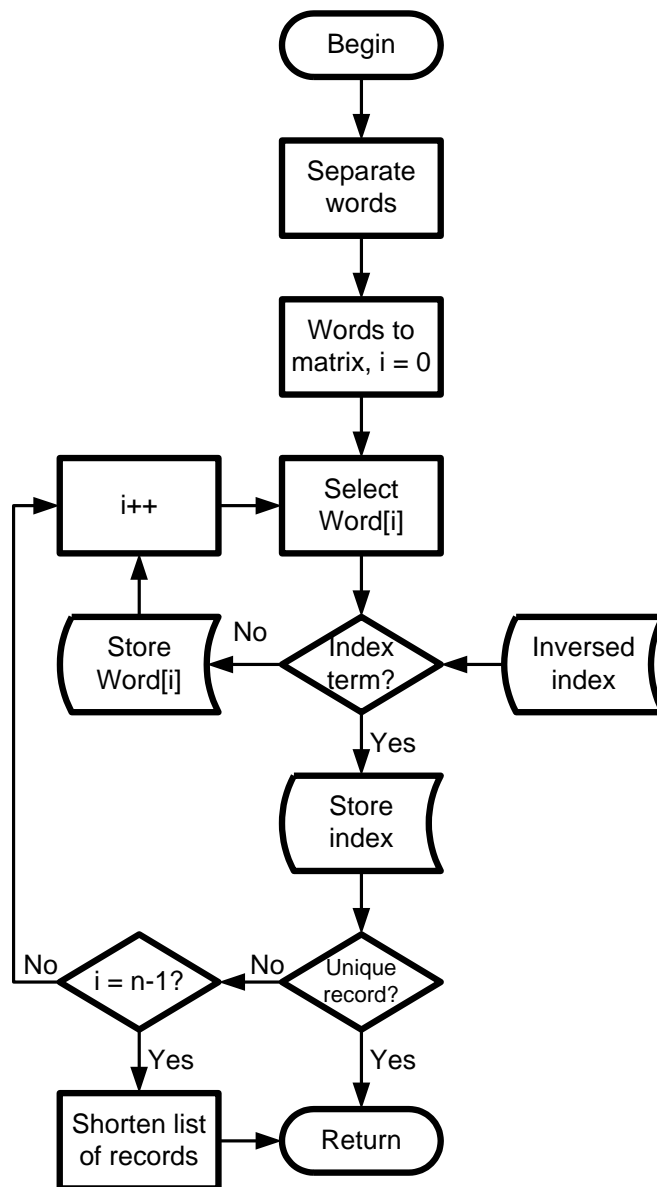
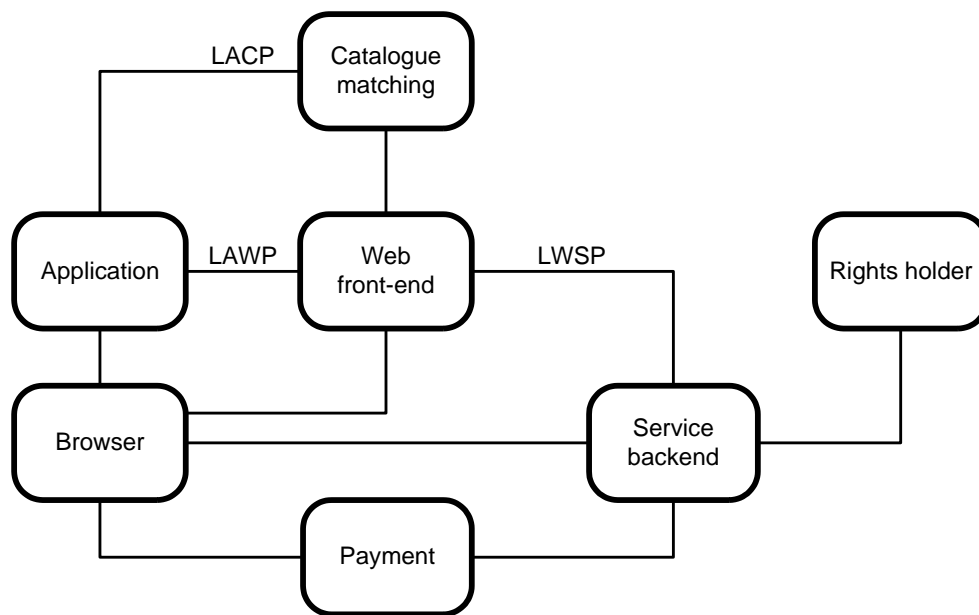


Figure 8. The flow chart of the catalogue matching algorithm

## 4.5 Protocols

The following post-payment protocols are described in this chapter: Laila Application Catalogue matching Protocol (LACP), Laila Application Web front-end Protocol (LAWP), and Laila Web front-end Backend Protocol (LWBP). The protocols are implemented with Hypertext Transfer Protocol (HTTP) Post messages. All protocols follow the Extensible Markup Language (XML) format. The Transport Layer Security

(TLS) protects the protocol messaging. Each message has a Hash based Message Authentication Code (HMAC) value ensuring the integrity of the message contents. The network elements use fixed Internet Protocol (IP) addresses, and the communication is only allowed from those pre-defined addresses. The post-payment applications in the user clients can have arbitrary IP addresses. The protocol architecture can be found in Figure 9.



**Figure 9. The protocol architecture**

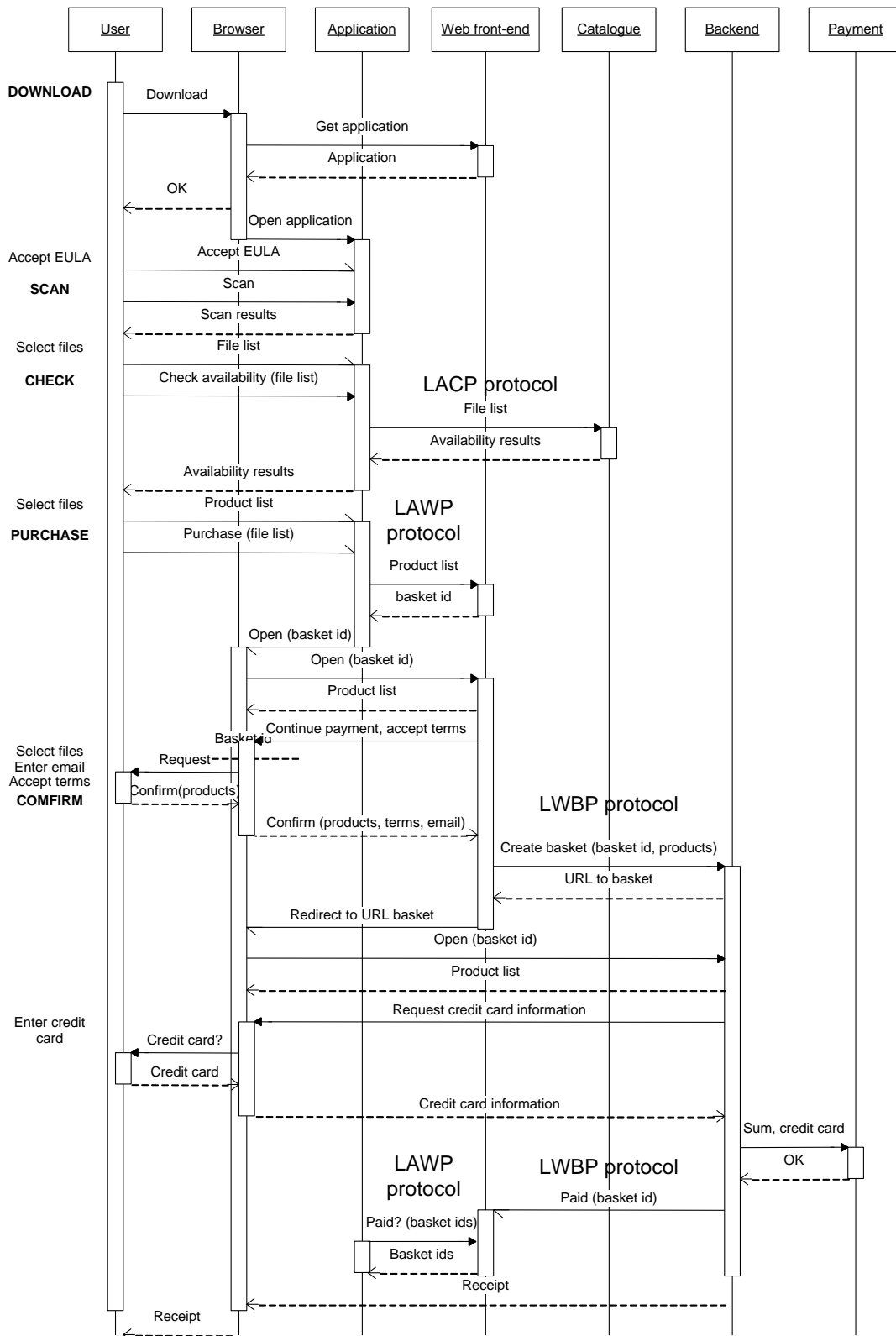
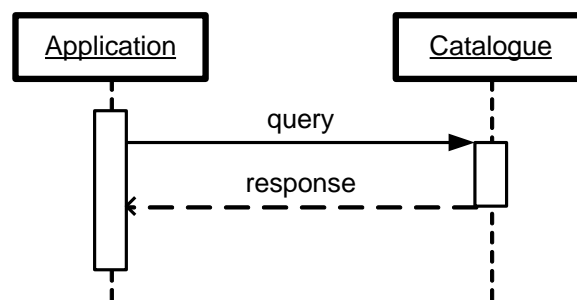


Figure 10. The UML Message Diagram for a successful payment in the post-payment service.

Figure 10 shows a Universal Model Language (UML) Message diagram of a successful payment of the rights in the post-payment service. The user experience of the post-payment service begins by getting a link to the post-payment webpage through a click on an advertisement, on a link on another webpage, typing it, or finding it through a search engine. On the web front-end, the user gets information about the service, but in order to proceed, the users must download the application. With the application, the user scans for MP3 files in the file system. After the scan, the files are listed on the user interface of the application. The user selects the files with which he wants to proceed. The information about the selected files is sent to the catalogue matching server. The server compares the file information to the catalogue information and suggests the best matches in the catalogue. The list of the catalogue items forms the shopping basket. The user is requested to give an email address to where the link to the receipt is sent. The user edits the shopping basket contents and continues to the payment. The payment takes place by using online banking or a credit card. After a successful payment, the user is directed to a webpage containing the purchase receipt. The link to the receipt page is also sent to the given email address. The user may print the receipt at anytime.

The post-payment application sends the file information to the catalogue matching server and receives the catalogue information about the files. Figure 11 shows the message exchange in the LACP protocol.



**Figure 11. The LACP protocol**



**Table 2. An example of an LACP query message**

```

<?xml version='1.0' standalone='yes'?>
<query>
  <items>
    <item id="17">
      <artist>Apulanta</artist>
      <title>Valon juuri</title>
      <album>Kiila</album>
      <length>254</length>
      <hash>74f8c0fe9958753e710745d88e9b467f</hash>
      <filter>2</filter>
      <path>C:\Music\Apulanta - Kiila\04 - Valon
        juuri.mp3</path>
    </item>
  </items>
</query>

```

The track or album is described with ID3 tag information containing the artist, track name, album, and length in seconds. A hash is calculated from the music file in order to accelerate the matching of the same track in future matching requests. The illegal indicators found are sent in the filter field. This information is used to research and develop the illegal matching algorithm further. An example of the query message can be found in Table 2.

The response to a found query item includes the same fields as the request. Additionally, it has item IDs of the track and the album in the database, and the price information. If the query item is not found, the contents of the item field are returned empty.

The LAWP protocol exchanges shopping basket information between the post-payment application and the web front-end. Because the user has carried out the catalogue matching, the information is given to the web front-end. The application stores the IDs of the paid shopping baskets on the user hard disk, but it does not store the names of the tracks. The application marks the purchased tracks by requesting a listing of the stored shopping basket ID contents. The message exchange diagram can be found in Figure 12.

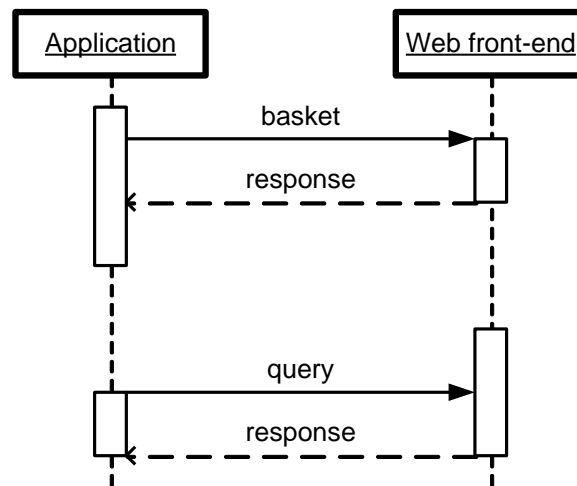


Figure 12. The LAWSP protocol

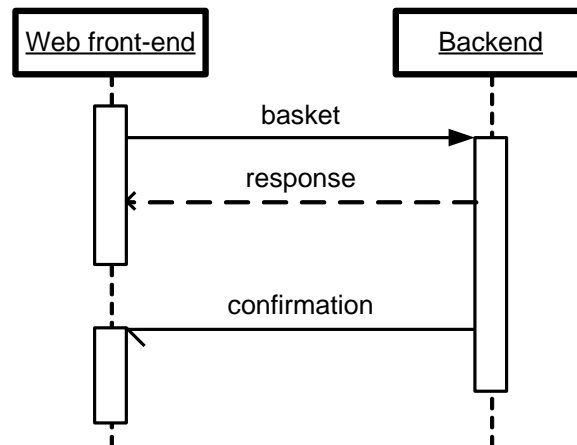


Figure 13. The LWBP protocol

The web front-end and backend exchange the shopping basket information using the LWBP protocol. The protocol message sequence chart can be found in Figure 13. The service backend saves the shopping basket, then creates a unique Uniform Resource Locator (URL) which leads to the basket, and sends the URL back to the web front-end in the response body with a HTTP status code 301. The XML element of the basket message is described in Table 3. The web front-end redirects the user's browser to the given URL, and the actual payment process may begin. The URL contains a hash of the unique basket ID to be sure that users cannot manipulate requests manually. After the user has carried out the payment procedure, the backend sends a confirmation message

to the web front-end including the status of the action: OK or FAIL, with error messages in the latter case.

In addition to the LWBP protocol, the music catalogue is updated at the web front—end - backend interface. The music catalogue is transferred as a text file using Secure Copy Protocol (SCP) protocol. Most updates to the catalogue take place with diff and batch functions, but also an update to the whole catalogue is possible.

**Table 3. The XML element and attribute values of a LWSP basket message**

<b>Field</b>	<b>Datatype</b>	<b>Description</b>
Basket: id	INT	Unique ID for the basket
Item: type	AN: {'song', 'album'}	Type of element
Item:code	AN36	Unique ID for the item
Item: price	INT	Price in eurocents
Email	AN255	Email address of the user
Hash	AN255	HMAC hash from the parameter values

## 5 Research results

This chapter summarizes the results of the articles in the dissertation. All studies involving users or a specific geographical context e.g., the selection of the jurisdiction is carried out in Finland. The results are Finland specific, and the applicability to other geographical areas should be studied separately. The primary target users in the questionnaire studies and in the laboratory tests are users of peer-to-peer applications. Only in the laboratory tests, are the users specifically selected from the target group. Otherwise, the experiments and questionnaires are available for everybody. As a result of advertising and the service appeal to the target group, P2P users are more strongly represented than in the general public. The results do not represent the behavior or opinions of all Finnish citizens, but they describe the target group characteristics.

Music services change very fast due to the revolutionary state of the industry and the fast pace of new business model experiments. Peer-to-peer applications come and disappear rapidly as the copyright holders fight against illegal copying through litigation against peer-to-peer services. These rapid changes limit the applicability of the results from a time perspective.

The content type in this study is music in MP3 format. It is the most commonly used digital music file format. The other music formats can easily be supported as long as they have a metadata structure containing information like a track, album, and artist. The idea of the post-payment service itself can in principle be applied to videos, games, books, and to any content that is sold in digital format, but many limitations apply in those cases. The recognition of illegal content is only partly applicable. The metadata is in different format. The copyright payments may have a totally different structure and value chain. The post-payment system has to be separately adapted to other content types, and that is outside the scope of this dissertation. Software piracy has network effects and videos are generally not watched so frequently as music is listened to. Compared to music, the value of the videos decreases faster after watching and the post-

payment value decreases at a similar rate. As the post-payment system does not transmit content files, the file size does not have a significant impact on the service. The file size affects two things in the post-payment system: the time it takes to scan the directory and to find the metadata in the file. Both of these times are increased by the file size. But the impact is small compared to the time taken for transmitting, copying or storing the data files in the system. On the contrary, if someone had downloaded a large file earlier, he might afterwards be reluctant to do it again from an online store.

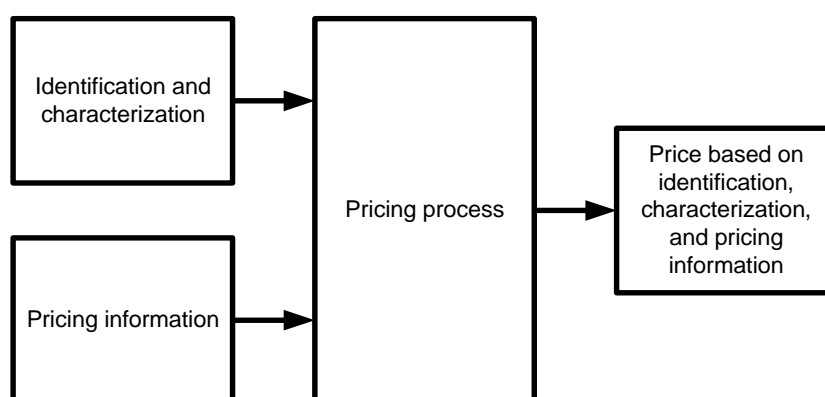
## **5.1 Technical validation of concept**

Article I introduces the post-payment concept for the first time. It opens the stream or research presented in this dissertation. The results of the article are the basic characteristics of the system. The post-payment concept addresses the issue of the rights holders. They have strict requirements on the content delivery system and the concerns that the newly introduced systems will increase illegal copying. On the other hand, the users are used to DRM free content in CD, MP3, and other music formats. The post-payment system offers a method to have DRM free content without increasing the amount of illegally copied files. The system provides the rights holders with a way to create revenue from the content that is otherwise outside the rights holders' control. The tools for the post-payment system are content selection, characterization, identification, pricing, and payment.

Article I partly describes a more detailed system than was implemented in this thesis. The differences are related to content identification, characterization, pricing, and content marking. The demonstration implementation was simplified as far as possible, and some of the advanced features of Article I were left out. The identification describes the process of determining the name of the content with high confidence. In addition to utilizing the track name in the metadata, Article I proposes numerical characterization such as content hashes, the file size, or the length of the content. Fingerprint identification is a technically sophisticated method. The application calculates the

fingerprint of the media file with an Open Media Fingerprint Architecture and gets the identification from the MusicBrainz identification database. The characterization of the content becomes important when the content price depends on the quality of the copy. In the demonstration implementation, only one price was used. With characterization and quality based pricing, the content price may depend for instance on the version of recording, track length, bit rate, coding method, or number of audio channels. The content marking serves two main purposes: proof of the payment and minimizing double payments. The receipt for the purchases is the primary proof of the purchase, but it can be supported by altering the content or metadata of the file so that the payment can be verified later. Similarly, the principal way to avoid double payments on a file is to match the possible user account or the client software with the data on a server or in a log file stored on the local hard disk. By checking the modifications of the earlier payments, the scanning process can be sped up and double payments can be avoided. The pricing process can be found in Figure 14.

The client software scans for the illegal files on the user hard disk. The user selects the files to be paid. The service is accessed using the client software of the terminal. The characterization and identification service determines the catalogue name of the file and characterizes its quality. Based on the item and the quality, the pricing system returns the price to the user client. In this way, the payment system helps the user in the final payment for the rights.



**Figure 14. The pricing process in Article I**

## 5.2 Consumer behavior

In the questionnaire research of Article II, 86 % of the respondents said that downloading content that is put on a peer-to-peer network without the rights holders' permission is not legal. The users understand that making illegal copies is against the law. The risk of getting caught when copying illegally is considered low, see Figure 15. The questionnaire subjects feel that it is 10 times more probable to get caught traveling without a ticket or parking without paying than for illegal copying. Winning in the national Finnish lottery is the only one with the same subjective probability level.

Post-payment has the second highest level of interest among the requested list of new music services, below that of the monthly paid music service where the downloaded files can be kept after quitting the service, see Figure 16. Over 40 % of people were willing to pay for the monthly paid service while over 15 % of people said that they were very interested and willing to pay for the post-payment service.

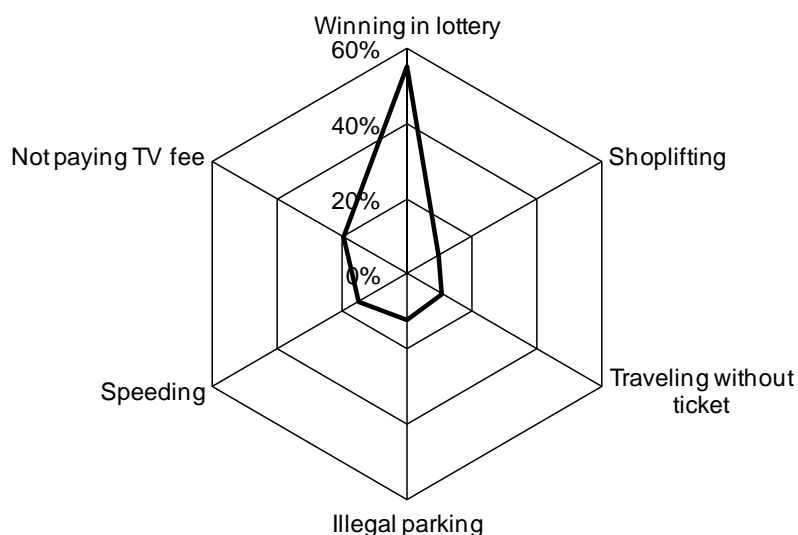
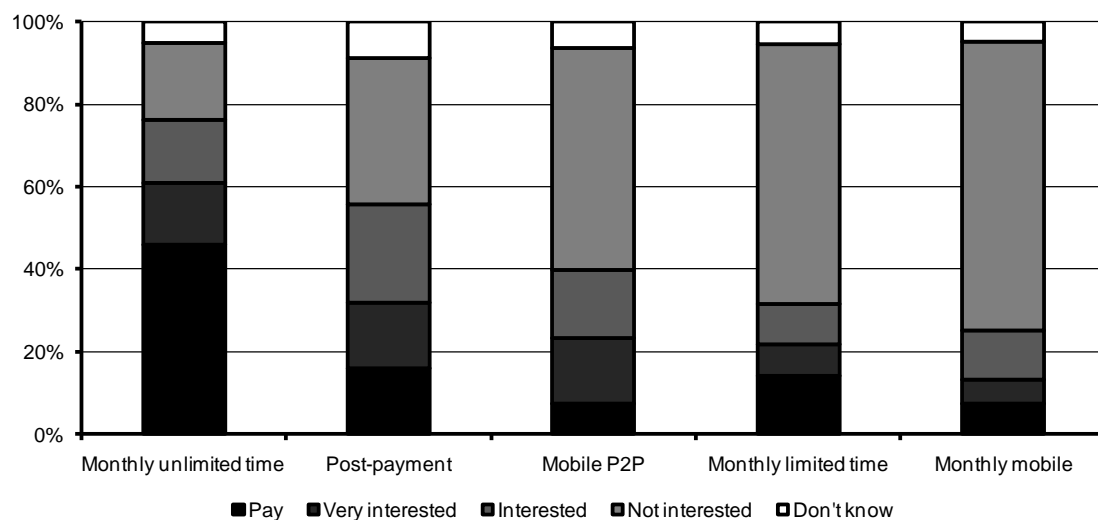


Figure 15. The subjective risk of getting caught when copying illegally compared to a few other

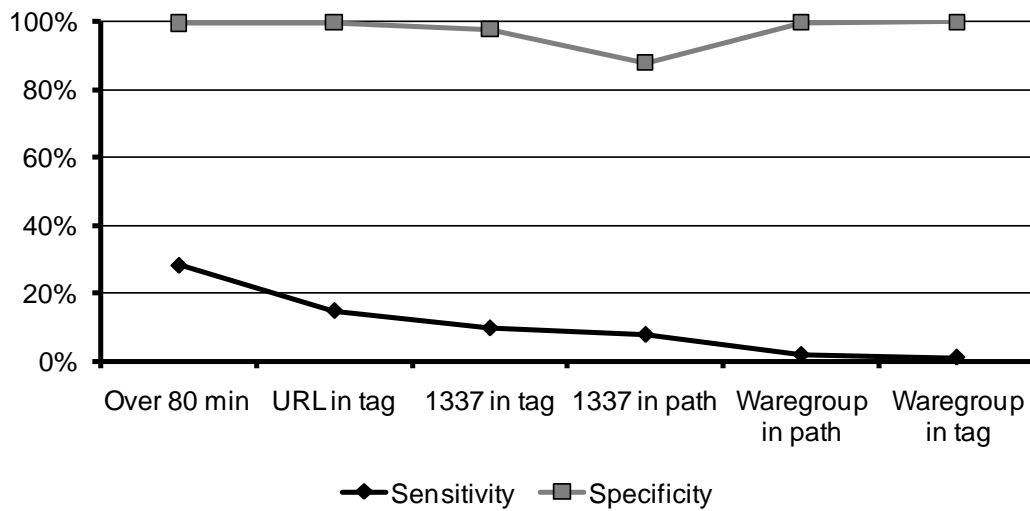


**Figure 16. How interested the users were in the selected new music services in Article II**

### 5.3 Indicators to recognize illegal files

In the forensics research paper (Article III), we introduce methods how to indicate illegally copied MP3 music files on the user device. The methods are based on the file indicators, directory indicators, and album indicators. Accurate methods like ware-group related metadata in the file are present only in a limited amount of files, see Figure 17. The most commonly found indicators are related to the way the users store the copied files in the file system. The group is best represented by the indicator showing whether there are more than 80 minutes of music in a directory. The waregroup names and URL in the metadata or file path have practically 100 % specificity. The 1337, pronounced leet, words mean that alphabetical characters are replaced with other characters such as numbers in the words. The low specificity numbers are a consequence of the non-optimally working algorithm used to recognize the 1337 words.





**Figure 17. The sensitivity and specificity analysis of selected indicators in Article III risks and probabilities in Article II**

It is not possible to differentiate illegally copied files from legal files with full certainty. Due to that, the recommendation is that these indicators are only there to assist the consumer in his selections and decisions. The consumer has the final responsibility for the copied file. In the classification phase, the DRM protected files are always considered legal. In Finland, personal copies are legal if they are made from a legal source. In most cases, if the person has had the hold of the original CD, from which the copy has been made, the copy is legal. The principal purpose of the indicators is to differentiate, which files are downloaded from peer-to-peer networks. The presented indicators have difficulties if the files of a CD have directly been put to a peer-to-peer network without any modifications after ripping. In practice, there often are changes in the files between ripping the files and another person downloading those files.

#### 5.4 Contracts with rights holders

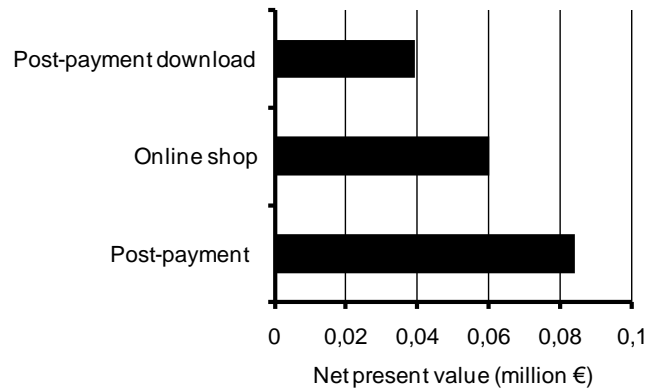
The result of the legal study is that freedom of contract prevails. The result is valid with the following assumptions: the contract is made between the rights holder and the infringer, and the offense is not subject to public prosecution, but to a plaintiff or a civil sanction. The terms of the contract can be negotiated between the parties of the contract.

In Article IV, we recommend at least the following issues to be covered by the contract: the service should cover file downloading, illegal copying, and file sharing related to downloading of published content, excluding uploading content as the first peer to the network. Due to the global reach of the Internet and practical difficulties in restricting downloading and sharing geographically, we recommend that the service would be free of regional marketing restrictions. The amount of content is probably the most important single factor in the service. The contracts with the rights holders define the available content. In the music business, rights holders are typically represented by record companies and composers' copyright societies (Teosto in Finland). The contract negotiations must be successfully completed with both groups before the service operation.

## **5.5 Competitive enhancement to online stores**

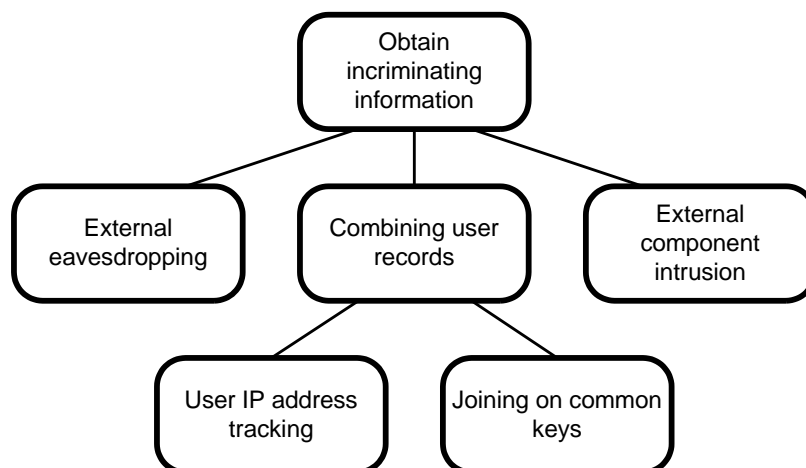
The qualitative analysis with STOF results in identification of the relevant partners and a working business model. The critical success factor study reveals that the service rollout may have a strong impact on post-payment success. The main challenges in the post-payment system are a low value for the customers and a low customer retention rate. Service bundling with online music is a potential business proposition.

The results of the Net Present Value (NPV) analysis are shown in Figure 18. The NPV is the profit gained by subtracting operating expenses, capital expenses, and taxes from the revenue; and taking the impact of time on the value of money into account. Article V compares three possible systems against each other: the post-payment, a normal online music store, and a download post-payment system, where the user replaces the illegally copied files with legal files. The results indicate that the post-payment scenario is more profitable than the online music store or the post-payment system with the download enhancement.



**Figure 18. The net present value in Article V**

The privacy in the post-payment copyright system is an even more sensitive issue than in typical Internet services, because the post-payment copyright system handles privacy information, which may be used as evidence against the user in copyright litigation processes. It is very important for the user to understand what information is collected, communicated, and stored in the system. The system must also be protected against possible intrusion and misuse scenarios. Figure 19 depicts the attack tree analysis of the privacy threats in the post-payment system. At a high level, the threats are divided into external threats and combining user information from different sources.



**Figure 19. The attack tree analysis of the privacy in the post-payment system in Article V**

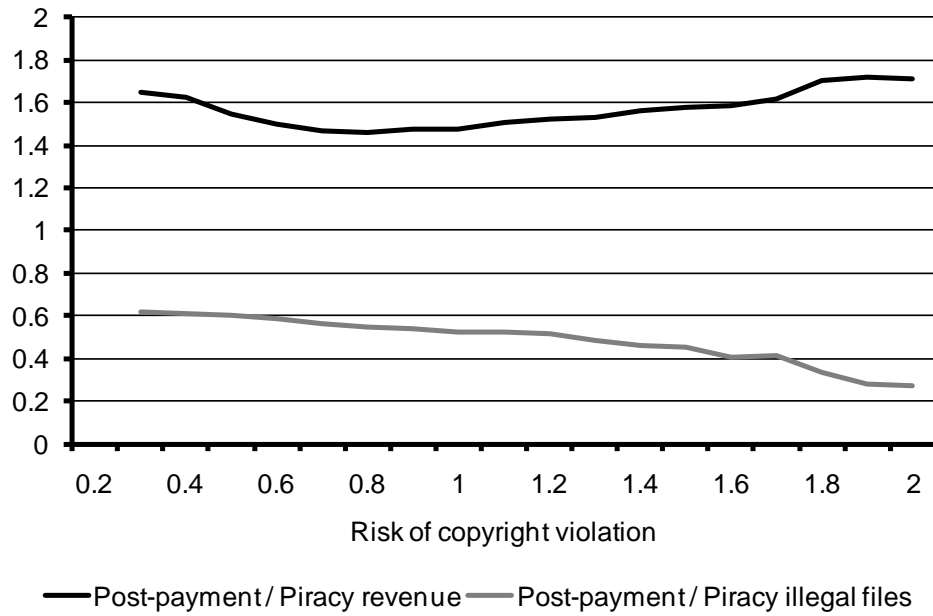
## 5.6 Increase in revenue and decrease in illegal files

The post-payment decreases the number of illegal files compared to a situation where piracy is widespread. It also increases the rights holder revenue. When the risk of consequences for illegal copying increases, the effect of the post-payment increases compared to piracy, see Figure 20. The post-payment boosts the anti-piracy actions of the rights holders. The revenue is over 45 % higher than without the post-payment, and the number of illegal files drops roughly 40 % or more compared to the plain piracy situation. The risk level must be considerably high before the post-payment can bring benefits.

The service provider has to be able to motivate the users to legalize their files. In Article VI, the reason for legalizing is risk optimization by the consumers. If they feel that there is a considerable risk of getting caught, they will try to reduce the risk, for example, by using the post-payment system. Other reasons include making the correct moral choice, and avoiding the related risk of making bad moral decisions, a general feeling of good induced by doing things that a person knows to be correct, showing an example to family, friends, or colleagues, and social pressure when the post-payment becomes business as usual.

We are not aware of any studies, which report the value of the illegal files on the users' hard disks. That total value describes the market potential of the post-payment system. Cisco (2010) estimates the global Internet traffic to be 15 exabytes per month in 2009. According to the Ipoque study (2009), peer-to-peer generates 43 to 70 percent of Internet traffic throughout the world. A study of Felten and Sauhard (2010) estimates that 99 % of the bittorrent files are copyright infringing. In the sample, music has a 10 % share of the traffic. If we estimate that a music track has a 1 € value and its size is 5 MB, the global market potential of post-payment for 2009 music p2p downloads alone is 1 780 billion €. Part of the calculated p2p traffic is not illegal, part of the calculated traffic is not stored, many of the consumers will not legalize their songs, and those who

legalize, do it only partially. Nevertheless, even with these restrictions, the market potential of the post-payment is significant for the music industry.



**Figure 20. The post-payment revenue / piracy revenue and number of illegal files in the post-payment / illegal files in piracy as a function of the illegal copying risk in Article VI**

## 6 Conclusions

The post-payment copyright system decreases the amount of illegal music files on user devices, and it increases the revenue of the rights holders. The post-payment system can successfully be applied in an environment where the risk level of consequences for illegal copying is substantial. The risk level is maintained with anti-piracy actions. The higher the risk level, the more relative benefit the post-payment can bring to the rights holders. The post-payment is a tool for the rights holders in their anti-piracy campaigns. It is a potential source of additional revenue for the online music business service providers, and it is a service for the users to clear their digital music of copyright violation risks.

My results are in-line with Rob and Waldfogel (2006) that piracy decreases the rights holder revenue, but they contradict the results of Oberholzer-Gee and Strumpf (2005). My statement that anti-piracy actions decrease the amount of illegal files is supported by Hill (2007). The need for new anti-piracy methods is expressed by Sinha and Mandel (2008). According to them anti-piracy is a strong deterrent for certain users, but it can actually encourage more piracy in others. Similarly, Nandedkar and Midha (2009) explain the paradox that piracy continues despite the increased anti-piracy actions by using a concept of optimism bias. Chiang and Assane (2007) find that although the users respond to the enforcement actions, the actions are not enough to reverse the tendency to piracy. The post-payment could be a solution to boost anti-piracy actions to a satisfactory level.

The post-payment is a new business model for the challenged music industry. The industry needs to try out many new models until business becomes satisfactory. An enormous business potential lies in the illegally downloaded files on the user hard disks. If that potential can be turned into a business as is suggested with the post-payment, even a small part of that potential creates a considerable opportunity. The current online piracy situation is far from satisfactory from the rights holder perspective. Though it has

been shown that the users respond to anti-piracy actions, piracy seems to continue. The rights holders need to try out new methods, one of them being the post-payment, to get online piracy under better control. The challenges of the post-payment system are a low value proposition for the user and low retention rate. The value of the post-payment grows, when the risk level of the copyright violation increases. Bundling the service with an online music store will decrease the post-payment service provider dependence on the retention rate. The nature of the system, however, means the system will face a privacy challenge. The challenge can be dealt with by implementing the system with care and by communicating the privacy issues properly to the users.

A service trial would ensure more visible changes of the music copyright in the society, and it would increase the value of the developed software and Internet services of the thesis. The recommendation for future research is to utilize deduction to confirm the theory developed in this thesis. The method could be to carry out consumer studies in which the willingness to pay in the post-payment is explored. When the post-payment system is in commercial use, it would be interesting to measure its practical impact on the rights holder revenue and on the amount of illegal copying, and to compare it to the theoretical results of this dissertation.

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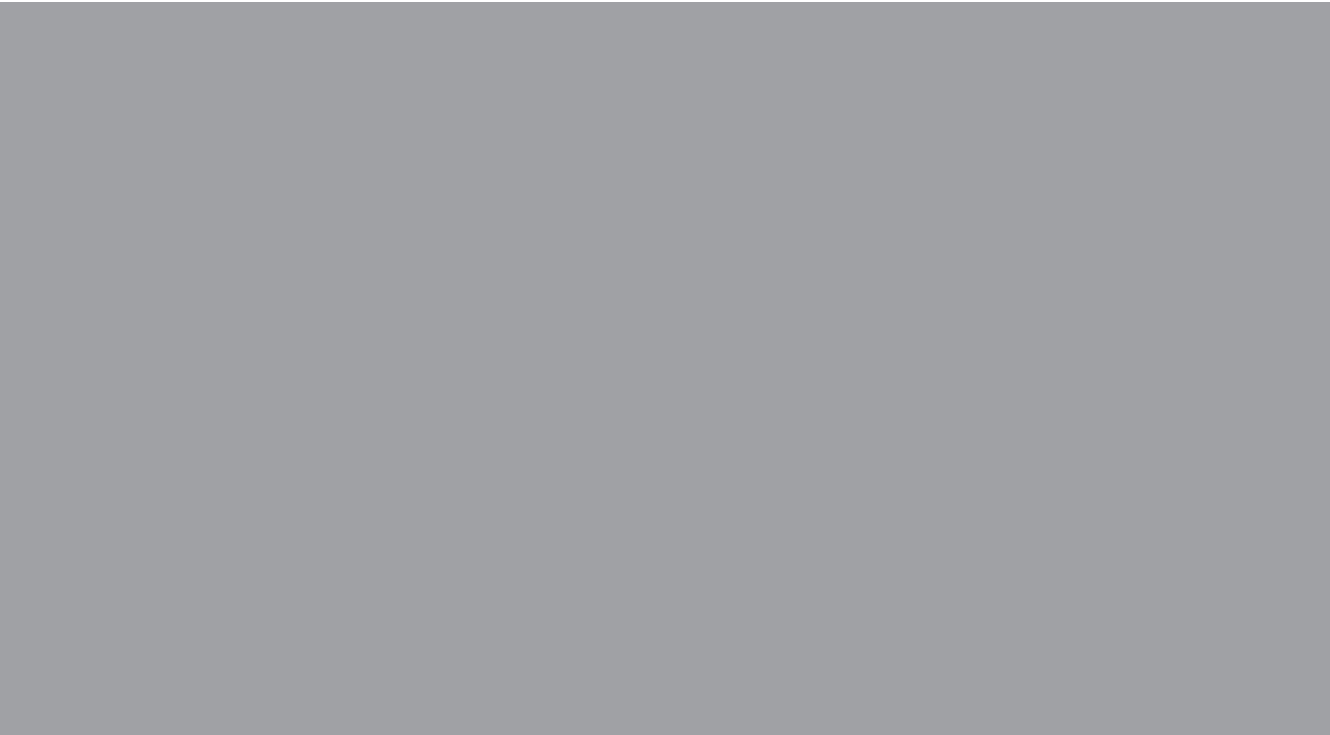
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ISBN 978-952-60-3492-8  
ISBN 978-952-60-3493-5 (PDF)  
ISSN 1795-2239  
ISSN 1795-4584 (PDF)