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Piracy in Musical Audio-Visual Production and Distribution: A Forensic Engineering Calculus Approach for the Economics of Deregulation

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Abstract— The last few years has been recorded an uncontrollable increase in music distribution over the Internet. This phenomenon is common in many countries and therefore involves many issues such as: Methods for distribution, music production organization, copyright issues, file and media formatting at the final stage for the audiovisual products to be circulated. The revolution in music prototyping (especially the MP3 music format and the MPEG-4 combined audio-video type for archiving) urged many people to turn to the Internet for free and easy-to-find music. Music files can be downloaded easily from the Internet anywhere in the world and be burned into a CD or DVD or transferred to a friend via USB sticks. Music is also widely available as streams in Internet through various services such as MySpace, YouTube and iTunes. Internet also is full of questions on what is legal and what is not, because the phenomenon of massive file exchange is hard to supervise and the laws valid in assorted countries diverge. Mathematical modelling of illegal distribution can be used for providing forensic services in an attempt to distinguish facts from speculation, evidence from erosive communication and trafficking. The technical, social, financial and legal parameters of this battlefield are examined in this paper under the prism of networked economies.

Keywords— Music and Video Broadcasting & Distribution; Piracy; Deregulation; Economics; Trafficking; Forensics

I. INTRODUCTION

The last five or six decades music recordings and productions worldwide have created a vast collection of high quality music resources, which lie interspersed in different media on earth. Several years ago, it would imagine impossible to organize suitably and make accessible to any interested user all this huge volume of music data. However, with the advent of new technologies, the digitization of sound gave new perspectives and capabilities to the music community. The growth of Internet, the small (in size) digital music files, the disks of enormous capacity and the development of computer music have led scientists to focus their efforts in organizing huge music collections, which are accessible via the Web. Digital Music Libraries offer their users new ways for interaction with music repositories and music stores online. Some of the capabilities of Digital Music Libraries are: classification, filing and sharing of music, Music Information Retrieval, aka MIR, etc.

On the other hand, a problem of our times, accelerated by the recent advances in technology, especially in the socially networked world, is the plethora of music streams, usually defined as *pirate emissions*, while the equivalent in classic television broadcasting is frequent and uncontrollable advertisement, both bombarding en-masse, uninvited, and with obtrusive persistence a significant portion of our everyday lives.

It is obvious that music is flooding the social dimensions of our everyday life virtually because it is a commodity of nearly *zero cost*!

Advertisement (with music investment), perceived as an expression and factor of the economy, is legitimate and desirable, but abusive practices cause multiple damage: invasion in our private communication space, homogenisation of morals and customs leading to globalized over consumption, and serious damage for the recipients, the legal advertisers, and the working population in communication services.

The conversion from analog to digital music brought revolutionary changes to the world of discography, to the way artists perform, to the resources with which audiences receive artistic content, and to the methods the telecommunications sector intervenes with the socioeconomic factors for audiovisual interaction. Indeed, as the article will exploit further, entertainment relies henceforth heavily on the way users interact with the Internet and how the mass media interface is manipulated. For starters, the digital format of music led to the necessity of creating enormous music libraries in the Internet, which provide the user with great possibilities for acquiring and listening to music. Inevitably, this development brought to surface copyright and legality issues because of the several services that offered free delivery of media content.

Of course, piracy is not confined to music file distribution; on the contrary, the most recent trend spotlights on cinema paraphernalia, provoking shimmers to an industry that considered its possessions beyond the limits of the shoot. However, we will commence our survey from on-line music illegal trafficking since

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a. It has been around for more than a decade and we can morph easier the parties involved.
b. A milestone legal action, that again Napster, has reshaped the music industry and still conducts the attitude towards persecution mechanisms.
c. Music files have by far smaller size than their equivalent video files; therefore, if the proposed model works on cases with significant discretive efficiency, it will be fail proof more or less on any case brought to litigation. The reciprocal, however, is not guaranteed.

Until now the dictating rule was that a person could transfer a music file to anyone else with impunity, unless the content runs foul of some content-regulating law. The new initiatives seek to promote ways to restrict exaggerations of electronic publicity so that the recipient-consumer does not become part of a massive network that easily participates in extended music trafficking.

The reason that in this paper music is convolved with television broadcasts is this: increase in broadband speeds has recently allowed the appearance of massive piracy mechanisms for film trafficking; with not considerable effort, the same technological provisions cover fraud, illegal broadcast, or other computer crimes. In general, file circulation that has as primary purpose product marketing or service duplication via trafficking, seriously undermines good commercial communication and secures bankruptcy of audio-visual industry producers, at least at local level.

It should be noted that litigation on illegal trafficking is sometimes problematic; laws are uneven over jurisdictions, and it is often hard to find the intruder. It is estimated that 90% of trafficking is committed via computers that cannot be personified. Moreover, bulk-file software has clever ways to get around built-in controls in messenger services by rotating the names used to broadcast pitches, or by generating new ones when old ones are "killed" [1].

On the socio-economic part, the advent of music piracy has caused deregulation both in financial terms as in provisional regulations for Internet trafficking. Although, as we will see, "piracy" does not have only evil aspects, it is an insidious malady over the backdoors of the Internet, afflicting the economies of the networked industries.

II. TERMS AND DEFINITIONS

Music can be found circulating in three, at least, major stockpiles: digital libraries, torrent network seeds, and streamlines within the cloud.

A. Digital Libraries

A library is defined as a catalogued repository of mass-produced physical objects (books, journals etc). It is local and generalized and is supported as a line item in an agency, institutional or corporate budget. It is a specific place with a finite collection of tangible information and it is geographically constrained [2].

However, things have changed and nowadays, besides the conventional libraries, another source of accumulated knowledge has become available. The enormous amount of information that exists on the Web has transformed it to a universal public information repository. Digital libraries are a set of electronic resources and associated technical capabilities for creating, searching and using information. In this sense they are an extension and enhancement of information storage and retrieval systems and support the analysis and processing of information [3]. The content of digital libraries includes data, metadata that describe various aspects of the data (e.g. representation, creator, owner, reproduction rights) and metadata that consist of links or relationships to other data or metadata, whether internal or external to the digital library.

Digital libraries are constructed, collected and organized, by (and for) a community of users and their functional capabilities support the information needs and uses of that community. In this sense they are an extension, enhancement and integration of a variety of information institutions as physical places where resources are selected, collected, organized, preserved and accessed in support of a user community.

A Digital Music Library (DML) is a digital library for music content. DMLs have the following features:

I. Digitized materials are delivered over a network (not always over the Internet)
II. They use technology to allow easy access to the material
III. Contents are stored as stand-alone collections
IV. Allow for simultaneous retrieval of information in multiple formats (audio, visual, textual)

A DML requires addressing complex issues of description, representation, organization, and use of music information. The fundamental question to be addressed is the nature of associations that exist among various types of musical objects.

Perhaps the most successful brand name, the canopy for Digital Libraries is iTunes. iTunes is a digital media player, created by Apple Inc., which can be used for organizing digital music and video files. The application also comprises an interface for managing the popular devices of the same company: iPod and iPhone. Moreover, iTunes has the capability of connecting to the online iTunes Store via Internet for purchasing and downloading of music, videos, TV series, applications, iPod games, audio books, several podcasts and ringtones. If we consider strictly music, then iTunes is a "digital jukebox" for organizing, sharing and listening to music [4].

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Apple presented iTunes for the first time in 9 January 2001 at Macworld Expo in San Francisco. Since then it can be installed in nearly all smart devices, ranging from desktops, laptops, Mac computers, iOS and Android smartphones, to name a few. iTunes is considered to be the most popular example for a ubiquitous music repository, being indeed the global admission standard for what a DML Library is capable of handling now.

B. Torrents, Seeds, Allomorphic Networks

Peer to peer (aka P2P) is a category of computer networks that enables two or more computers to equipollently share their resources. This network exploits the processing power, the storage potential and the bandwidth of its nodes. In more polymorphic rendition, P2P nets could share cameras, microphones, sensors etc. All the participating parties have "equal" standing, hence the term "peer". Presumably they equally split the burden of any ethical aberration. Information that is located on node *n*, depending on predetermined rights when forming the network, can be accessed from all the other *n-1* equipotent peers, and vice versa.

Three categories of P2P networks can be readily discriminated as frontline players of the game:

Centralized P2P networks

Many refer to these as "first generation P2P networks". In such an arrangement, a central Index Server is the essential hub where information is located, in some kind of lists, about the content that participants wish to share. The users can query their Index Servers on files they seek for, using a suitable client program. When the desired file is found, a network connection is established between the two interested parties for data transfer. Brand names that enjoyed full glare of publicity, amongst others, are Napster, DC ++, and the WinMX.

Decentralized P2P networks

Their viewpoint is completely different. Each participant to the formation comprises simultaneously a client and a server (or, as it is alternatively known, a servent). As soon as somebody is connected, a propagation mechanism is invoked: the newcomer, via an appropriate client program, denotes his presence to a rather limited number of P2P nodes; they, in turn, propagate his declaration statements even further, each to another sub network, and so on. Henceforth, very soon the entrant has the possibility to seek any information concerning the shared files over a really big network of interconnected computers, varying in time, in number of nodes, and in formations. Easily identifiable names for this category of P2P services are Kazaa, Gnutella and BearShare, to mention a few indicatively.

Third Generation P2P networks

Their main characteristic is anonymity, while label names like Freenet, I2P and Entropy had the lead role. They are decentralized, and apart from secrecy and some sort of confidentiality, they rely their high viability on a constantly reshaping mechanism that reshuffles the sharing scheme, which frequently changes, along with their encoding methodology. Virtually, no one can easily have control of the files shared, nor he can visualize the morphing network. This type of file sharing is the dominant paradigm nowadays, mutating constantly the functional characteristics and revamping rather frequently the P2P net brand names, for the fear of persecution. Indeed they are "small World Nets" within the Internet.

It is generally acceptable that the use of such networks links users from all over the world, functioning without *censorship*, border controls or barriers, promoting the basic idea for a world network within the web, an advocate for free thinking; simultaneously the delivery of free consultation and the unlimited circulation of support services are promoted. These services may encompass a wide variety of software utilities, audiovisual learning objects, or heaps of textual information.

From the user's point of view, P2P networks have a rather simple interface to use and navigate in an ocean of information; maybe it's not the best way to plot a route or contrive reliable workflows, but the participants may be rewarded by downloading material with considerable added value at *zero cost*! Additionally, they partake in colossal formations, dynamically expanding day by day, whose content is calibrated and directed by the constantly increasing user participation.

From the other, P2P networks render the possibility for an unlimited carbon copy and distribution between users of files, as songs, films, and software, which bear more or less explicit intellectual property protection. The holders of these intellectual rights usually do not consent to the unlimited circulation of their property. Therefore, the wide use of such networks has acquired them the synonymity of "illegality" and characterizes them as the most prominent doorway to the "deep" Internet.

C. Streaming Media

Although hanging around for a while, streaming media appeared in practice when personal computers gained considerable processing power and bandwidth. The boom decade was the 1990's. Indeed, back in 1993, an Australian rock band named "Severe Tire Damage" was the first group performing live via the Internet for a global audience.

Since then, technological advances have propelled audio, and recently video streaming, at unparalleled levels. Some facts give the big picture:

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- Constant Internet access is required; when geographical dispersion is involved, for instance when the user is commuting, a 3G mobile network is required. With 4G increased speeds are expected to be met, while costs are due to cast down.
- High quality radio stations broadcast at 128KBps at least.
- Some indicative average Internet speed test figures [5]: at the high end, South Korea with 21.9 MBps; at the lower end, Bolivia, just beyond 1.1 MBps; Estimated global speed: 3.9MBps; Greece, just beyond 4.9 MBps. Obviously, these performance characteristics depend not only on technological investments, but also on the geographical dispersion for each country. By any means however, web radio standards are surpassed globally by far.
- It is estimated that with a minimum threshold reception rate of 200 KBps, smartphones outperform classic radio reception in interactivity and sound quality, not to mention geographical distribution.

This class of media is descriptive for all forms of multimedia content transcription. Therefore, television broadcasting currently includes, in particular, analogue and digital television, live streaming, web casting and video on demand, the thriving audiovisual media service. Their main difference with classic broadcasting is that the client media player, usually a piece of software, may begin the reproduction of data (as is a film or a piece of music) without having to transmit the entire file.

A lot of music is available in the Internet through streaming also. Streaming is an accelerating multimedia service that is constantly presented to the end user in real time and no files need to be permanently downloaded at the receiving computer. In this sense, its main market focus is the ever growing community of smartphone holders and 4G network users; since these devices by default have rather limited storage capacity, and tend to achieve absolute population penetration, streaming media is the enabler for ubiquitous entertainment, training, and on line learning at unprecedented levels. For instance, recently it has been estimated that there are 6.8 billion mobile phones [6], from which 3.5 billion are smartphones, and the tendency is incremental by at least 20% per annum! Indeed, the possession of mobile devices has become synonymous to existence.

Streaming media is a remarkable technology that allows a web site visitor to click on a button and seconds later listen to a sporting event, tradeshow keynote, or CD-quality music [7]. Usually, in stream based services, the files are uploaded to the media library on the services server by the users, when in many cases it is arguable whether the uploader legally has the rights to upload the piece of media in hand. Many streaming based services are internationally popular and have billions of every day users, such as YouTube and MySpace.

Also, Internet radio is mainly based on streaming. The neologism for Internet Radio alternates to web radio, network radio, streaming radio or e-radio, more or less designating a sound service which is transmitted via the Internet. It includes mainly streaming media, presenting to listeners a continuous flow of sound which may be repeated on demand. Although its progenitor corresponds to the traditional, one way radio station we all empirically recognize, its Internet based mutation includes many contiguous services that range between instant messaging, spot coverage, and interactive multimedia services.

In Fig. 1 the black columns display the monthly Internet Radio listeners, i.e. the Internet users who have listened to online broadcasts of terrestrial radio stations, online –only radio stations, or audio podcasts via any available device, at least once per month. The red line depicts the percentage between Internet users this group comprises, while the blue line shows what percentage of the total US population they represent.

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III. PROBLEM FORMULATION: CLUES, TRACES, AND EVIDENCE

The rapid Internet spread with its various possibilities, like the new coming 4G services for cheap, high speed geographical coverage for the smartphone community, has formed the landscape for an unrelenting provision of multimedia files to each user, virtually everywhere, anytime.

The first archiving format used by Internet service providers for audio transmission was the MP3 encoding scheme. MP3 is abbreviation for MPEG Audio Layer 3. MPEG emerges from the initials for Moving Pictures Experts Group, a organisation that provides international standards for digital files of sound and picture. The particular technology emerged as a patent of the Fraunhofer Institute in Germany. MP3 is at its palpable form a digital file, stored within the computer memory before being able to be distributed or reproduced.

To save space and gain more flexibility, the captured media should not have a large size. Thus, audio compression was an important pre-processing stage for creating music libraries. The basic task of a perceptual audio coding system is to compress the digital audio data in a way that (a) the compression is as efficient as possible, i.e. the compressed file is as small as possible and (b) the reconstructed (decoded) audio sounds exactly (or as close as possible) to the original audio before compression [8].

The MP3 encoding scheme was the most commonly used compression technique for music. Not exactly fully open, and proprietary, patent-and royalty dependent at some stages for the creation of audio files, it was by far the prevailing format for mid to high quality (8kHz-48.0kHz,16+ bit, polyphonic) audio and music at fixed and variable bitrates from 16 to 128 KBps/channel. Once the sound had been encoded and placed on the server, it was ready for access by the public.

One of the first MP3 oriented pieces of software for personal computers was Winplay3, introduced on September 9, 1995. Till the end of that decade, many other MP3 coding and decoding programs made their entry, although the encoding process usually involved the purchase of a codec. However, most mainstream pieces of software involved like Nullsofts's WinAmp (in 1997) and Napster (in 1999) were entirely free as far as music downloading, reproduction, and distribution was involved, and contributed to the MP3 frenzy.

Without compression an audio file would be bigger in size by a factor of 10. For example, before compression the average track from an audio CD would be some 40 MB in size, more or less, while afterwards the transmitted file size decreased to 4-5 MB without damaging irretrievably its hearing depth and richness. With MP3 technology, a computer connected with the typical 56K modem back in 1993, could download a song within a few minutes.

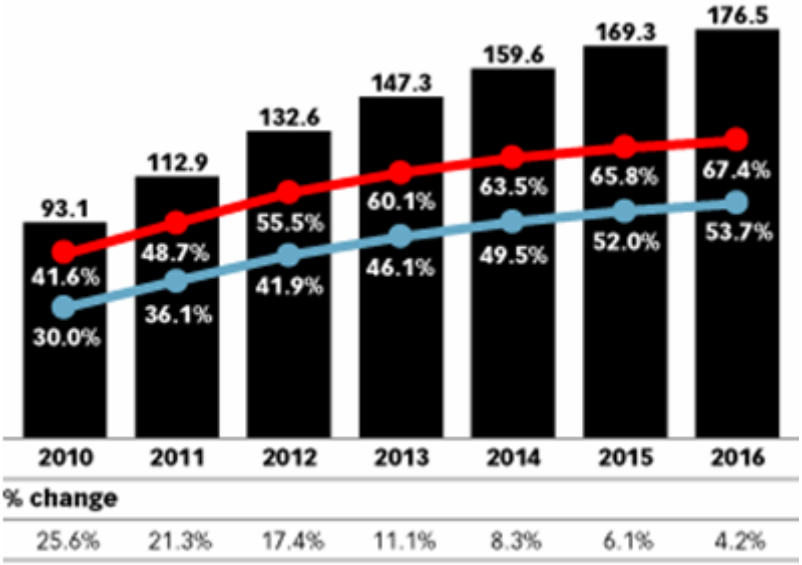

Fig. 1 Current trends for Internet Radio penetration in USA. Source: eMarketer, August 2012. Figures represent millions of users involved, and their percentage of Internet users, and percentage of total population.

Of course, such boasts impress currently nobody, and consequently MP3 is by no means the only resource for music downloading; moreover, one could note that it is not the pioneering audio format for music trafficking. However, in its diachrony, the downloading process has embraced the notion for interacting with the providing mechanism, then the Web, now the "cloud", which remains intact: you just need a few minutes to posses the desired song!

What has changed in recent years is that the average user is not confined only to audio synaesthesia, but to enhancements with advanced visual effects.

Most streaming formats allow sound to be delivered over the network at different speeds. The higher the rate of transmission, the better the sound is, since faster speeds allow more data to be sent in real time through the network, and

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the increased data sizes yield higher fidelity. Faster transmission speeds therefore advance larger sound or video files, which in turn require larger storage repositories.

Currently, the average global user can track and download within a few minutes the equivalent of an audio track in video format, with considerably optimized audio encoding; in communication terms it means we can download digital television broadcast quality streams at some 4MBps, usually in MPEG-4 format.

The MPEG-4 format commercially appeared in 2001, and a second version made its entry 2003. This encoding scheme is dominant for combined storage of audio and video signals, while being simultaneously container for collateral data as subtitles, images, and labeling information.

MP3 encoding was successful for the PC based industry, but has lost its primacy for the mobile device paraphernalia. The AAC or Advanced Audio Codec that has appeared in 1997 deploying, like MP3 a psychoacoustic model for frequency overlap, seems to perform better for audio synaesthesia. For instance, 96 KBps AAC streaming offer hearing satisfaction equivalent to 128KBps MP3. Additionally, AAC can encode signals with sampling frequency up to 96 kHz, and comes with better sound manipulation as is the adoption of Joint Stereo. In 2003 an MPEG-4 compatible ACC version made its appearance, for audio signals. This codec was popularly referred to as MPEG-4 AAC and became an imminent success when Apple decided to support it actively with iTunes. In the beginnings, Apple used to sell via iTunes all the songs with copy protection technologies, because of Digital Right Management (aka DRM) issues. The reaction of the consumers and the continuous evolution in the competitive market of digital music towards zero cost, forced Apple Inc. to remove the protection, and upgrade the encoding of the marketed songs to higher ratings (256 KBps).

Currently, the prevalent encoding for this scheme is Coding Technologies' HE AAC (for High Efficiency AAC), commonly known with its trademark aacPlus. It first appeared in 1999.

Apart from these key players worthy to mention are Windows Media Audio, Ogg Vorbis, and the legendary and once pioneer in streaming business Real Audio and Real Media technologies.

Windows Media Audio, aka WMA, is the proprietary codec for Windows, omnipresent in every Windows installation via the corresponding Windows Media Player. Alas, while it was in parallel developed with MP3 foundations, and in certain cases managed to surpass them in quality, it failed to gain market momentum and it's totally absent from the mobile device arena. Its recent versions, however, offer MPEG-4 compatibility, and amongst other features, lossless compression schemes, subtitle management, and support for multichannel surround sound.

To give a panoramic view for recent trends in media production and distribution, the Ogg Vorbis codec is mentioned, introduced back in 2000, while its first stable version appeared in 2002. This encoding scheme relies on a lossless open source algorithm marketed as Vorbis. It uses Ogg files and was developed around the xiph.org user community. The Modified Discrete Cosine Transform (aka MDCT) is used for signal transformation.

Vorbis also implements entropic encoding that supports variable bitrate adjusting on the signal's properties. The advantage of this encoding scheme is that it offers very good quality while being open source and royalties free. In practice, it can be developed by device manufacturers and the user community without any charge!

Similar to Ogg is FLAC, for Free Lossless Audio Codec, introduced in 2001. Maybe it is the most important codec of its kind, with easy access for both manufacturers and users.

Its main advantage is the handling of metadata, i.e. information about the content and the rights management of the encoded music piece. Although this produces slightly bigger files than its MP3 counterpart, FLAC files render better performances. Additionally, due to its metadata, huge audio server repositories can be readily archived, searched, and retrieved.

To keep up in competition with its rivals, Fraunhofer Institute presented a MP3 surround audio enhancement in 2004. This encoding increases file size by a mere 10%, and already companies that focus on music performance interfaces like DivX, Inc, and Magix support multichannel surround sound for home theater arrays.

Recently, as expected, more exotic encoding algorithms and protocols made their appearance, like OPUS, first introduced in 2012. Its development commenced in 2009 and was assorted with Skype. It is a lossy form for audio encoding, already certified by the Internet Engineering Task Force (IETF). It is highly interactive for real time two parties applications and can be used for recording or saving audio streams. It is not confined to Skype only; it is a freely available to serve as plug-in to browsers, communication software etc.

IV. ADVERTISEMENT - THE SOCIAL AND ECONOMIC BACKGROUND OF PIRATE NETWORKS

The rapid Internet spread with its various possibilities, like the new coming 4G services for cheap, high speed geographical coverage for the mobile world, promote the idea of an omnipresent, highly interactive, easy to find commercial medium for the propelling of social media.

Although spaces like YouTube are not officially social media, in most people's perception they are the ultimate, thus far, social place for high quality, media based transcendence.

Multimedia repositories are well aware of that reality: they have great technological and economical successes not because they provide their users with material for entertainment, training, interplay, etc., but for the reason that they have engaged vast communities feeding constantly this sphere of everyday interaction.

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We have come to a point where city dwellers frequent more in social media spaces and spheres than to down town quarters! Therefore, the business model beyond this bizarre relation is the following [9]: The multimedia repository provides highly added value audiovisual material for free, the users get content (by far more) and simultaneously give content (by far less), and create within some depth of time such trail nets, that the repercussions and ramifications, in different languages, cultures, and regimes, provoke an immense interest from the advertising sector!

Indeed, advertisement within such an environment is highly targeted and compensating: usually the social network has a more or less centred view of who is navigating, from which country, in what communication language, and avoids phenomena such as when an adult male receives advertisements focusing on how little girls play with their dolls, and vice versa.

Therefore, the corporations behind the media repository, having gathered enormous capitalization, exceeding many times the GDP of small countries, do not intend to saw off the branch which they lie on. They really intend to feed in reciprocally the industry from which they draw inspiration from.

The point is that the audiovisual and music production sector have recently suffered grave losses [10] and protest vigorously, usually by litigation, to the newly established social customs: they consider piracy the main reason for their desperate diminution and do not seek emersion from financial ruin to a creative engagement with the new business model [9].

A. Charging for pirated material: Napster

The legal adventures of Napster clearly demonstrate how industry repels to provoking piracy mechanisms. Napster was a web file sharing system. Although Napster could be used for sharing any kind of file, its success came from sharing multimedia files, especially MP3s. Its first release was inaugurated in 1990. From humble beginnings, it soon developed really fast and reached 32.000.000 users worldwide. As it was natural, Napster created enemies. The reason was the significant profit loss from declining music disks sales. A great protest against Napster brought the case to the US courts, since Napster distributed all music files for free. The U.S. court decided to stop Napster in July 2001. In November 2002, Roxio bought Napster, which recommenced functioning, this time legally.

At this stage Napster counted about 2 million visitors per month and 600.000 subscribers. The new face of Napster imposed some kind of subscription to its users. The offer contained listening to over 2 million songs for free. The users could listen to a song for three times for free. After the three audiences, they had to either subscribe or buy the song, in order to listen to it again. The installation of client software, called Napster Player was prerequisite for subscribing or buying songs from Napster.

Napster' s web page gave options for searching music songs, viewing new releases, viewing prepared playlists and viewing artists' photos. A user could also share his files with other users, provided he had joined as a subscriber.

Typical charges were some $0,99 for buying a single song, or $9,95 per month for unlimited reception of music pieces. Purchases were promoted via Pay-Pal or credit card transactions.

However, Napster could not survive as a charging distributor, and after turmoil it merged with Rhapsody around 2011.

Rhapsody is one of the most popular and known names in the online music industry. It contains over 11 million songs and it offers great search possibilities and reliable and easy downloading features. Rhapsody offers both the pay-per-song and the subscription business model. Subscription on its services allows its user to download unlimited number of songs on their PCs or MP3 players. However, all the files are encrypted with DRM and do not function, in case of cancelling the subscription.

Rhapsody, a dominant player for music distribution, uses a similar to Napster business model. And of course, after the Napster legal adventure, corporate Internet services do not trade pirated material.

B. Advertisement: the economic backbone of piracy

Internet advertising is not a recent phenomenon. It remains the dominant business model for business-to-consumer e-commerce: apart from promoting products via the Internet, advertisements are placed on or near them. The charges of Web-based advertising space are dependent on the "relevance" and the "popularity" of the surrounding Web content.

It is clear that most revenues come not from the traditional way of doing business, but from the electronic counterparts, since our community's shift to Internet services has altered the business model.

A classic example comes from the media sharing field. These companies are heavily dependent on advertisements, just about the exclusive source of all their revenues. Although most of these sites offer delivery services or subscription mechanisms that induce a considerable income, their immense size is directly proportional to the income from advertisements.

A very clever location service tracks the country from which the client enters the Digital Media Library, and stirs up advertisements originating from that country or from relevant countries using the same language with the user. Of course, part from the revenues are voluntarily or forcibly (i.e. via litigation) redirected to the copyright holder of the media clip, but there are ambiguities on what should be a fair or proportional compensation calculation. Even more, we do not want to turn the Internet to a police state that closely monitors the netizens' behaviours.

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Since the advertisement market is estimated to an annual 24 G$ [12] for the predominant hub, the US, it is obvious that claims are summing up to several hundred millions per lawsuit.

In order to explore and estimate the socio-economic impacts of advertising on pirated material, it is essential to define piracy as an advertising enabling factor. The more pirated material the service distributes, the better social media attention it draws, and therefore, more income it yields. If the equivalent in TV broadcast is considered for pirated uploading and broadcasting services, we can say that the user community stacks trendy and desirable media material for viewing, in any case difficult to trace by the central hub, the uploading mechanism, but the same time, responsible for distributing copyrighted material without paying royalties or compensation.

Piracy is a social phenomenon arising from an on-line promotional orientation that technology has created. First, for broadcast or multicast technology there is no significant extra cost if a media clip proves successful and is downloaded by millions of users instead for few thousand ones; second, it is not always known to what extend the violation of intellectual property rights has taken place. It is the multiplying factor that makes things worse, and a security violation, that would otherwise pass unnoticeable hits hard when millions of downloads are concerned.

And of course, searching in vast repositories for a specific media clip is such an unstructured process that does not guarantee delivery for the targeted good. There is some assistance in Information Retrieval terms, i.e. one can query metadata files for given names, labels, genres etc, but MIR on multimedia content grounds is still rather primitive.

So, from the advertising point of view, the important characteristic of pirated media distribution is that it is practically with no charge. It is not the best promotional technique for service quality, it is not either the most efficient, but it attracts people because of its free ride.

The service provider to respond to increased user access has to invest on significant resources. This means that he has to buy storage, communication equipment, and support for an increasing, immense volume of uploading and downloading traffic. Although some key players of the game have gained significant corporate gains, some others could not make it and have left the arena.

In order to propose a model for charging piracy, the author of this article conducted a qualitative survey on piracy. It is true, several sources have appeared on the Internet claiming that they have concluded on some metrics for the phenomenon [13], but there several objections on how well documented are the findings presented; even further, people leaving on the periphery, may confirm that piracy for music and audiovisual products has devastated the commercial landscape to such an extent, that apart from some hefty multinational companies, locally bred retailers have eclipsed. By inference, and before any official results come up, one may say that things are much worse.

Suppose that there are n potentially pirated media clips, claimed by a certain intellectual property rights holder, indexed by i = 1, …, n. Each of them is transmitted to q_i recipients over the Internet, so the aggregate number of piratically transmitted media files in a given period is $Q \overset{def}{=} \sum_{i=1}^{n} q_i$. The network is supposed to have a limited capacity, denoted by $\bar{Q}$, which is measured not in communication terms, since the present Gigabit Ethernet does not seem to congest from multimedia files, but from user dysphoria, caused by imponderable damage due to excessive piracy.

For instance, if in Greece excessive piracy is recorded, then the music industry staggers and very few quality songs will be produced; in such a case, the music industry is deregulated, and very soon production for both legal and pirated media clips will decline steeply.

Consumers gain utility when they can find media clips not previously seen or heard, and gain disutility when most of their interaction with the service provider produces noise or silence. In the latter case, the service provider is of no use to them; they cannot find a movie to watch or a song to hear with pleasure.

In the former case, there is a price *p* per transmitted media file, whether this is charged a-priori, as a pre-emptive strike, or afterwards, as an *ad-hoc* fine at the courts of law[1].

Therefore, the utility function of each consumer is defined as follows, according to Shy [14]:

$$U_i \overset{def}{=} \sqrt{q_i} - \delta \frac{Q}{\bar{Q}} - pq_i = \sqrt{q_i} - \delta \frac{\sum_{j=1}^{n} q_j}{\bar{Q}} - pq_i \qquad (1)$$

where δ>0 measures the intensity of disutility caused by piratical emissions. The "latency" caused by the piracy effect is measured by $Q/\bar{Q}$ which is the actual ratio of piracy, whether supply via on line servers or via CD/DVD distribution

[1] Needless to say that the charging mechanism should be fair; for instance if a CD track costs 1 $ for an online legal delivery, since the pirated counterpart it is not usually of the same quality, *p* should be less than 70% of that price. The same goes for video files since home reproduction is not equivalent to a cinema ticket in value.

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occurs. If $Q < \bar{Q}$ the network is not congested by piracy. If, however, $Q > \bar{Q}$ the network bristles with piracy and user discontent increases. Virtually, sales for industrial goods collapse and economy is at default.

Since each consumer participates as a peer in this communication, he takes the network usage by other consumers $\sum_{j\neq 1} q_j$ and chooses his usage q_i that solves

$$\max_{q_i} U_i = \sqrt{q_i} - \delta \frac{q_i + \sum_{j\neq 1} q_j}{\bar{Q}} - pq_i \tag{2}$$

yielding that the first and second order derivatives, regarding the transmitted packets q_i for maximum conditions are given by

$$0 = \frac{\partial U_i}{\partial q_i} = \frac{1}{2\sqrt{q_i}} - \frac{\delta}{\bar{Q}} - p \quad \text{and} \quad \frac{\partial^2 U_i}{\partial (q_i)^2} = \frac{-1}{4\sqrt{(q_i)^3}} < 0 \tag{3}$$

Hence, the individual and aggregate packet transmission levels are

$$q_i = \frac{\bar{Q}^2}{4(\delta^2 + p^2 \bar{Q}^2 + 2\delta p \bar{Q})} \tag{4}$$

Proposition:

Provided that a charge p is assigned to each piracy attempt, as shown by equation 4, the levels q_i of attempts to distribute piratical media per file will be reduced dramatically, as inversely proportional to p. In the case of a non charging network, i.e. virtually the current situation in the Internet, eq. 4 becomes

$$q_i = \left(\frac{\bar{Q}}{2\delta} \right)^2 \tag{5}$$

meaning that the only way to reduce the freebooting effect is to increase the piracy capacity of the network. This was the situation before the exaltation of the piracy effect, when pirated copies circulation was under some control. This can be achieved again if software tools prove successful in preventing pirated trafficking.

If this does not take place, then only legal action and fines, in the sense of eq. 4 can be the only means to combat piracy.

Example:

Suppose that an intranet simulates the real Internet. In our case, that "net" is comprised by all our active students at the Aristotle University of Thessaloniki. For the sake of simplicity we say we have 50,000 students, researchers and employees.

From surveys the author has conducted when teaching Computer Music to his sample audience, he has concluded that each students listens to music for an average 3h per day, at least. Listening to music, either by conventional radio, the TV or the Internet, includes pirated music, which right now is the vast majority of streamlined music in Greece, estimated by the author with a minimum threshold $Q/\bar{Q} \approx 80\%$, not to say more. Even radio stations have repositories of MP3 files that have been created by extensive downloading from various sources over the Internet. These files are re-emitted via radio frequencies or web radio portals.

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Considering that a song lasts for 4 minutes, 180 minutes of daily audio hearing correspond to 180/4 ≈ 45 songs per day per student.

If 80% of these hearings has been pirated, then, 45*0,8 ≈ 36 of them are not legally acclaimed. However, not all of them are new hearings. I.e. from the 45 songs that an average student may take advantage for every day hearing, the 90% is estimated to be previously reused. Only 10% seems to be a new material, not previously seen or heard, in a daily basis. This figure comes from the hit charts that circulate every now and then, and have in detail the sales of newly produced songs.

So, he will be charged for about 3.6 songs, that he has taken benefit from as illegal possessions.

These acquisitions are circulated within the "net" simulating the performance characteristics of the Internet in various ways: by social networks, by servers offering material, by hand-to-hand distribution, by face-to-face advertisement etc.

So, the 50.000 Aristotle University users circulate per month

$$\bar{Q} = 3.6 \text{ x } 50.000 \text{ x } 30.5 = 5490000 \quad (6)$$

Hence, solving equation (5) we have that

$$\delta = \frac{\bar{Q}}{2\sqrt{q_i}} = \frac{54900000}{2\sqrt{109.8}} = 261963.7 \quad (7)$$

Solving equation (4) for *p* yields $p \approx 1$ \$ per every pirated song distributed.

This seems to be very close to reality, since most CDs for instance sell for about 10\$ - 15\$ apiece.

V. EPILOGUE AND CONCLUSIONS

The rapid Internet spread with its various possibilities, like the new coming 4G services, has accelerated distribution of piratical copies within social networks and multimedia delivery services. The combined action of substantial legal countermeasures and advanced techniques for content filtering may abate the exaltation of piracy. The piracy issue is part of a more complex phenomenon concerning the governance of the Internet, the economics of networked industries, technological advances and software development.

In the prospect of new technological initiatives like the launch of digital television, the convergence of the Internet with broadcasting networks, it has importance on major e-commerce practices like advertisement.

The deregulation issue does not merely threaten the future of a self governed Internet; it tests the tolerances of many factors for the networked economies.

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