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Timo Ilonen

FILE SHARING SERVICES AND TECHNOLOGIES

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Timo Ilonen

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The purpose of this thesis was to study file sharing in its many forms, focusing on the services and technologies behind it, as well as gauging its effects on companies and consumers alike.

The thesis begins with a relatively brief overview of how file sharing worked in pre-Internet times, from the first floppy disks to early forms of networked sharing such as Usenet, the thesis then moves on to its main focus: file sharing in the Internet age. It covers a wide variety of topics, starting with torrent technology, explaining how peer-to-peer based file sharing works. The thesis then covers a topic closely related to torrents: digital piracy. It explains how illegal file sharing took place before the Internet, how Internet-based piracy works and how peer-to-peer technologies aided its emerge. The thesis also briefly covers legal and ethical matters and examines the impact piracy has had on various industries. The thesis also addresses cloud storage services, streaming services and digital distribution and the technologies behind these services, as well as the kind of consumer experience they provide. Finally, the thesis examines digital rights management, an ever-pressing issue in the field of file sharing.

These topics are then included in an online survey carried out to gather real-life data on consumer behavior. A total of 42 people answered the survey. The survey's main findings include support for the claims made in the thesis regarding the popularity of various file sharing methods, since the answers fell largely in line with the assumptions of the author. In addition, a number of more interesting findings were made, mainly regarding attitudes toward region locking and willingness to pay for the use of cloud storage services.

KEYWORDS:

File sharing, Torrents, Networking.

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LIST OF ABBREVIATIONS

BBS	Bulletin Board System, software run on a computer that allows users to connect to it using a terminal program.
OEM	Original Equipment Manufacturer, for example, a company that manufactures laptops and make's use of Microsoft's volume licensing system for its Windows operating system.
UUCP	The Unix-to-Unix Copy protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
NNTP	Network News Transfer Protocol
FTP	File Transfer Protocol
HTTP	Hypertext Transfer Protocol
GUI	Graphical User Interface
IRC	Internet Relat Chat
P2P	Peer-to-peer file sharing – file sharing without a centralized server.
DHT/PEX/LPD	Distributed Hash Table/Peer Exchange/Local Peer Distribution, different methods of finding peers used by the BitTorrent protocol.
SHA-1	A common hashing algorithm.
ISP	Internet Service Provider
ADC	Advanced Direct Connect, a peer-to-peer file sharing protocol.
DRM	Digital Rights Management

1 INTRODUCTION

Humans, as social, intelligent creatures, feel the need to hoard and share information. Starting with the earliest writing systems, efficient sharing and storing of information has always been a valuable asset. For millennia, written, physical form was the dominant method of storing information – however, with the rise of computing, this would come to change. As the price of computing came down, electronic means of storing information became available to consumers and were no longer restricted to businesses and academia. The purpose of this thesis is to cover that development and go through the most common forms of file sharing today, the history and technologies behind them, as well as their impact on consumers and businesses.

Today, billions of people make use of online file sharing in its many forms, making the topic a very relevant target of study. This thesis relies mainly on online articles to support the claims it makes about the very rapid development in various industries that deal with file sharing. Some of the topics covered are very recent and thus somewhat lacking in literature dealing with the subject matter, and the literature that does exist becomes outdated rather quickly, as new trends emerge and industries shift their focus on consumer demand.

The first chapter begins with file sharing as it took place in pre-internet times, covering the most common forms of offline and online sharing of past decades. The second chapter deals with BitTorrent technology and other forms of peer-to-peer file sharing, which have enjoyed great success among internet users due to their efficiency and decentralized nature. This topic naturally ties into the third chapter, digital piracy. In this section, the relationship between established peer-to-peer file sharing methods and piracy is covered, and closer inspection on their impact on various industries is granted. Moving on to more recent developments, the following chapters cover online cloud storage as well as streaming and digital distribution services, examples of file sharing industries that have become prominent in the daily lives of many people thanks to increases in internet bandwidth. To tie these topics together, the penultimate chapter covers digital

rights management, explaining how companies ensure their intellectual property stays free of infringement. Finally, the thesis finds support for the findings made with real life survey data, mapping the file sharing habits of consumers.

As a whole, these topics should provide the reader with new insight into the field of file sharing from a technological, economic and consumer perspective.

2 FILE SHARING IN PRE-INTERNET TIMES

For practical purposes, it is necessary to set a starting point at which file sharing as we know it today could be said to have begun. While the advances in early computing the Second World War brought about, as well as the very first hard disk drives of the 1950's are an interesting topic from a historical perspective, they did little to affect the daily lives of ordinary people for a few more decades to come. This section will cover the most common methods of file sharing from before the internet, many of which still find use today in niche markets.

The introduction of the first floppy disk by IBM in 1971 is when file sharing as we know it could be said to have entered the consumer space. At 8 inches and with a storage capacity of 80 kilobytes, it was the first commercially available means of file sharing. It would then be followed by a smaller five and a quarter inch variant in 1976, introduced by Shugart Associates and adopted by other companies. Floppy disks would find use for several decades to come, with a 3.5 inch 1.44MB variant being the most popular. Floppy disk drives (FDDs) came installed in most OEM-supplied computers until slowly being phased out starting in the early 2000s, with CD/DVD drives and USB media taking over.

While floppy disks were the first commercially available, physical means of file sharing, the first network-based system that allowed for sharing of files among users was the Bulletin Board System, or BBS, introduced by Ward Christensen in 1978. As described by The BBS Corner, "a Bulletin Board System, or BBS, is a computer system running a software that allows users to connect and log in to the system using a terminal program." [1] BBSes were initially accessed via a phone line and later Telnet, among other methods. They were typically run by hobbyists and provided for free, although subscription-based BBSes were also run by companies to provide services to their customers. Typically, BBSes operated locally, largely due to additional fees associated with long distance calls.

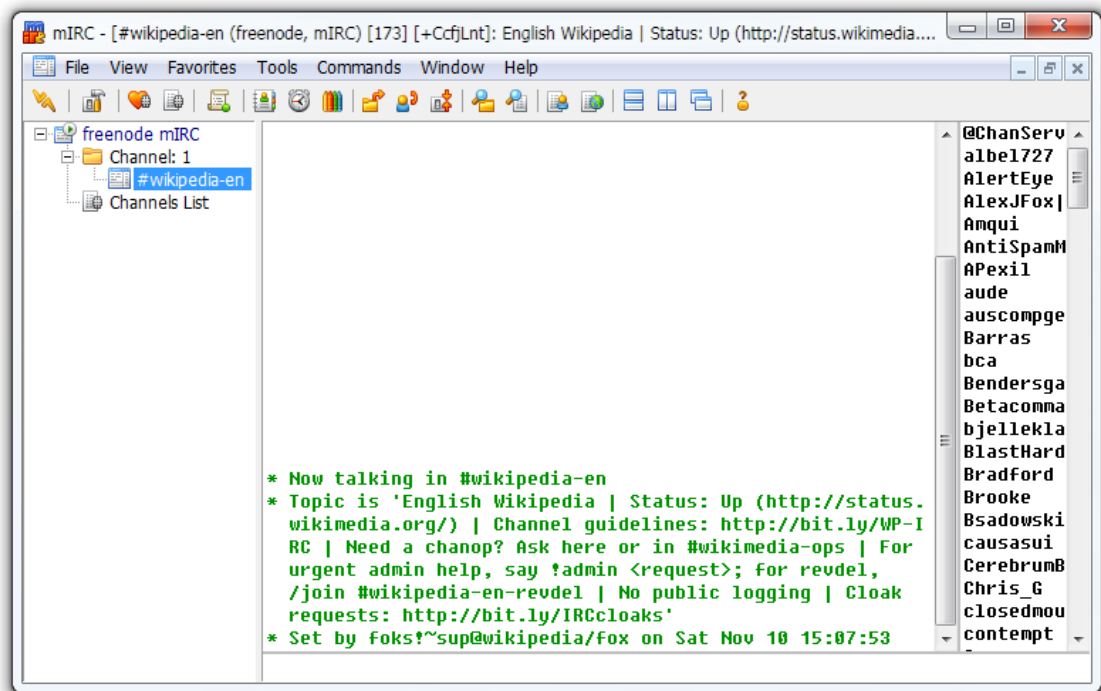
Usenet, the first attempt to create a network beyond local communities like those formed by users of BBS, was first developed in 1979. In many ways, Usenet could

be thought of as the progenitor of Internet. It initially started as a tool for sharing news among users, making use of Unix-to-Unix Copy (UUCP) to connect computers together. The underlying software was rewritten several times to support Usenet's rapid growth. By 1986, the TCP/IP protocol had reached widespread usage and the Network News Transfer Protocol (NNTP) was conceived to bring its features to Usenet, also helping to reduce operating costs. Today, Usenet still sees fairly widespread use, due to its private nature allowing for discrete sharing of files. However, high-speed Usenet servers carry a subscription fee.

In 1985, the second iteration of the commonly used File Transfer Protocol (FTP) was introduced. FTP allows for sharing of files over a TCP/IP based network and is the second most widely used protocol for that purpose today, after HTTP. It operates based on a client-server model where files are stored on a server running FTP software, which is then accessed by a client. Early clients were command line based, while several GUI-based clients exist today.

The final noteworthy means of pre-Internet file sharing is IRC, or Internet Relay Chat. It was created in 1988 by Jarkko Oikarinen at the University of Oulu as an extension for the BBS software he was the administrator for. IRC operates on a server model and allows for the creation of channels that users can then join using a client. Popular servers include IRCnet, Quakenet and EFnet, while mIRC, Hexchat and Irssi are some of the more commonly used clients. IRC's file sharing capabilities were originally not very robust due to the limitations of the DCC protocol – however, XDCC was developed to overcome those limitations and today remains a niche method of P2P file sharing.

Picture 1 demonstrates mIRC being used to access the Wikipedia channel on the Freenode network.



Picture 1. mIRC connected to the Wikipedia channel on the Freenode network

(Source: https://en.wikipedia.org/wiki/File:MIRC_Screenshot.png)

3 BITTORRENT AND OTHER PEER-TO-PEER FILE SHARING METHODS

Of all forms of peer-to-peer file sharing, BitTorrent may very well be the most ubiquitous. The first implementation of the protocol was developed by programmer Bram Cohen in 2001, while its most recent version was released in 2013. BitTorrent traffic amounts to around one quarter of all upstream traffic in North America today, a percentage that has gone down from what it was a decade ago, largely due to services such as Youtube and Netflix. [2] This section will cover client software, the technical side of the protocol and its impact on file sharing and the internet, and also discuss other methods of peer-to-peer file sharing.

3.1 BitTorrent's method of operation

BitTorrent is a peer-to-peer based protocol, meaning that sharing of files happens between users directly, rather than via a server. To download files using BitTorrent, a user typically first needs a .torrent file and client software. Upon loading a .torrent file, the client contacts a tracker specified in the file – a server that keeps track of all the computers sharing the same files. The tracker does not share any files itself, only IP addresses to permit users to connect to each other. Once the user has selected the files they wish to download, they are connected to the swarm, which is a collection of all users connected to that torrent, and begin downloading from other users, known as seeds. Files are downloaded non-sequentially and in pieces – this means that downloading any single file can be halted at any time and then resumed with no loss of progress. For example, given a .torrent file listing three 100MB files, these files might be broken into pieces of 256kB and may finish downloading in any order – it could be that one user in the swarm has finished downloading two of the files but decided to skip the third one, and so a new user joining the swarm could not download all three from that user, but would have to rely on other users in the swarm to provide the remaining file.

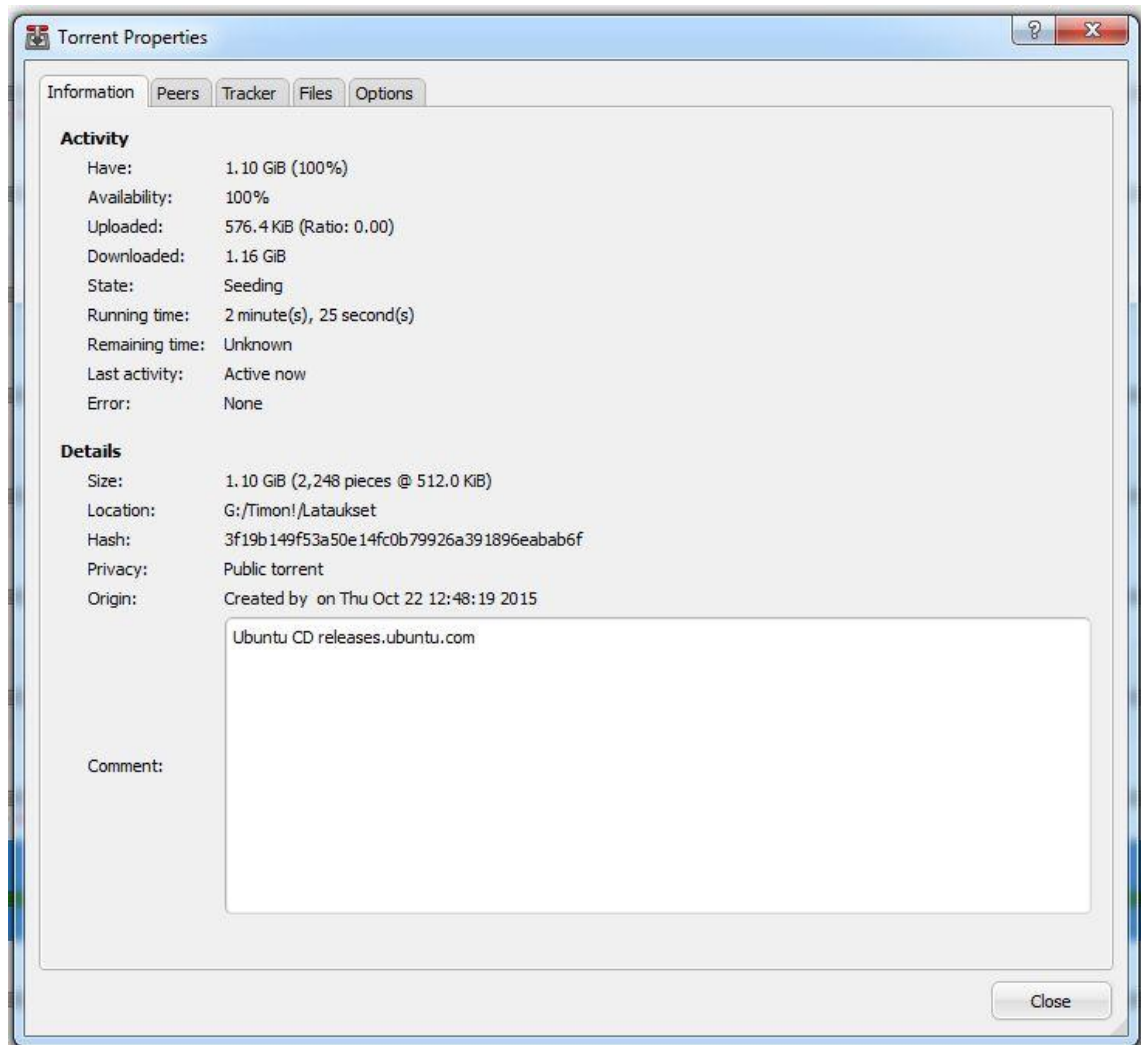
This is a simplified scenario – in reality, with a healthy torrent shared by several users, it is likely any single file would ever be provided to one user by another in its entirety, rather it would be downloaded piece by piece from several users in the swarm.

With BitTorrent, each user in the swarm is typically downloading and uploading files simultaneously. This ensures higher speeds for everyone and means no central server is stressed. Thanks to the choking algorithm, peers who upload more are rewarded with higher download speeds. A peer who does not contribute to others is known as a leech. Initially, when a torrent is created, a single user must have the entire contents of the torrent to share to others. This file is then uploaded online to make it available to other users who use it to begin downloading the files from

While the BitTorrent company provides its own client software, several third party alternatives exist. Examples include μ Torrent, Transmission and Deluge. These offer robust management features to give users more control, such as halting and resuming sharing at different times of the day and remote management. Some clients are not recommended due to coming bundled with other suspicious software or using tweaks to promote unhealthy practices such as severely limiting download speeds by default. Picture 2 depicts the torrent properties screen for a recently finished Ubuntu 15.10 download using Transmission 2.84. It displays the size of the download, the user's download/upload ratio and the state of the torrent (in this case, 'seeding'), among other information.

However, it is not necessary to use a torrent tracker to allow peers to connect to each other. Using distributed hash table (DHT) technology, clients can connect to each other directly, without the need for an external tracker server. Rather than downloading a .torrent file, the user clicks a "magnet link", which causes DHT to connect to other nodes to obtain information about the torrent directly from other users. While .torrent files use TCP to discover peers, DHT listens to UDP ports to discover peers. Regular .torrent files and magnet links can be combined to provide redundancy. [3] In addition to DHT, Peer Exchange (PEX) is another method of finding the IP addresses of peers. Using peer lists, PEX asks other

peers for information about other peers downloading the same files. Both DHT and PEX do this by comparing SHA-1 hash values with other peers. Finally, Local Peer Distribution (LPD) uses UDP to find local peers, with the goal of minimizing traffic going through the ISP and maximizing the use of higher LAN bandwidth.



Picture 2. Torrent Properties screen in Transmission-Qt 2.84.

(Source: picture self taken. Original software developed by the Transmission Project, unofficial Windows fork pictured above developed by user rberber on SourceForge.)

3.2 Advantages and disadvantages of BitTorrent technology

BitTorrent carries several advantages and disadvantages, when compared with traditional server/client based file sharing and other P2P technologies. Due to its decentralized and community-run nature, file sharing via BitTorrent enables higher speeds compared to the same files being distributed by a central server. Each peer in the swarm can make full use of both their own and other peers' bandwidth, meaning a popular torrent can typically be downloaded fast. With a typical server-client approach, the opposite is true, since servers have limited bandwidth and more users downloading the same file from a single server will result in throttling. Herein lies BitTorrent's second major advantage – while servers require upkeep and as such come with associated costs that need to be covered, with BitTorrent, the workload is shared across users and a single tracker server can serve millions with relatively low bandwidth. A third advantage is data integrity – when downloading a file from a server, it is downloaded as a single chunk and as such carries the risk of corruption. In addition, connection time outs typically force the entire download to be started over – with large files, this can be especially troublesome. Due to BitTorrent breaking files down to pieces, any corrupt bit will be detected by the client, discarded, and a new one will be requested. This ensures that a completed download is always an exact copy of the original file provided by the creator of the torrent.

BitTorrent could be said to have become a victim of its own popularity. It enabled the rapid growth of P2P file sharing, which caught many ISPs by surprise. This greatly increased the stress on ISP networks, resulting in many ISPs resorting to increasing costs and possibly throttling BitTorrent traffic by default. Thus ISP clients who do not make use of torrents may experience a worse browsing experience in the form of lower bandwidth and increased bills. In addition, BitTorrent carries the stigma of being easily associated with piracy, despite the

technology enabling easier and legitimate file sharing between users. As a result, some institutions outright ban the use of torrents within their networks.

3.3 Tracker index sites

While BitTorrent is an impressive piece of technology, users still need to gain access to .torrent files or magnet links to actually download files. This is where tracker index sites come to play. Tracker index sites are websites maintained by third parties that permit users to upload and subsequently search for .torrent files for the content they wish to download. The total number of tracker sites is comparatively low and large ones are typically under constant threat of shutdown due to large amounts of copyright claims, since they typically also carry .torrent files permitting users to download copyrighted content. Some trackers specialize in certain types of content and set strict rules for what can be uploaded while others make little distinction over what types of content they permit and who can download it. Examples of large, general purpose trackers include the infamous The Pirate Bay and the now defunct ISOHunt. These sites are called public trackers due to not requiring users to go through a registration process and thus making their files available to all. Due to this, they typically have several users and can be used to quickly find the most popular types of content – however, they often impose very little quality control and they do not require users to maintain a ratio, meaning torrents typically have a high number of leeches only looking to quickly download what they want while contributing back very little. Thus, advanced users looking for specific types of content and a proper community will only settle for private trackers – sites requiring users to register for an account that typically impose strict rules, such as requiring users to maintain a ratio and defining what types of content can be uploaded. Private trackers often require new members to receive an invitation from an existing user or go through an invitation process to join. As a result, users have increased privacy. Private trackers typically focus on specific types of content – for example,

What.cd focuses on music, while PassThePopcorn is a tracker favored by movie enthusiasts.

However, as mentioned before, the use of torrent tracker websites for the purpose of downloading .torrent files is not strictly necessary. While it is highly unlikely that trackers, especially private ones, will completely disappear in the foreseeable future, many BitTorrent clients now include their own search engines that enable users to search for torrents directly using their client, rather than relying on tracker websites.

3.4 Other peer-to-peer file sharing methods

BitTorrent is by no means the only popular method of P2P file sharing. Advanced Direct Connect (ADC) is a P2P file sharing and chat protocol and the successor to the Direct Connect (DC) protocol. ADC operates on a hub basis where clients connect to a central server which provides chat, search and connection request services. All file sharing happens directly between users – the hubs themselves do not host any files. Hubs typically enforce sets of rules. The most commonly used client for accessing ADC hubs is DC++, with an estimated 90% market share. [4]

Another popular P2P file sharing network is the eDonkey network. eDonkey is a decentralized network best suited for sharing large files, and for long term storage. It is currently not supported by any corporation, with the community and client developers being solely responsible for its maintenance. By far the most popular eDonkey client is eMule, also with a market share of approximately 90%. [5]

Besides these, many companies also make use of P2P technologies to provide services to their customers, rather than making use of a typical server-client approach. One example is Blizzard Entertainment, whose game launcher makes use of P2P to provide updates.

4 DIGITAL PIRACY

Digital goods are an investment and thus often carry monetary value. Be it music, video games or software, it is no surprise that artists and companies have an interest in ensuring that their hard work cannot be acquired by illicit means, and will often go to great lengths to hamper and punish any attempt to infringe their copyright. The purpose of this chapter is to cover the history and methods of digital piracy, estimate its impact on industries, and offer some insight into why it takes place and what kind of measures companies take to prevent it, in addition to discussing its relationship with the BitTorrent protocol and tracker index sites, the most common tools for such activity.

When commercially available software first arrived in the 1970s, legislation had yet to catch up. It was not until the Computer Software Copyright Act of 1980 that software would be considered intellectual property – before this, there was no such thing as stealing software in the legal sense. Then, in 1989, the U.S. Patent Office started issuing patents for software, leading to the notion that software was the intellectual property of the author, who owned the program and its source code. [6]

Digital piracy (henceforth referred to as ‘piracy’) could be considered to have truly begun with the creation of the first piracy groups under BBS. It was a natural progression – BBS was the first major form of networking users together, permitting them to chat and share files with each other. As BBS grew in popularity, so did piracy, leading to software firms feeling the negative effects for the first time – however, law enforcement lacked the means of effectively cracking down on groups and only a few of the thousands of groups active were arrested in any given year by the early 1990s. Thus the early days of piracy were relatively care free and most pirates did not have to worry of getting caught.

Piracy in its early days was outside the reach of most people and largely reserved for enthusiasts. By far the most common form of pirated content was software – however, with the introduction of the Internet, both of these facts would soon

come to change. The .com bubble of the late 90s greatly increased the number of software companies – pirates would crack every piece of software, regardless of its popularity, and upload it online. It mattered little if anyone actually made use of the cracked software – it was a contest of speed among piracy groups. As connection speeds grew, BBSes slowly started becoming obsolete and the Internet would become the new battleground of piracy. For the first time, music and movies were also pirated – movies could be compressed down to manageable sizes to permit regular users to download them, and the MP3 file format was vital in boosting online music piracy. [6]

The breakthrough would take in place in 1999 with the introduction of Napster. Developed by Shawn Fanning, it was the first major peer-to-peer based method of sharing music. Combined with a user-friendly experience, Napster would grow to have approximately 80 million registered users at its peak. Napster operated from June 1999 until July 2001, when it was shut down by court order, after being sued by the Records Industry Association of America (RIAA) on grounds of copyright infringement. [7] Brian Hiatt of the Rolling Stone magazine argues that while the lawsuit by RIAA was a logical course of action, it may have been better of them to instead harness Napster as a legitimate service. Between the shutdown of Napster and birth of the first legitimate digital distributors, such as iTunes, too many years passed that allowed for online music piracy to grow. [8]

Napster's shutdown did little to stem the growth of online piracy, and its users would move on to other services, such as BitTorrent, Kazaa, and Limewire. Many of these services would meet the same fate as Napster – however, BitTorrent would come to be the dominant method of online piracy.

4.1 The role of BitTorrent and torrent trackers

BitTorrent has come to be most prominent method of illegal file sharing - the RIAA estimates that BitTorrent software accounts for 75% of piracy. [9] The BitTorrent company has been under considerable heat from entertainment industry representatives to help with the fight against piracy, while the company itself has done extensive PR work to promote BitTorrent as a legitimate method of file sharing and pleaded to not be associated with piracy by default.

The most common source of .torrent files pointing to copyrighted content are torrent index sites such as The Pirate Bay. For this purpose, such sites are under constant pressure for facilitating copyright infringement. Such sites often claim innocence by pointing out that they do not host any copyright infringing content on their own. They are often hosted in countries with loose copyright laws, or at the very least, not in the United States. In some cases, ISPs have been forced by court ruling to block access to some sites – such was the case with The Pirate Bay and Saunalahti in 2012. Such blocks are incredibly ineffective, however, and can be circumvented via use of a proxy site, VPN server, or a mirror site.

It is no surprise that BitTorrent is used so widely for piracy purposes. Its peer-to-peer nature means it is decentralized and community driven. One method that parties interested in preventing copyright infringement is called torrent poisoning. The goal of torrent poisoning is to hinder or outright prevent the sharing of copyrighted content via several different means. With decoy insertion, corrupted or invalid files are inserted into the network, typically backed up by a high-speed server to entice users to download the file. In the process, the deployer of the decoy acquires the IP addresses of the downloaders. With index poisoning, garbage information is injected into the index to make it more difficult to find legitimate peers and to make users waste time. In this sense, it could be described as a method of social engineering – if the user gives up on attempting to illegally acquire content, the index poisoning attempt will have been successful in achieving its purpose.

However, there are barriers to torrent poisoning. For one, it can be expensive and time-consuming, leading it to be discontinued after a short period of time and only be used with popular content. In addition, the BitTorrent protocol is highly resistant to poisoning due to its hashing functionality that verifies the contents of the files. Poisoning on private trackers is often a wasted effort, as users found to be distributing poisoned content will be swiftly banned and their torrents removed from the index. [10]

Private trackers carry several benefits over public ones for advanced users. They typically take quality control very seriously and will delete any content not matching their guidelines. Specialized sites often have a greater selection than general purpose public sites, and also carry rare content. Due to ratio requirements, download speeds are also typically high. In addition, they also offer higher levels of privacy to users due to their exclusive nature, although users should not expect to be safe from the legal consequences of copyright infringement simply for using a private tracker.

4.2 Effect on industries and incentives for piracy

The impact that piracy has on various industries is a source of never-ending debate. When conducting research, one must be very critical of the source – industry representatives have a natural interest in painting piracy as having a strictly negative influence, while third parties acting in favor of consumers may be more likely to give a more objective and well-rounded analysis that also takes into account more factors than purely financial ones and those dealing with intellectual property.

Forbes compared two recent studies regarding music piracy, carried out by the European Commission and OfCom, respectively. Of the two, the study carried out by the European Commission suggests that digital piracy results in a slight increase in sales and that pirates actually buy more than non-pirates. Meanwhile, the OfCom study reaches a different conclusion, suggesting that consumers want to pay less for albums. They also reached the same conclusion that pirates buy

more – however, a later report showed that copyright infringement is up, while digital sales are down. These two studies show how multi-faceted the question is. [11]

For popular bands signed to major labels, piracy is more likely to have a negative impact. However, less known bands may benefit greatly from the publicity, as having their albums circulate the Internet is essentially a free method of advertising.

TorrentFreak carried out an interview with four movie directors, asking them questions about what they think the movie industry should do to reduce piracy and how it is affecting the industry, among other topics. Even as industry insiders, they admitted that they do not know what kind of an overall impact piracy has – however, it was suggested that indie movies are more likely to suffer, compared to larger Hollywood titles. One filmmaker suggested that piracy has become a scapegoat that can be used to justify lower wages and worse contracts. It was also suggested that piracy could be a response to consumers not being content with legal options to see new films. Geoblocking and different selections across regions on services such as Netflix were mentioned as examples as to why consumers may not be satisfied with legal options and may thus resort to piracy, even if they were otherwise prepared to pay to see the film. [12] A recent report released by Sandvine further suggests that piracy could be seen as a service issue – it noted how the streaming service Netflix's success has resulted in less BitTorrent-based piracy. [13]

Gabe Newell of Valve, the company behind the digital distribution platform Steam, further echoes the idea that piracy is primarily a service issue. Using Russia as example, he noted that in 2011, Russia had grown to be Steam's second largest European market, despite the country being notorious for its high levels of piracy. Rather than employing antipiracy methods, the goal was to provide a better service than what pirates have to offer. [14]

From a consumer's standpoint, it is easy to agree with the claims made here. In developing regions, it is no doubt true that money is the primary reason many

people resort to piracy. However, in the first world, educated consumers may very well have the means to pay, but still resort to piracy for other reasons. Even if the content itself is high quality, be it music, a film or a game, one may still find themselves hesitant to pay for it. The publisher could be known for unethical business practices, or the consumer may be unhappy with unequal treatment compared to consumers in another region – for example, the content may have been released late, be censored, or carry other qualities that negatively impact the product and make a pirated copy more attractive due to its superior quality. In addition, digital rights management (DRM) technologies often have a negative impact on the end product while not serving their function, leaving legitimate customers with an inferior product, once again making piracy an attractive option. Examples include DRM technologies that restrict the number of times a game can be installed, or worse, serve as security vulnerabilities on the end user's computer. Thus, educated consumers have the upper hand – it is no longer enough that the product itself is of high quality, but it must not carry any secondary negative qualities enforced by the company that would make the consumer unwilling to pay for it. As an avid gamer, the author pays great heed that any game he spends money on is not only DRM-free, but that the companies behind it do not engage in unethical behavior that he considers harmful to the industry or games as a medium.

5 CLOUD STORAGE IN FILE SHARING

Moving on to more legitimate methods of file sharing, the 2010's have seen a rapid growth in the popularity of cloud storage services. High-speed internet connectivity has made upload and download of large personal files hassle-free and brought about a new market that several old time players as well as newer companies compete in. This chapter will cover the method of operation behind such services, what kind of technical requirements they should meet, the differences between consumer and business cloud storage, as well as how cloud storage differs from simple online backup.

Online storage services could be divided into two categories: cloud storage and online backup. This division is not set in stone, as many companies provide overlapping services, but it is important to make nonetheless. At its simplest, a cloud storage service allows the user to upload their file on the service provider's server and then access it from anywhere, typically with their browser, or through a mobile application. The file can also be shared with other users using the same platform. In addition, some services integrate an office suite into their cloud service that permits users to work on the project together, be it a presentation, worksheet or document. Examples of such services include Google Drive and Microsoft OneDrive, which make use of Google Docs and Microsoft Office to provide office suite functionality, respectively. Google, Microsoft and Apple are the three most well-known companies that combine their cloud services with their other offerings into seamless ecosystems that provide incentives for consumers to stick to one service over another. Google has in the past released its Nexus line of Android devices with limited local storage and no room for expansion, pushing for Google Drive to be used for media consumption – however, consumer reception has been lukewarm at best. The Google Chromebook is a line of laptops running Google's Chrome OS – essentially, the Chrome browser turned into an operating system that makes extensive use of cloud functionality. They come with very little local storage and have limited offline functionality. Other Chrome OS based devices include the Asus Chromebox and Chromebit.

Cloud storage services aimed toward regular consumers typically come with a set amount of free space in the range of a few gigabytes, with an option to purchase additional space. For example, Google Drive offers 15GB of storage for free, with additional storage available for purchase at an optimal rate of \$9.99 per terabyte at time of writing, while Microsoft OneDrive offers storage at a slightly cheaper rate and occasionally offers deals on their Office software to go with the storage. These companies compete on the basis of complete ecosystems and integration of services.

Another consideration for any consumer is security. Ideally, any files a user uploads on any service should be encrypted and the company should take care of backups. This is where some companies show their strength. Consumers with a particular interest in services focusing on privacy might prefer to steer clear of Google Drive, for example, due to Google gathering data on their users for advertising purposes, and instead opt to go with a company such as SpiderOakONE, which places emphasis on privacy and file integrity. [15]

5.1 Cloud storage in business

Business use brings a new level of requirements for cloud storage companies to meet. Security and file integrity become top concerns as the cloud will most likely be used to store sensitive business information and projects. Ideally, the company should make use of AES encryption for secure file transfer. In some cases, the administrator may be supplied with the master key, meaning that even if a successful hack takes place, the hacker only gains access to encrypted files. In addition, whereas consumer accounts can typically only be used by a single user, business accounts have multiple users whose privileges need to be managed by the administrator. Business accounts typically also come with the ability to set limits on files and folders as well as additional collaborative functions not found in standard consumer accounts.

Cloud storage offers companies several benefits. Besides being able to store files online and thus serving as a backup function, the collaborative tools permit

employees to work together more efficiently. Rather than having to deal with emails and attachments, they can make use of office suite functionality to work on a project together over the Internet.

In addition, making use of existing cloud storage services introduces cost savings. Setting up a dedicated cloud service would introduce hardware and management costs, making it a less than sensible solution for small and medium sized businesses. Some companies and their employees may also find it a more flexible solution to permit employees to use their own devices, which can then be granted access to the cloud service, rather than relying on company-issued, fixed-specification hardware. In some cases, companies may opt to go with a service provider that also provides cloud computing services. Most cloud storage companies offer plans for consumers and businesses both. Payment plans are typically flexible, with cost depending on both user count and the amount of storage rented. [16]

5.2 Online backup services

The main difference between cloud storage and online backup services is that the latter is not for frequent retrieval of files. It is intended as long term backup, typically to be used parallel with local backup. Thus, backup services lack many of the features found in cloud storage services, such as office suite functionality and sharing of files between users. Typically, they offer cheaper storage than that offered by cloud storage companies – Backblaze offers unlimited storage at \$5 per month, while Carbonite's Basic plan starts at \$60 per year. Some services, such as Crashplan, offer higher levels of encryption for an additional fee. They also offer the option where the customer may order a hard drive to which they backup the files locally and then send it back to Crashplan, which take care of the backup, although this service is limited to the US. Some services place restrictions on which types of files are backed up by default, or set limitations on file sizes.

One service that is worthy of notice is Amazon Glacier. Described as an archival service, it offers lower rates than any other service and work on a pay-per-use basis – however, retrieval of files costs money and will take several hours to complete, due to Amazon using tape drives for storage. This may make it an attractive option for consumers looking to add an extra layer of redundancy to their already existing backup plan.

6 STREAMING AND DIGITAL DISTRIBUTION SERVICES

Another new development in the past few years is the change in how entertainment is delivered to consumers. Physical media has taken a backseat as high-speed internet has allowed for entirely new methods of content delivery in the form of digital distribution and streaming. This chapter deals with the various services, how they compete, as well as the challenges companies operating in this space have met.

6.1 Digital distribution services

Digital distribution refers to the delivery of goods such as video games, music, software and literature via digital means, rather than as physical goods. Today, many different digital distribution platforms exist, many with overlapping services, while others fill their own niche.

Of video game distributors, by far the most popular is Valve Software's Steam. Launched in 2004 alongside Half-Life 2, it originally only served as a platform for Valve's own games. It later started serving third-party titles as well, with better profit margins being a major selling point to attract developers. Today, Steam offers several thousand video games on Windows, OS X and Linux and has over 100 million active user accounts.

Several large video game publishers have set up on their own platforms to ensure better margins for major titles as well as to combat Steam's dominance. Examples of such services include Ubisoft's UPlay and EA's Origin. In some cases, PC versions of major titles published by these companies require their respective platforms to play.

Perhaps the best example of a niche platform is GOG. Focusing on classic games, they offer several titles not found on other services. In addition, GOG employs a strict no-DRM policy – all games sold on GOG are DRM free. Due to this, their selection on major titles is quite limited, as several publishers are not

comfortable with the concept of selling their games without anti-piracy protection. GOG recently introduced their own Galaxy client.

In the music space, the largest single player is Apple's iTunes. Using the application available on several operating systems and smart devices, it serves as a hub for the consumption of music, TV shows and movies bought from the iTunes Store. Music bought from iTunes is DRM free – however, it is encoded in a lossy format, making the quality inferior to that of a bought CD.

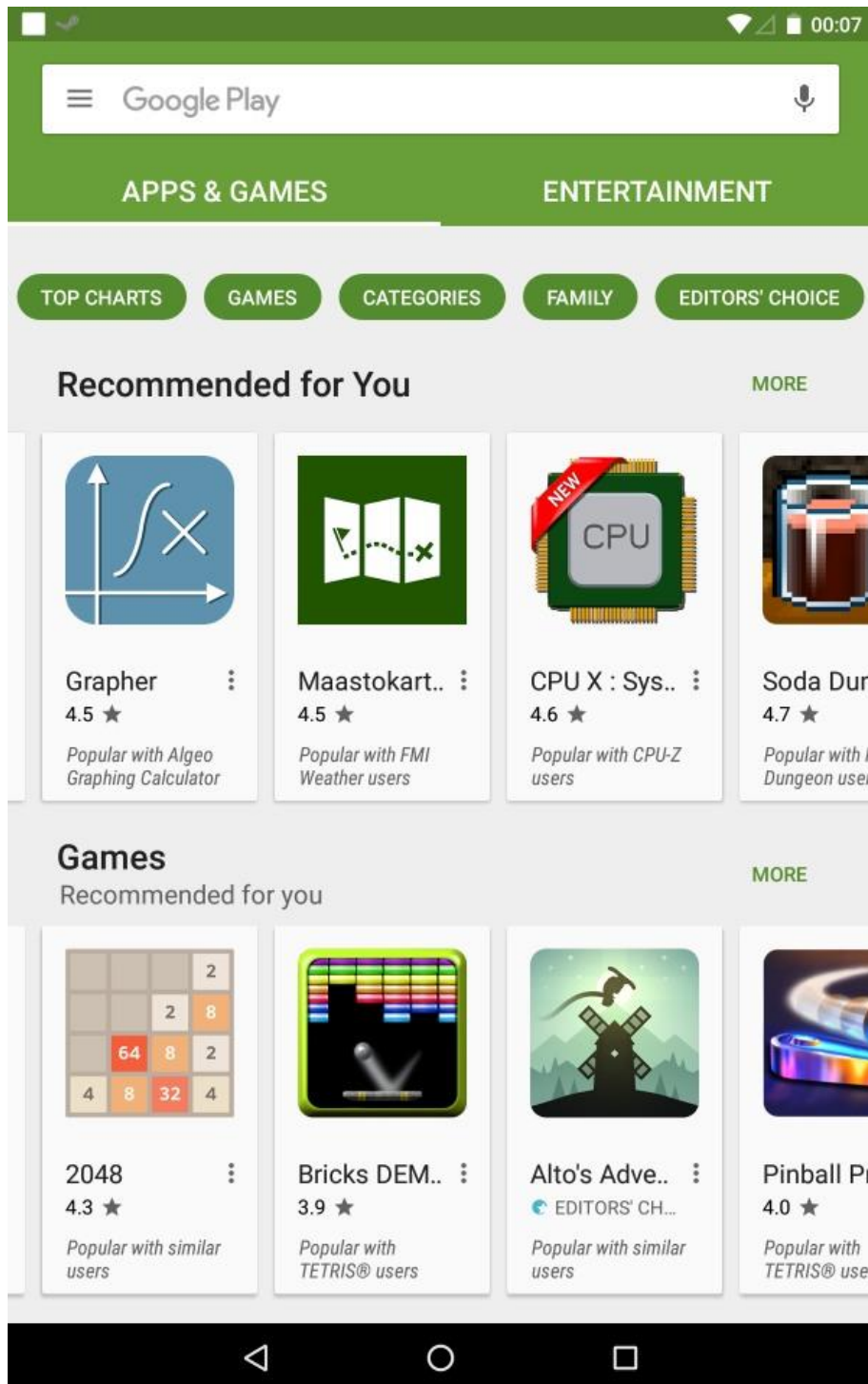
Other music distributors include companies such as Bandcamp and Soundcloud. These companies take upon a more artist-centric approach, citing close collaboration and ease of uploading as features to attract artists with. In addition, they support more audio formats, including lossless formats such as FLAC.

Books distributed in digital format are called e-books. Popular services include Apple's iBooks and Amazon's Kindle ecosystem. Compared to other media, e-books have arguably been negatively affected by DRM the most. For example, books bought for an Amazon Kindle device are tied to that ecosystem and cannot be read on any other device – Apple's iBooks have a similar restriction.

Outside commercial distribution, libraries have also begun offering e-books for download. However, they typically face a dilemma – since digital books can be endlessly copied, scarcity must be introduced artificially. To this end, most libraries make use of third-party services to enable loaning of e-books. For example, the Turku city library uses Ellibs and Overdrive as their e-book vendors. These require a constant internet connection to use – if the user wishes to read a book without an active internet connection, they need to sign up for an Adobe ID account, which functions as DRM.

On smart devices, each ecosystem typically includes its own store for the purchase of applications. Three major players in this field are Apple's App Store for iOS devices, Google Play for Android devices and Microsoft Store for Microsoft phones. The Google Play front page is displayed in Picture 3 below. While Android devices allow applications to be installed from third-party sources, iOS devices require all installed apps to be download from the App Store. This

serves as a method of locking down the ecosystem, but also introduces an extra layer of security, as no malicious applications are allowed on the store.



Picture 3. Play Store front page on an Android device, displaying recommended applications.

(Source: picture self taken – apps listed property of their respective developers)

6.2 Streaming services

The difference between a streaming service and digital distribution platform is not always clear cut, as many companies provide overlapping services. With a streaming service, as the name suggests, the content is streamed to the consumer in real time, rather than downloaded beforehand.

In the video game industry, streaming has not reached widespread popularity due to a number of factors. To deliver high graphical fidelity over the internet, large amounts of bandwidth are needed. The largest service in this field was the now-discontinued OnLive, which permitted users to rent video games and play them over the Internet, with the games hosted on the company's servers. The service suffered from input lag, leading to a suboptimal experience in games requiring quick reflexes. OnLive's patents were eventually acquired by Sony Computer Entertainment, which offers Playstation Now, a similar service for its Playstation line of consoles.

Valve Software offers a similar service called Steam In-Home Streaming, which works on the same principle as the above mentioned services. It enables users to run the video game on a capable computer locally and then stream it to another device in the same house, making use of higher LAN bandwidth. This reduces input lag as long as local networking hardware is strong enough to handle the high-bandwidth stream.

Perhaps the most popular content to stream is video. To this end, many different services exist. YouTube has become the most ubiquitous general-purpose video streaming platform, enabling a whole new method of content creation for profit. Users subscribe to channels, the most popular of which have tens of millions of subscribers, to watch high quality videos free of charge. Content creators and YouTube itself profit via ads embedded into videos – however, Youtube has yet to break its investments even, despite several attempts at more efficient monetization. Other specialized video streaming services exist as well – for

example, Twitch.tv is aimed at gamers, spawning a whole subculture revolving around video game streaming.

There are many streaming services aimed at delivering TV shows and movies, with Netflix being the most popular. Challenging cable television, they compete with pricing and content, with some services offering exclusive series. Today, video streaming accounts for more than half of peak hour traffic in the US. [17]

Music streaming has become a popular method of music consumption, as well. Services such as Spotify and Google Play Music enable users to stream music to their smart devices from a huge collection of artists. Free versions of these services often employ advertisements. Some services allow users to buy albums directly and then offer the option of both direct download and streaming, while others focus on a niche, such as the recently launched Tidal, which only provides lossless audio, compared to the rather heavily compressed audio most services provide, even to paying customers.

7 DIGITAL RIGHTS MANAGEMENT (DRM)

Finally, we reach the concept of DRM, or digital rights management. Playing a part in practically all methods of digital file sharing, it is a topic any party, be they a company producing a digital product, or the consumer spending their money on said product, should have an interest in. This chapter covers the various forms of DRM and its impact on industries and consumers, in addition to discussing the kind of reaction it has received from people and organizations invested in digital rights.

For any company dealing in digital goods, protecting their content is a natural concern. Few trust the goodwill of people, and thus opt to employ different methods of digital rights management. However, DRM very rarely proves effective at its intended task, and only ends up providing paying customers with an inferior product, while pirates end up enjoying the content as intended. In addition, employing DRM can be costly.

First, it is important to define what the term 'DRM' actually refers to. It is an umbrella term and can be used to describe any method used to protect digital content from copyright infringement.

Of all industries, the video game industry arguably makes use of the widest array of different DRM technologies. The most common method of DRM are serial keys. Also used by other software beyond video games, a game that makes use of serial key activation requires the user to input the key during installation to verify that the game is genuine. Games before the Internet era used a similar form of validation where the game would typically ask the user to input a specific word from the player manual to verify the game is legitimate – naturally, this form of validation is completely obsolete today. Serial keys are generally not considered a very effective form of preventing piracy and are today commonly combined with online registration for a two-step verification process.

Single time online verification is a common method of verification, but some companies take the process a step further, requiring the user to verify their game

online within regular intervals. There have even been a few cases where a single player game has required a constant internet connection to play, with the publisher typically justifying such a move by making the game require resources located on a server. A notorious example of such a game is Blizzard Entertainment's Diablo 3, which suffered from massive problems at launch due to server overload, preventing even people wishing to only play locally from playing the game, and the single player component suffering from high pings due to the requirement of a constant internet connection. Always-online DRM could be considered the most intrusive form of DRM – however, it is effective, as the only way to circumvent it is by reverse engineering the entire game.

With hardware-based DRM, the game checks the computer hardware and validates the game as legitimate on the basis of that configuration. Typically, the change of even a single component causes the computer to be recognized as a separate machine, requiring revalidation for the game to be run again. The number of available validations is usually finite, but most companies offer a way to revoke previous validations. Examples of such DRM include Denuvo and SecuROM. [18]

Online game stores with client functionality vary in this regard. For example, Valve permits developers publishing their game on Steam to make use of any DRM scheme, and also those offered by Valve. Any game bought on Steam is tied to that account, and requires the Steam client to be active to run. An offline mode is offered, enabling users to download a game and then be able to play it without an active internet connection, with the Steam client running in offline mode. Other client-based stores such as UPlay offer the same functionality, as well.

Due to the locked down nature of video game consoles, they very rarely make use of any additional DRM schemes. Running illegitimate software, such as pirated games burned onto discs, typically requires software or hardware modifications making use of vulnerabilities in the console software. Thus, the console manufacturing companies have an interest in ensuring no software vulnerabilities exist that would allow for such exploits, and are quick to release

software patches to fix any that arise. Some video game publishers have in the past cited high piracy rates on PCs as one reason for opting to only release their games on video game consoles – however, with the PC video game market becoming ever more profitable, this reasoning has become less valid in recent years.

Most people do not have a problem with less obtrusive DRM schemes such as Steam, but complete freedom from DRM is an attractive concept that other companies such as GOG have approached. Any game sold on GOG is completely free of DRM and the user has complete control of the files. This has helped them carve a niche market that appeals to a certain user base that is aware of the issues with DRM.

In the music industry, there are different approaches to DRM. Many online music stores now sell music without DRM, but in the past several have used DRM that restricted what types of devices or software the music could be played on. In 2005, Sony BGM introduced a new form of DRM on their audio CDs which installed itself on users' computers without clear notification. It included a rootkit which served as a security vulnerability. This led to class action lawsuits, with Sony BGM being forced to recall affected CDs, compensate consumers and distribute software for removal of the rootkit.

DRM is widely used in the e-book industry, to prevent unauthorized copying, printing and sharing. For example, any e-book purchased on the Amazon Kindle Store may only be read on a Kindle device. Adobe's ADEPT DRM is supported by many third-party e-book readers. [19]

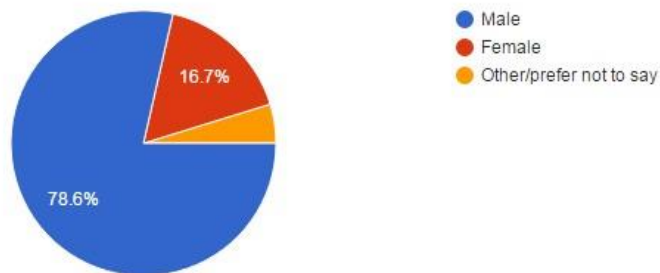
Public opinion on DRM varies. For example, the Electronic Frontier Foundation is highly critical of DRM, claiming that it violates consumer rights, stifles innovation and only serves the interests of companies. Many consumers may not be educated in what DRM is and how it works, while those invested in such matters are likely to reconsider their purchase, if the product comes with particularly intrusive DRM. The author has personally in the past opted not to buy

video games he was otherwise interested in due to them being sold with obtrusive DRM.

8 SURVEY

Thus far, the thesis has covered various methods of file sharing from a technical, industrial and consumer perspective. To back up claims made in this thesis, an online survey asking various questions related to the topics covered was carried out. The survey was carried out using Google Forms and posted on the r/filesharing, r/piracy and r/torrents sub-Reddits, an online message board, as well as on the author's personal Facebook page.

State your gender. (42 responses)



State your age. (42 responses)

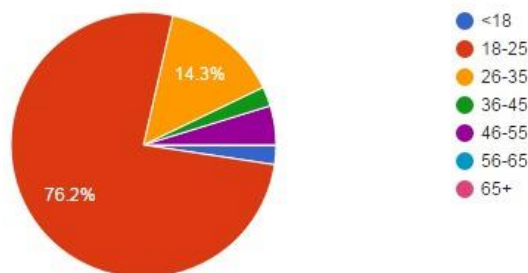


Figure 1. Questions regarding the surveyees' gender and age.

Figure 1 shows that the majority of respondents were young men, with women and people above 35 a minority. Given the themes of this thesis as well as the demographics of the sites the survey was posted on, this result is not particularly surprising.

Select any service you have actively used in the past. (32 responses)

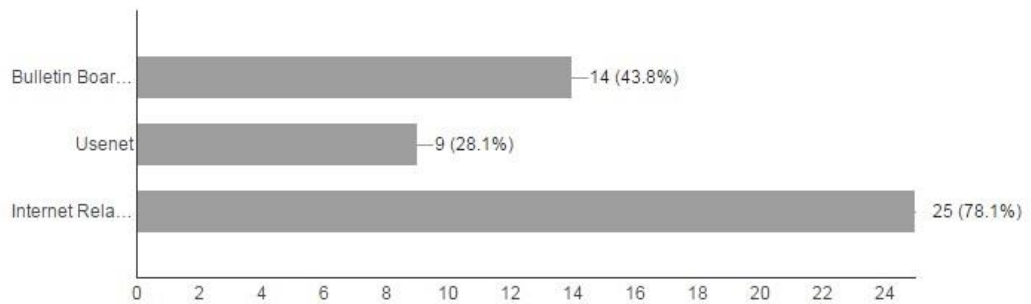
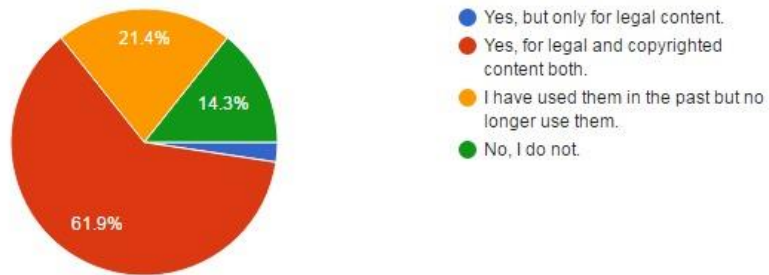


Figure 2. Questions regarding the use of legacy file sharing services.

Of legacy file sharing services, Internet Relay Chat proved quite popular, with Bulletin Board System and Usenet still having a relatively strong niche market, as shown in Figure 2.

Do you make use of torrents? (42 responses)



If you make use of torrents, please state your primary BitTorrent client.

(34 responses)

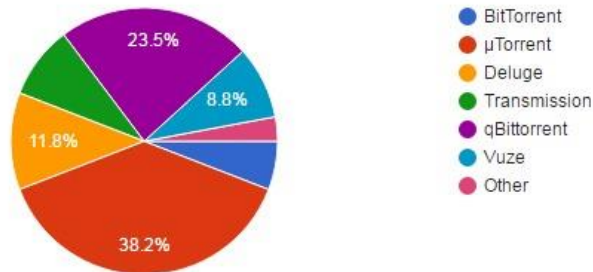
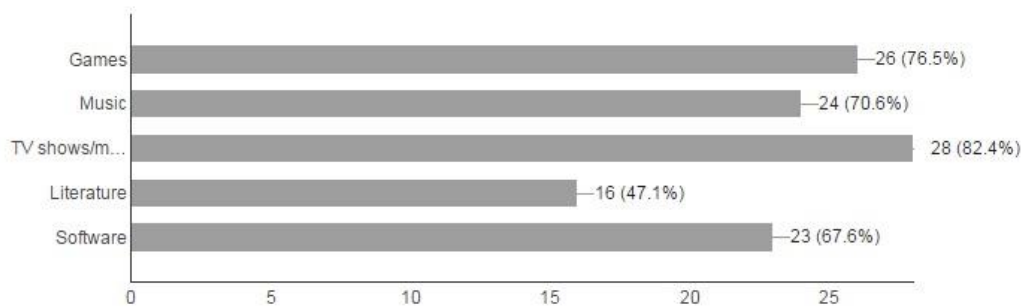


Figure 3. Questions regarding BitTorrent.

Figure 3 shows that a majority of respondents admitted to using torrents for copyrighted content, with a minority no longer making use of them, or never having used them. Only one respondent used torrents for strictly legal content. µTorrent proved the most popular BitTorrent client, with the distribution among the remaining client being relatively even.

Have you illegally downloaded any of the following within the last year?

(34 responses)



If you have, what were your reasons for doing so? (34 responses)

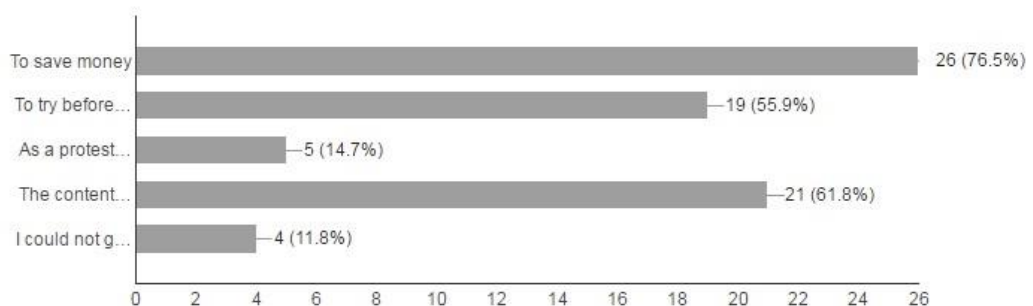


Figure 4. Questions regarding digital piracy.

Figure 4 shows that there was no major variation regards to the types of content people most commonly pirate, with TV shows and movies being slightly more popular than other types of content, and literature being less popular.

Unsurprisingly, most people pirate in order to save money, or at the very least, try out the content before deciding whether it is worth their money. What is quite surprising that even in 2016, regional locks hamper people's consuming habits, with half of all respondents claiming they have pirated content because it was otherwise not easily available in their region. 'As a protest move' and 'I could not get legally acquired content to work' were less common reasons.

Are you a member of any private torrent tracker? (42 responses)

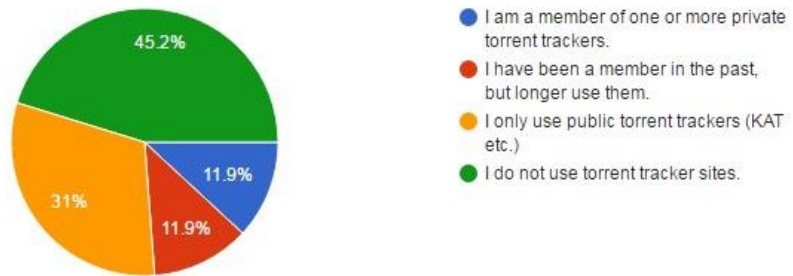
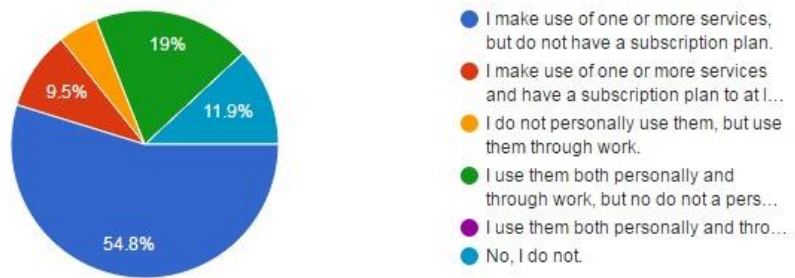


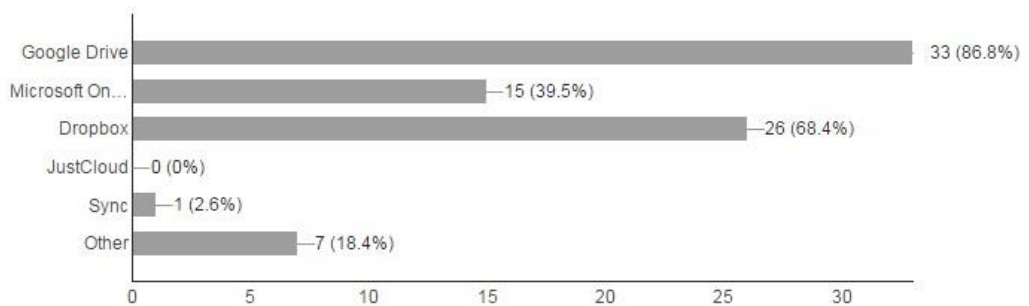
Figure 5. Question regarding torrent trackers.

Figure 5 shows that only a small minority of respondents make use of private torrent trackers, or have used them in the past. Around a third only use public trackers, while a bit less than half do not make use of torrent trackers at all.

Do you make use of any cloud storage services? (42 responses)



Select any cloud storage service you use. (38 responses)



Select any online backup service you use. (5 responses)

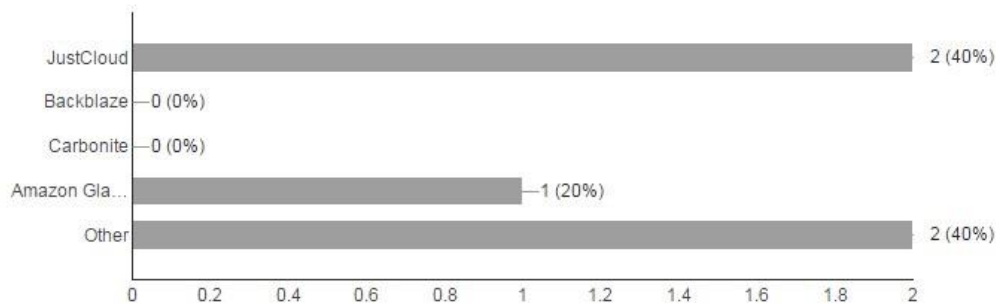


Figure 6. Questions regarding cloud storage services.

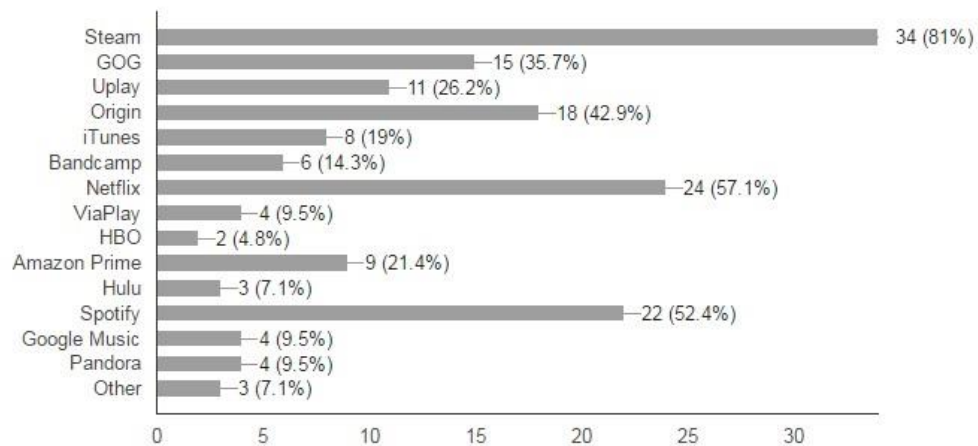
Based on Figure 6, more than half of all respondents make use of free cloud storage services. Only around 10% have a personal subscription plan. Around 20% use them both personally and through work, but do not have a personal subscription plan. A minority do not use cloud storage services at all.

Google Drive, Microsoft OneDrive and Dropbox were the most popular services, with a minority making use of services not listed here.

Online backup services were not very popular, with only 5 respondents using them. For most consumers, it appears cloud storage is enough.

Select any digital distribution platform or streaming service you use.

(42 responses)



Has the growth in popularity of digital distribution platforms and streaming services affected your consuming habits?

(42 responses)

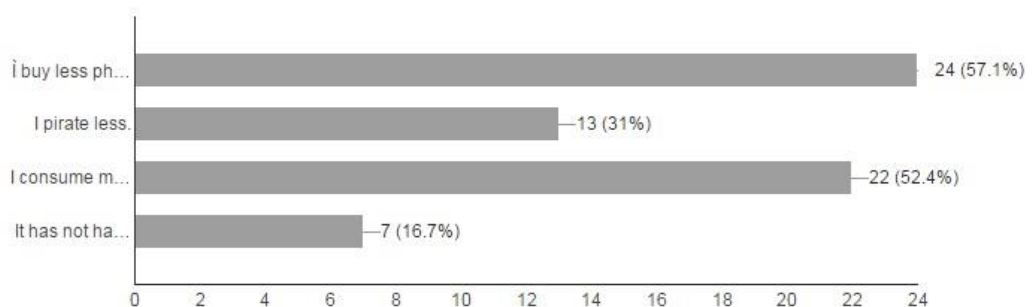


Figure 7. Questions regarding digital distribution and streaming services.

Figure 7 shows that digital distribution and streaming services proved very popular, with Steam, Netflix and Spotify being the most popular services of their respective industries. More than half of respondents claimed that the increase in popularity of these services has led to them buying less physical content, and

consuming more content than they used to. A sizeable minority pirate less, with a small minority claiming these services have not had a major impact on their consumption habits.

What kind of a role does digital rights management (DRM) play in your purchasing decisions?

(42 responses)

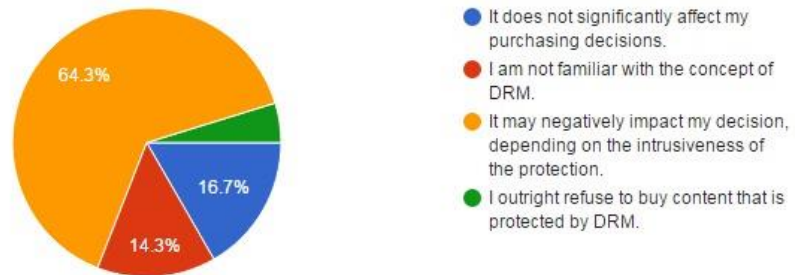


Figure 8. Question regarding DRM (digital rights management).

Finally, moving on to the topic of digital rights management, Figure 8 shows that for most people, DRM may play a negative role in their purchasing decision, depending on the intrusiveness of the DRM. A minority of respondents claimed that it does significantly affect their decision, or they were not familiar with the concept of DRM in the first place. Two respondents claimed to steer clear of all products protected by DRM.

9 CONCLUSION

The goal of this thesis was to cover file sharing, a broad topic in itself, and to draw meaningful conclusions based on the findings made. For people already invested in these topics, it is unlikely much truly new information was uncovered, but I personally learned quite a few things in the process, particularly regarding topics I was less familiar with, such as cloud storage, as well as the intricacies of torrent technology. People less versed in these topics hopefully learned something useful as well – for example, despite BitTorrent's popularity, its inner workings are a mystery to many.

The bulk of valuable insight provided came from the survey. While one could speculate about consumer interests to a great extent, real-life data can be immensely valuable for any company already operating in these industries, be they an established corporation, or a startup looking to find their own market. For example, a company looking to enter the cloud storage market is well off knowing that a majority of cloud storage users are content with the free options provided, and only a small minority pay for their cloud storage. Similarly, for a company dealing with content streaming, it is good to know that region locking is a quick way to earn unhappy customers. From a consumer's perspective, it is good to see that people are aware of the issues with DRM and are unlikely to spend their money on a product protected by obtrusive copy protection.

Regarding future work, a good research target would be to cover other file sharing methods not discussed here, and to continue monitoring these industries, as they evolve at quite a fast pace. There is much to be learned here for everyone, be they an enthusiast, or an entrepreneur looking to make an educated investment.

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Appendix

Survey questionnaire

Below are the questions and answers for the survey.

1. State your gender. [Male / Female / Other/prefer not to say]
2. State your age. [<18 / 19-25 / 26-35 / 36-45 / 46-55 / 56-65 / 65+]
3. Select any service you have actively used in the past. [Bulletin Board System (BBS) / Usenet / Internet Relay Chat (IRC)]
4. Do you make use of torrents? [Yes, but only for legal content. / Yes, for legal and copyrighted content both. / I have used them in the past but no longer use them. / No, I do not.]
5. If you make use of torrents, please state your primary BitTorrent client. [BitTorrent / μ Torrent / Deluge / Transmission / qBittorrent / Vuze / Other]
6. Have you illegally downloaded any of the following within the last year? [Games / Music / TV shows/movies / Literature / Software]
7. If you have, what were your reasons for doing so? [To save money / To try before buying / As a protest move / The content was not readily available in my region / I could not get legally acquired content to work.]
8. Are you a member of any private torrent tracker? [I am a member of one or more private torrent trackers. / I have been a member in the past, but longer use them. / I only use public torrent trackers (KAT etc.) / I do not use torrent tracker sites.]
9. Do you make use of any cloud storage services? [I make use of one or more services, but do not have a subscription plan. / I make use of one or more services and have a subscription plan to at least one. / I do not personally use them, but use them through work. / I use them both personally and through work, but no do not a personal subscription plan. / I use them both personally and through work and have a personal subscription plan. / No, I do not.]
10. Select any cloud storage service you use. [Google Drive / Microsoft OneDrive / Dropbox / JustCloud / Sync / Other]
11. Select any online backup service you use. [JustCloud / Backblaze / Carbonite / Amazon Glacier / Other]
12. Select any digital distribution platform or streaming service you use. [Steam / GOG / Uplay / Origin / iTunes / Bandcamp / Netflix / ViaPlay / HBO / Amazon Prime / Hulu / Spotify / Google Music / Pandora / Other]

13. Has the growth in popularity of digital distribution platforms and streaming services affected your consuming habits? [I buy less physical content. / I pirate less. / I consume more content than I used to. / It has not had a significant impact on my content consumption habits.]
14. What kind of a role does digital rights management (DRM) play in your purchasing decisions? [It does not significantly affect my purchasing decisions. / I am not familiar with the concept of DRM. / It may negatively impact my decision, depending on the intrusiveness of the protection. / I outright refuse to buy content that is protected by DRM.]