POSTER: Dynamic analysis of an intra-institutional conflict within the music industry

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Abstract

Peer-to-peer technology has made massive music piracy possible, which, in turn, has arguably had a significant economic impact on the recording industry. Record labels have responded to online piracy with litigation and are also considering self-help measures. It is currently not obvious whether or not these counter-piracy strategies will ultimately stifle online file sharing in the long term. With this paper we attempt to add to our understanding of the conflict within the institution that is the commercial music industry. We conduct an institutional analysis of the industry in transition and extend the traditional pattern modeling methodology with a formal resource-based model of a representative online music network. The model accounts for complex causal interactions between resources, private provision of common goods, free riding and membership dynamics. In a series of experiments that emulate anti-piracy scenarios we show that a peer-to-peer system may be quite resilient to outside disturbances. The experiments also demonstrate that policies rank differently in their effectiveness based on a selected yardstick.

Keywords: institutional economics; online piracy; digital music; copyright; litigation; self-help; peer-to-peer technology; peer-to-peer networks; P2P; system dynamics; computer simulation

Since they first appeared in 1999 online music-sharing networks have been very popular: 65 million people traded music files on the Napster network within the first 20 months of its existence (Leuf 2002: 191). The rapid growth of these networks led many music and legal professionals to forewarn that, if left uncontrolled, unauthorized exchange of music may soon become rampant (Yu 2003). The expected loss of millions of dollars in CD sales due to online piracy (CNN Money 2002) will erode financial incentives to produce new material (Gallaway and Kinnear 2002), which may quite possibly result in the collapse of the entire music industry in five to ten years (BBC 2002; Mann 2003). According to the Recording Industry Association of America (RIAA), which represents music copyright owners, the 9 percent decline in CD sales in 2002 is a premonition of the future colossal losses, unless piracy is subdued (Recording Industry Association of America 2003).

In response to pirating on a grand scale afforded by peer-to-peer (P2P) technology, the commercial music industry launched a fierce anti-piracy campaign comprised of litigation, lobbying, and self-help (Yu 2003). Often trying the boundaries of legal and regulatory systems, the anti-piracy war set off sharp and sagacious debates on the nature of intellectual property, the role of the copyright law, and fundamental notions of citizenry, such as, freedom of speech (Lessig 2001; Goldstein 2003; Harmon and Schwartz 2003; Green 2003). Since institutions invariably affect the economy (North 1992), the outcomes of the polemics in courts will have considerable pecuniary consequences for the recording industry and the entire economy. New laws and new interpretations of old laws may cause new industries that are attempting to grow on the platform of peer-to-peer technology flourish or decline (for examples see Non 2000 and Elkin 2002).

It is still not clear if the anti-piracy campaign will work (France and Grover 2003). Some analysts predict that peer-to-peer networks will ebb under pressure, while other experts prophesize a continuous raise in popularity (BBC 2002). With this article we hope to add to the understanding of the institutional conflict within the commercial music industry. The framework for our analysis is rooted in the descriptive pattern modeling approach of institutional economics (Wilber and Harrison 1978). However, acting on a proposition that the traditionally narrative analysis of institutional economics may be buttressed by formal methods (North 1992; Hodgson 1998), we use the approach of *institutional dynamics* (Radzicki 1988; Radzicki 1990a; Radzicki and Seville 1993) to build a resource-based model of a peer-to-peer community. Then in a series of computer experiments with the model we simulate counter-piracy actions by copyright holders; the experiments reveal that the internal feedback structure of a peer-to-peer system renders it extremely resilient to outside disturbances. Experiments also suggest that anti-piracy measures are likely to differ in their effectiveness.

We proceed by describing the institution of commercial music industry. Then we explain actions that copyright owners have tried or may undertake against online piracy. Subsequently, we develop a formal model of a representative peer-to-peer network that is then tested against a reference year. We devote one section to a series of experiments that examine the consequences of three anti-piracy policies inspired by litigation and self-help approaches. We offer a brief summary of findings and conclusions in the last section.

The institution of Commercial Music Industry

An institution is operationally characterized by the presence of: (i) participants; (ii) rules that govern activities within the institution; and (iii) folk views that explain and justify actions within the institution (Neale 1987). Rules and folk views are constraints that define an institution and they may be formal, such as the copyright law, common law, government regulations, and informal, such as, conventions, and socially accepted or self imposed norms of behavior (North 1992). The commercial music industry has all the characteristics of an institution, as we describe in this section.

Participants

Participants of the commercial music industry are legion and, among others, include: artists, recording studios, agents, customers, trade publications, disk jockeys and many more (Dolfsma 2002; France and Grover 2003). Since an organization is a particular form of an institution created for a purposeful coordination of activities (Hodgson 1998: 180), some of these players are institutions in their own right. New participants emerge and old ones wane away as the importance of players changes over time. Dolfsma (2002) offers an account of an institutional transformation that led to the disappearance of a music "presenter" and its replacement by a "disk jockey." Players also merge, as the recording industry undergoes consolidations. Unlike in the early days when there were no national music conglomerates (Gallaway and Kinnear 2001), the industry is currently dominated by five major international corporations, commonly referred to as The Big Five; they are: Vivendi's Universal Music Group, AOL Time Warner's Warner Music Group, Sony Music Entertainment, Bertelsman's BMG, and EMI Group. On a recent account these companies controlled 75 percent of world-wide music sales (Mathews 2003).

Players may appear and gain prominence due to novel technologies. For example, the introduction of the point-of-sale retail information systems in the 1980s led to the invention of a new music popularity chart. Adoption of the chart in 1991 by the leading trade publication *Billboard* transformed the industry by boosting positions of a small number of record companies, allowing greater segmentation of the music market, giving prominence to country music, and negatively impacting albums from some independent labels (Anand and Peterson 2000). Similarly, music-sharing communities owe their existence to the novel peer-to-peer technology.

Rules

Observing that institutions do not exist in isolation (Neale 1987), institutional economists have long recognized the inseparable amalgamation of legal and economic activity in the market world (e.g. Medema 1992); the alliance has been dubbed a legal-economic nexus (Samuels 1989). Soon after its formation in the 1880s, the music industry secured the extension of the copyright law to music (Anand and Peterson 2000). By constituting what is property and establishing ownership rights, the legal system since then defined the structure of the music industry (Samuels 1989; Coase 1992: 717) and protected copyright owners against piracy (Lister 1998).

Folk views

People use folk views to "justify the activities or explain why they are going on, how they are related, what is thought important and what unimportant in the patterns of regularity" (Neale 1987). The wide adoption of music-swapping technology showed that the public at large does not see music sharing as a criminal act, even though the recording industry believes that using peer-to-peer networks is akin to stealing (Harmon and Schwartz 2003). This perception of legitimacy of music-sharing comes from the underlying socio-cultural values of a society (Dolfsma 2002) – a great number of the Internet users perceive online music as a free public good. The origins of this view may come from two facts: (i) music has been available as a free public good for years through the radio media (Gallaway and Kinnear 2001; Harmon and Schwartz 2003); and (ii) content on the Internet for the most part is free (Gallaway and Kinnear 2001). Moreover, "institutions constitute the arenas in which people try to accomplish their aims" (Neale 1987). Thus when faced with a choice of distribution channels they choose the least costly and most convenient one. As Gallaway and Kinnear (2002) succinctly put it, talking about P2P networks: "In the commercial milieu, one does not expect rational individuals to reject the option which offers lower prices, lower transactions costs, and better variety."

Attitudes toward the new technology among artists are less uniform. Many of them disapprove of the peer-to-peer music distribution (The Economist 2003; Roberts 2003). Besides the pure revenue considerations, a strong incentive for artists to resist P2P is that it undercuts the current sales-based performance charts (Nelson 2003), which are the most important signaling tool in the industry (Anand and Peterson 2000). However, many "non-marketable" artists welcomed the P2P revolution because it gives them visibility and allows them to reach a wider audience (Gallaway and Kinnear 2001).

Interaction between incumbent structures and file-sharing networks

Institutions exhibit inertia in terms of habit, persistence, and institutional lock-in (Hodgson 1998). SoundScan, Inc. waited five years before its new music popularity chart was adopted by *Billboard* in 1991 (Anand and Peterson 2000). Following the same behavioral trend, the constituent members of the RIAA do not welcome changes brought by the peer-to-peer technology. In an attempt to control the development and adoption of the technology the RIAA have applied litigation and considered using potent self-help measures against file-swappers (Yu 2003). We review these anti-piracy tactics below.

Litigation

The first sortie launched by the copyright owners against the new file-sharing movement concerned the future of Napster, Inc. After lengthy proceedings and many expert witness testimonies by prominent economists and legal scholars on the merits and downfalls of the novel technology, a federal judge in California ruled that Napster was a contributory and vicarious copyright violator (Hilden 2002; The Wall Street Journal 2001). Unable to comply with all the requirements imposed by the court, Napster shut down its servers in July 2001, two years after the service started in 1999. Combating peer-to-peer technology, however, proved to be not unlike fighting the mythical Greek serpent Hydra who, for every cut off head, grew two new heads in its place. Napster was succeeded by dozens of imitators that are more resilient to attempts to shut them down for a number of reasons (Yu 2003; Woody 2003). Firstly, while Napster utilized a central database of all shared files, the new networks do not have central servers. Secondly, some software companies resorted to legal and ownership maneuvering that made it difficult to track and prosecute them. A prominent example of the latter defense strategy has been Sharman Networks, Inc., which distributes software for the popular KaZaA network (see e.g. Yu 2003; Woody 2003; CNN 2003). Thirdly, U.S. courts do not seem to be willing to hold distributed networks responsible for copyright violations, which is a dramatic departure from the Napster ruling. In April 2003, a U.S. District Court ruled in favor of Grokster Ltd. and StreamCast Networks Inc. – two companies involved in the development of file sharing software – citing that the companies do not control the traded material (Mathews and Wingfield 2003; CNN 2003).

After the April 2003 setback, the RIAA and its movie industry counterpart, the Motion Picture Association of America (MPAA), revised their anti-piracy tactics by announcing that they would go after individual users. The RIAA threatened with hundreds of lawsuits against sharers (Holloway 2003). To prepare the battle ground, copyright owners sued and won a case against Verizon, in which a federal judge ordered the telecommunications company to reveal the names of its two Internet subscribers who shared copyrighted material (The Economist 2003). Until that ruling P2P participants were protected by the right to anonymity (Yen 2001). At the time of this article, a few hundred cases against peer-to-peer network users have been filed and are still pending in American courts (Semple 2003).

Self-help

Another line of offense considered by copyright owners is *self-help*. After a federal judge ruled in favor of StreamCast Networks Inc. and Grokster, the RIAA began spamming KaZaA and Grokster hosts with instant messages warning of legal penalties (Mathews 2003). Madonna posted bogus music files to P2P networks posed as songs from her new album; they contained nothing but profanity (The Economist 2003). Record companies have also been known to post song files with random sounds inserted in them, such as, for example, the Gettysburg Address and car horns – all aimed at frustrating the pirates (Roberts 2003).

More potent self-help weapons against peer-to-peer networks will be available if the effort to pass the Peer-to-Peer Piracy Prevention Act succeeds in Congress. This piece of legislation is an example of future-binding encapsulation, that is, the legitimization of new innovations that will perpetuate the ceremonially warranted power structure (Bush 1987: 1094). U.S. Representative Howard L. Berman, who sponsors the bill, explains that the new law would protect record labels from liability if they resort to using "limited self-help measures" (Berman 2003). The Berman bill would legalize actions that are currently prohibited under various federal and state laws (Hilden 2002). It may override, for example, the Massachusetts Computer Crime Law enacted in 1995 that makes unauthorized access into a computer system illegal. All large record labels are readying for the self-help phase of copyright warfare by investing in companies that develop programs for attacking the computers of music pirates. The programs will either freeze offending computers or redirect peer network users to legitimate sites for music purchase (Russell 2003).

Model Development

Actions by copyright owners affect peer-to-peer networks in ways that are complex and multidimensional in nature. In this section we develop a computer model of a music-sharing network that will help us to understand system responses to anti-piracy measures. After reviewing the workings of a typical peer-to-peer network we proceed to define the boundary and overall structure of the model. The model is implemented using the computer tools of system dynamics. Before we describe individual sectors of the model, we offer a brief introduction to system dynamics.

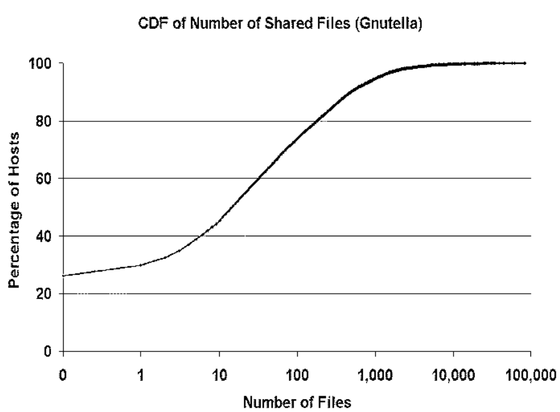
A representative peer-to-peer network

The peer grid of a system such as Gnutella or KaZaA is a virtual network formed at the application level that is distinct from the underlying physical network (Ripeanu, Foster et al. 2002). A person can participate in a peer network by either downloading a piece of software commonly referred to as a “servent” or by logging to a dedicated web site (Bolcer 2000). A Gnutella node forwards the search query to other nodes that it is connected to until the message travels the maximum allowed number of hops determined by the Time To Live (TTL) parameter. Hosts that contain the material in the query, respond with a message that is traversed along the path it arrived. The original Gnutella protocol treated all nodes equally, irrespective of their network connection speed, memory, or clock speed (Bolcer 2000); currently, more advanced algorithms for peer communities are being developed (e.g., Lv, Cao et al. 2002).

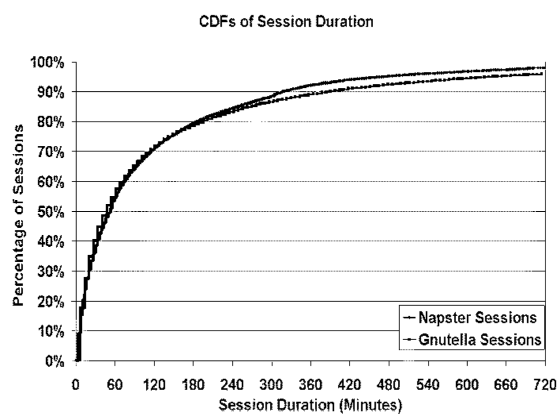
Peer-to-peer systems have been compared to an Internet potluck: nodes contribute to the network by offering files and by routing network traffic (Kan 2001). Users, however, clearly have incentives to free ride with respect to content and bandwidth, which means “taking their share of it and keeping their own resources for themselves” (Marwell and Ames 1979). Providing content to other peers is costly not only because acquiring the content may impose fixed costs on the altruistic peer in terms of purchasing a CD, but also because each additional upload slows down the serving computer and its own downloads (Adar and Huberman 2000; Yang and Garcia-Molina 2002). Peers may also choose not to stay connected to the network for long periods in order to avoid the exposure to computer worms and hacker attacks (Rincon 2002).

Free riding may be accomplished in a variety of ways. By default most of the peer-to-peer software shares all downloaded files (Golle et al. (2001); http://www.limewhier.com). However, Adar and Huberman (2000) found by analyzing P2P traffic data that only about 30% of users shared files on Gnutella and 20 percent of hosts shared 98 percent of all the files available on the network. A number of other studies confirmed the existence of significant free riding tendencies on music networks. Figure 1a shows file-sharing statistics that typify the situation. Providing undesirable content is also a form of freeloading (Adar and Huberman 2000). Adar and Huberman reported that 1 percent of hosts provided 47% of answers to file requests and 25% provided 98% of the responses. Bandwidth and processing capacity offered to the network can be controlled through the number of allowed connections and by misstating the connection speed. Extreme cases of free riding are browser-based search web sites, for example, asiayeah.com and gnute.com, that allow users to enter a peer network and search the shared database without contributing any content or routing the network data traffic.

A person may also shirk by simply turning the computer off. There is a special term used in the peer-to-peer community to describe this type of behavior – *fishing* – a user logs into the network, downloads what he needs, and promptly leaves the system. Withdrawal of a host results in lost queries and failed uploads. Data presented in Figure 1b show that about half of the connections are 60 minutes or shorter and only 20% of hosts remain continuously in the network for longer than 3 hours.



(a)



(b)

Figure 1: Resource sharing in peer networks: (a) a cumulative distribution function (CDF) for the number of files shared on Gnutella; (b) session duration on Napster and Gnutella. Source: Saroiu et al. (July 2001)

It has been suggested (Adar and Huberman 2000) that rampant free riding can be the reason behind variations in network performance, which may be measured in terms of search response latency and the probability of successful downloads – as more users join the network without adequately contributing to the common pool, public resources of a file-trading network become depleted leading to poor performance. Economic literature on the private provision of public goods suggests that typically the free riding problem worsens with the group size (see, for example, Isaac and Walker 1988 and Gaube 2001). Group size has been also found to be important for online communities, just like for physical groups (Butler 2001). Statistical analysis of P2P network traffic by Asvanund, et al. (2002) confirmed the declining marginal value, and increasing marginal cost, of each additional peer.

Model structure

We model a representative network, while holding influences from copyright owners external to the model. The model boundary and its structure are shown in Figure 2 within the grayed area. The Recording Industry represents a collection of copyright owners, artists, record labels, the RIAA, and lawyers. The two arrows entering the Representative P2P Network symbolically show litigation and self-help efforts by the Recording Industry. Notice that the commercial impact of the peer network on the traditional recording industry is not part of this analysis and thus there are no connections from the Network to the Recording Industry.

The model has been implemented numerically using the integral equation methodology of system dynamics. Radzicki (Radzicki 1988; Radzicki 1990b) examined the many similarities between the approach of institutional economics and the computer modeling approach of system dynamics and proposed a formal *institutional dynamics* synthesis between the two disciplines. Resembling the analysis of institutional economics, system dynamics analysis is interdisciplinary, begins with a review of various facts pertinent to the case, uses extensively historic information about institutions, and is not tied to the idea of homoeconomicus, but rather recognizes the bounded nature of human decisions. The only essential difference between the methods is that a system dynamics analysis concludes with a formal computer model. In this journal, Radzicki and Seville (Radzicki and Seville 1993) have successfully used numerical simulations to support their institutional analysis of a township in Massachusetts; Saeed (Saeed 2003) applied the methodology of system dynamics to the analysis of institution building for the case of mitigation banking. An authoritative primer on system dynamics is an encyclopedic book by Sterman

(Sterman 2000); the reader may also consult Warren (2002), which contains a collection of models designed for resource-based analysis of various economic and business cases.

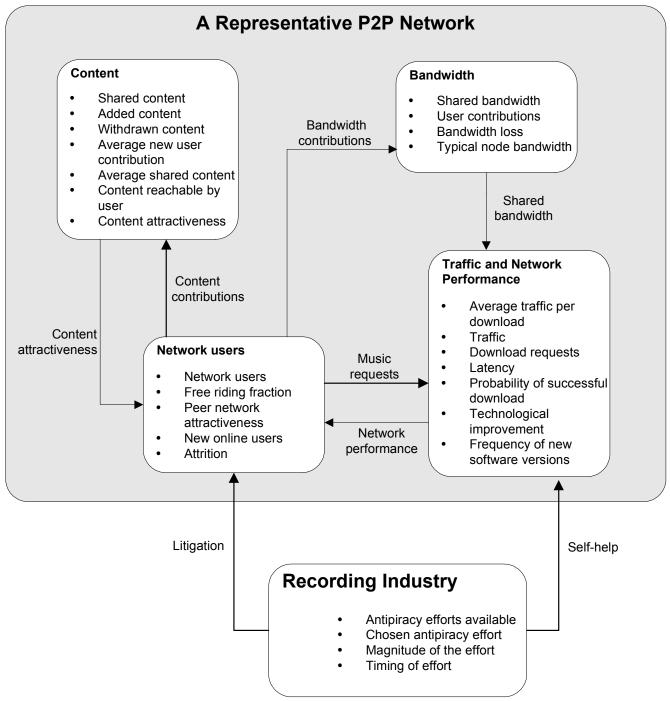


Figure 2: Model structure

Sectors

In this section we review the four sectors that comprise the model representation of a peer network; they are: *Network users*, *Content*, *Bandwidth*, and *Traffic and network performance*. Complete computer code and model documentation are available from the authors upon request.

Membership sector

The membership sector, as shown in Figure 3, captures the daily average number of peers logged into the system. We assume some normal adoption and attrition rates; then, if the system is useful for current users and attractive in the view of potential users, the network use will increase. Word of mouth and media exposure are two typical mechanisms that stimulate such a growth. Since the introduction of Napster, the technology has drawn a lot of attention from the media, which contributes to the formation of public perception of the network's usefulness. Changes in the peer network attractiveness modify the typical growth rates of the system: lower attractiveness increases churn and leads to the reduction in the new user arrival rate; greater attractiveness has the opposite effect. Normally users respond with some delay to changes in the network's performance. Since media, including on-line news groups, is quick to report and discuss any performance glitches of a popular network, the shortest delay among the three delays in the model is the opinion formation delay for the media. The value of network attractiveness is determined by the content attractiveness (which in turn depends on available content), latency of responses to requests, and the average probability of completing a successful download. There are first-hand and second-hand reputation effects (Warren 2003): new customers join based on second-hand reputation information and customers leave based on their first-hand information. The variable free riding multiplier moderates the effect of network size on the magnitude of the free loading problem. The contribution fraction measures the average share of individual content and bandwidth that is being made available by each peer to the rest of the network; the share is equal to $1 - \text{free riding fraction}$.

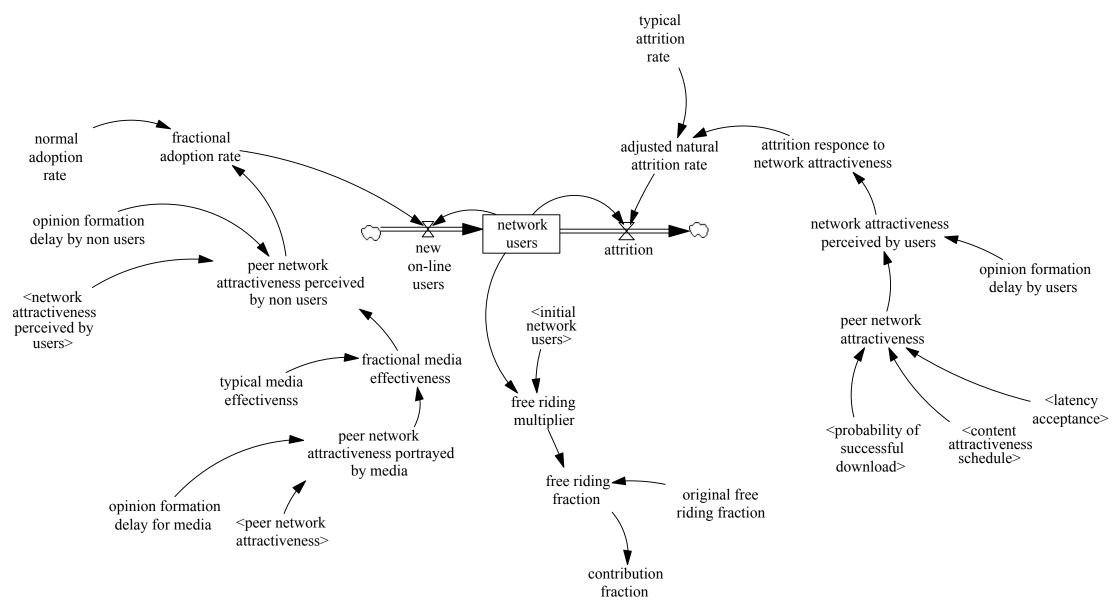


Figure 3: Membership sector

Shared content sector

Figure 4 presents a rendition of the shared content sector. This sector keeps track of the number of files available through the network. The maximum content a new peer can bring to the group is the number of music files on his hard drive, which we code as maximum new user contribution. It is achieved when contribution fraction is equal to one; otherwise, the average user contribution is a fraction of the maximum user contribution. We use a coflow formulation (Sterman 2000) to determine the increase in the common pool of files: added content is proportional to the new on-line users, which is defined in the Membership sector. We assume that the possibility that a node drops out of a network does not depend on its level of altruism. Thus, withdrawn content is proportional to the attrition and average shared content.

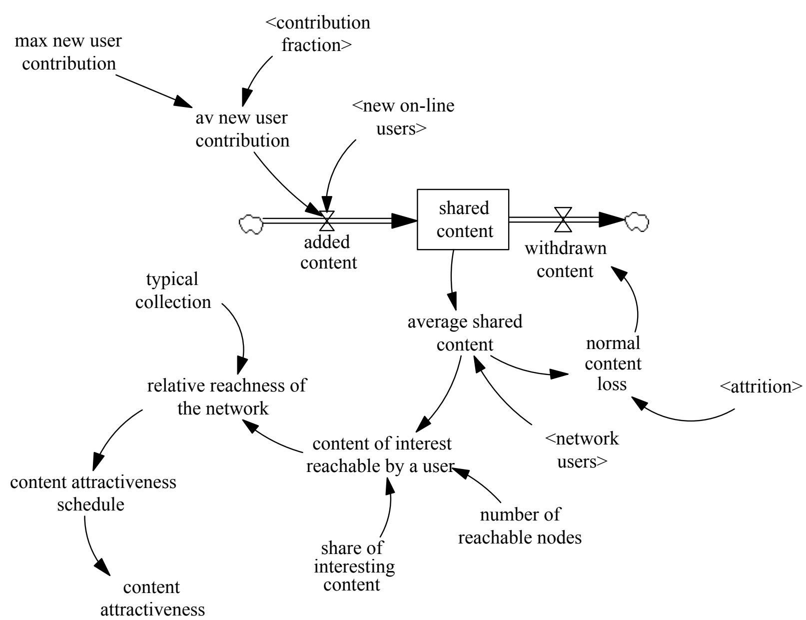


Figure 4: Content sector

A common feature of peer networks is that due to the limited connectivity and the finite time to live (TTL) parameter, the potential reach of each node is significantly smaller than the entire network (Leuf 2002: 199). For data collected for a seven month period starting in November 2000, Ripeanu, Foster et al. (2002) found that the average number of hosts visible to a node is independent of the network size. Ritter (Ritter 2001) estimates that for a network in which each node has on average 3 edges and TTL is set to 7 (a typical number in Gnutella), at best 381 nodes are visible from each peer. The variable content reachable by a user captures this fact. The relative richness of the network is the ratio of the reachable content to the typical collection of a user who does not participate in the music exchange. In the current version of the model, we assume that there is some average collection of music owned by a typical user; the relative richness of the network, which is inversely proportional to the typical collection, determines content attractiveness through a diminishing returns schedule.

Capacity sector

The Capacity sector is shown in Figure 5. Similarly to the shared content the network capacity, measured in terms of the shared bandwidth, increases with each additional new peer and diminishes when peers leave the network. At best, each peer contributes its entire available bandwidth, which is the typical node bandwidth. However, in most situations the contribution is below this maximum value and is controlled by the contribution fraction.

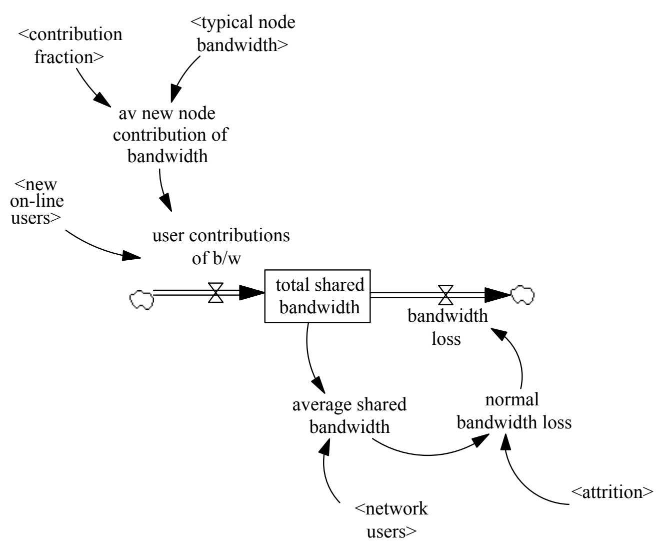


Figure 5: Capacity sector

Traffic sector

Sector shown in Figure 6 models traffic in the network. Following Ritter (Ritter 2001) we assume a linear relationship between the number of queries and the size of a peer network, that is, peers submit some average number of requests per node to the system. Additionally, we assume, following Yang and Garcia-Molina (2002), that some average aggregate bandwidth (in bytes) is generated by a representative query, response to the query, and the following download – all summed as the average traffic per download. The variable traffic is an aggregate measure for the entire file-sharing network.

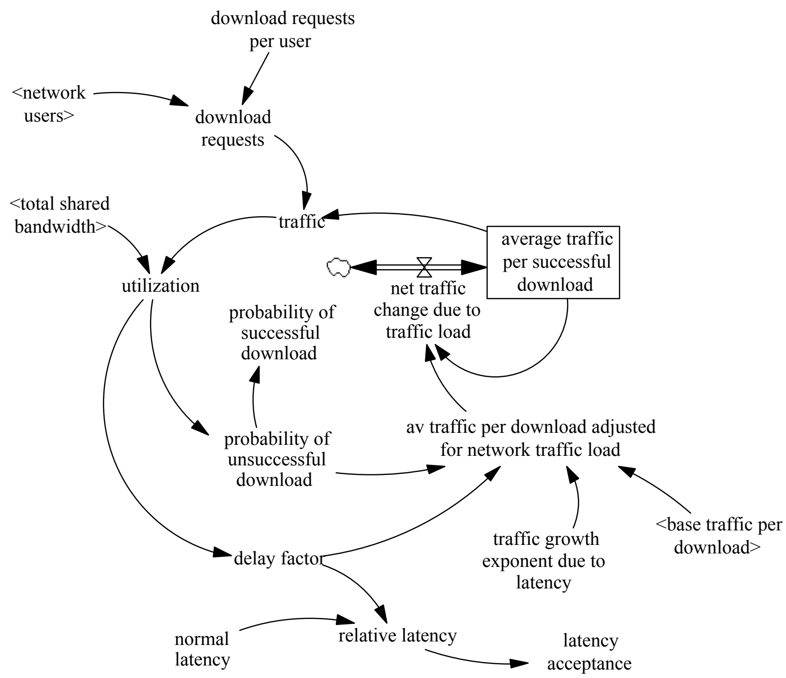


Figure 6: Traffic and network performance sector

Utilization is the ratio of traffic to the connection capacity. In general, once a node's bandwidth is saturated a number of things may happen (Leuf 2002: 121). Firstly, a connection might be dropped. This would lead to lost return paths, unfulfilled requests and repeat of request broadcasts. Secondly, the node may simply ignore some of the request traffic. Thirdly, the node can buffer some messages and wait till bandwidth frees up, but this would slow down computer performance and also contribute to the latency along the path. Network theory suggests that delay (latency) and network traffic for a given capacity are related as shown in Figure 7. This relationship is included as a delay factor. In a busy network, relative latency will increase beyond the benchmark value of normal latency. Consumers expect short response times to their searches. It has been suggested (e.g. Leuf 2002: 130) that Napster was able to achieve explosive popularity in its heyday because it provided quick responses to queries for music files. We represent the consumer reaction to delays with the latency acceptance variable. Latency acceptance is declining with increasing marginal dissatisfaction in relative latency.

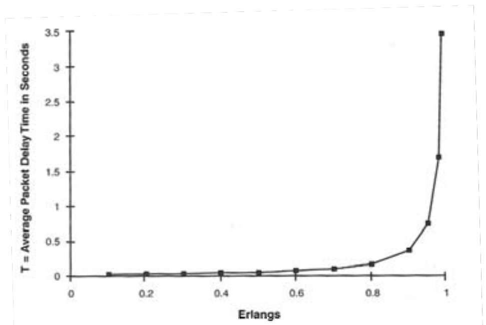


Figure 7: Average packet delay as a function of traffic load.
Source: Pecar and Garbin 2000: 429.

Users tend to resubmit song queries if the reply has not arrived within some short time interval. Users will also resubmit a query if the download is interrupted. Additionally, the peer software itself will resend query packets if it does not receive confirmations of its messages from other nodes. This forms a reinforcing loop: more traffic slows down the system, which, in turn, gradually stimulates more traffic. The loop is balanced by the decline in traffic as users disconnect from the network because of the poor mesh performance.

Decision Support System

We developed a "flight simulator" that is based on the system dynamics computer model[1]. Decision support systems (DSS or a "flight simulator") facilitate semistructured and unstructured decision making [Laudon and Laudon 1998: 591], which is characterized by the lack of knowledge of how to search for an acceptable solution due to the unclear nature of the problem and its structure [Eom 2000]. The P2P piracy problem demonstrates all the features of an unstructured problem. The problem is relatively new and no working solutions are known. Additionally, the complexity of the technical, legal, and economic issues makes the problem obscure. Many experts of varying backgrounds may need to be involved in finding an adequate solution, thus a user-friendly interface is highly desirable. The simulator permits anyone with basic knowledge of the Windows environment to conduct computer experiments in order to gain

[1] We used the simulation software package *Vensim DSS*.

a better understanding of the behavior of a P2P network under various business and regulatory scenarios. Figure 8 shows one of the screens of the DSS. We used the DSS to conduct numerical experiments that are presented below.

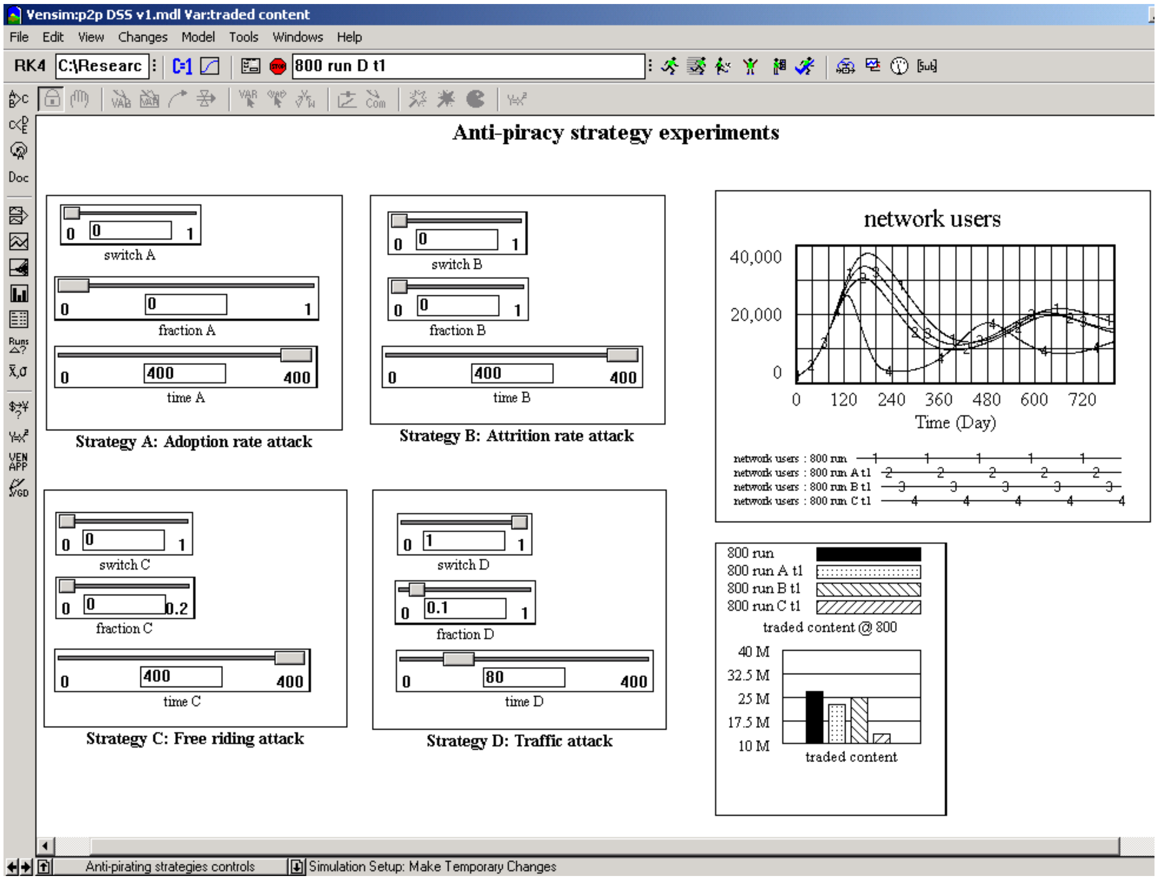


Figure 8: User interface of the P2P decision support system

Base case simulation

Figure 8 shows a fairly good fit between some data on the actual number of connected hosts in a peer-to-peer network over the course of a year and the simulated time series generated by our model. The pattern exhibited in the figure is an outcome of a complex interaction between the private provision of public resources (bandwidth and content), private demand for music exchange, and the performance properties of a computer network. One immediately notices the absence of high frequency fluctuations in the synthetic data. The fast oscillations in the actual data are due to the hourly variations in online usage – more people are on the Internet around midnight than at 6 o'clock in the morning (Kitz and Essien 2002). We do not replicate hourly variations in order to avoid the potential problem of stiffness that arises when time constants of significantly different magnitudes are employed in a model (see, for example, Maron and Lopez (1991) for discussion).

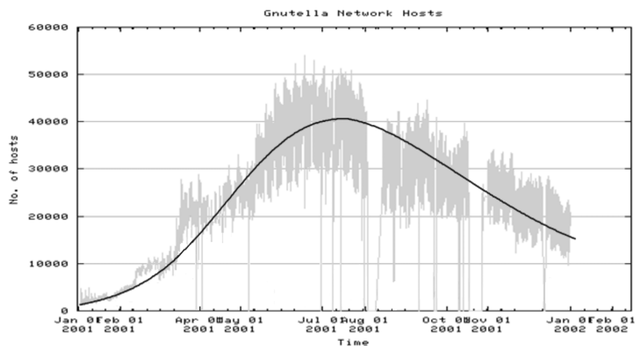


Figure 8: Simulated trajectory (smooth curve) and actual data (jiggered time series). Actual data are the number of Gnutella network hosts during one year between 1/1/2001 and 2/1/2002 (source: http://www.limewire.com)

The graph in Figure 10 is a causal loop diagram (Radzicki 1988) of a peer-to-peer system; it consists of all important state and flow variables and cause-and-effect links between them. As the initial small group of network users grows, so does the amount of shared content (the User Contributed Content Loop R1 in Figure 10) and so does the bandwidth available to the network traffic (the User Contributed Bandwidth Loop R2). The network's popularity is further enhanced by the media attention (the Publicity Loop R5) and through the word of mouth (the Word of Mouth Loop R4).

The growth in network resources is clearly visible in the data from the base simulation (Figure 11a). The free riding tendencies, however, become more prominent as the system scales up (the Content Free Riding Loop B3 and the Bandwidth Free Riding Loop B2). This leads to the gradual decline in the average membership contributions of content and bandwidth. Additionally, a larger network generates more traffic (the Traffic Growth Loop B1). The exacerbating inadequacy of resources increases the network's search response latency and lowers the probability of a successful download (Figure 11b). Increase in latency will induce some hosts to resubmit their requests (the Overload Escalation Loop R3). A decline in network performance contributes to the growing overall dissatisfaction with the network, leading to a fall in the network usage starting around day 176 of the simulation (Figure 11). This, however, reduces the traffic and network performance begins to improve (Figure 11b and the Traffic Growth Loop B1).

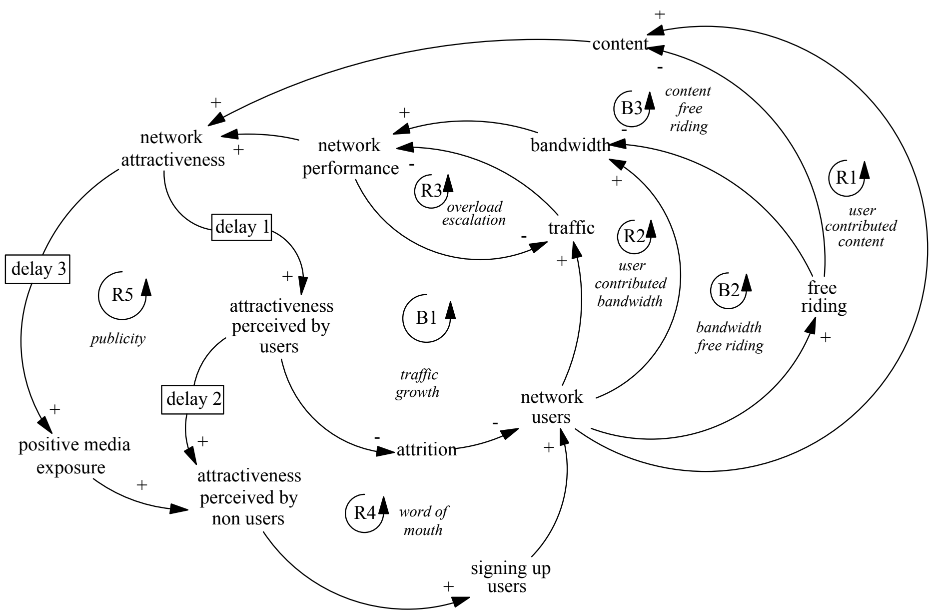
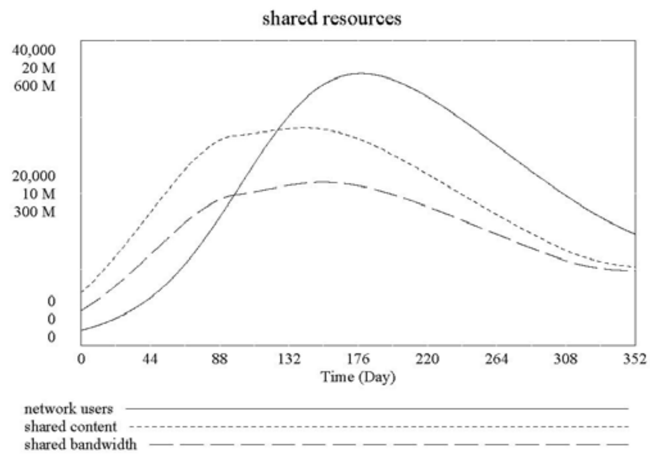


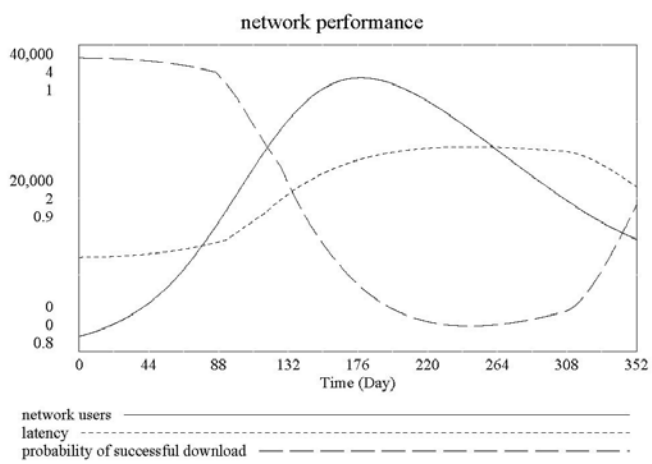
Figure 10: Causal structure of a peer-to-peer network

Anti-piracy policy experiments

Copyright owners may obstruct the file-sharing activity within peer-to-peer networks by a number of means. In this section we review three anti-piracy policy alternatives: (i) using either litigation or self-help copyright owners target large-scale contributors to the network, which are not necessarily its heavy users; (ii) corporations attempt to limit file swapping by eliminating the most grievous copyright violators, that is, those users who download significant amounts of files, by either suing them or by disabling such nodes online; and (iii) recording companies opt to disrupt the infrastructure performance by generating bogus traffic that clogs the system, which is a variant of a self-help approach. We investigate how the system responds to these policies and then compare the effectiveness of the strategies against each other.



(a)



(b)

Figure 11: Simulated network dynamics

Policy 1: Targeting large-scale contributors

Since the early stages of the battle against music piracy, the RIAA has been threatening to prosecute the offenders. On September 8 of 2003, it made good on the promise by filing suites against users in the United States who contributed significant music libraries to the network (Semple 2003). Information on file-sharers was collected using automated Net crawlers (France and Grover 2003). The move prompted many users to scale back on their generous file offerings (Harmon and Schwartz 2003; The Associated Press 2004). Because only a very small percent of users contribute most of the shared
files, the expectation is that such a reduction may negatively affect the common pool of free songs. However, there were still reports that the system continued to function and exchanges were still occurring. We would like to understand how the system responds to such an anti-piracy measure.

In highly uncertain situations people rely on rules of thumb (Hodgson 1998). After observing the trials, users may develop a rule of thumb similar to the following: "to avoid prosecution share only a limited amount of files." We simulate such a decline in maximum contributions by lowering the maximum new user contribution in the Content sector, Figure 4, by 30 percent, from 3000 to 2000 files. We begin our simulations in a steady state in order to eliminate the transient adjustment effects and concentrate on the system's response to the policy. The policy has an immediate impact on shared Content (Figure 12): users connecting to the network no longer bring the same amount of content as before, thus sharply reducing the inflow to the stock of content (Figure 4). This is followed by a quick decline in the stock of shared content, which, in turn, reduces the attractiveness of the network and leads to the erosion of the user base (the Shared Content Loop R1 in Figure 10, exacerbated by the reinforcing effects due to the Word of Mouth Loop R4 and the Publicity Loop R5). Smaller network size, however, eases the free riding problem (the Content Free Riding Loop B3 and the Bandwidth Free Riding Loop B2). Improved average user contributions slow down the erosion of network resources (Shared Content in Figure 12), which, with some delay, encourages new growth in online membership (Network Users in Figure 12).

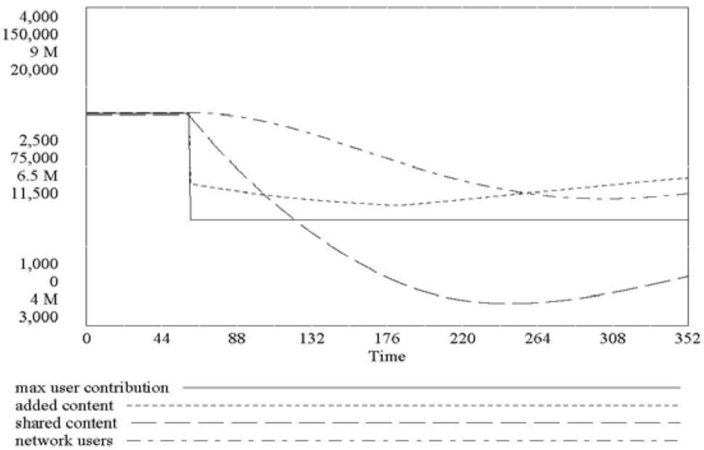


Figure 12: Shared content decline due to Policy 1 implemented at time 60

Policy 2: Targeting active downloaders

The best way to change a complex system in a desired direction is to align goals of its participants (Radzicki 1988: 649). Accordingly, the ultimate goal of the lawsuits against online music-sharers is to change the behavior of the online community (France and Grover 2003; Harmon and Schwartz 2003). In this experiment we test a situation in which people respond to the RIAA suing heavy music network users by adjusting their downloading habits – they download fewer songs, which is a realistic response (Harmon and Schwartz 2003). Thus, for this experiment, we lower the typical download request per user in the Traffic Sector (Figure 6) to about one half of the original frequency: from 1.87 to .9 song requests per person per day (Figure 13). The immediate consequence is a reduction in network traffic. But lighter traffic results in better performance (the Traffic Growth Loop B1 and the Overload Escalation Loop R3 in Figure 10), that is, shorter latency and greater probability of a successful download (Figure 13). This attracts a greater number of occasional users – that is the network users trajectory in Figure 13 is upward sloping immediately after the policy is implemented at time 60. Interestingly, a rise in users shortly after lawsuits began has been observed in selected music networks (Harmon and Schwartz 2003). The growth in the number of nodes gradually degrades network performance and attractiveness, which overturns the membership growth pattern (Figure 13).

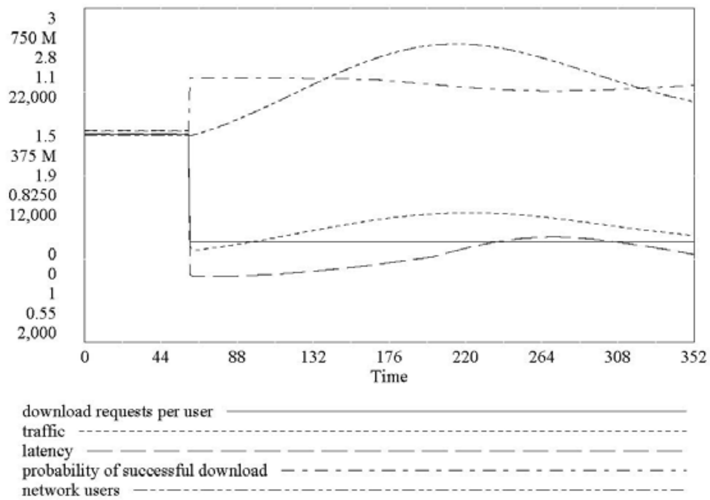


Figure 13: Network response to Policy 2 implemented at time 60

Policy 3: Targeting infrastructure

Litigation of individual online network members is expensive and impractical (Yu 2003). The majority of individual pirates are not attractive legal targets because they are not rich enough to pay monetary judgments (Yen 2001). The RIAA may hope to recover only between $2000 and $15000 per each settled case (Aftab 2003). Therefore, music companies have strong incentives to search for more cost-effective methods to fight pirates. For example, they may choose to introduce automated bogus peer-to-peer nodes that act as ultimate free riders (not unlike the existing network sites asiayeah.com and gnute.com). By generating numerous requests and not contributing any content or processing traffic from other peers, such nodes clog the peer network bandwidth, increase latency, and lower the probability of successful downloads for network users. If sufficient traffic is generated, then the system may collapse completely. In effect, such an intrusion is equivalent to artificially increasing the average number of file requests per each real connected user.

To simulate this situation, we increase typical download requests per user in the Traffic Sector (Figure 6). Its value is changed from 1.87 to 3 per user per day, which is about a 60 percent hike. As expected, traffic increases (Figure 14) leading to a surge in latency and a drop in the probability of successful downloads. Accordingly, fewer users join and stay online – network users trajectory falls. But this leads to less traffic (the Traffic Growth Loop B1 in Figure 10), which allows the system to recover in terms of the probability of successful download and latency (Figure 14).

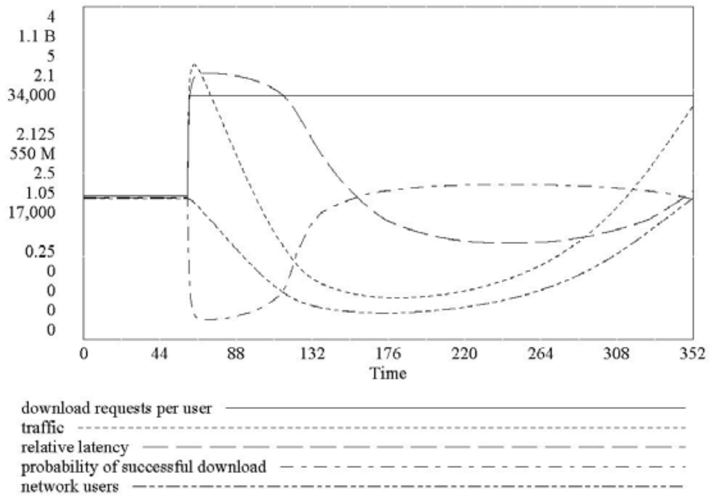


Figure 14: Network response to Policy 3 implemented at time 60

Policy effectiveness

Based on their background, participants who are involved in policy implementation may want to use different criteria to gage policy effectiveness. From the legal and regulatory standpoints the best anti-piracy strategy may be the one that allows the least number of violators. On the other hand, a recording industry executive is likely to have pecuniary objectives, and thus, she may prefer a strategy that is best at restoring music sales. Because of this discrepancy, we compare the effectiveness of anti-piracy policies along two dimensions: the number of network users and exchanged content volume.

Measure: number of network users

A network's response to the three policies with respect to the number of daily users is pictured in Figure 15. Each simulation was run for the time sufficient for the transient behavior of the system to settle. Table 1 summarizes the simulation statistics. Policy 2 is the least effective among the three policies because it allows the greatest average number of users (Table 1) and in the long run the network use upticks beyond the pre-policy level. Though our implementations of Policy 1 and Policy 3 are nearly equally effective in the long run -- they reach about the same steady state membership numbers (Figure 15) – the attack on infrastructure, Policy 3, results in a highly unstable transient trajectory. Additionally, Policy 3 is more effective on average at discouraging network use (Table 1). Hence, in the long run, either Policy 1 or Policy 3 may be preferred to Policy 2; but if the average criterion is also important, then Policy 3 is superior to Policy 2 and Policy 1.

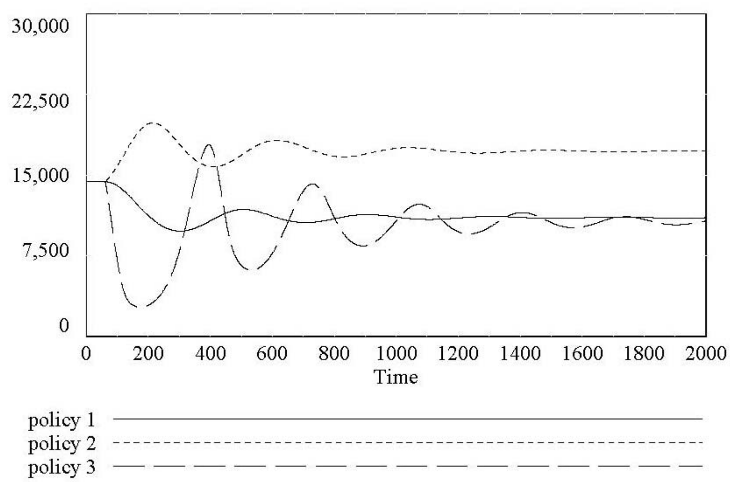


Figure 15: Policies compared with respect to the number of online nodes

Measure: exchanged content volume

Figure 16 presents daily figures for traded content while summary statistics are presented in Table 1. The response to Policy 3 was, again, the most volatile; it also led to the highest average and steady state volumes of traded content. Policy 1 is better than Policy 3 at suppressing file swapping in the long run as well as on average (see Table 1). Interestingly, in the long run, Policy 3 induces greater network use in terms of file swapping than before the introduction of the policy. Policy 2 achieved the lowest long run and average traded content volume. Thus, if one cares about the impact music piracy has on sales then she may choose Policy 2, that is, a policy against active downloaders.

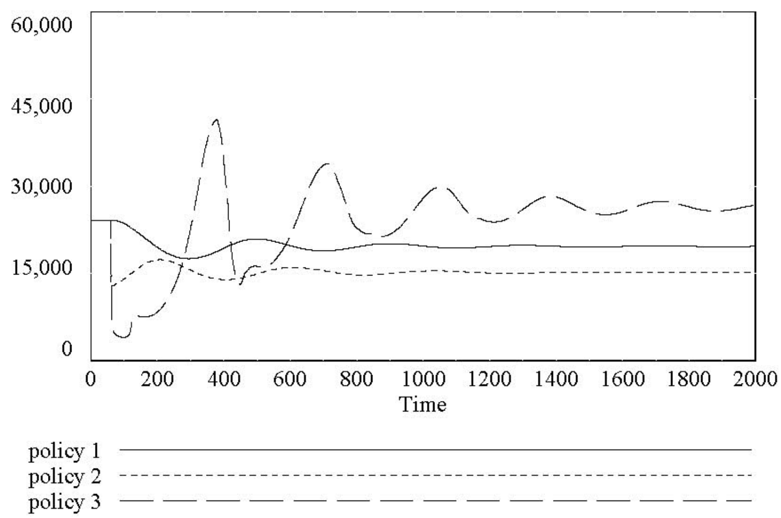


Figure 16: Policies compared with respect to the traded content

Table 1: Policy response summary statistics

	Measure 1: Online nodes				Measure 2: Traded content			
	Max	Min	Average	St. deviation	Max	Min	Average	St. deviation
Policy 1	14,374	9,799	11,236	896	24,169	17,519	19,873	1,259
Policy 2	19,861	14,374	17,197	927	24,169	12,751	15,482	1,673
Policy 3	17,834	2,705	10,147	2,891	41,421	3,985	23,805	7,037

Conclusion

Peer-to-peer technology has transformed music into a widely available and easily copied public good by allowing consumers to obtain music without paying royalties to copyright owners. In this article we have considered several actions that have been either implemented or reviewed by the recording industry as counter-piracy measures. Starting with an institutional description of the commercial music industry, we amended the traditional methodology with a formal computer model. To build the model, we carefully reviewed a representative online music community, including technological and behavioral characteristics of such a system. A base run confirmed model's ability to reproduce the behavior of the reference network.

After a satisfactory model was built, three policy experiments were performed. Policy 1 simulated a strategy that targets large-scale file-sharers. Policy 2 and Policy 3 were based on attempts to control downloading and network performance respectively. Each of the strategies has a real-life counterpart. One of the most striking observations from the experiments was that some of the measures led not only to temporal, but also to the long-term increase in network use. Such effects were created by the complex feedback nature of the popular networks, making the nets extremely resilient to any attempts to disrupt them. Network robustness suggests that the RIAA is not assured of gaining an upper hand in this copyright battle. A review of two measurements logged during the computer runs displayed a discrepancy in policy ordering based on the counter-piracy effectiveness: a policy using automated nodes that slowed down the system (Policy 3) was the most potent in terms of the decline in the number of connected nodes, but it lost to a policy that targeted heavy downloaders (Policy 2) when compared by traded content. This suggests the importance of selecting an adequate yardstick when discussing policy alternatives and their potential impact on peer-to-peer systems.

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