Digital Business Models for Peer-to-Peer Networks:
Analysis and Economic Issues

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ABSTRACT

Peer-to-peer (P2P) services allow users to share networked resources, notably bandwidth and content, from the edges of the network. These services have been popularized because of file sharing — particularly the sharing of unlicensed copyrighted files. Concerns about such P2P file sharing were highlighted by content owners' recent lawsuits against individual users and P2P network operators.

However, content owners are increasingly exploring the ability of peer-to-peer networks to accommodate legitimate content distribution and promotion. In this article we review the economic characteristics of P2P networks and outline the implications of these characteristics on efforts to counteract illegal piracy and on potential uses of P2P networks in a commercial media distribution strategy.

1. Introduction

Peer-to-Peer (P2P) networks have generated tremendous interest recently as a way to allow distributed users to share networked resources, notably bandwidth and content, from the edges of the network. Unlike a traditional client-server architecture, nodes in a P2P network function as both clients and servers — downloading from and providing content to other peers on the network. In this way P2P networks facilitate the direct exchange of files between users without the need for mediation by centralized servers.

Although the history of P2P networks can be traced to early Internet applications, such as Usenet and DNS, P2P networks have gained particular popularity in recent years because of file sharing — notably the sharing of (frequently unlicensed) copyrighted files. This illegal file sharing led media companies to initially eschew P2P networks as content distribution platforms and to resort to a series of lawsuits against these services. Those networks that were able to transition to "legitimate" content delivery services, such as Napster, were frequently forced to adopt a centralized delivery mechanism instead of a traditional P2P architecture.

Recently, however, media distribution companies have started to test the use of P2P networks as part of their promotion and distribution strategy. Established artists such as Steve Winwood have used P2P networks to distribute free copies of their songs intended to promote recently released albums. Extending this concept, companies such as INTENT Mediaworks, Altnet, SnoCap, Peer Impact, and weed-files.com offer media companies and artists with secure distribution of content over P2P networks and platforms to allow consumers to sample and purchase desired content. Other companies are using P2P for the distribution of digital radio (AudioFeast, Indie911), "broadcast" video (Cybersky, DAVE TV, NetCableTV, Kontiki), and independent films (Trans-

mission Films, Cinequest Film Festival). More recently, Warner Brothers Home Entertainment Group announced that they will use BitTorrent to distribute protected copies of their movies and television shows (see Marlowe 2006).

Other companies have also incorporated P2P services into a wide-variety of business applications. For example, P2P-based sharing of compute capacity has been adopted for collaborative computing (e.g., SETI@Home), instant messaging, enterprise information sharing (e.g., Bad Blue), and distributed data storage (PeerioData). Recently, there is blurring of distinction between different P2P-based applications. For example, at one point the Kazaa user agreement gave Kazaa's parent company, Brilliant Digital Entertainment, the right to sell extra processing power as part of their business model (Carlson 2002).

In this article, we analyze the economic characteristics of P2P networks, and discuss how these characteristics impact their use as distribution mechanisms for both legitimate and illegitimate content. The remainder of the article proceeds as follows. In Section 2 we analyze the characteristics and history of P2P networks, highlighting why P2P networks may be important for online business models. In Section 3, we discuss the economic characteristics of P2P networks and review the relevant economic and computer science literatures on P2P networks with an emphasis on the efficiency issues that need to be addressed when P2P networks are used as part of a business model. In Section 4, we conclude that although P2P networks have potential advantages over traditional distribution channels, they have many important characteristics that need to be considered for P2P to be used as part of a business model.

2. Background

As noted above, the peer-to-peer architecture has its roots in the early design of the Internet and many early Internet applications, such as the early ARPAnet backbone, and Domain Name Server (DNS) system, and USENET news groups (see http://www.anu.edu.au/people/Roger.Clarke/EC/P2POview.html for a good overview). In each of these cases, services were provided by nodes directly to one another (e.g., in USENET messages were passed between nodes without intermediation via a central server).

While the P2P architecture was present in the early Internet, it wasn't until June 1999, with the release of the Napster client that P2P networks began to gain a place in the public consciousness. Initially, Napster was intended for a small group of friends to share MP3 files, because standard search engines were unreliable to locate these files and available music indexes were out of date. Within just a few days after its release, the client was downloaded by 10,000 to 15,000 people (Spencer 2000), and by the end of the year 1999, the number of Napster users reached 1 million (Merriden 2001). At its peak, Napster had 13 million registered users, with about 1.6 million of these users logged into the service at any one time (Romer 2002). College students were among the first to embrace Napster. By late 1999, Napster was consuming up to 30% of the Internet bandwidth at a number of universities such as Oregon State and Florida State. In February 2000, New York University became one of the first schools to ban Napster. As the Napster community kept growing, it also drew attention from the Recording Industry Association of America (RIAA), who sued Napster for copyright violation. In July 2001, a U.S. District Court judge ruled Napster to close, which forced the company to shut down the service (Moon 2003).

However, the demise of Napster did not diminish demand for pirated media files. If anything, the publicity surrounding the case may have increased demand for P2P file-sharing services. In the

years after Napster, a collection of P2P networks have gained popularity and notoriety including iMesh, OpenNap, Gnutella, Kazaa, and most recently BitTorrent. In spite of an increasing number of lawsuits against these networks and their users, P2P usage has also increased. By other estimates, BitTorrent currently accounts for one-third (Thompson 2005) to over half (Borland 2005) of all Internet traffic. Figure 1 shows that, according to slyck.com, the average number of users logged into P2P networks worldwide increased from 3.8 million in August 2003 to 9.7 million in January 2006 and cache logic estimates that these online users are sharing on the order of 10 Petabytes of data, which is the equivalent of about 2 million full-length DVDs or 230 million CDs.

The cost to serve 10 million customers with 10 petabytes of data would be astronomical using current technology. Yet, P2P networks accomplish this by using spare bandwidth, storage, and processing cycles shared for free by its members. And here-in lies one of the important advantages of P2P networks for legitimate media distribution: their ability to scale to accommodate millions of users, sharing billions of large files.

Network scalability is a function of architectural design. Prior research (Asvanund et al 2000b) has identified three classes of P2P architectures: centralized, distributed, and hybrid. Napster, iMesh, and Audiogalaxy are examples of a centralized P2P architecture, where there is a central directory storing an index of P2P content, but where the physical copy of the content still resides on individual peers. The advantage of this architecture is that query processing imposes low overhead on individual peers, because peers pass their queries directly to the central index. However, the main disadvantage of this approach is that the central server serves as both a bottleneck on query processing and a single point of failure for the network — as illustrated by the court-order shutdown of the Napster network's central servers. The BitTorrent protocol adopts a simi-

lar architecture. BitTorrent users typically locate files they are interested by search one of a number of "tracker sites" that maintain a searchable index of metadata associated with various files available for download from other BitTorrent nodes.

A second generation of P2P networks sought to address concerns surrounding this single point of failure by adopting a fully decentralized architecture. For example, in the Gnutella v0.4 protocol, there is no index of content in the network. Instead, individual peers maintain connections to a small set (typically 4-5) of other peers in the network. Queries are then passed through this interconnected mesh network, with query depth being determined by a time-to-live parameter (TTL) which is typically limited to 7 or fewer hops in the network. This architecture overcame the single point of failure problem, but at the expense of scalability: Query processing imposed a large externality on other members of the network, degrading network performance.

Hybrid P2P[1] architectures seek to adopt the best of both the centralized and decentralized architectures. Examples of hybrid P2P architectures include Gnutella v0.6 and Kazaa. In the hybrid architecture, there are intermediate nodes (a.k.a. ultrapeers) maintaining directories of local content among the peers they are connected to. Individual peers connect directly to these ultrapeers, and ultrapeers are connected to each other in a mesh network similar to decentralized networks. Ultrapeers are chosen by the network based on their bandwidth, processing power, and stability on the network. Searches propagate from individual peers to their locally connected ultrapeer, and then through the mesh of interconnected ultrapeers, providing the network with improved query processing efficiency versus Gnutella 0.4 networks.

[1] DHT (Distributed Hash Tables) provide an alternative approach to the ideas discussed in this paper. A prototypical example of a DHT that is well known is CHORD (see http://pdos.csail.mit.edu/chord/). DHT's are outside the scope of our discussion in this paper.

3. Economic Issues

3.1. Incentives, Public Goods, and Club Goods

While differing in specific architectural design, P2P networks share some economic characteristics that are similar to public goods and club goods (Cornes and Sandler 1996). Goods that are not excludable in supply and are non-rival in demand are called public goods (Varian 1992). Lighthouses are a typical example of public goods. Club goods are excludable in supply (i.e., to club members), but usually non-rival in demand, although an individual's consumption may depend on the number of other persons with whom he must share his benefits (Buchanan 1965). Examples of club goods include country clubs, and cable TV broadcasts. The purpose of clubs is to exploit economies of scale and to share public goods. There are numerous papers on the efficiency of clubs for facilitating the sharing of public goods in traditional environments (Sandler and Tschirhart, 1980). Among them, Berglas (1976) established a result about the competitive provision of club goods, which states that club theory doesn't necessarily exclude efficient provision by market. Helsley and Strange (1991) examined the competitive provision of club goods with costly exclusion and consider two alternative exclusion regimes: fine and coarse exclusion. With fine exclusion a provider can charge both a membership fee and a per use price. With coarse exclusion a provider can charge a membership fee only. This solution essentially suggests two pricing mechanisms, which may also apply to P2P networks, as we discuss in section 3.3.

We find several notable similarities in the manner in which resources are shared in P2P networks and with the provision of public and club goods. Specifically, goods provided in P2P networks are typically non-excludable in supply in the sense that once they are made available on the network, they are made available to all network users. Moreover, in an ideal case, P2P goods can be thought of as non-rival in demand in the sense that when one peer downloads a file they also

share that file back with the rest of the network. However, two factors can increase rivalry among users. First, downloading over an asymmetric connection (one where the download speed is greater than the upload speed) may cause rivalry through a net reduction in download bandwidth available to other peers. More importantly, however, free-riding (where a peer consumes network resources without sharing their own resources in return) can also increase rivalry. Goods provided in P2P networks can also be thought of as excludable in supply if they are provided on a priority or exclusive basis to members of a local group of interconnected peers (Asvanund et al. 2003).

3.2. Encouraging Contribution in P2P Networks

The most fundamental question in P2P networks is how to stimulate peers' incentives to cooperate or contribute resources in P2P networks (Bredin 2004) — a problem that is also common to public and club goods settings. As discussed above, this problem is directly related to the nature of these networks. In most P2P protocols, peers can download without sharing content/bandwidth in return; and the network does not impose a penalty on the free-riding peer. Moreover, when free-riding is high, all nodes in the network are subject to congestion.

The problem of free-riding has been studied widely in the economic literature (Lindahl 1919; Samuelson 1954, 1955, 1969; Olson 1965; Hardin 1968; Clarke 1971; Groves, 1973; Groves and Ledyard 1977; Palfrey and Rosenthal 1984; Cornes and Sandler 1996). In the public goods setting, the failure of each consumer to consider the benefits for others of her public good provision is known as the *free-rider problem*, or following Hardin (1968) as simply "the tragedy of commons." It is also well known that the free-rider problem may worsen in a larger group (Olson 1965).

Numerous mechanisms have been proposed to address the incentive problem aka free-rider problem in public goods provision. Groves and Ledyard (1977) proposed a mechanism that achieves a Pareto efficient allocation, but it does not satisfy individual rationality (Saijo and Yamoto 1997). Subsequently, a variety of mechanisms have been proposed that satisfy both Pareto efficiency and individual rationality, as well as other desirable properties such as individual feasibility and balancedness (Groves and Ledyard 1987, Hurwicz 1994).

Most of the above mechanisms, however, share one undesirable property, that is, participants in the mechanisms do not have freedom not to participate. What will happen if voluntary participation is allowed? Palfrey and Rosenthal (1984) analyzed the provision of a binary public good with voluntary contributions. The private provision of discrete public goods (Bagnoli and Lipman 1989) is of particular interest to P2P research, because it assumes voluntary contributions by individual player — a feature that typical P2P networks also possess. Different from P2P networks, in the private provision of public goods, if a sufficient number of contributions are made, the good is provided. Otherwise, the good is not provided. For this reason, the problem is also known as "voluntary contribution threshold games" (van de Kragt et al 1983; Bliss and Nalebuff 1984). When each individual has incomplete information about certain characteristics of other individuals, for example, the cost of contribution, the value of the public good, or the "altruism" component, this asymmetry underlying the incomplete information will explain why some of the players will contribute while others won't. In the private contribution game, public goods can either be overprovided (Gradstein and Nitzan 1990) or underprovided (Nitzan and Romano 1990).

The incentive problem in P2P networks poses an obvious obstacle for P2P to be used as a distribution channel. Lacking incentives, free-riding will likely abound. There is recent growth of P2P

literature from the computer science and economics perspective that address this problem. The most common solution is through a tit-for-tat protocol. For example, Vishnumurthy et al (2003) propose KARMA to track each user's contribution and consumption. The "karma" score is used to prioritize peers who have high contribution. BitTorrent is a real world example of building incentives into protocol design (Cohen 2003). With BitTorrent, when multiple people are downloading the same file at the same time, they upload pieces of the file to each other. The basic idea is to make a peer's download rate proportional with its upload rate.

While most of the research studying the free-riding problem in P2P networks focuses on direct and explicit incentives to encourage peers to share, Krishnan et al (2004) analyze the possibility that users may share their content based entirely on self-interest. The intuition is that sharing will draw traffic away from other peers in the network to the sharing peer, thereby increasing the chance that the sharing peer will be able to get her desired content from other peers on the network. Thus, it is possible for a peer to increase her private utility through sharing. They propose to differentiate the quality of service provided to peers based on whether they share content. Significantly, they also find that it may not be socially optimal for all users to share their content, because the sharing cost is not justified by the potential benefit.

Another popular solution to overcome the free-rider problem is to implement incentives through explicit reputation systems (Dellarocas 2003). Such systems track a user's contribution over a longer time period (Krishnan et al 2003). These systems are built on the premises that peers have repeated interactions — a characteristic that tends to distinguish P2P networks from public goods. Therefore, some peers may choose to contribute in some periods, while in other periods, they free-ride. Meanwhile, duplication of the content will exist with the passage of time. The dynamic provision of public goods provides a partial solution to peers incentives to contribute in a

repeated setting (Gradstein and Nitzan 1990, Gradstein 1992, Konrad 1994). When incorporating time dynamics and incomplete information, public goods may be underprovided due to a delay in the provision. Not only time dynamics can change the equilibria; in addition, if players decide to contribute or not in more than one period, their incentives are likely to change. Sometimes, sequential contribution may even exacerbate the free-rider problem (Varian 1994).

However, in P2P networks, since the identity of peers are dynamically changing, it is hard to keep track of peers. The design of reputation systems is further complicated by the administration of the evaluation system in a fully decentralized P2P network (Krishnan et al 2003). Klaas (2004) uses a game theoretic model to show that if the users in a distributed file-sharing network are reputation-motivated, the free-riding problem can be mitigated. Morselli et al (2004) analyze the robustness of a reputation-based protocol, where a user who free-rides will be punished to the extent that others refuse to share resources with her. The game-theoretic reputation models used in the above papers have one desired property, that is, if the reputation system is designed properly, trust should be the outcome of the equilibria of a repeated game (Despotovic and Aberer 2004).

Other work in this area studies specific reputation and trust mechanisms. For example, Hwang and Lee (2004) analyze an Eigenvector-based reputation system (Kamvar et al 2003) with differentiated admission. Peers have more incentives to contribute because of access priority. They emphasize the importance of relative magnitudes between different kinds of rewards. Their mechanism also allows the transaction of reputation score among agents. Lai et al (2003) also study reputation-based mechanisms and find the prisoners' dilemma maybe overturned. Wang and Vassileva (2003) propose a Bayesian network-based trust model for building reputation in

P2P networks. They show that the system where peers communicate their recommendations outperforms the system where peers do not communicate with each other.

Since P2P networks share some characteristics with club goods as noted above, the design of a reputation mechanism can also exploit this feature. Abrams et al. (2004) propose an EigenTrust-based reputation system, in which peers are partitioned into groups and incentives are structured so that a peer only downloads from peers in one particular peer group. They demonstrate that the total error in trust values decreases with the number of groups. Similarly Asvanund et al (2003) propose a file sharing architecture in which a Gnutella ultrapeer and its local network of leaf nodes form a "club." By simulating the performance of the architecture, they show that the club model can organize self-interest peers into local clubs and increase peers' incentives to share content at the same time.

Despite the promise of using reputation and trust to promote sharing in P2P networks, a drawback of the reputation system solution is that the system can deteriorate by the spread of false reputation ratings. Buchegger and Le Boudec (2004) propose a system that can avoid this problem. In this system, everyone maintains two ratings: one rating is about others' reputation; the other rating is about how honest the others are in the reputation system. Over time, reputation ratings are modified by accepted information using a Bayesian approach. The trust ratings are updated based on the compatibility of second-hand reputation information with prior reputation ratings. This approach is robust against false ratings and efficient at detecting misbehavior.

3.3. Pricing

The free-rider problem can of course cause public goods to be underprovided. This is also seen empirically in P2P networks where sharing levels are frequently below the social optimal level

(Krishnan et al 2004). Another companion problem is that peers often fail to consider the impact of their consumption of network resources on other users. For example, if one user sends too many download requests, the responding node may be too busy to processing the requests, and therefore unable to handle other users' requests. This phenomenon is often referred to as an externality, specifically in this context, consumption externality. That is, the utility of one consumer is directly affected by the actions of another consumer (Varian 1992 pp 432).

Various mechanisms have been studied in the context of public goods to deal with externality. All bear the same idea — to endogenize the externality. Proposed by Pigou (1920), Pigouvian taxes charge firms the externality cost to reduce their production, which may cause externality to consumers or other firms. Pigouvian taxation faces one information problem, though: the costs imposed by the externalities have to be known. Subsequently researchers have examined alternative pricing and compensation mechanisms. Among them are Coase (1960) and Varian (1989).

The pricing mechanism has also been used in the context of P2P networks. In Adler et al (2004), each contributing peer offers a different price, while a downloading peer selects from multiple peers its objects. Downloading peers can select from a subset of the peers that can provide the service at lowest cost. Tamilmani et al (2004) examine a trading model in which peers use a pairwise currency to reconcile trading differences with each other. Peers who contribute to the network will receive a higher benefit. In particular, peers who set high upload rates receive high download rates in return, while free-riders download very slowly. Golle et al (2001) propose a micro-payment mechanism to charge for the use of P2P network resources. Chandan and Hogenborn (2001) also study the implementation of a micro-payment system in wireless P2P networks and find that it can mitigate the free-riding problem. Gupta and Somani (2004) also examine architecture for pricing and sharing of computing resources in P2P networks.

Interestingly, the reputation-based mechanism and the pricing mechanism can complement each other. Ranganathan et al (2003) compare reputation and pricing-based mechanisms and find these incentive schemes can be used effectively to counter selfish user behavior. Without incentive mechanisms, no contribution is an equilibrium, but this equilibrium is inefficient since users could have obtained higher payoffs had they all made the opposite choice. This result is reminiscent of prisoners' dilemma. Moreton and Twigg (2003) find that both reputation and pricing mechanisms induce similar incentive schemes, because both can be ascribed to a more general protocol "stamp trading".

In summary, in order to use P2P networks as a distribution channel, one should consider its similarity to public goods or club goods. However, the unique features of P2P networks also need to be taken into account. For example, the size of the endowment of resources in a P2P network varies based on how many peers contribute (Krishnan et al 2004), which means that each peer who shares resources increases the size of the endowment to all other members. Peers have dual roles of being consumers of the P2P resources and providers as well. Over time, the same content can be distributed to many peers, which can potentially alter the quality and quantity of available resources and thereby the dynamics of user participation.

3.4. Pollution

P2P networks greatly facilitate the sharing of resources among Internet users, whether the shared content is legitimate or not. The sharing of copyrighted content raises serious concerns on the copyright holders, such as RIAA and MPAA. Forrester research estimates that the music industry lost over $700 million?? in CD sales in 2003 due to sharing of copyrighted songs in P2P networks (Bernoff et al 2003). Copyright holders, therefore, have a very different goal. Instead of promoting sharing and efficiency of P2P networks, they aim to shut down the file sharing net-

works. Besides legal efforts that the RIAA and MPAA have taken, one technique that is particularly prevalent is pollution or poisoning.

Pollution seeks to deposit tampered files into P2P file sharing networks. When these files are downloaded by unnoticeable users, they are spread into the network, causing "pollution" of the content on the network (Liang et al 2005). Two forms of pollution exist: content pollution and metadata pollution. Content pollution alters the original digital content by replacing all or part of the content with white noise, cutting the duration, or inserting other irrelevant content. Metadata pollution changes the metadata, instead of the content, thereby making it difficult for users to locate the right content. No matter what form of pollution is used, the goal is simple: proliferate P2P networks with useless content, so that they can no longer be used to distribute copyrighted materials for free. Given the large volume of polluted content usually deposited, pollution seems to be a serious threat for P2P networks to be used as a legitimate channel for distribution of digital content.

There have been a number of studies on the nature and magnitude of pollution in P2P networks. For example, Liang et al (2005) develop a measure of pollution in the FastTrack P2P networks based on the number of unique versions and copies available for popular audio content and find that pollution is pervasive for recent popular songs. The content rating mechanism of KaZaA is incapable of dealing with frequently introduced polluted versions of a particular song. Similarly, it is found that in the spring of 2005, pollution was highly prevalent in the FastTrack and eDonkey systems, with as many as 50 percent of copies of popular titles being polluted (Liang et al 2006). Pouwelse et al (2005) draw a different conclusion for the integrity in the BitTorrent/Suprnova network. Because a direct measurement of polluted files in the BitTorrent networks is difficult, they try to create a measure by inserting fake files into the network. They find

that the system of moderators is effective in removing polluted content. This finding seems to be consistent with the discussion on P2P message boards, which suggests that BitTorrent/Suprnova is virtually immune to pollution. Nevertheless, BitTorrent networks are subject to DoS attacks on trackers. Kumar et al (2006) also examine how the injection of multiple versions of decoy content impacts a user's ability to receive a valid copy. Their models incorporate user behaviors such as preferences for popular versions and abandonment after repeated failure to download a good version. They find that users are better off selecting a version without considering its popularity because the content that is very popular and spreads quickly is very likely to be a polluted version.

Given that pollution is a prevalent phenomenon in P2P file sharing networks, a variety of mechanisms have been proposed to deal with the pollution attacks in P2P systems. Liang et al (2005) have described several anti-pollution mechanisms. Some of the mechanisms require downloading a file before detecting pollution. For example, in a matching mechanism, downloaded files are compared with authentic content stored in a trusted database. In a user filtering mechanism, users need to check the integrity of downloaded files before letting others copy them. Interestingly, some mechanisms do not need downloading to detect a polluted content. Blacklist is one example, where sources that frequently inject polluted content are blocked.

Another mechanism to prevent pollution is to use reputation and trust. Similar to the reputation and trust mechanisms used to encourage sharing of content, the reputation mechanism in the context of detecting pollution relies on rating one peer by others. However the latter reputation mechanism would rate objects, rather than peers. Walsh and Sirer (2005) propose a decentralized system for evaluating the reputation of objects. The system employs a network-wide voting scheme, where users evaluate objects. Evaluation from users can be weighted using the correla-

tion between different peer opinions. Liang et al (2005) also discuss anti-pollution mechanisms using reputation and trust. For example, users may only trust friends who have provided them with "clean" content before. This idea can also be generalized to the whole P2P network, so that a user may download from the friends of his trusted friends. Despite several anti-pollution mechanisms proposed, all have their drawbacks. For example, the downloading-based mechanism demands a trusted database to maintain authenticated copies of content, which not only has a maintenance cost but could itself be the target of an attack. On the other hand, the design of a particular reputation system may be subject to deceptive ratings and high complexity of implementation.

4. Discussion

P2P networks are going to play a critical role in the business models of the firms distributing digital content. P2P networks are either going to pose challenges for firms as a convenient channel to distribute content illegally or as a new distribution tool to be harnessed to get a leg up on the competition. A New York Times articles sums this up very well (The New York Times, March 6, 2006). According to the article, even if the music executives want to stop releasing the singles very early in the album life-cycle (so as to sell more album CDs), availability of singles on P2P networks have essentially tied their hands.

In particular, P2P networks have had a deep impact on the sale and distribution of music. For one, it has popularized the sale of singles. In fact, the sale of singles has grown so fast that it has compensated for the loss of album sales and more (The New York Times, March 6, 2006). P2P networks have also made it easier for small artists and minor labels to market and promote their albums. Typically, marketing an album is quite costly and only a few major albums (like Sony, BMG etc) have the resources to do it. However, P2P networks provide artists an opportunity to

spread the word about their music at a significantly lower cost. A recent study by Bhattacharjee et al (2005) finds that minor labels have actually benefited from file-sharing networks. Thus P2P networks might actually reduce the concentration in media market by lowering entry costs of promotions and advertising.

P2P networks have also made it possible for users to browse and search niche artists and albums which may not be readily available in record stores (For example, tower record stocks less than 6% of the CDs in circulation). Such a phenomenon of long tail is already observed in books and apparels where the rule of 80/20 (80% of the sale is due to 20% of the products) is changing (Bryjolfsson et al 2005). Because, users can search easily and find better fit, a lot more niche and specialized products are being sold than otherwise. Thus a more variety is being made available to consumers leading to higher consumer welfare (Ghose, Smith Telang 2005). Music industry will witness similar phenomenon as well. More obscure CDs and DVDs are going to find a re-newed interest due to easy availability.

P2P networks can and will play crucial role in the distribution of large digital content. P2P networks have unlimited scalability and can support millions of users at the same time (more than 3.5 million users log into P2P network at a given time). Many high bandwidth applications like digital radio (AudioFeast, Indie911), broadcast video (cybersky, DAVE TV etc), independent films (all films in Cinequest Film festival downloadable over BitTorrent), independent music (Steve Winwood used P2P promotion; Altnet licensed content distribution; weed Files - distributed on P2P networks. Users can play 3 times and then require purchase), and news magazines are already finding place on P2P networks and this speed will accelerate with time.

Moreover, promotion on P2P networks might become more effective and efficient as P2P networks spawn self-forming communities of mutual interest (Asvanund, Krishan, Smith and Telang 2005). Users within these communities share common interests and typically tend to be early adopters. Thus P2P networks would provide a more effective way of targeting. Such attempts are already visible when a new movie or video games are released. Movie studios try to influence many web based user communities which play an important role in success of these movies and products.

For many of these business models to succeed, our understanding of both technology as well as business models would need to evolve. Exciting research in computer science and Information technology is making P2P networks more efficient, user friendly and ubiquitous. Business community is already taking notice of these changes. There are several exciting research avenues for social scientists and economists. There is a need for rigorous theoretical and empirical work that would provide deeper insights into how P2P networks are utilized and how they influence the market, market structure and underlying business models.

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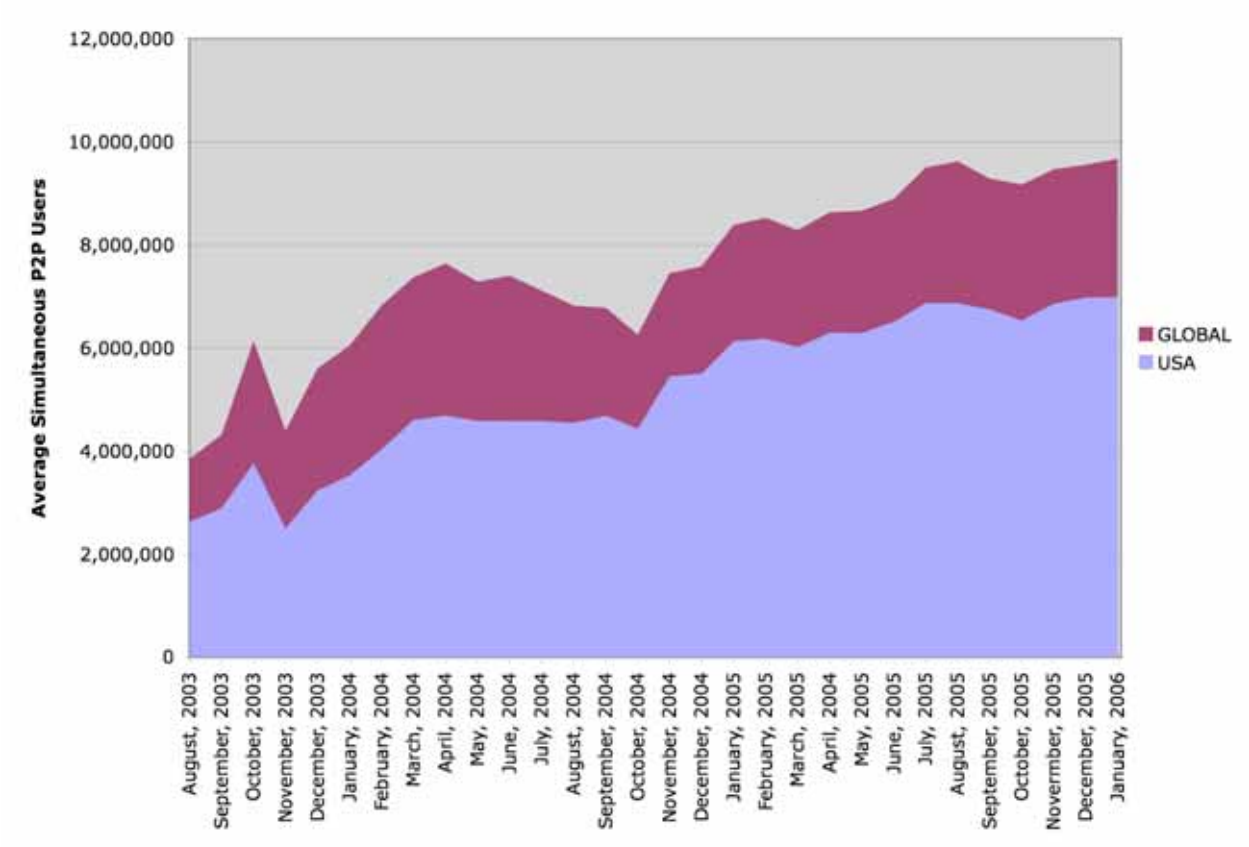

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Figure 1: Average Simultaneous P2P Users