OWN NOTHING, HAVE EVERYTHING:
PEER-TO-PEER NETWORKS AND THE NEW CULTURAL ECONOMY

by

GREG GOLDBERG

A dissertation submitted to the Graduate Faculty in Sociology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

2009

This manuscript has been read and accepted for the
Graduate Faculty in Sociology in satisfaction of the
dissertation requirement for the degree of Doctor of Philosophy.

Professor Patricia Ticineto Clough

Date	Chair of Examining Committee

Professor Philip Kasinitz

Date	Executive Officer

Professor Stanley Aronowitz

Professor Steve Brier

Professor Richard Dienst

Professor Anahid Kassabian

Supervision Committee

THE CITY UNIVERSITY OF NEW YORK

Abstract

OWN NOTHING, HAVE EVERYTHING:
PEER-TO-PEER NETWORKS AND THE NEW CULTURAL ECONOMY

by

Greg Goldberg

Adviser: Professor Patricia Ticineto Clough

This dissertation investigates the relation between digital piracy and the economic viability of reproducing and distributing cultural content online. While scholars often characterize piracy as resistant or oppositional to capitalism, I propose that peer-to-peer networks played an integral role in the success of markets for content online. Drawing from historical and technical documentation in information theory and network science, and from Marxist cultural criticism of film and television, legal analysis, and social and political-economic theory, I argue that peer-to-peer networks, in circumventing the technical inefficiencies and juridical obstacles that held back other forms of piracy, catalyzed a novel form of economic value native to the Internet. Responding to what Marxist cultural critics have written about film and television, I explicate how the Internet produces value not only though the attention of its users (as television does), but through the transmission of data—value realized by Internet Service Providers. This is made possible, I argue, by the socialization of a non-human mode of the time: the time of uploading and downloading data. Lastly, I examine how lossy digital audio compression technologies, such as the MP3, participate in the socialization of this “transmission time.”

Acknowledgements

By the time you finish your dissertation, words do not come easily. I would be remiss, however, if I did not express my sincere gratitude to everyone who has helped me along the way.

My peers (and mentors) at the Graduate Center are so smart and so funny. They taught me a lot of things about a lot of things and I will sorely miss their company: Ananya Mukherjea, Sam Han, Polly Sylvia, Heather Wiley, John Andrews, Kim Cunningham, Elizabeth Bullock, Kara Van Cleaf, Rebecca Tiger, Josh Howard, Alex Frenette, Hosu Kim, Jamie Skye Bianco, Emily Pugh, Grace Cho, and Will Weikart. Special thanks to Rachel Schiff and Soniya Munshi for their care and coaching and, importantly, their gossip.

Professors Juan Flores, Stacy Pies, Steve Duncombe, Marian Arkin, and Peter Hitchcock helped push me along. Rati Kashyap gracefully provided assistance over the years. Jonathan Cutler and Jonathan Beller gave me invaluable feedback on rough drafts.

My dissertation committee—Steve Brier, Richard Dienst, Anahid Kassabian, and Stanley Aronowitz—let me do my thing, even (or perhaps especially) when I veered off the beaten path.

My adviser, Patricia Clough, profoundly changed the way I thought. When she didn't have my head in a vice, she had me in stitches. Working with her has been a great honor and the delight of my graduate education.

Craig Willse, "my friend and sister throughout our turbulent and co-symbiotic becomings," (Terranova, 2004) was kind, generous, and patient with me, and humble—more-or-less. What tacky intellect I might have developed without his compassion and guidance, I'll never know.

My friends Kora Wilson, James Rubin, Chelsea Ross Green, Cayden Lovejoy, Marina Miranda, Rebecca Ross, Katie Halper, Kate Levin, and Daniel Barrow got me out of the house and kept me sane. August Wolf Lovejoy and Avery Wolf Green made me smile everyday despite my better judgment. Adrian McNicholl and Ted Baab listened patiently when I struggled, challenged me when I was cocky, and reminded me that it is possible to live between the two.

My Marxist-Leninist(ish) parents Mark and Isabel Goldberg encouraged me every step of the way, even after they read Chapter Three. I owe to them both my wishbone and my backbone, and to my older sisters Rita Verga and Denise Ficker, who taught me at an early age that shorter legs have to run faster to keep up.

Table of Contents

List of Figures

Introduction

In 1990, when Scott Lash published his critique of postmodernism, I was in the seventh grade. By the time I got to college, more than 10 years after Frederic Jameson's seminal critique was published in the *New Left Review*, the backlash against postmodernism had exhausted itself. It was an intellectually awkward time to be an undergraduate. If the idea of the postmodern once generated excitement or enthusiasm—even if mostly for its critics—the excitement had dissipated. Nonetheless, students of my generation were still asked to grapple with the concept of the postmodern, not so much as a threat to this or that intellectual tradition (as many of our mentors would have it), but rather as if we would be asked on a final exam to write its obituary. Not having gone through the throes of it, we often struggled to understand the most basic tenets of postmodernism: was it an organizing principle, a set of aesthetic priorities, a time period (without history?), a perspective? Was it a choice one made or the circumstances one found oneself in? Was it one coherent idea, and if so, didn't that contradict its own philosophical premises? Of course, some of our confusion was a product of the concept, which as Jameson argued (2001: xxii) is contested, internally conflicted, and contradictory.

If it was not always easy to define postmodernism, it was less difficult to hone in on the concerns of scholars writing about and against the postmodern. Primary among these concerns was the relationship between culture and economy. What did a postmodern framework make possible or impossible in terms of conceptualizing these fields? Lash saw it simply: “Postmodernism is … confined to the realm of *culture*. Post-industrialism is one important property of contemporary capitalist economies. But it is a strictly economic, not cultural property” (1990: 3). If Lash’s description confines postmodernism to the cultural, opening a space for scholars wary of the postmodern to engage with contemporary economic issues, Jameson’s account allows for more slippage between culture and economy. He writes, “To say that my two terms, the *cultural* and the *economic*, thereby collapse back into one another and say the same thing … is also to suggest that the base, in the third stage of capitalism, generates its superstructures with a new kind of dynamic” (2001: xxi). Is the collapse of culture and economy so intolerable that Jameson could not complete his sentence without asserting their continued viability, albeit in a new dynamic of base and superstructure? What is it about culture and economy that compels scholars to police so insistently their boundary?

The answer to this question is, I suspect, politics. Underlying Jameson’s argument is the insight that postmodernism had blurred the already tenuous boundary between culture and capital, a boundary on which the politics of the Left had rested. After the Frankfurt School’s critique of the culture industry, the laborious task of maintaining a distinction between culture and economy lead scholars of culture away from questions of the market and towards questions of meaning and interpretation. Economy had become a losing front, politically speaking. The most successful post-Frankfurt school work on culture involved an intellectual sleight of hand—focusing on questions of meaning and interpretation while questions of economy vanished. Just because people buy culture, scholars argued, does not mean that they buy into it. However, postmodernism rendered this approach less viable. As Jameson writes, “Aesthetic production today has become integrated into commodity production generally” (2001: 4). In this way, economy was thought to have infiltrated not only the production of artistic goods but artistic production. It is no wonder that at this moment scholars on the Left rushed to defend the continued viability of the separation between culture and economy.

If focusing on questions of economy made it difficult for scholars of culture to locate possibilities for resistance given the shrewdness of capital, then Jameson’s argument also showed—perhaps unwittingly—that being lead by one’s desire to locate resistance could make it difficult to account for contemporary social and economic transformations. Even Jameson’s own model of resistance (cognitive mapping) struggled to gain a toehold against the postmodern condition he described, revealing a lag between where the world was and where the politics of the Left was. In the pages that follow, I will offer little in the way of a politics of cultural/economic resistance, not because I believe resistance to be futile, undesirable, or unimportant but because I think that the viability of resistance and politics more broadly depends on a careful study of the contemporary moment.

It is instructive to revisit the intellectual concerns of scholars of culture at the moment of postmodernism, the moment before what I will propose was a major transformation of culture and economy occurred. Looking back at Lash’s and Jameson’s arguments 15 years later, it strikes me that my confusion was not simply a product of having missed the moment of postmodernism, but of living in a world that had changed since postmodernism captured the attention of academics interested in culture and economy. In particular, what had changed since Jameson and Lash published their critiques was that a new technology had worked its way into everyday life, a technology which changed how culture is reproduced and distributed, drawing into question more than ever before the distinction between culture and economy. The technology was the Internet.

Broadly speaking, the aim of this dissertation is to interrogate the ways scholars of the social have conceived of culture, economy, and their relation, and to suggest ways in which this thinking must change in light of the Internet. To do this, I will focus on the nuts and bolts of digital network technologies, which I will argue are the motor of a contemporary transformation of culture and economy. Importantly, this represents a departure from how technology is typically dealt with in sociology. Unlike most social studies of technology, the argument presented here will be less concerned with the intricacies of how technologies are used in everyday life. Use is only one facet of the social life of technology. Instead, I will address the more fundamental question of what the social might be in the context of these technologies.

While much of the material I will cover is technical, I became interested in digital network technologies not because I am a techie, but because I have a strong personal and academic interest in one form of culture that has been particularly effected by these technologies: music. As an undergraduate, my interest in music for the most part evaded questions of technology. An amateur musician from a (far) Left family, I was interested primarily in how people make and use music in ways that resist structures of power in society. Most often my inquires revolved around questions of meaning and interpretation, questions with practical importance to me as a fledgling songwriter. It did not take long, though, for the increasingly common occurrence of subcultural cooptation to leave its cynical mark on my thinking, not to mention my doubts about the ultimate purpose of exploring, examining, and explaining this or that musical genre or subculture. Was this the best our politics could do?

It was around this time that a major shift occurred in the way that music is consumed, redirecting my attention from questions of meaning and interpretation to questions of technology. Before this shift affected my academic work, though, it affected my music-consumption habits. As a teenager, my desire to consume music far exceeded my minimum-wage income at the local bookstore. To satisfy my appetite for music, I was resourceful. The music I could not afford to buy I taped from the radio or received from friends. Through the judicious use of cassette tapes, my friends and I shared the expense of buying CDs while also spreading the gospel of new bands we had discovered. Given how useful and relatively inexpensive cassette tapes were, it felt like an investment to pay 12 or 15 dollars for a CD. At that price, when I liked a CD I bought, I felt vindicated. When I didn't, I was sorely disappointed.

I had grown accustomed to restraint and frugality in my music consumption when Napster, the first peer-to-peer network, launched in 1999. Almost overnight, Napster changed my music-consumption habits. Almost every song I could think of was out there, on somebody's computer waiting to be downloaded. The scale of it was overwhelming. I could scarcely make up my mind about what to search for. Every artist or genre I had ever been curious about but had passed up, every one-hit wonder that could not justify buying an album padded with filler—it was all freely available through Napster. Perhaps more dauntingly, with a little ingenuity one could search for and download music according to new classification logics. In retail stores, albums are most often classified by genre and artist, but through Napster songs were searchable by file name. When users labeled their files with additional information, such as the year of the recording, that information too was searchable.

As innovative as it was, Napster was not without a number of drawbacks. First, downloading songs took time. In 1999, most Internet users had dial-up connections, with the notable exception of users on many college campuses, a group widely credited with jumpstarting the peer-to-peer movement. With a dial-up connection it might take an hour or more to download a single song. Second, because users were constantly connecting and disconnecting from the network, there was always a possibility that an uploader might disconnect before the whole song had been downloaded, not to mention the possibility that the song might be mislabeled. Third, once a song was successfully downloaded, it was in a cumbersome form: a digital file. When Napster became popular there were limited options for listening to digital files. The most attractive option for many users was to purchase a recordable CD drive, burn audio CDs with downloaded files, and listen to these CDs on a stereo or Discman if those devices would accept home-recorded CDs. Fourth, unlimited Internet access was not yet widely available. Even if users did not pay for CDs, they would pay for the time spent connected to the Internet, downloading each song.

Even with these drawbacks, Napster grew more popular every day. By the time I entered graduate school in 2001, Napster had attracted more than 25 million users globally (Mariano 2001), provoking widespread panic in the music industry. According to the Recording Industry Association of America (RIAA, 2008), a trade group that represents the collective interests of large commercial record labels in the United States, the record industry sold approximately 13 billion dollars worth of music in 1999. In 2008 it sold 8.5 billion dollars worth. The record industry quickly blamed Napster and subsequent peer-to-peer networks for its declining profits. Spearheading the attack against peer-to-peer networks, the RIAA first targeted the companies that helped to build and maintain peer-to-peer networks, beginning with its 1999 lawsuit against Napster. When this strategy proved ineffective (despite tactical victories), the RIAA began to litigate individual file-sharers, hoping that the threat of heavy fines would serve as a deterrent. Since September of 2003, when its lawsuits against individual file-sharers began, the RIAA has filed, settled, or threatened legal action against more than 30,000 people (Electronic Frontier Foundation 2008). While the majority of those accused have chosen to settle out of court, paying thousands of dollars in fines to the RIAA, these lawsuits too have failed their strategic purpose. Not only do peer-to-peer networks continue to rise in popularity, but the record industry's business practices now face intense public scrutiny. Having tried everything from lawsuits and legislation to sabotage in order to shut down peer-to-peer networks, the music industry is at its wit's end: nothing has worked.

Why did peer-to-peer networks elicit such a forceful response from the music industry? This was not the first time music had been duplicated without permission from or payment to the record industry. When Napster was released my friends and I had been duplicating music on cassette tapes for years. However, unlike small groups of friends making mix tapes for each other, peer-to-peer networks operate at an unprecedentedly enormous scale, bringing together millions of users—strangers to each other—in what has become (with the spread of broadband Internet access) a sort of instantaneous online swap-meet. This congregation of users is not, in itself, notable. What is notable is how effective peer-to-peer networks are, and how difficult they are to control. Were they easier to shut down, many of the transformations of culture and economy that are the focus of this dissertation might not have happened, or at least not in the same way. It is for this reason that I first thought it necessary to understand how peer-to-peer technologies work, how exactly they make possible the massive unauthorized duplication of music while evading control. In short, this is how I moved from questions of meaning and interpretation to questions of technology.

As interested as I was in questions of meaning and interpretation, and as pervasive as this type of questioning has been, scholars have addressed questions of technology throughout the history of cultural studies, albeit in much smaller numbers than they have addressed questions of meaning and interpretation. This work has focused largely on how technologies are used, with particular attention to technologies that offer some promise of libratory participation and/or cultural resistance. In the realm of music, objects of study have included independent record labels, mix tape culture, zine writing, and home-studio recording. While peer-to-peer networks might easily fall into this paradigm, seeing as how they appear to thwart the power of the entertainment industry, a closer inspection of peer-to-peer and other digital network technologies will reveal that they are in many ways surprisingly integral to capitalism. Following work by Jonathan Sterne, Alexander Galloway, Tiziana Terranova, and Eugene Thacker, I will focus instead on how these technologies work in order to explicate their integrality to capitalism.

To explain the success of peer-to-peer networks in the face of formidable opposition from the music and entertainment industry, I will take a two-pronged approach. In the first chapter, I will discuss peer-to-peer networks as networks, that is to say as participating in a particular form of social organization—the network—which engenders a new mode of power resistant to juridical methods of control. To do this, I will draw from work by mathematicians and social scientists who study diverse types of networks—from neural networks to terrorist networks—as well as work which draws into question the contemporary popularity of the network as an explanatory concept. In the second chapter, I will discuss in detail the mechanics of peer-to-peer networks, and how they circulate this new mode of power. Because peer-to-peer networks' resilience against juridical attack is primarily a technical characteristic, a detailed explanation of peer-to-peer technologies is required to understand how they catalyze a transformation of economies of culture online.

The particularities of peer-to-peer and digital network technologies have not gone entirely unexamined by scholars. However, the work done on the peer-to-peer movement has mostly evaded the social sciences, taking root instead in legal studies, through the work of a group of scholars affiliated with the Berkman Center for Internet & Society at Harvard University (coincidentally founded the same year Napster was released). Early in the game, these scholars understood that the laws being passed, policies being changed, and courtroom battles being fought as a result of the perceived threat of peer-to-peer networks would likely have lasting effects beyond the conflict between the music industry and peer-to-peer networks—effects on the future of copyright, government control over technological development, and the legality of methods of surveillance and policing. While legal scholars were not the only ones paying attention—entrepreneurs, programmers, musicians, parents, university administrators, silicon valley and its enclaves, and of course downloaders were also paying attention—it was legal analyses of and interventions into the conflict between peer-to-peer networks and the music industry that formatively shaped the discourse surrounding the peer-to-peer movement, with a primary focus on its legal and economic repercussions.

Implicit in the approach taken by legal scholars is the idea that the state wields tremendous power in its function as intermediary between the developers of technologies and society at large. As Internet scholar Manuel Castells writes:

> What must be retained for the understanding of the relationship between technology and society is that the role of the state, by either stalling, unleashing, or leading technological innovation, is a decisive factor in the overall process, as it expresses and organizes the social and cultural forces that dominate in a given space and time. (1996: 13)

Much of the work done by legal scholars on peer-to-peer and digital networks takes this point to heart, aiming to impact the organization of social/cultural forces by informing and intervening in the state's control over technological development. While it is true that the state wields power with regard to technological development, and while the efforts of legal scholars have undoubtedly impacted this process, I will argue (in Chapter Three) that the work of legal scholars around peer-to-peer and digital network technologies has been shortsighted—focusing on the economic health of the market while a much broader transformation is underway, a fundamental transformation in how culture yields economic value.

Though I started this project guided by an interest in music, I soon realized that music was only the tip of the iceberg. As broadband Internet access became more readily available, users started to share much larger files through peer-to-peer networks: software, television episodes, and feature-length films. But more than this, the long-predicted exodus of culture to the Internet started to happen in earnest following the success of peer-to-peer networks. Increasingly, forms of culture that had been consumed through diverse and mutually exclusive technologies started to be consumed through one technology (or rather a number of converging technologies): the Internet. These forms include not only television, movies, and music, but also radio programming, news and other forms of print (magazines, trade and academic journals), games, and reference materials (maps, technical manuals, dictionaries and encyclopedias, etc.). Furthermore, because of the interactive nature of the Internet, these forms of culture were not simply migrated but were fundamentally transformed in terms of their production and consumption. There is no shortage of examples to illustrate this point: the open source encyclopedia Wikipedia, the massively multiplayer game World of Warcraft, the video sharing site YouTube, and the photograph sharing site Flickr, to name a few. Perhaps most importantly, the Internet generated new endemic forms of culture such as blogs, social networking sites, and search engines, that cannot be described as simply migrating or even transforming previously existing forms, even while they may resemble them.

While culture on the Internet flourishes, its technological predecessors have fallen on hard times. As I have already noted, the record industry is widely considered to be in crisis, and the movie industry has taken hits as well. Magazines are folding by the dozens. As Quincy Jones, the founder of the recently kaput *Vibe* magazine declared, "I'm'a take it online because print and all that stuff is over" (Samuels Gibbs 2009). By 2008, the popularity of online news sites began to threaten the viability of several prestigious newspapers. Even the New York Times has been widely rumored to be under financial strain as a result of the decreasing popularity of print journalism. Television too has taken a hit. In June of 2009, the New York Times reported that so far this Summer the four major broadcast networks have received the lowest ever combined ratings for viewers between the ages of 18 and 49 (Carter).

It would be a stretch to argue that peer-to-peer networks caused the migration and transformation of culture online. Peer-to-peer networks did not make the Internet popular and furthermore, many of the transformations cited above had begun before peer-to-peer networks existed. However, while they did not cause these transformations, it is my contention that peer-to-peer networks catalyzed the form of economic value which underlies the successful planting of culture on the Internet. Before peer-to-peer networks, the economic viability of culture online was hindered by content providers' attempts to charge users for access to data. Users simply did not want to pay. In making accessible data for free, peer-to-peer networks sped-up the "chemical reaction" of culture and economy online, catalyzing viable markets for cultural content despite financial losses incurred by record labels, movie studios, newspapers, etc.[1] To reiterate, this is not to say that the success of Google or the New York Times online or YouTube is caused by peer-to-peer networks. Nor is it to say that these sites must offer content for free, as peer-to-peer networks do, in order to be successful. Rather, I am arguing that a new form of economic value native to cultural content on the Internet was first realized by the massive free reproduction and distribution of cultural content through peer-to-peer networks. Put simply, peer-to-peer networks changed the rules of the game.

In this way, what began as a project about the reproduction and distribution of music through peer-to-peer networks has become a larger project about economies of culture online. What was it about the Internet that made difficult cultural business as usual? Part of the problem was that the entertainment industry's profitability was wrapped up, in part, in the exchange of culture in commodity form: records, CDs, VHS tapes, DVDs, books, newspapers, magazines. As Jameson's disparaging comments in *Postmodernism* about the commoditization of culture indicate, this was still true of culture in the 80s. However, this started to change in the late 90s and early 00s, as culture was increasingly introduced into digital networks. Put simply, culture in digital networks resists commodification. It exhibits a fundamentally different materiality than the commodity, both in its pronounced informational character and in its fundamentally non-rivalrous ubiquity, such that it is not exchanged through digital networks in the formal

[1] In retrospect, we might interpret the bursting of the dot-com bubble as indicative both of the poor fit of pre-existing paradigms of cultural economy, and of the period of adjustment required for businesses to adapt to the new paradigm established through the success of peer-to-peer networks.

sense of the word.[2] Rather, it is endlessly reproduced. For Marxist scholars of culture, this presents a curious problem. Given the centrality of the concepts of exchange and exchange value in Marx's analysis of capital, how should we make sense of the production of value in such a system? I will address this dilemma in Chapter Three, as well as some notable (if not problematic) attempts of Marxist scholars of the Internet to think through these issues.

If the entertainment industry's profitability has been wrapped up in commodity exchange, it is important to note that it has also been wrapped up in the transmission of cultural content; cultural commodities are not only exchanged, they are also broadcasted. While Marxist scholars have not had an easy time thinking through the economic ramifications of the non-exchange of data, others have been more productive thinking through the economic ramifications of broadcasting, and in particular the broadcasting of television.[3] Interestingly, scholars of the Internet have not followed their lead. Of the many tomes written on television, I will focus on a few that best help to explain how the transmission of data may produce value. In particular, in Chapter Four I will assess Richard Dienst's argument that television produces value through socializing television audiences' viewing time, which is sold to advertisers as ratings and bought from

---

[2] Curiously, in the absence of commodity exchange, many of the metaphors Marx used to explain the production and circulation of value need to be rethought. For example, can value "crystallize" in the absence of a commodity? Of course, there are other reasons to rethink some of these metaphors. For one, many of the scientific understandings from which they are drawn have changed considerably. See: Clough, Patricia Ticineto, Greg Goldberg, Rachel Schiff, Aaron Weeks, and Craig Willse. 2007. "Notes towards a theory of affect-itself." *Ephemera: Theory and Politics in Organization* 7: 60–77.

[3] While I will ultimately argue that the Internet is more economically similar to television than it is to markets for cultural commodities (CDs, DVDs, etc.), it is interesting to note that the Internet greatly diminishes the distinction between owned content and broadcasted content which has long cleaved analyses of cultural technologies. While the Internet offers its own versions of these types of content – streamed content and content for download – the difference between them is increasingly little more than a set of security parameters.

networks as segments of value-producing time. Taking cues Marx's labor theory of value, Dienst suggests that it is the passive labor of consuming cultural content—the labor of sitting in front of the television—which produces value in the context of television.

The Internet, like television, asks users to attend to it in certain ways. When users surf the Web, check their e-mail, or watch videos online, they lavish on their computer screens the same value-rich attention audiences give to their television screens. For this reason, it is possible to conclude that the Internet can produce or extract value much in the way that television does, i.e. from human attention. However, as I will argue in Chapter Five, there is a fundamental way in which users' attention to the Internet differs from audiences' attention to television. When audiences watch television (for now I will assume radio transmission) they tap into a signal that floats in the ether whether they watch it or not. They do not use up television signals when they watch television, nor do they diminish the capacity of anybody else to receive television signals. Like light from the sun, as long as audiences' access is unobstructed, they can soak up as much television as they want without straining the system. In fact, the more television they soak up, the better it is for the economic health of television. What makes possible this economic dynamic is the political-economic organization of television, which is controlled through a system of government-issued licenses. Unlike television, the Internet turns every user into a broadcaster. Without a system of licensing to control the quantities of data users upload and download, Internet bandwidth (defined as its capacity to transmit data) has become a rivalrous resource. Owing to the rivalrous character of bandwidth, the Internet produces economic value not only through attention, but through transmission, that is to say when units of bandwidth, having been socialized (like units of attention), are used up.[4]

With regard to the reproduction and distribution of cultural content, the Internet thus produces economic value in two ways: through attention (like television) and through the transmission of data. This does not mean, however, that the Internet produces twice as much value as television. Because Internet bandwidth is rivalrous, the consumption of cultural content on the Internet—unlike the consumption of television content—depletes available bandwidth, producing a curious and important tension between content providers and Internet Service Providers (ISPs). Whereas the interests of television stations and television content providers are aligned—both want to attract as many viewers as possible—Internet content providers generally want large audiences, while ISPs generally want users to upload/download as little data as possible. This was not always the case, however. Early users of America Online (AOL) will recall that Internet access was for a time organized in a similar way to television: AOL provided its users with access to the Internet as well content. With the popularization of the World Wide Web and independent ISPs, however, services for access and content were decoupled. While the long-term economic interests of ISPs and content providers remain aligned—one cannot survive without the other—their immediate profitability is opposed for the simple reason that attention, in an indirect way, consumes bandwidth.

---

[4] A more orthodox Marxist approach might consider the human labor that goes into fabricating servers and routers, producing cable and laying it into the ground, performing network upkeep and maintenance, etc. While I accept that these forms of labor produce value, this value cannot begin to account for the economic productivity of the Internet. Furthermore, in the analysis that follows, I will argue that the human/machine dichotomy which subtends Marx's labor theory of value is less viable in the context of digital network technologies.

As a result of the conflict between attention and bandwidth, the Internet has given rise to a different cultural economy with a distinct logic from earlier media. Television, for example, simply wants to capture as much attention as it can for as long as it can; the better it does this, the more robust its economy. Unlike television, the Internet, as a machine of cultural economy, cannot be satisfied to simply capture users' attention. Because attention brings with it the consumption of costly bandwidth, the Internet must also minimize the impact of attention on bandwidth. One of the most crucial ways it does this, as I will examine in Chapter Six, is through a material reorganization of the faculties of human perception which subtend our attention. Here I am thinking in particular of the advent of perceptual compression technologies, which remove from digital files those pieces of data which are likely to fall below the threshold of human perception: sounds that are inaudible, aspects of images that go unnoticed. I will explain how perceptual coders work in order to show why it is necessary to move beyond questions of the human subject (central to analyses of television) to consider questions of bodily matter: how can the productive powers of the body be mobilized towards the production of value? In responding to this question, my argument will lend weight to recent rethinking of the labor theory of value in the context of affective or immaterial labor.

While there are many ways in which the impact of attention on bandwidth can be minimized, the perceptual compression of audio data is a particularly interesting method to examine because of its historical connection to the success peer-to-peer networks. Before the advent of perceptual coders, audio files were too big to transmit easily through the Internet; it would take too long to upload or download a single song. Reducing the amount of data contained in audio files without seriously compromising their quality, psychoacoustic coders made it not only possible but desirable for users to share music with each other. Essentially, they set in motion the series of events which catalyzed transformations of culture and economy which are the subject of this dissertation. Writing ten years after Napster was launched, it is now possible to look back and see how the tension at the heart of this transformation was, in a sense, present in the perceptual compression technologies that sparked it all.

Some final (introductory) thoughts

My argument is, I hope, new, though it is not a new kind of argument. Scholars have long appreciated the centrality of technology to the social, political, and economic—that is, if the three can be separated (Massumi 2002). Up for debate is the nature of this centrality: does technology determine social, political, and economic forms, or is it called forth by these forms? In his (pre-Internet) assessment of the social/political/economic, Jameson was deeply skeptical of the idea that technology could instigate social transformation. He writes:

> I want to avoid the implication that technology is in any way the "ultimately determining instance" either of our present-day social life or of our cultural production: such a thesis is, of course, ultimately at one with the post-Marxist notion of a postindustrial society. Rather, I want to suggest that our faulty representations of some immense communicational and computer network are themselves but a distorted figuration of something even deeper, namely, the whole world system of a present-day multinational capitalism. The technology of contemporary society is therefore mesmerizing and fascinating not so much in its own right but because it seems to offer some privileged representational shorthand for grasping a network of power and control even more difficult for our

> minds and imaginations to grasp: the whole new decentered global network of the third stage of capital itself. (2001: 37)

In retrospect, Jameson's dismissal of an immense communicational and computer network seems, perhaps, a bit hasty, and his characterization of the third stage of capital as a decentered global network, imprecise. At the very least, it is no longer possible to diminish the importance of global communication networks, as Jameson did, without understanding how they work. What makes it difficult to theorize contemporary capitalism is not a misguided focus on communication networks as Jameson suggests, but rather not *enough* focus on these networks, in terms of how they work, how they inform network discourse, and how they produce value. In light of the economies of cultural production catalyzed by peer-to-peer networks, we can no longer afford to ignore these issues.

Perhaps some of the difficulty cultural Marxists have had understanding the Internet stems from the association Jameson makes between "some immense communicational and computer network" and the "distorted figuration" of post-industrial society. Clearly Jameson's observation is not without merit, at least historically speaking. The first and perhaps most comprehensive social and economic analysis of the Internet, Manuel Castell's *The Rise of The Network Society*, forged a critical link between the rise of digital networks and post-industrial society, replacing Karl Marx with Daniel Bell and Alaine Touraine. Writing a few short years after the Internet first became popular, Castells argued that a new mode of development, what he termed "informationalism," had arrived alongside a new social structure. Sensitive to the complex patterns of interaction that inform the development of technology, Castells was careful to avoid in his argument the technological determinism that Jameson critiques. Castells writes:

> While there is a historical coincidence between the clustering of new technologies and the economic crisis of the 1970s, their timing was too close, the "technological fix" would have been too quick, and too mechanical, when we know from the lessons of the Industrial Revolution and other historical processes of technological change that economic, industrial, and technological paths, while related, are slow-moving and imperfectly fitting in their interaction. (1996: 51)

Still, Castells was unambiguous about the positive correlation between informationalism and contemporaneous social, political, and economic transformations. The information revolution, Castells writes, "originated and diffused, not by accident, in an historical period of the global restructuring of capitalism, for which it was an essential tool" (13). Put simply, in Castells' view, digital networks did not transform society or economy, but were the basis for these transformations (14).

In a sense, I aim to continue Castells' project of closely examining Internet technologies, though from a Marxist perspective. Unlike Jameson I do not think that a "post-industrial" framework is mutually exclusive with Marxist analysis, though concepts like human labor and exchange value will need to be reexamined in light of technologies that create new economic objects and that use new kinds of labor to produce them. Ultimately, I hope to show that Marxism remains a useful framework despite an altered mode of production, what I will describe as a digital network mode of production.

Chapter One: Why Networks?

Every time some A is said to be related to some B, it's the social itself that is being generated. (Latour 2005: 103)

"Networks are everywhere," begins the introduction of a recent collection of seminal texts in the field of network studies, assembled by Mark Newman, Albert-László Barabási, and Duncan Watts (2006: 1). Looking back at the second half of the 20^{th} century, the appeal of this simple statement is difficult to deny. From the birth of the Internet, to the formation of terrorist networks, to the discovery of neural networks, networks are everywhere. The focus of this dissertation is one specific kind of network—the peer-to-peer network—and the larger network in which it is situated: the Internet. In particular, I will examine the role of peer-to-peer networks in what I see as a contemporary transformation in the economics of cultural production.

The relation between peer-to-peer networks, the Internet, and shifting economics of cultural production is rooted in how these technologies work, what they make possible, and what they make difficult or impossible. To explicate this relation, I will examine these technologies in detail. However, there is also something to be learned from understanding peer-to-peer networks and the Internet on a broader level, i.e. as networks. In other words, if peer-to-peer networks and the Internet are specific networks with unique properties, then they also, on a broader level, share some qualities or characteristics in common with all networks—neural, terrorist, linguistic, or otherwise.

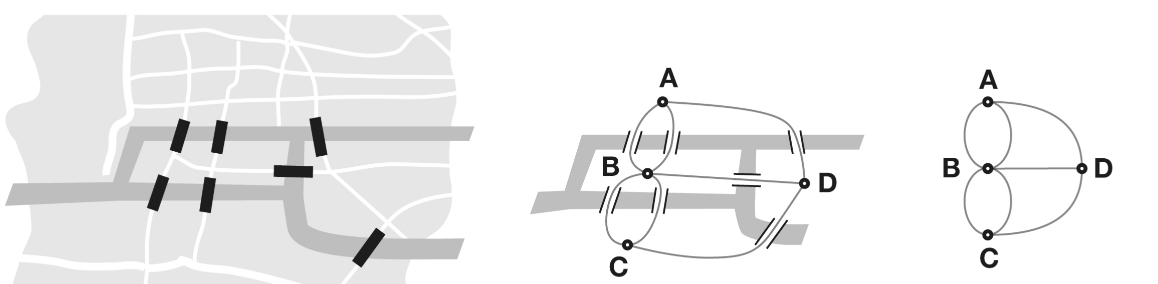
What are these qualities or characteristics in common and what truths about peer-to-peer networks and the Internet do they reveal?

Responding to these questions, I will consider the rising popularity of the network as an explanatory concept. How have networks been historically isolated and defined? What discourses and technologies have network scholars drawn from and used to these ends? Following my discussion of the history and composition of network scholarship, I will offer a critique of the network as an explanatory concept. That is to say, I will critique the notion that labeling material phenomena as a network simply helps us to understand objective characteristics of these phenomena that would otherwise be obfuscated. Drawing from social theorists as well as science studies and critical network scholars, I will interrogate the underlying epistemological assumptions and exclusions made in order to isolate, identify, and analyze networks. In particular, I will focus on issues related to ontology and measurement which are central to theorizing the mode of power endemic to networks. I will argue that the concept of the network as it is defined through academic and scientific discourse does not simply describe pre-existing material relations but rather participates in their production. In contextualizing peer-to-peer networks and the Internet in this way, I ultimately aim to show that peer-to-peer networks participate in a mode of measure endemic to all networks, and to extricate its logic.

History of the network

The founding conceptualization of the network is typically dated to the publication of mathematician and physicist Leonard Euler's seminal paper on the seven bridges of Konigsberg in 1736 (Newman, Barabasi, and Watts 2006: 1), although scholars have identified earlier appearances of the network in thought (see Erikkson 2005: 307). In Euler's paper, he offers a solution to the mathematical problem of whether one can traverse the city of Konigsberg while only crossing each of its seven bridges only once. In order to solve the problem, Euler abstracted the terms of the problem. Each body of land was reduced to a single point or "node," while each bridge was reduced to a single line or "edge" connecting these points. Simplified in this way, the problem became easier to understand (see fig. 1.1). Euler's solution to the Konigsberg bridge problem is commonly regarded as the first theorem of graph theory, as well as being foundational to topology and computer and network science.

fig. 1.1 **Euler and Konigsberg**



The geography of Konigsberg with its river and seven bridges.

The problem abstracted, with points standing in for each section of the city.

Abstracted to only points and lines, the problem gains clarity.

The graph devised by Euler in response to the Konigsberg problem contained two defining elements: points (or nodes) connected to each others by lines (or edges). As Newman et al. note, "In its simplest form, a network is nothing more than a set of discrete elements (the vertices), and a set of connections (the edges) that link the elements" (2006:

2). In this way, the concepts “network,” “node,” and “edge” are mutually defining: to describe a network is to describe a multitude of nodes connected to other nodes by edges; to describe a node is to describe a point where an edge begins, terminates, and/or continues in a network; to describe an edge is to describe a connection between nodes.

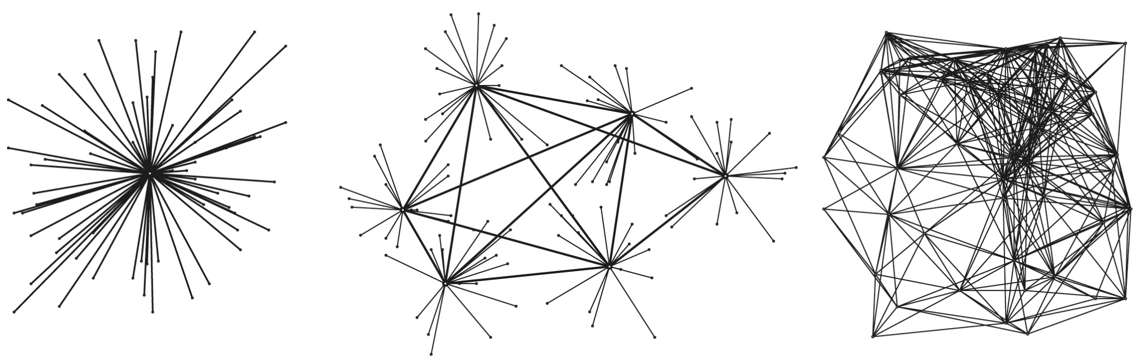
Over the course of the 20th century, the network as an explanatory concept grew in popularity, germinating dedicated sub-fields in a number of disciplines—sociology, economics, and biology, to name a few. While scholars from varied disciplines do not ordinarily attend to each other’s research, the mathematical character of network studies allowed scholars to share insights across disciplines, which often held regardless of the “content” of the network studied—whether the spread of social norms or the circulation of neural impulses. Despite the heterogeneity of the types of networks analyzed, network scholarship can thus be characterized by historical periods of shared academic understandings and interests. I will focus briefly on two moments which are particularly central to theorizing the mode of power endemic to networks: topological analyses popular from the 1950s through the 1970s, and analyses of network dynamics popular since the mid 1990s.

Network topology, network dynamics

The nodes and edges of a network are by definition organized into some kind of topology or structure. A network’s topology may be centralized (peripheral nodes connected to each other through one centralized node), decentralized (peripheral nodes connected to each other through various centralized nodes), distributed (all nodes connected to each other in an evenly dispersed manner, without centralized nodes), or some combination thereof (see fig. 1.2). In this way, two networks with the same number of nodes and edges may exhibit radically different topologies. As network scholars Alexander Galloway and Eugene Thacker note, “The same sets of entities can result in a centralized, rigidly organized network or in a distributed, highly flexible network” (2007: 32).

fig. 1.2 **Network Organization**

Three examples with roughly an equal number of peers.



In the 1950s social scientists began to apply mathematical understandings of network topology to social questions. As Newman et al. note, in this period of time “the structural properties of networks, especially their connectedness, became linked with behavioral characteristics like the expected size of an epidemic or the possibility of global information transmission” (2006: 3). They continue, “By abstracting away the details of a problem, graph theory is capable of describing the important topological features with a clarity that would be impossible were all the details retained" (3). Put simply, mathematical abstraction made legible the network and its topology.

Despite the successful incorporation of network analysis into the social sciences, for most of the 20th century network scholars lacked a reliable method to examine large "real world" networks, as well as the computational power to fuel such examinations (Christakis 2008). By the end of the 20th century, however, innovations in computing coupled with the popularization of the Internet provided network scholars with unprecedented access to large real world networks as well as the computational power to crunch sizable data sets, sparking renewed interest in networks (Newman, Barabasi, and Watts 2006: 6). These two technological innovations made possible a methodological shift in network scholarship, from the theoretical models of graph theory and the static empiricism of sociometry to what is seen by network scholars as a simultaneously theoretical and empirical project of capturing the complexity of large real world networks.

The resurgence of interest in networks in the late 20th century has been termed by Newman et al. the "new science of networks," and is distinguished from its antecedents in three primary ways:

(1) by focusing on the properties of real-world networks, it is concerned with empirical as well as theoretical questions. (2006: 4)

In other words, the new science of networks claims to narrow the gap between the expected properties of networks, as determined through modeling, and their actual, empirical properties, promising an increasingly accurate read of the social or cellular or economic (etc.) landscape.

(2) it frequently takes the view that networks are not static, but evolve in time according to various dynamical rules.

(3) it aims, ultimately at least, to understand networks not just as topological objects, but also as the framework upon which distributed dynamical systems are built. (4)

As network scholar Nicholas Christakis writes, “Once you have recognized that there is a topology, the next thing you must understand is that there can be a contagion as well—a kind of process of flow through the network” (2008). The new science of networks dedicates itself to mapping and ultimately modulating this flow. Consider, for example, Christakis’s 2007 discovery that obesity can be socially contagious. While not discounting other social factors, Christakis’s study proves that knowing an obese person increases one’s likelihood of obesity. As *The New York Times* put it, “Obesity can spread from person to person, much like a virus” (Kolata 2007). In this way, the focus of network analysis has shifted from capturing static topologies to mapping the dynamics of flows.

The politics of measure

The new science of networks purports to provide a more in-depth and accurate analysis of networks. More than a revolution, though, it is an evolution, staying true to the foundational premises earlier established: that networks exist independent of their identification or analysis, and that processes of identifying and analyzing networks can be undertaken without affecting them. While it claims to narrow the gap between modeling and empiricism, the new science of networks nevertheless recognizes a distinction between the two, as well as a distinction between analysis and intervention, i.e. between the process of observing real world networks and the process of intervening in or modulating networks. These two epistemic cuts are the discursive foundation upon which the study of networks historically coheres, asserts its scientific relevance, and becomes affective on an institutional level.

Underlying these discursive cuts, the most basic presumptions of network scholars concern the ontology of the network. In particular, scholars presume three things: 1) that there exist discrete material entities—nodes; 2) that these entities have the capacity to affect one another through interaction; and 3) that the aggregation of interacting nodes forms a larger, cumulative entity—the network—which exhibits characteristics more complex than the sum of its parts. In the section that follows I will examine in more detail these basic presumptions in order to draw into question the explanatory power of the network. In contrast to much of network scholarship, I will argue that the concept of the network is not explanatory, but rather productive or performative.

Interaction

Do nodes exist, such that they can be said to interact? In recent years, contemporary social theorists have drawn into question the very existence of individual entities, a presumption that subtends not only network analysis but most of social science. Brian Massumi (2007), for example, has argued that there is no physical interaction between discrete objects. Following Gilles Deleuze, Massumi suggests we replace the concept of interaction with “immanent relation.” He explains:

> [Interaction] has no reality, because there is no actual connection between things. This requires adjusting the whole vocabulary we use to talk about “interactivity.” We have to continually translate that concept into relational terms … so that when we say “interaction” we’re saying “immanent relation,” with all the adjustments that come along with that in the way we think about what things actually are, what their action really (virtually) is, and how they communicate. (83)

Massumi concludes, “We have to take distance on the rhetoric of connectivity that has been so dominant in the areas of new media and new technology. We will have to treat connectivity as a narrative, a metafictional revisionism” (83).

Following Massumi and other social theorists, we might approach network scholarship as participating in such narrative or metafictional revisionism, that is to say in falsely representing reality. Considering the affectivity of network discourse, most apparent in the technological artifacts surrounding this discourse (e.g. the Internet) though also in the interdisciplinary incorporation of network discourse, this position ultimately falls short. Whether or not the network has any reality, whether or not network scholarships mistakes “immanent relation” for “interaction” is beside the point, owing to the materializing power of the concept of the network. What is this power and what are its ends? To answer these questions, I will draw from work by Bruno Latour, Karen Barad, Kai Erikkson, and Alexander Galloway.

Despite his long-time association with actor-network theory (ANT), Latour is not an obvious source for critical insight on network discourse. As Latour himself notes:

> When this term [ANT] was introduced twenty-five years ago, the Internet had not struck—nor had al-Qaida for that matter. So, network was a novelty that could help in elucidating a contrast with "Society," "institution," "culture," "fields," etc. which were often conceived as surfaces, floods of causal transfers, and real matters of fact. But nowadays, networks have become the rule and surfaces the exception. It has lost its sharp edge. (2005: 131)

Latour argues that ANT does not aim to produce knowledge about those objects of study we commonly refer to as networks—communication grids, terrorist organizations, etc.—but rather aims to produce knowledge about the social landscape through observing the interactions of its participants (Latour's "mediators"). In other words, ANT is not a study of networks, but rather is a networked form of study. For this reason, as Latour notes, it is possible to provide ANT accounts of non-networks (e.g. "a symphony, a piece of legislation, a rock from the moon, an engraving") just as it is possible to produce non-ANT accounts of technical networks (e.g. "television, e-mails, satellite, salesforce").

Although ANT may not specifically produce knowledge about networks, its networked form of knowledge-making has produced a useful shift in sociological methodology: allowing non-human entities to be treated as "actants." Latour eloquently articulates this flattening of the human and non-human when he writes, "Every time some A is said to be related to some B, it's the social itself that is being generated" (103). Latour's nonchalant treatment of actors as "some A" and "some B" is notable for its implication that discourse itself is productive of the social. In other words, Latour implies that the social is not simply created or enacted through relationality, but when relations are brought into discourse; the social is generated when relations are identified, examined, and analyzed. ANT thus makes it possible to think all networks, whether biological, communicative, interpersonal, etc., as social networks, while also implicating observation and analysis in the production of these networks.

Despite his intimation that all discourse is productive, Latour, like Massumi, implies that it can also be reductive. For example, in a passage addressing graphic representations of network topologies, Latour writes, “[They] have the drawback of not capturing movements and of being visually poor” (133). He continues, “The very poverty of graphical representation allows the inquirer not to confuse his or her infra-language with the rich objects that are being depicted: the map is not the territory” (133). While Latour acknowledges that scientific methodologies do not simply uncover truths but participate in their production (143), and for this reason the social sciences are “powerful” (230, 232, 260), Latour ultimately presents ANT as an empirical project of “drawing more and more accurate roads maps.” This leads him to conclude that “the more disinterested the science, the more engaged and politically relevant it is” (258), even as he states “we write texts, we don’t look through some window pane” (122). Whatever one might ultimately conclude of ANT on the basis of these contradictions, for the present purposes it is sufficient to recognize that despite ANT’s methodological utility, its contradictions make it a poor fit for theorizing the network, as the concept of the network is not reductive, I will now argue, but rather exclusionary.

Intra-action

In contrast to Latour's argument, Barad's (2007) argument is consistent in its treatment of the productivity of discourse. Barad's argument is rooted in what she calls the "philosophy-physics" of quantum physicist Niels Bohr. Following Bohr, Barad argues that thought and matter are inextricably intertwined. She refuses the distinction commonly made in the sciences between theorizing and experimenting; she argues that both are material practices (55). For Barad, concepts do not represent so much as they materialize, calling into question the very foundations of western thought. In particular, Barad is critical of the belief, central to western thought, that "the world is populated with individual things with their own independent sets of determinate properties" (19). According to Barad, there are no such individual entities; subject/object distinctions do not precede processes of measurement, but rather emerge from them. As Barad writes (again, following Bohr), "*Concepts are defined by the circumstances required for their measurement.* That is, *theoretical concepts* are not ideational in character; they *are specific physical arrangements*" (her italics, 109). In this way, processes of measurement play a formative or "determining" role in the production of phenomena—a term which Barad introduces to describe "*a specific intra-action of an 'object' and the 'measuring agencies'* " (her italics, 128).

Barad's shift from interaction to intra-action aims to recognize the participation of measurement in producing phenomena. As she explains:

> Since individually determinate entities do not exist, measurements do not entail an interaction between separate entities; rather, determinate entities emerge from their *intra-action*. I introduce the term "intra-action" in recognition of their ontological inseparability, in contrast to the usual "interaction," which relies on a metaphysics of individualism (in particular, the prior existence of separately determinate entities. (her italics, 128)

While the concept of intra-action, like Massumi's "immanent relation," proposes the impossibility of individually determinate entities, "intra-action," unlike "immanent relation," recognizes the productive role of measuring agencies.

Underlying Barad's conceptualization of measurement as a productive process is the idea that measurement is exclusionary. That is to say, all measurement produces/analyzes certain phenomena at the exclusion of other phenomena. As Barad writes, "Although no inherent distinction exists, every measurement involves a particular choice of apparatus, providing the conditions necessary to give meaning to a particular set of variables, at the exclusion of other variables, thereby placing a particular embodied cut delineating the object from the agencies of observation" (115). This is not to say that matter (or what Barad calls "substance"[5]) has no material existence in the absence of measure. Rather, processes of measure create objects from an undifferentiated soup of matter, objects that can never exhaust the matter from which they are constituted. As Barad writes, "Indeterminacy is never resolved once and for all. Exclusions constitute an open space of agency; they are the changing conditions of possibility of changing possibilities" (179).

Following Barad's argument that measurement is both productive and exclusionary, it is possible to theorize network discourse not as a false, inaccurate, or reductive narrative or representation of reality but as a productive exclusion, what Barad describes as performative. Performative approaches, Barad writes, "focus inquiry on the

[5] "*Matter is substance in its intra-active becoming—not a thing but a doing, a congealing of agency. Matter is a stabilizing and destabilizing process of iterative intra-activity*" (her italics, 151).

practices or performances of representing, as well as the productive effect of those practices and the conditions for their efficacy" (49). What is real then, is not that which exists independent of observation (as there are no "individuals with inherent attributes, anterior to their representation,") but that which emerges through observation/intervention (46). As Barad cites Ian Hacking: "We shall count as real what we can use to intervene in the world to affect something else, or what the world can use to affect us" (50).

Following this line of thought, it is now possible to rethink the distinction drawn by network scholars between theory and empiricism. This is not to say that the tasks of theorizing (modeling) possible network behaviors and observing/analyzing real world networks are one and the same, but rather that theory and observation/analysis constitute two complementary facets of a single measuring agency—a network mode of measure. In other words, modeled networks and real world networks are at the same time theoretical *and* material; they are performative. Rather than theorize modeled networks as a reduction or revision of real world networks, and real world networks as a reduction or revision of the actual world (as Latour's and Massumi's arguments might lead us to conclude), it is now possible to recognize that both real world networks and modeled networks simultaneously determine and represent network phenomena. In Barad's terms we might say that networks do not exist independent of the conditions of their measurement. Rather, they are produced as phenomena in conjunction with those sciences dedicated to their analysis and invested in their intervention. This theorization of networks and network scholarship is confirmed by Erikkson (2005) who similarly argues that networks are not simply made up of objective material relations that can be represented through scientific research. Rather, networks emerge in conjunction with network scholarship as a “horizon of thought and action” (318).[6]

Modeling, empiricism

If the concept of the network is not explanatory, but performative, what should we make of the distinction drawn by network scholarship between modeled networks and empirical networks? Certainly there is a difference between the ways networks are theorized to behave and the ways they are observed to behave, even if concepts are performative as Barad suggests. At the very least, there is a difference between the methodologies of modeling networks and those of observing networks; the former entail the application of mathematical instruments to hypothesized network topologies, while the latter entail the recording of connections between observed entities. Increasingly, however, the networks observed by network scholars are established on a foundation of modeling. This is because the networks observed are often located and identified through the Internet, the proper functioning of which is dependent on the modeling of technical protocols. This is evident, for example, in the simulations run by programmers to test

[6] In describing the relation between network discourse and practices, Erikkson, like many of the scholars discussed, draws heavily from Foucault’s analytic of power. Following Foucault, Eriksson argues that discourse and form-making practices together produce an “effective history,” where discourse makes possible form-making practices and vice versa. Clearly much of the work referenced above is indebted to Foucault’s conceptualization of discourse, a point worth noting though an analysis of the relative merits of these scholars’ interpretations of Foucault’s work is beyond the scope of this chapter. Rather, I find their interpretations, elaborations, and re-imaginings of Foucault’s work sufficient for the present purposes.

peer-to-peer protocols for their cumulative network effects. As Kunzmann et al. note, "Especially in Peer-to-Peer (p2p) applications, where an arbitrary large number of users may participate in the network, simulation is required to prove the protocol's scalability and verify its correct behavior" (2007: 1). In this way, simulations allow programmers to revise network protocols in response to their expected large-scale dynamics. Digital networks do not so much exhibit behaviors, as they are programmed to exhibit (and avoid) them. If the methodological differences between modeling and observing networks has in the past allowed network scholars to assert the objective, explanatory power of the network, the methodological centrality of the Internet to the new science of networks should lead us to draw into question this power. Can the new science of networks really continue to claim that the networks it observes are naturally occurring, when in fact they are built on a foundation of modeled protocols?

Despite the ways the Internet draws together the modeling of networks with the building of networks, the new science of networks does not contest or alter network scholarship's long-standing separation of the theoretical from the empirical—a separation central to asserting network scholarship's scientific legitimacy. Because this legitimacy is rooted in the idea that networks exist independent of their measurement, network scholars must presume that Internet technologies simply facilitate social processes while making their complexity more visible than ever before.[7] In other words, the new science of networks must turn a blind eye to the Internet's technical character in order to take

---

[7] Interestingly, Latour—for different reasons—similarly assumes the neutrality of Internet technologies. He writes, "Information technologies allow us to trace the associations in a way that was impossible before. Not because they subvert the old concrete 'humane' society, turning us into formal cyborgs or 'post human' ghosts, but for exactly the opposite reason: they make *visible* what was before only present virtually" (2005, p. 207).

advantage of the Internet as an immense and accessible data set—a social network made visible through technical means. More precisely, it must disregard the modeled aspect of the Internet, assuming that successful protocols simply allow real world social networks to manifest electronically. As Christakis writes, "People are leaving digital traces of where they are, who they are interacting with, and what they are saying or even thinking …. We have vast amounts of data that can be reapplied to investigate fundamental questions about social organization and about morality and other concerns that have perplexed us forever" (2008). In this way, online social networks such as Facebook can be understood as naturally occurring, despite the intermediation (or, perhaps, intra-mediation) of layer upon layer of technical protocols. Were the Internet's technical aspect understood as coloring or otherwise determining or interfering with the natural formation of social networks, the Internet's integrity as data set would be compromised.

In light of network scholars' unwillingness or inability to fully account for the Internet's technical character, we must take distance from the rhetoric of network discourse, as Massumi suggests, if not for different reasons. In particular we must be skeptical of the separation in network discourse of the theoretical from the empirical, not because network discourse falsely imagines the existence of individual, interacting, entities where none exist, as Massumi suggests, but because network discourse is unwilling or unable to theorize its stake in measuring and determining these entities. As with other scientific scholarship, network scholarship is unwilling or unable to do this because it asserts its legitimacy through claims of revealing hidden or invisible objective truths which are theorized to exist and then proven or disproven through empirical research. If network scholarship does not simply uncover the secretly networked nature of the universe and everything in it, but rather has some stake in the determination of networks, we can finally ask: what is this stake?

The power of networks

For network scholars, establishing a split between theory and empiricism is crucial to asserting the scientific legitimacy of network scholarship. One would only expect network scholars to grow increasingly adamant about the continued relevance of this separation as the distance between the work of modeling, identifying, and analyzing networks and the work of building networks narrows. For those critical of network discourse, a perspective I hope to advance here, focusing on this narrowing distance helps to reveal how the concept of the network is not explanatory but rather is performative (to use Barad's term). The concept of the network participates in a particular form of measure—one that identifies, designates, analyzes, and/or modulates nodes, edges, topologies, and network dynamics—to the exclusion of other possible materializations. To what end do network discourse and practices participate in the performance of networks? To answer this question, I will examine the network as a mode of power. In particular, I will theorize the network as participating in what social theorists have described as a contemporary shift in modes of power from the juridical (or preventative) to the endemic or endogenous (or productive).

In his theorization of the power of networks, Alexander Galloway emphasizes the role of protocol, which he defines as “a set of recommendations and rules that outline specific technical standards” (2004: 6). He elaborates, “These regulations always operate at the level of coding—they encode packets of information so they may be transported; they code documents so they may be effectively parsed; they code communication so local devices may effectively communicate with foreign devices” (7).[8] Galloway focuses on protocol for several reasons. First, his use of protocol is meant as a critical response to the metaphorical use of the concept of the network by scholars of culture (xviii). Second, Galloway, like network scholars Newman et al., is more interested in network dynamics than he is in network topology. However, Galloway’s interest does not so much lie in understanding real world networks in greater detail or complexity, as it does for contemporary network scholars, but rather in accounting for the role of protocol in producing networks. The difference between these two perspectives is crucial; the former sees network dynamics as naturally occurring while the latter sees network dynamics as a byproduct or epiphenomenon of protocol. In other words, Galloway focuses on network dynamics because they are a locus of management, of control. If network topologies are less interesting to Galloway, it is not because they inaccurately or reductively represent networks, but because they are insufficient to explain the productive power of networks. A network’s topology is a static moment of the process by which a network comes into being, the process of its individuation. Like a shed skin, a network’s topology is an artifact of the process of its becoming.

---

[8] For specific examples of protocols (TCP/IP, UDP, DHT, etc.) see the next chapter.

Again, this should not indicate that measures of network topology are reductive, but that measures of topology account for certain features at the exclusion of others, and in so doing, make possible certain interventions. For example, if any given population is understood as a network, a topological analysis can reveal how "clustered" it is, and therefore how quickly a disease might spread through it and what percentage of the population must be vaccinated in order to prevent an epidemic. Of course, the outcomes of network interventions can be difficult to predict. As Christakis points out in reference to his study of the spread of obesity through social networks:

> If you have a lot of people of one body type and you introduce somebody of a different body type, it is unclear who will influence whom. The thin person might gain weight, or the overweight people might lose weight. Or both. It is a very complicated dynamic, which again requires a kind of deployment of a certain kind of data and methods to begin to understand. (2008)

If network scholars are now more interested in "lines of flight" (i.e. network dynamics) than in "areas of stability" (i.e. network topology) as Erikkson has suggested, this should indicate to us not simply that network scholars know more about networks than they used to, but that analyses of network dynamics have the capacity to occasion new forms of power—what contemporary social theorists have described as control. Control, in this context, describes a distributed form of power that is not exercised from above, but rather is native to the conditions according to which action, movement, or connection can occur. Writing about cybernetics, sociologist Tiziana Terranova defines control as "the opposite of mechanical rationality (step-by-step programming), because the latter is too rigid and ultimately too brittle to operate on such terrain; and also as the antithesis of centralized government, because the latter presupposes a complete knowledge of each individual component of the overall system, which is impossible to achieve in these types of structure (2004: 122). She also calls this form of control "immanent control"; Galloway calls it "endogenous" (2004: 51). He elaborates, "Perhaps it is a different type of control than we are used to seeing. It is a type of control based on openness, inclusion, universalism, and flexibility. It is control borne from high degrees of technical organization (protocol), not this or that limitation on individual freedom or decision making (fascism)" (142).

Control is a distributed rather than hierarchical form of power. That is to say, in (distributed) networks, there is little centralized power over network organization. Rather, a network's organization is loosely proscribed through technical protocols which define and are followed by distributed nodes. It is for this reason that networks are difficult or impossible to control; control is not something that can be exerted over a network, but must be embedded into the protocols that dictate how communication can be established through the network, forming the network. In this way, networks are not *to* control, but *of* control. Protocol lies at the heart of this form of control, setting the rules or guidelines according to which networks are established and unfold.

Because networks are formed through protocols—a point that will be graphically illustrated in the following chapter— all nodes of a (distributed) network are equally equipped to confront whatever might be exterior to the network and to refuse it, attack it, absorb it, grow off of it, or co-exist with it (Terranova 2004: 59). As Terranova writes, "Incompatibility, understood as a tension between divergent moments, is not relinquished but brought into the network through a process of *horizontal addition* and/or *vertical* *subsumption*: a network is added to other networks; a new protocol is inserted between layers" (her italics, 59). For this reason, (distributed) networks are fairly robust; they cannot be dismantled by removing nodes. This resilience is central to the network mode of power, as has often been pointed out in reference to the military origins of the Internet.

For Galloway and other scholars critical of network discourse, the resilience of networks evidences a break from previous modes of power. Galloway contrasts the network mode of power with juridical modes of power characterized by their targeting of individual human subjects. Erikkson takes a similar approach to Galloway, identifying previous modes of power through commonly used metaphors for society such as the machine and the nervous system. In these previous modes, Erikkson argues, action constitutes a closed, consistent system or whole that can be separated from its context or environment. As such, action is governable on a systemic level through pre-defining rules and sanctioning transgressions (2005: 319).

It is important to note that juridical power, in this context, is not synonymous with legal power, though, as legal scholar Victor Tadros has argued (following Foucault), juridical power can incorporate legal methods. He writes, "What Foucault calls 'the juridical' is not equivalent to legal power. It describes any form of power which attempts to prevent a certain type of action through the threat of legal or social sanctions" (1998: 78). Furthermore, as Tadros cites Foucault, if the juridical is not confined to the legal, neither is the law limited to circulating juridical power: "With government, it is a question not of imposing laws on men, but of disposing of things: that is to say of employing tactics rather than laws, and even of using laws themselves as tactics—to arrange things in such a way that, through a certain number of means, such and such ends may be achieved" (92). As I will later describe, the system of copyright—which balances private rights of reproduction with fair use rights in order to stimulate economic growth (among other goals)—exemplifies the tactical use of the law.

While I do not want to underestimate the extent to which, as Foucault points out (and Tadros reminds us), modern law is not prohibitive but regulatory, "intervening in the social construction and government of the modern subject," it is important to note that distributed networks are regulatory (or productive, performative) in a fundamentally different way—they do not individuate human subjects but rather communicative nodes, whether human or non-human. They do this by establishing through protocols the conditions under which communication can occur. As Galloway points out, protocol is the point of intersection of nodes and edges; it is protocol that ultimately defines what counts as a node or edge. If earlier forms of power participated in the determination of human subjects through sanctioning their behavior, protocol participates in the determination of nodes through allowing or disallowing communication between them. As Galloway writes (citing Delueze), "We're no longer dealing with a duality of mass and individual" (2004: 86). Rather, "individuals become '*dividuals*,' and masses become samples, data, markets, or '*banks*'." While it is true that information may cluster around a specific user (69), it seems more appropriate to address the individual as Terranova does, that is as an epiphenomenon, a byproduct of emergence (2004: 122). In other words, networks do not simply displace individuals. Rather, the individual can be considered as an effect of other modes of power: juridical, disciplinary, etc. Modes of power do not cohere in order to reach their targets, they participate in the determination of these targets. Juridical modes of power participate in the determination of individual human subjects, while the network mode of power participates in the determination of nodes/edges.

It is also important to note that modes of power are not mutually exclusive: immanent or endogenous control operates in the presence of "previous" forms of power, whether disciplinary, juridical, hierarchical, or otherwise. For example, Internet protocols are standardized and disseminated through centralized bureaucratic institutions such as the Institute for Electrical and Electronics Engineers (IEEE) and the Internet Corporation for Assigned Names and Numbers (ICANN) (Galloway 127, 141). Furthermore, as Castells thoroughly documents (1996), the interrelationship of computer/Internet technologies and the state has been an essential and at times determining aspect of their development.[9] This interrelationship is evidenced by the entertainment industry's continued attempts to shut down peer-to-peer networks both through juridical methods (such as sanctioning users for copyright infringements) and through regulatory methods (such as crafting legislation which makes infringement more difficult and consumption more desirable)—a strategy whose failure I will examine in the following chapter. As I will show, methods that successfully combat other forms of copyright infringement have had the opposite effect on peer-to-peer networks, making them more resilient and adaptive.

[9] Consider, for example, the government-enforced monopoly of AT&T, parent company of Bell Laboratories (p. 59).

The tactics and strategies of Internet Service Providers (ISPs) have been more successful, largely because they work with or "perform" network modes of power. A recent example of this came to light in late 2007 when Comcast, one of the largest ISPs in the U.S., was discovered to be selectively slowing down the transmission of data uploaded/downloaded through BitTorrent, one of the most popular peer-to-peer protocols (Labaton 2008). The technique used by Comcast, called packet discrimination, inspection, or filtering, examines transmitted data as it passes an inspection point to determine what kind of data it is, whether it contains spam or viruses, and whether it conforms to transmission protocols. Once a packet of data has been identified as a BitTorrent packet (for example), its transmission can be slowed down by an ISP.

Whether or not packet filtering by ISPs is ultimately permitted or forbidden by the Federal Communication Commission, it evidences the emergence of anti-piracy tactics rooted in a network mode of power. Rather than combating peer-to-peer networks by shutting them down, a form of attack not possible with post-Napster peer-to-peer networks (for reasons I will explain in the following chapter), these tactics take advantage of peer-to-peer networks' endemic reliance on flow, strategically modulating this flow as with packet filtering, or adding to the flow in ways that undermine the distribution of data through peer-to-peer networks. An example of the latter point: shortly after Napster became popular, record labels began to proliferate fake MP3s—audio files with the titles of popular songs, but with missing, looped, or distorted segments, a tactic known as decoying or spoofing. As MediaDefender, a corporation hired by content providers and industry organizations such as the RIAA, boasts on its website: "With our protection applied it would be easier to find a needle in hay stack than a real file amongst our countermeasures" (Mediadefender.com).

Interestingly, corporations like MediaDefender do not simply combat peer-to-peer distribution through decoying/spoofing, but work to harness the power of peer-to-peer networks for their clients. As SafeNet, one of the largest online content protection services, writes on its website:

> In an increasingly fragmented digital landscape, knowledge and insight are critical to understanding both the threats and the opportunities available within this growing channel. SafeNet's intelligence services provide valuable metrics and insight around how content propagates across file-sharing communities so clients can make informed decisions around their protection and distribution strategies. (Safenet-inc.com)

Corporations like SafeNet do not simply aim to target and eliminate the unauthorized duplication of copyrighted material through peer-to-peer networks, but to use information gathered about peer-to-peer activity to allow their clients to more efficiently identify and reach target markets. Consider, for example, the Business Intelligence (BI) Direct Measurement service offered by SafeNet:

> The BI Direct Measurement service represents a significant opportunity for content owners and online advertisers to achieve an unprecedented level of visibility into P2P networks that have historically proven difficult to measure and understand. By leveraging a combination of SafeNet's proven techniques for identifying and tracking content online and the unique analysis tools and reporting capabilities offered with BI Direct Measurement, customers will now be able to monitor, track, and understand user behavior and consumption on global P2P networks. This insight into global consumer demand across one of the world's largest bases of content seekers can be used by content owners and online advertisers alike to understand emerging markets and measure consumer response to new distribution techniques, marketing initiatives and advertising campaigns.

As John Desmond, vice president of MediaSentry services at SafeNet, put it simply, "With more than 12 million users at any given time, peer-to-peer networks represent a tremendous business opportunity.” As evidenced by the success of companies such as MediaDefender and SafeNet, content providers have begun to supplement their juridical and regulatory attacks against peer-to-peer networks with a new strategy: trying to undermine the efficiency of peer-to-peer networks while also competing with them in the market.

Conclusion

The entertainment industry continues to argue that its profits are undermined by the unauthorized duplication of content through peer-to-peer networks. Its motivation to understand peer-to-peer networks is largely pragmatic: it needs to understand them in order to combat them and to compete with them. At best, content providers hope to use peer-to-peer networks to more precisely identify and target their customer base. Network scholars, on the other hand, have no such clear interest. They do not compete for consumers’ dollars (but rather for research grants), and have nothing to lose from peer-to-peer networks’ popularity. In fact, network scholarship can only be legitimated by the increased public and academic interest in networks that the success of peer-to-peer networks has brought, even as peer-to-peer networks occupy uncertain legal and ethical territory.

This does not mean, however, that network scholars have no stake in studying networks. Despite the observational tone of their findings, network scholars are no less interested than are content providers in channeling what I have described as a mode of power native to networks, a mode which works immanently or endogenously to make possible certain forms of being, relationality, and intervention while rendering others difficult, impractical, or impossible. What might these forms of being, relationality, and intervention look like? Several contemporary examples come to mind: impoverished populations understood as networks of disease and health-related information and misinformation, which can be modulated by identifying and targeting a statistically determined percentage of the population and/or type of member of the population[10]; terrorist organizations whose resilience is a function of their networked organization; biological networks whose identification occasions the development of new medical technologies and treatments. It is not that these networks are imagined, that they do not exist except to serve the unstated and unexamined interests of network scholars. Rather, following Ian Hacking's definition of the real as that which can be used to intervene in the world, we can conclude that all networks—modeled, observed, and built—are real. They are real not because they exist prior to their measurement, but because they can be measured. It is in this way that network discourse is performative, not representative; it selects one possible "reading" of matter—the network—because this reading occasions desired forms of intervention. Because network discourse does not represent, but rather

[10] In this context, populations are "not simply human beings or individual human subjects of right," as Patricia Clough and Craig Willse point out (following Foucault), "but rather are statistically organized as groupings of characteristics, features, or parts." This definition of "population" lends itself to the description of networks elaborated in this chapter. We might say that if the concept of population describes a static organization of "groupings of characteristics, features, or parts," the concept of the network describes the flow between and among groupings. Again, this is not to say that a concept like the population is reductive (insofar as populations are "snapshots"), but rather that it occasions different forms of intervention and modulation than does a concept like the network. See Clough, Patricia Ticiento and Craig Willse. Forthcoming. "Human Security/National Security: Gender Branding and Population Racism." in *Beyond Biopolitics: Essays on the Governance of Life and Death*, edited by P. T. Clough and C. Wilse. Durham: Duke University Press.

performs, we can understand the network as a selective and exclusionary measurement, not as an incomplete or reductive representation.

What are the ends of the network mode of measurement? Rather than answer this question by focusing on the practical uses of networks, some of which I have intimated, I have tried instead to extricate the logic of the mode of power native to networks. If the study and construction of networks embody political ends ranging from the unauthorized distribution of music to global health initiatives it is because there is a mode of power native to networks, what scholars critical of network discourse have theorized as immanent or endogenous control. This mode of power is central to a transformation taking place in how cultural content yields economic value. Peer-to-peer networks are one (and perhaps the primary) motor of this transformation.

Chapter Two: Fast, Cheap, and Out of Control

In 1994, copyright scholar Paul Goldstein imagined that in the future a single device, a "celestial jukebox," would consolidate our media consumption:

> A technology-packed satellite orbiting thousands of miles above the earth, awaiting a subscriber's order—like a nickel in the old jukebox, and the punch of a button—to connect him to any number of selections from a vast storehouse via a home or office receiver that combines the power of a television set, radio, CD player, VCR, telephone, fax, and personal computer. (199)

Fifteen years later, Goldstein's vision seems to have come to pass, though not quite in the way he imagined. The mid-1990s witnessed the beginning of a major shift in methods of reproducing and distributing cultural content—text, images, music, movies and television, games, and software—that would ultimately lead to the creation of electronic devices very much like Goldstein's celestial jukebox. This shift is characterized by the gradual displacement of industrial forms of reproducing and distributing cultural content with digital forms. Since the mid-1990s, consumers have increasingly accessed cultural content through a single source—the Internet—rather than purchasing hard copies. A statistic underscores the extent to which this shift has taken hold: in April of 2008, Apple announced that it had sold more than four billion songs through its iTunes Store (since its inception in 2003), surpassing Wal-mart to become the top music retailer in the U.S. (Apple 2008c). This statistic is surprising not simply because more digital files were sold than compact discs—a feat in itself—but because Apple does not primarily sell music, but computers.

How did industrial or analog methods of reproducing and distributing cultural content give way to digital methods of reproduction and distribution? The shift to digital was long in the making, beginning most generally with the development of cybernetics and information theory in the 1940s and continuing through the establishment of Internet infrastructure and the birth of personal computing in the latter half of the 20th century, and more specifically with the commercialization of the Internet in the early 1990s and the development of compressed digital file formats and content delivery systems in the 1990s and 2000s. In light of this history, it is difficult to attribute responsibility for the contemporary success of digital methods. However, the shift to digital was not simply inevitable. Digital methods of reproducing and distributing cultural content were met with hostility from industries heavily invested in the old methods, hostility that threatened the success of digital methods at every turn. As technology historian John Alderman notes, the music industry was disinclined to release songs in the form of "seductive little packets of freely traded digits" (2001: 1). This apprehension is typified by a comment made by Jim Griffin, chief technology officer at Geffen Records, about an early and tentative foray into online reproduction and distribution: "The parent company was not pleased …. They knew that this sort of thing was the future, but I think their goal was to slow it down, as opposed to speed it up, and here we were speeding it up" (21). It was not simply that digital files were easier to pirate than compact discs (for example), but that the Internet could be used to take piracy to profit-shattering proportions, or so content providers feared. Faced with resistance from content providers, many early attempts to distribute and reproduce content online failed. Without the support of the music industry, for example, online music and software retailers such as RealAudio, Liquid Audio, Nullsoft, and MP3.com had little chance of building and sustaining a market for digital audio.

Ironically, what finally compelled content providers to embrace digital methods was the very thing they feared most: the unauthorized reproduction and distribution of content online through peer-to-peer networks. Defined broadly, peer-to-peer networks are comprised of computer users connected through the Internet for the purpose of downloading songs, movies, software, and other kinds of cultural content from each other. Napster, the first peer-to-peer network, launched in 1999 and quickly became a popular method of acquiring music for free and with relative ease. Several basic factors led to Napster's success: the software was free and easy to download, install, and use, and it was an effective way to search for and download MP3 music files. Napster's ease of use attracted users, some with extensive MP3 collections, whose presence expanded the network. The network's growth, in turn, made it easier for users to find and download desired music. The symbiotic relationship between Napster's growth and its popularity proved volatile. The Napster network expanded from 1.1 million users in February of 2000 to 6.7 million users in August of 2000, an increase of more than 500 percent (Media Metrix 2001).

Content providers did not respond well to Napster's sudden popularity. It was as if their greatest fears of the digital had come to pass. Almost immediately, Napster provoked a wave of panic throughout the music industry. Record label executives were convinced that peer-to-peer networks would undermine markets for CDs and other hard copy formats. As the saying goes: why buy the cow when you can get the milk for free? The music industry's panic was quickly channeled into legal action. In December of 1999, the Recording Industry Association of America (RIAA) filed suit against Napster for contributory copyright infringement. As a result of this lawsuit, Napster was forced to shut down its service in July of 2001.

Despite the music industry's intentions to put an end to file-sharing, the forced closure of Napster catalyzed the further development of peer-to-peer networks. By the time Napster was shut down, other peer-to-peer networks had already surfaced, eager to fill the void left by Napster's closing. Since 2001, these other networks have continued to grow, having been made largely immune to legal attack through their technological ingenuity. Unable to legally force post-Napster peer-to-peer networks to shut down, the music industry shifted tactics, suing individual file-sharers and lobbying for stricter copyright legislation and enforcement. When this too failed to put an end to peer-to-peer networks, the industry, in a state of desperation, began to supplement their legal assault with a more pro-active strategy, experimenting with their own methods of digital reproduction and distribution so that they might compete with peer-to-peer networks. I will later describe in detail some of these methods.

Peer-to-peer networks have been a perfect storm, bringing together a number of factors that taken together make them a much more potent economic threat to content providers than other forms of piracy. Unlike pirated content on websites, for example, which operate on a large scale but are easily controlled through threats of legal action, or pirated content sent through e-mail or instant message, which is impossible to control through legal action but operates on too small a scale to represent a serious threat to commercial interests, post-Napster peer-to-peer networks both operate on a massive scale and are difficult to control through juridical means. In this way, while many developments in computing and networking led up to content providers' eventual adoption of digital methods of reproduction and distribution, it was the development of peer-to-peer networks in particular that pushed content providers over the edge, forcing them to embrace digital methods and catalyzing a transformation in the economics of cultural production at the most fundamental level: the level at which cultural content yields economic value.

In order to theorize this transformation, it is necessary first to understand the conditions which make it possible—in other words, how peer-to-peer technologies enact the mode of power endemic to networks, thwarting juridical modes of power while maintaining efficiency on a massive scale. As I will illustrate below, the basis of this shift is material; peer-to-peer technologies materially reconfigure social relations in such a way that falls outside the purview of existing juridical modes of power. Because this is largely a technical feat, I will examine in detail peer-to-peer networks' technical tactics, examining their relative advantages and disadvantages. As I will show, some tactics are best suited to large peer-to-peer networks, while others are more successfully employed in smaller networks. Some are designed for networks in which peers join and leave frequently, while others work best in more stable networks. Some are useful in networks in which large files are commonly transferred, while others work better in networks in which the files uploaded and downloaded tend to be small. Some are mutually exclusive—a network can only employ one or the other—while others are complementary—a network can use both simultaneously. Furthermore, the advantages and disadvantages of any given tactic change over time as content providers' legal strategies evolve and as new technologies develop. While these complex conditions have produced a large and varied pool of peer-to-peer technologies, I will focus on key innovations, drawing when necessary from relevant technical documentation.

Peer-to-peer

The term "peer-to-peer" has been used widely in popular and academic discourse, often in varied, inconsistent, and even contradictory ways. As peer-to-peer scholars Androutsellis-Theotokis and Spinellis (2004: 2) note, for some the term describes an internal operation and architecture, including networks of shared resources such as SETI@home (the scientific experiment that takes advantage of idle computers connected to the Internet to search for extraterrestrial intelligence), while others use it to describe networks that give an external appearance of being peer-to-peer, such as Napster, though it is not strictly peer-to-peer, topologically speaking. Depending on how one defines peer-to-peer, the advent of peer-to-peer networks can be dated as early as the invention of the Internet itself in the 1960s, or as late as the release of Napster in 1999 (Aberer, Alima, Ghodsi, Girdzijauskas, Haridi, and Hauswirth 2005; Barkai 2002).

My goal is not to rescue a definition of peer-to-peer from overuse or misuse, but rather to define peer-to-peer networks in a way that clarifies how networks such as

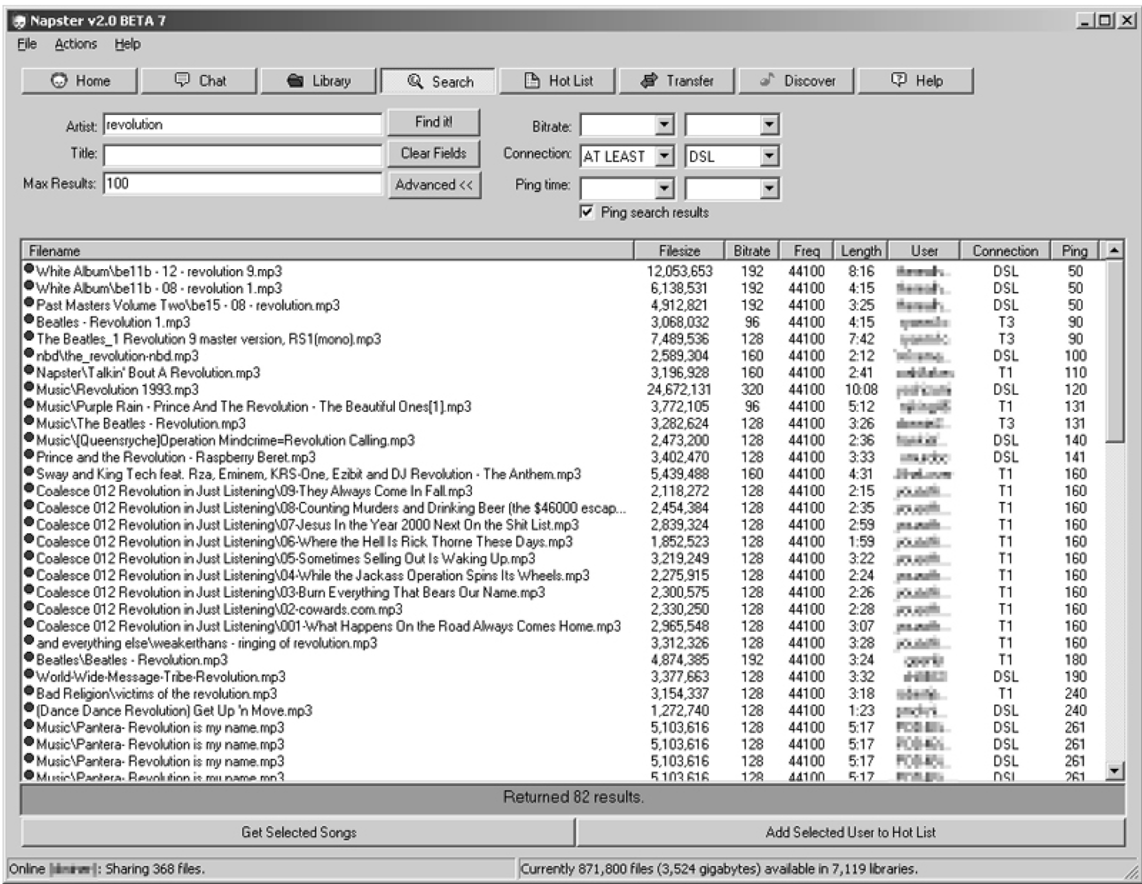
Napster, Gnutella, and eMule thwart juridical modes of power while maintaining efficiency on a massive scale. While it is necessary to address the technical specificity of peer-to-peer networks in order to understand this dynamic, a strict technical definition of peer-to-peer networks would exclude historically significant networks such as Napster. While networks like Napster are not strictly peer-to-peer, I will use the term "peer-to-peer" anyway, as it draws attention to networks' internal operation and architecture as well as to the activity of sharing files. If the peer-to-peer networks considered below are not always strictly peer-to-peer topologically speaking, then at least the term "peer-to-peer" draws attention to the material differences of these networks in a way that a term like "file-sharing" does not.

To fully account for their variety, I will define peer-to-peer networks broadly as networks made up of a multiplicity of peers (or nodes) connected through the Internet for the purpose of uploading and downloading files to and from each other. While it is tempting to think of peers as users—human participants in an online swap meet of digital files—such an assumption erases the centrality of technical protocols in establishing and managing the formation and dynamics of peer-to-peer networks. Following my discussion of Actor Network Theory in the previous chapter, we can define peers provisionally as network actants (as delineated through technical protocols) whose primary function is to send, receive, or forward data. It might also be helpful to think of peers in opposition to servers: permanently accessible networked computers that accept incoming requests for data from computers connected to the Internet and dispatch requested data in response. Unlike servers, peers are unstable. Their location within a network is often temporary, and their capacity to handle multiple requests for data is low. For these reasons, websites are hosted on servers. As a result of peers' transiency and their limited reliability, the task of building an efficient peer-to-peer network poses a formidable technological challenge to programmers. However, as the case of Napster will illustrate, this challenge must be addressed in order for peer-to-peer networks to avoid the legal vulnerabilities that result from the use of centralized components.

Searching with a "center"

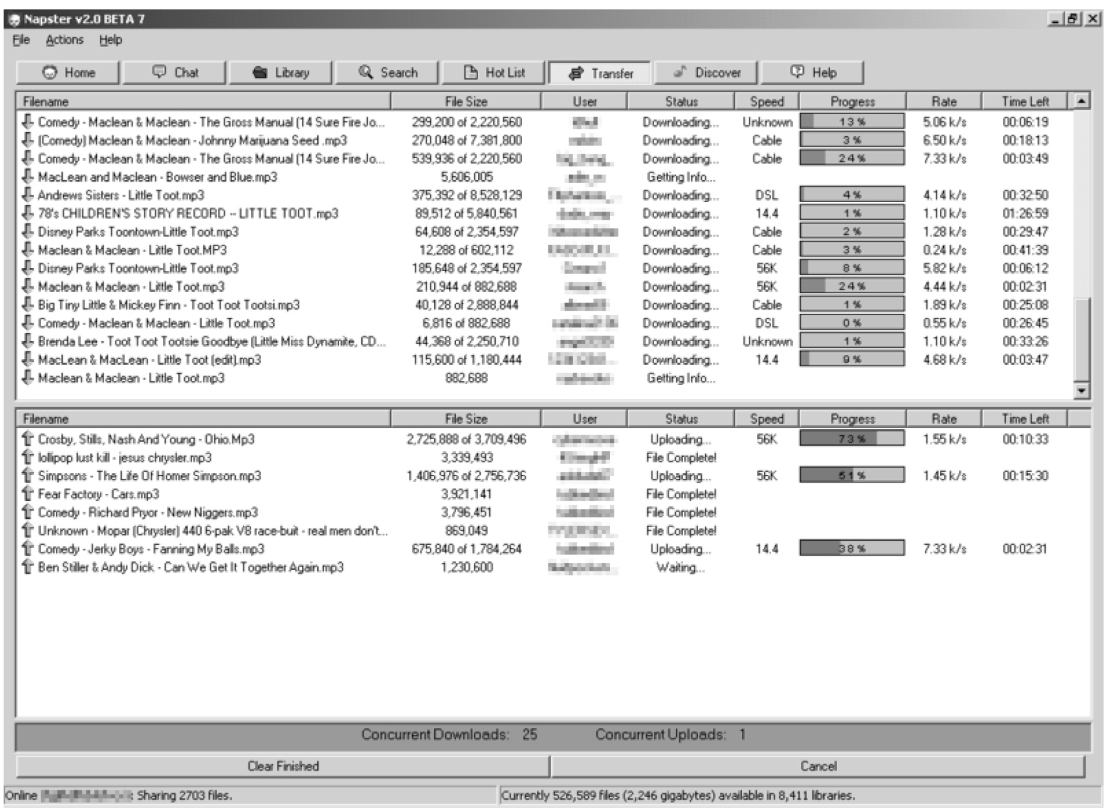
The successful operation of peer-to-peer networks depends on certain basic peer functions: joining and leaving the network, searching for desired files, and uploading/downloading desired files. While it is the uploading of copyrighted files which legally constitutes copyright infringement, uploading is nearly impossible to police. For this reason, litigious content providers have instead targeted users who make available copyrighted files, an act which constitutes contributory copyright infringement. The act of making available copyrighted files available for download can be easily exposed by searching for those files. In order for a peer to be able to locate a desired file, peers who have that desired file must announce to the network its availability; the act of making files available for download through a peer-to-peer network is by necessity a public act. If all of the peers connected to a network refused to announce the availability of their files, that network would immediately cease to function. However, because of the public nature of announcing files, litigious content providers are also able to locate copyrighted files and the peers that make them available. Searching for desired files is therefore the most problematic of the basic functions prescribed by peer-to-peer protocols, insofar as it opens a network or its users to legal attack.

fig. 2.1 Napster Search Interface



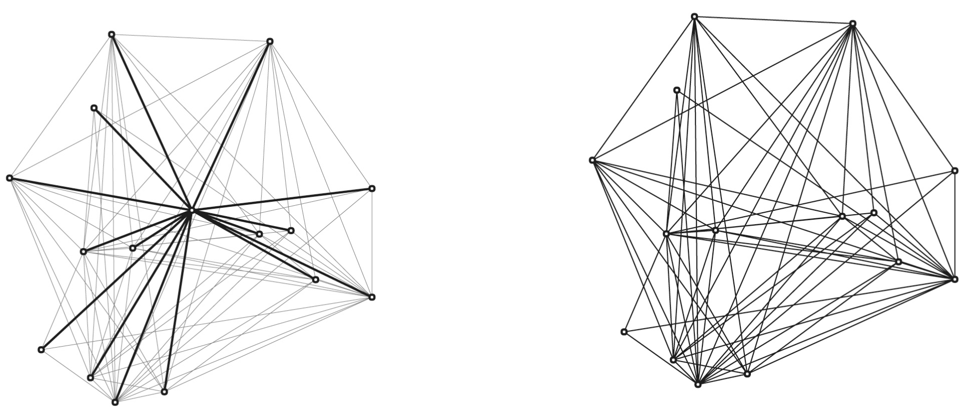
In order to allow connected peers to search for MP3s, the Napster network maintained on its servers an index of the MP3s made available by its users. Napster did not monitor this index for copyrighted material; users could share whichever songs they wished. Peers' search requests would be routed to Napster's servers, which would respond by returning a current list of available MP3s whose file names contained the search string along with other pertinent information such as the screen names of uploaders, the speed of their Internet connections, file sizes, and bit rates (see fig. 2.1). Based on this information, a user could then select a file to download. Because the network required a centrally maintained file index, Napster's server was integral to the network's ability to function. Even so, the actual uploading and downloading of MP3s did not require the intermediation of Napster's server, but rather occurred through a direct connection between peers (see figs. 2.2 and 2.3). Napster can therefore be categorized somewhere between centralized models of downloading hosted content from servers and distributed models of uploading and downloading content among peers.

fig. 2.2 **Napster Upload/Download Interface**



As I have noted, the music industry responded with hostility to Napster's success, filing suit against Napster for contributory copyright infringement. In July of 2001, this lawsuit was successful and Napster was forcibly shut down. The court's decision was largely based on the integral role of Napster's server in the functioning of the network. Because Napster's server (like all servers) was centrally maintained—i.e., established and administered by Napster—the corporation was held responsible for the server's role in contributing to copyright infringement, even though the actual uploading and downloading of copyrighted material transpired without Napster's intermediation. Presumably, the RIAA initially chose to target Napster's server rather than Napster's users in order to avoid alienating its customer base, though the industry's desperation would eventually lead it to target peer-to-peer users directly.

fig. 2.3 **Napster Organization**



Centralized organization for log-on, indexing, and searching employs Napster servers.

Distributed organization for file transfers connects peers directly without intermediation from Napster servers.

Without its server, the entire Napster network was swiftly brought to a halt. Napster's closure did not, however, signal the end of the peer-to-peer movement, but rather catalyzed the development and growth of other peer-to-peer networks, much to the chagrin of the music industry. As cultural historian and media scholar Siva Vaidhyanathan (2004: 44) has argued, the industry might have avoided the post-Napster development of legally resilient peer-to-peer technologies had it struck some kind of deal with Napster. Unlike Napster, post-Napster networks typically incorporate search protocols that do not depend on centrally maintained (and legally-vulnerable) indexes, and are therefore resistant to legal attack and other forms of juridical governance.[11] In other words, post-Napster peer-to-peer networks developed in strategic response to the ability to monitor and control centrally administered Internet content; peers, unlike servers, are practically ungovernable.

While it is not impossible to police peers who make copyrighted content available for duplication, it is significantly more difficult than policing servers. Still, the industry continues to pursue legal action as a strategy to combat peer-to-peer networks. By the end of 2007, the RIAA had filed, settled, or threatened legal action against more than 30,000 users for sharing copyrighted files through peer-to-peer networks (Electronic Frontier Foundation 2008). While these lawsuits may deter some users from participating in peer-to-peer networks, they do not successfully deter peer-to-peer activity on the massive scale at which it operates. I take this as evidence that post-Napster peer-to-peer networks have successfully transformed an external obstacle—the litigious nature of content providers—into an internal one—how to function at a massive scale in the absence of centralized components. What was once a legal issue—the use of centralized components—has become a technical issue—the efficiency of networks in the absence of centralized components.

[11] This is not say that servers are never used. However, they are generally not used to perform central functions.

Searching without a "center"

There are several endemic obstacles to the efficiency of post-Napster peer-to-peer networks. The primary obstacle is the volume of network traffic created by peers' search requests. The Napster network did not suffer this problem, as all search requests were sent only to Napster's central server. Since post-Napster peer-to-peer networks cannot employ legally-vulnerable centralized components, they instead proliferate search requests by forwarding them from peer to peer. In very small networks this tactic is viable, as each peer can easily request desired files without creating an excessive amount traffic. However, in very small networks a peer's chance of locating a desired file is small. For this reason, most successful peer-to-peer networks are very large, with hundreds of thousands or even millions of users connected simultaneously. The greater the number of peers that are connected, the greater and more diverse the quantity of files that are available for download, and, in turn, the greater the likelihood that connected peers will offer desired files.

The increased likelihood that at least one peer in a large peer-to-peer network will offer a desired file is undercut by the difficulty with which desired files are located in large peer-to-peer networks. Simply put, it is not viable for a searching peer to ask every connected peer for a desired file; so many requests would consume too much of a large network's available bandwidth. It is also not viable to limit the number of peers that can connect to a network, because of the negative impact this would have on its performance.

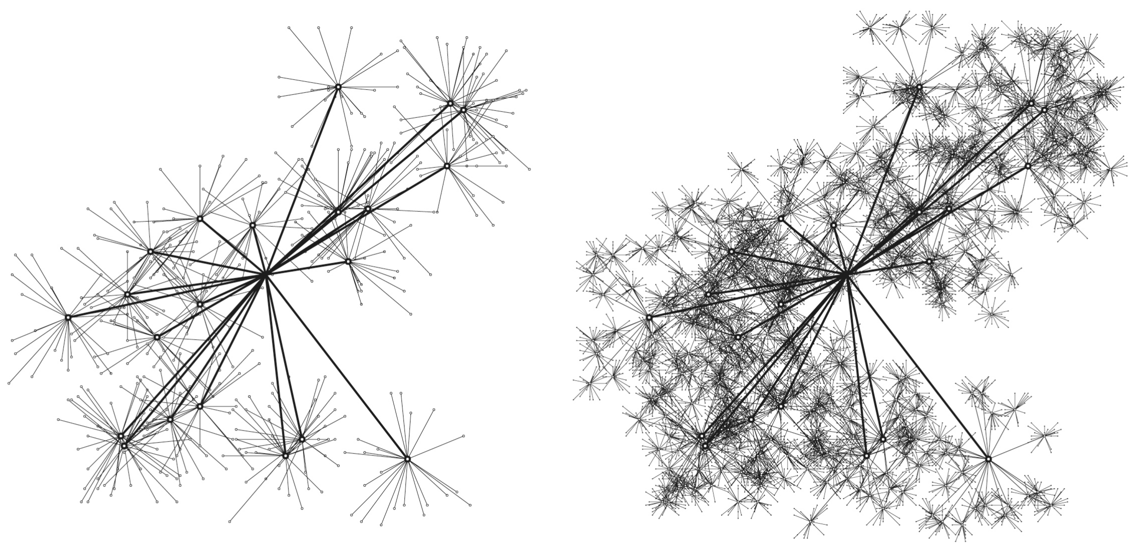
The question therefore is how to make it possible for peers to search for files in a way that quickly yields results without greatly increasing network traffic, even when a network is very large. I will now turn to consider the technical methods that allow peers in post-Napster peer-to-peer networks to search for files in the absence of legally-vulnerable centralized components while minimizing network traffic in a way that does not deter network growth or efficiency.

Flooding

After the demise of Napster, the first method to allow peers to search for files in the absence of centrally maintained indexes was “flooding” or “blind flooding.” Flooding protocols dictate that a peer’s search request is sent to a small group of connected peers, typically chosen at random. If one of the peers in this small group has the requested file, it sends a confirmation back to the searching peer. If not, the search request is forwarded to a different small group of connected peers. If one of the peers in this second group has the requested file, it sends confirmation back to the searching peer through the forwarding peer. If not, the search request is forwarded to a third group of peers, and so on (see fig. 2.4). In the event that a peer is forwarded a search request it has already received through a different forwarding peer, it disregards the request. In order to prevent search requests from circulating interminably through the network (which would consume the network’s bandwidth), each search request is forwarded a certain number of times. This number is known as “hops to live” or “time to live” (TTL). As Androutsellis-

Theotokis and Spinellis explain, “At each hop, the value of this [TTL] field is decremented, and when it reaches zero, the message is dropped” (2004: 12). TTL values are calibrated by programmers to increase the chances that search requests will yield results, while preserving the efficiency of the network.

fig. 2.4 **Flooding Protocol**
The path of a search.



2 steps
Polling 20 random peers at each level, two steps results in a search reaching 20^2 or 400 peers.

3 steps
Still polling 20 random peers at each level, three steps results in a search reaching 20^3 or 8,000 peers.

While somewhat inelegant, flooding the network with search requests nonetheless allows peers to search for files in the absence of legally-vulnerable centralized components. Aside from meeting this basic requirement, the primary advantage of flooding is that it is well suited to networks in which peers connect and disconnect frequently—a characteristic of networks called “churn.” As Aberer et al. explain, “Participation of peers … dynamically changes over time. Each peer can freely decide to join or leave an overlay network at any time. These changes … can happen quite frequently” (2005: 5). Median session times range from one minute to one hour (Qiao and Bustamante 2005). Flooding is well-suited to networks with high churn, as it only requires that search requests be sent or forwarded to a small number of connected peers. However, in networks that employ flooding protocols, network efficiency does not increase if peers remain constant over a period of time. As I will explain shortly, it is possible to take advantage of networks with low churn, organizing or "structuring" the network to render it more efficient for searching. For this reason, networks that flood search requests are commonly referred to as unstructured. This is not to say that such networks have no structure, but that their structure is not planned; it forms ad hoc and constantly changes as users connect and disconnect.

Despite the increased efficiency flooding offers to networks with high churn, flooding has generally fallen out of favor due to its inefficiencies. Firstly, the volume of search requests created through flooding often consumes a significant portion of a network's available bandwidth, compromising its efficiency. Network efficiency is further compromised when flooded search requests take circuitous routes through the network, unnecessarily consuming bandwidth (Lien and Xu 2007; Wang and Xiao 2006). As Liu et al. explain:

> The mechanism for a peer to randomly choose logical neighbors, without any knowledge about the physical topology, causes a serious topology mismatch between the P2P overlay networks and the physical network .… Because of the mismatch problem, a pair of logical neighbors can be far away from each other, causing a message to traverse the same physical link multiple times and wasting a huge amount of network bandwidth. (2007: 1)

Secondly, flooding protocols often unintentionally segment a peer-to-peer network into smaller sub-networks, further reducing the efficacy of search requests (Androutsellis-

Theotokis and Spinellis 2004; Terranova 2004: 56). Dissatisfied with these inefficiencies, programmers began to experiment with more directed methods of searching.

Controlling traffic in unstructured networks

Searching the Napster network for files was extremely efficient, as it entailed a simple back-and-forth between peer and server. Because post-Napster networks cannot employ a central server in this way, their efficiency is much more difficult to secure. In order to make flooding protocols more efficient, programmers tweaked them in several ways. For one, they altered flooding protocols to take advantage of the inherent discrepancy in peers' computation and bandwidth capacities, so that peers with faster bandwidth connections shield peers with slower bandwidth connections from search requests. These faster peers, called supernodes (or ultrapeers) create temporary indexes of shielded peers' files. When a shielded peer searches the network, it does not send its search request to a random group of peers, but rather to a supernode. Supernodes respond to search requests on behalf of shielded peers whose files they have temporarily indexed. In this way, the routing of search requests through supernodes decreases network traffic while increasing search efficacy (see fig. 2.5).

In addition to designing flooding protocols that take advantage of peers' bandwidth capacities, programmers have experimented with a number of other methods of reducing network traffic in unstructured networks. For example, query routing protocols allow search requests to be sent only to peers likely to have the file requested.

Dynamic querying allows search requests to be terminated once a sufficient number of results are obtained. User Datagram Protocol, while not specific to peer-to-peer technologies, allows search results to be sent directly back to searching peers rather than forwarded through each peer enlisted in the search. While these methods may not render unstructured networks as efficient as Napster, they nonetheless increase unstructured networks' efficiency while securing their immunity to the kinds of legal attack which plagued Napster.

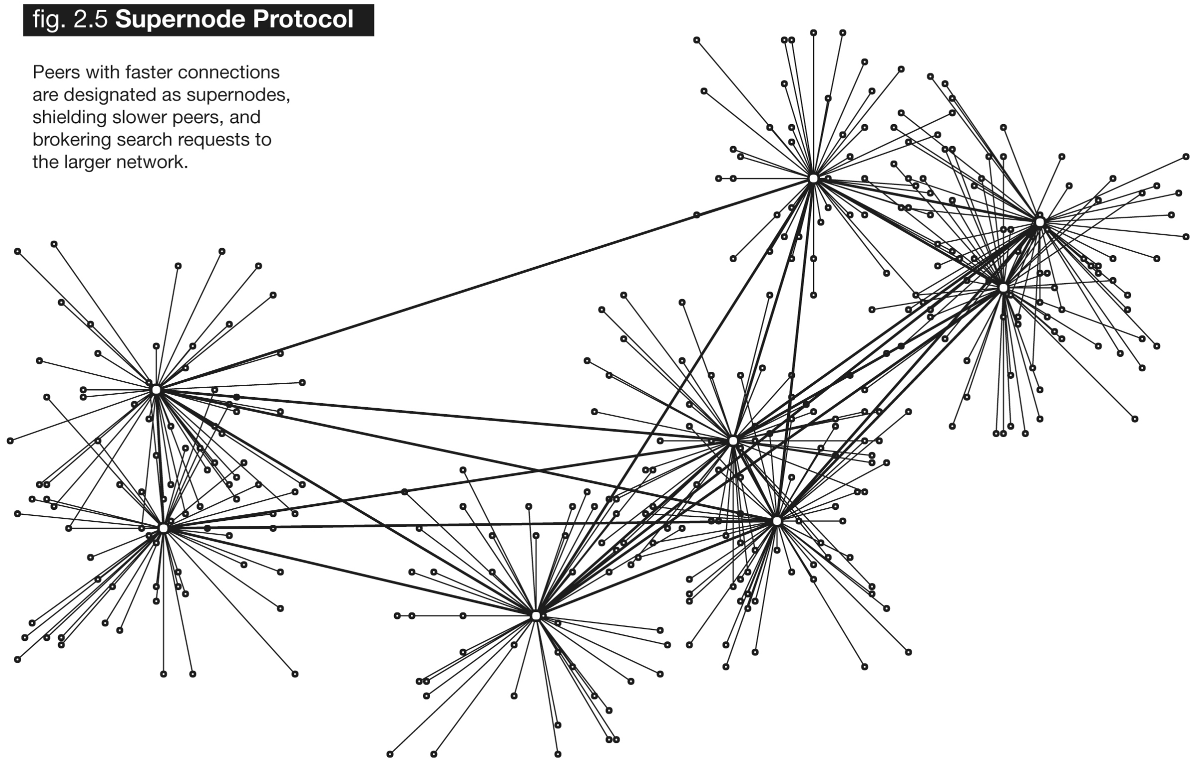


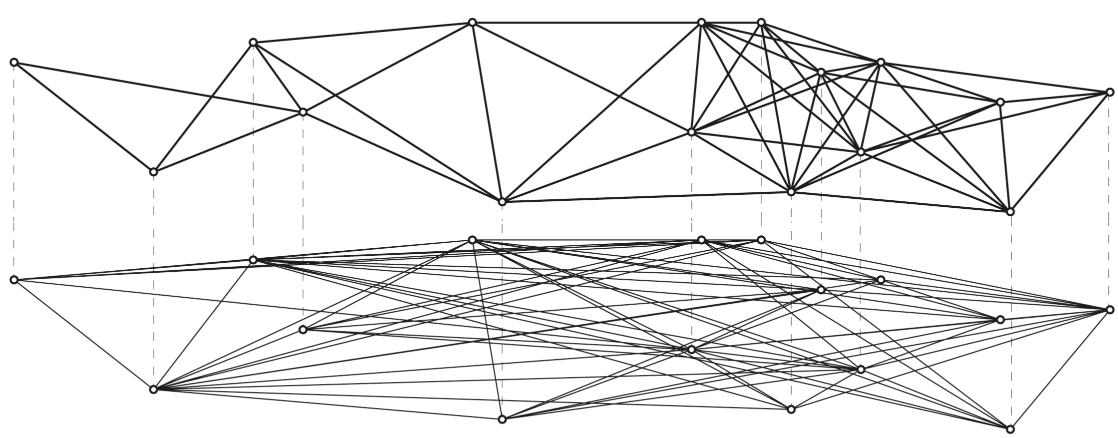
fig. 2.5 **Supernode Protocol**

Peers with faster connections are designated as supernodes, shielding slower peers, and brokering search requests to the larger network.

Structuring the network

Despite programmers' best efforts, unstructured networks become increasingly inefficient as they grow in size. If a peer-to-peer network becomes too inefficient, it does not matter whether or not that network successfully avoids legal attack. Responding to the inefficiency of large unstructured networks, programmers designed protocols which organize (or structure) how peers' search requests are routed through the network. Unlike unstructured peer-to-peer networks, which form ad hoc and are constantly changing, the organization of structured peer-to-peer networks is protocologically prescribed. This is not to say that unstructured networks are established in the absence of protocols; all peer-to-peer networks, whether structured or unstructured, are established through protocols. However, the protocols that govern the organization of unstructured networks specify that peers will select at random who they connect to (for the purpose of searching for files), while structured networks use pre-defined criteria to determine how peers will search for files.

fig. 2.6 **Overlay Network**



Overlay Network
Organizes connections between peers without altering underlying network infrastructure.

To understand how the rules of structured networks alleviate network congestion, it is first necessary to understand the concept of overlay networks. As peer-to-peer programmers Zeinalipour-Yazti et al. explain, "The basic idea is that an overlay network of nodes (peers) is constructed on top of heterogeneous operating systems and networks. Overlays are flexible and deployable approaches that allow users to perform distributed operations without modifying the underlying physical network" (2007: 1). In other words, an overlay network is a network that is built over another network, shaping it, in a sense, without modifying it (see fig. 2.6). In the case of peer-to-peer networks, the Internet is the underlying heterogeneous network on top of which peer-to-peer networks are established (Androutsellis-Theotokis and Spinellis 2004).

Because peer-to-peer networks are built "over" the Internet, they must conform to the Internet's basic system of locating devices and transmitting data, much like other overlay networks (such as the World Wide Web) do. In particular, peer-to-peer networks must employ the Internet's core protocols—those protocols which prescribe basic Internet functionality—the most familiar of which are Transmission Control Protocol (TCP) and Internet Protocol (IP). These protocols prescribe a method for breaking digital files into smaller packets and transmitting these packets from one device to another. In order to alleviate network traffic, structured peer-to-peer networks supplement core Internet protocols with application-specific protocols that take advantage of the fact that peer-to-peer networks are overlay networks. In other words, peer-to-peer networks use core Internet protocols to establish basic connectivity, while also employing additional protocols to organize (structure) underlying connections towards the efficiency of the network.

An example will help to clarify. Chord, one of the most widely-used structuring protocols, specifies that peers who join the network must occupy particular logical positions in the network. Each peer who joins the network is assigned responsibility for maintaining a small portion of an index of available files—what is called a Distributed Hash Table (DHT) (2005: 5; Androutsellis-Theotokis and Spinellis 2004). Different structuring protocols employ different methods for assigning peers portions of this distributed index. With Chord, responsibility is assigned in such a way that each peer occupies a logical position on the perimeter of a circle. In order to locate a desired file in a network that uses Chord, a peer's search request is efficiently routed from peer-to-peer around the perimeter of the circle until it reaches the peer responsible for the portion of the index which contains information about the location(s) of the file.[12]

The most commonly cited drawback of structured networks is their inability to respond to peer transience (churn) without generating excessive network traffic. To be certain, all peer-to-peer networks, whether structured or unstructured, must have a maintenance strategy which responds to churn. However, because they generate network traffic, the maintenance strategies of structured networks threaten to undermine the efficiency achieved through structuring the network. In other words, unstructured networks prescribe inefficient search methods and efficient maintenance strategies while

---

[12] It should be noted that DHTs are not the only method of structuring a peer-to-peer network. Another method employed is structuring the network according to the geographic proximity of peers, since great distances between connected peers can produce unnecessary network traffic (Zeinalipour-Yazti et al., 2007: 2).

structured networks prescribe efficient search methods and inefficient maintenance strategies.[13] As Wang and Xiao write, "How to balance the costs between searching and indexing becomes a critical design issue in such a dynamic environment. An intriguing question is: 'Can we improve the search efficiency of P2P networks with zero or minimal indexing cost?'" (2006: 1).

BitTorrent

While most peer-to-peer protocols can be categorized as either structured or unstructured, there is one very popular protocol, BitTorrent, which does not fit into either category. BitTorrent is an important case to examine for this reason, and because it facilitates the transmission of very large files, namely video files (television shows, feature length movies), not easily distributed through other peer-to-peer networks. In describing how the BitTorrent protocol works, I aim both to suggest the expanding scope of peer-to-peer networks beyond their audio-file origins, and to further explicate the complexity and diversity of methods employed by peer-to-peer networks in their dual goals of promoting efficiency and avoiding legal attack.

BitTorrent prescribes a search method different from structured and unstructured protocols. Rather than asking connected peers for desired files, BitTorrent users first locate tracking files. These files, called .torrents, are typically hosted on public websites,

[13] It should also be noted that there are networks that are neither totally unstructured nor totally structured but rather loosely structured. In these networks, "the location of content is not completely specified" but can be affected by "routing hints" (Androutsellis-Theotokis and Spinellis, 2004: 10).

and contain the information necessary for a peer to locate and download the desired file. As BitTorrent's inventor Bram Cohen explains:

> The .torrent contains information about the [desired] file, its length, name, and hashing information, and the URL of a tracker. Trackers are responsible for helping downloaders find each other. They speak a very simple protocol layered on top of http in which a downloader sends information about what file it's downloading, what port it's listening on, and similar information, and the tracker responds with a list of contact information for peers which are downloading the same file. Downloaders then use this information to connect to each other. To make a file available, a 'downloader' which happens to have the complete file already, known as a seed, must be started …. The tracker's responsibilities are strictly limited to helping peers find each other. (2003: 2)

In order to initiate a BitTorrent session, a user will search the Web for a .torrent file that contains the tracking information for the file she wishes to download. Once she has located and downloaded an appropriate .torrent, she opens the .torrent with a BitTorrent client (e.g. µTorrent, Vuze). Reading the details stored in the .torrent, the BitTorrent client communicates with the tracking URL specified in the .torrent in order to connect the downloading peer with other peers who have made available for download the desired file or pieces of it.

In most peer-to-peer networks, the transmission of a file occurs between two peers—the uploader and the downloader. If the uploading peer disconnects from the network in the middle of uploading of a file, the downloading peer will be left with an incomplete file. The larger a file is, the longer it takes to upload/download, and the greater the chance that the uploading peer will disconnect before the file has been successfully transferred. To avoid this scenario, BitTorrent prescribes a method for peers to download different pieces of a file from a multitude of connected peers, taking advantage of the fact that large numbers of users often want to download the same file.

As Cohen explains, “With BitTorrent, when multiple people are downloading the same file at the same time, they upload pieces of the file to each other. This redistributes the cost of upload to downloaders … making hosting a file with a potentially unlimited number of downloaders affordable” (1). If one uploading peer disconnects, there may still be many other peers that can continue uploading the file. For this reason, BitTorrent has become a popular method of downloading larger files such as television shows and movies. In order to coordinate the downloading of different pieces of a file from different peers, each .torrent contains hash information. A file’s hash functions like a fingerprint and an index, allowing downloading peers to verify that the pieces they download contain the correct data, and to assemble these pieces in their proper order.

Like other peer-to-peer protocols, BitTorrent prescribes a method for breaking files into smaller packets of data and transmitting these packets. To ensure that the transmission of a file is as efficient as possible, BitTorrent creates a “pipeline of sub-pieces”—a continual stream of packets awaiting transmission. Furthermore, BitTorrent dictates the order in which sub-pieces should be downloaded. As Cohen explains:

> Selecting pieces to download in a good order is very important for good performance. A poor piece selection algorithm can result in having all the pieces which are currently on offer or, on the flip side, not having any pieces to upload to peers you wish to … BitTorrent’s first policy for piece selection is that once a single sub-piece has been requested, the remaining sub-pieces from that particular piece are requested before sub-pieces from any other piece. This does a good job of getting complete pieces as quickly as possible. (6)

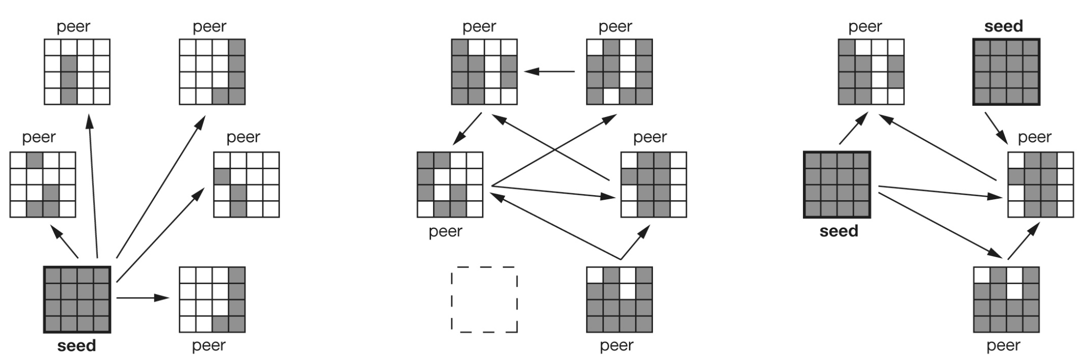
In addition to prescribing a method for transmitting sub-pieces, BitTorrent dictates that peers should always download those pieces of a file which are rarest on the network—

that is to say, those pieces that have been downloaded by the fewest number of connected peers. As Cohen writes:

> This technique does a good job of making sure that peers have pieces which all of their peers want, so uploading can be done when wanted. It also makes sure that pieces which are more common are left for later, so the likelihood that a peer which currently is offering upload will later not have anything of interest is reduced. (3)

For example, if 100 peers (called "leeches") simultaneously download the same file from a small group of peers (called "seeds") who have already successfully downloaded the entire file, and these 100 peers download pieces of the file sequentially, it is possible that no single peer will have downloaded the entire file before all seeds disconnect from the network. However, if peers prioritize the downloading of (non-sequential) rare pieces, they will each download a different piece of the file from connected seeds, and will thus be able to continue downloading missing pieces from each other after all seeds have disconnected. In other words, while there may be no individual seed connected, the pieces downloaded by different peers may together constitute a seed (see fig. 2.7).

fig. 2.7 **BitTorrent**



A seed with a complete file makes pieces available to peers in the swarm.

Once each piece has been transfered to at least one peer, the seed is no longer needed for downloading to continue.

As peers download and upload missing pieces to each other, additional peers become seeds.

Despite the extent to which BitTorrent's "rarest first" policy extends the lifespan of a file on the network, all files transmitted through BitTorrent eventually become unavailable for download after a period of time. As Cohen explains, "In a typical deployment, the number of incomplete downloaders, (meaning ones which do not have the whole file), increases very rapidly after the file is made available" (2). This number may be very high—Cohen cites deployments that have sustained more than one thousand simultaneously downloading peers.[14] Eventually the number of incomplete downloaders "peaks and then falls off at a roughly exponential rate." Concurrently, "the number of complete downloaders increases slowly, peaks some time after the number of incomplete downloaders does, then also falls off exponentially." In other words, as time passes, fewer and fewer peers participate in the uploading/downloading of any given file, until there is no complete seed of that file and downloading ceases.

Despite BitTorrent's clever avoidance of the inefficiencies of both structured and unstructured networks, it suffers from one major flaw: it depends on two centralized components—websites that host .torrent files, and BitTorrent trackers, which send uploading/downloading peers' contact information to each other. For this reason, .torrent sites and trackers have faced some of the same legal issues that plagued Napster. And like Napster, .torrent and tracking sites have been shut down through legal means, despite the fact that these sites do not themselves distribute copyrighted data. However, even as .torrent and tracking sites have been shut down, BitTorrent—like other post-Napster

[14] In this way, BitTorrent is extremely scalable, limited only by the tracker's bandwidth (5).

peer-to-peer networks—continues to thrive, comprising half of total global Internet usage (Stone 2008).

Conclusion

Examining the network protocols that have made peer-to-peer networks successful despite legal obstacles, it is possible to conclude that the relationship between peer-to-peer networks and juridical power is too complex to be simply adversarial. Peer-to-peer technologies do not simply thwart legal methods of control, but rather adapt in response to the successes and failures of litigious content providers' campaigns. If the success of peer-to-peer networks has been continually threatened by content providers' legal actions, it has also been made possible, in a sense, by these actions. More precisely, peer-to-peer networks respond to a juridical problem—the tricky legality of centralized components—with a technical solution—efficient decentralization. If I have made this solution sound easy or obvious, we should remember that the technical toolkit at programmers' disposal is not infinite. They must work within the confines of the Internet's core protocols, finding ways to secure network efficiency while avoiding legally-vulnerable centralized components.

It would be a gross oversimplification to argue that peer-to-peer technologies singlehandedly cause a shift in modes of power from the juridical to the immanent or endogenous. As I have argued, immanent or endogenous control is endemic to networks, whether they are networks of peers, business contacts, or highways. Whether this shift in modes of power is caused by networks or whether they result from this shift is unimportant for the present argument. What is important is that peer-to-peer networks, because of what we might now call their socio-technical organization, play a central role in upsetting the economic relation between content providers and their customers, a relation built on a foundation of juridical power. This upset sets the stage for what I will begin to describe in the following chapter as a transformation in the economics of cultural production.

Chapter Three: Own Nothing, Have Everything

To become a commodity a product must be transferred to another, whom it will serve as a use-value, by means of an exchange. (Marx 1967: 41)

It is as if someone had found a way to form and then mine a new phenomenological substrate. (Thrift 2006: 296)

The Copyright Question

Since Napster was released in 1999, peer-to-peer networks have been the subject of many news stories and academic articles, most of which have focused on the antagonism between peer-to-peer networks and the entertainment industry. Because this antagonism has played out largely on the legal stage, through litigation against peer-to-peer developers and their users and anti-piracy legislation, the non-technical scholarship on peer-to-peer networks has focused almost exclusively on the legal issues associated with peer-to-peer networks, with particular attention to the purview of copyright.

Established in the U.S. in the 18^{th} century, the system of copyright grants authors exclusive rights for the reproduction of their work for a period of time determined by law (currently up to 120 years), while also granting the public "fair use" rights to partially reproduce others' works for the purposes of criticism, comment, news reporting, teaching, or research. Legal scholar Lawrence Lessig offers an instructive example to highlight the difference between rights of reproduction and fair use. When a consumer purchases a book, Lessig writes, it is his to use in almost any way he sees fit: he can read it as many times as he likes, give the book to a friend or sell it (2004: 141). These uses are all permitted under U.S. copyright law. However, he cannot the copy the book or extended sections of it without permission from the author.

In separating rights of use from rights of reproduction, copyright was designed to balance the financial interests of authors with the interests of society at large, establishing a give-and-take: authors are permitted to build on others' works, though any new work that results is exclusively their own to reproduce. This makes possible the remuneration of authors, offering them a financial reward for their work as well as an incentive to continue working, while also promoting cultural, scientific, and technological innovation. This rationale is made clear in the U.S. Constitution, which states that "the Congress shall have power to promote the progress of science and useful arts, by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries."

As legal scholars have noted, digital network technologies throw a wrench into the system of copyright. In digital networks, data *must* be reproduced in order to be used, as when a user visits a website and an html document is copied onto her computer. Siva Vaidhyanathan elaborates:

> In the digital environment, one cannot gain access to a news story without making several copies of it. If I want to share my morning newspaper with a friend, I just give her the object. I do not need to make a copy. But in the digital world, I do. When I click on the web site that contains the news story, the code in my computer's random access memory is a copy. The source code in hypertext markup language is a copy. And the image of the story on the screen is a copy. If I

> want a friend to read the story as well, I must make another copy that is attached to an e-mail. (2001: 152)

Digital network technologies' conflation of reproduction and use has made it possible for content providers to control not only the reproduction of content, but its use as well. As Lessig writes, "The technology expands the scope of effective control, because the technology builds a copy into every transaction" (146). Continuing with his example of the book, Lessig notes that while one is free to sell a book that one owns, one is not free to sell or lend an electronic copy of a book that one owns, insofar as these uses entail reproduction. Furthermore, one may only be permitted to read an electronic book a limited number of times or for a limited period of time, if reading can be tied to reproduction. Such restrictions are the result of a number of pieces of legislation passed since the Internet came into widespread use in the mid-90s, most notably the Digital Millennium Copyright Act (DMCA). Passed in 1998, the DMCA criminalizes the production and distribution of devices and services that circumvent access-control technologies as well as acts of circumvention, even when no copyright infringement occurs. While the DMCA is more nuanced than this, for the present purposes it is sufficient to note that the DMCA ultimately allows content providers to set the terms for the use of content (Lessig 2004: 159).

While the legal scholarship addressing peer-to-peer networks varies in approach and emphasis, it is unified around a shared critique of the methods used by entertainment industry to curtail digital piracy. In particular, scholars like Lessig, Vaidhyanathan, Yochai Benkler, and Jonathan Zittrain have argued that the entertainment industry's efforts to curtail piracy represent an abuse of copyright, encroaching on fair use and threatening to undermine the public domain and, as a result, innovation and social progress. Despite how difficult it may be for content providers to control the reproduction of content through digital networks, these scholars believe that copyright still remains a useful method of balancing the needs of authors with those of society-at-large, if not with a few adjustments (see Currah 2007: 482). In particular, scholars have argued for a return to what Vaidhyanathan calls "thin" copyright: "just strong enough to encourage and reward aspiring artists, writers, musicians, and entrepreneurs, yet porous enough to allow full and rich democratic speech and the free flow of information" (2001: 5).

To justify its war on fair use, the entertainment industry has often claimed that it is simply protecting the integrity of intellectual property, a concept which it conflates with copyright. However, as Vaidhyanathan notes, "copyright in the American tradition was not meant to be a 'property right' as the public generally understands property. It was originally a narrow federal policy that granted a limited trade monopoly in exchange for universal use and access" (2001: 11). In other words, the idea of intellectual property inappropriately characterizes cultural content as a form of property, a concept that applies only to scarce, rivalrous goods such as houses, cars, and parcels of land. As the framers of copyright understood, cultural content exhibits a fundamentally different materiality than scarce, rivalrous goods—a materiality that copyright was uniquely designed to manage.

While these scholars have been fiercely critical of the methods used by the entertainment industry to curtail digital piracy, they clearly understand the entertainment industry's plight. It has not escaped them that the Internet conflates use and reproduction, and that this conflation has made business difficult for content providers whose profitability is rooted in controlling the reproduction and distribution of content. As Lessig writes, “No doubt, current technologies threaten existing businesses. No doubt they may threaten artists” (2004: 211). However, these scholars are less concerned with the continued profitability of existing businesses than they are with the long-term vitality of the market, which they believe depends on allowing new technologies to flourish even if they might be used in illegal ways. Furthermore, as Lessig notes, “the industry and technologists have plenty of ways to use technology to protect themselves against the current threats of the Internet. This is a fire that if let alone would burn itself out” (211). In other words, Lessig believes that in time the market will outperform peer-to-peer networks.

Legal scholars’ criticism of the entertainment industry hinges on an affirmation of the premise underlying copyright—i.e. that social progress depends upon cultural, scientific, and technological innovation, and that innovation, in turn, depends on a careful balance between public rights of use and private rights of reproduction. According to this logic, innovation is slowed when authors are not remunerated for their work but also when authors are not permitted to draw from or reference other authors’ works. Copyright was designed to establish and maintain this symbiosis, balancing public rights of use with private rights of reproduction such that public and private nurture one another. In this way, innovation/progress are thought to be inextricable from if not coterminous with the vitality of markets, making it difficult to distinguish between the "economically efficient" and the "socially beneficial" (see Currah 2007: 472). As Lessig writes:

> Digital technologies, tied to the Internet, could produce a vastly more competitive and vibrant market for building and cultivating culture; that market could include a much wider and more diverse range of creators; those creators could produce and distribute a much more vibrant range of creativity; and depending upon a few important factors, those creators could earn more on average from this system than creators do today. (2004: 9)

While these arguments tend to linger on the dangers of eviscerating the public domain, legal scholars have also made it clear that they support the other side of the copyright equation: the financial remuneration of authors. As Vaidhyanathan writes of peer-to-peer users, "Although some might behave ethically, many do not. Let's face it, plenty of people are compiling entire Eminem albums from peer-to-peer systems and opting out of the commercial music economy" (2004: 62). Lessig elaborates: "This kind of piracy is rampant and just plain wrong. It doesn't transform the content it steals; it doesn't transform the market it competes in. It merely gives someone access to something that the law says he should not have" (2004: 65). As I will argue shortly, Lessig is wrong here; it is precisely digital piracy which has transformed markets for cultural content.

Despite these condemnations, legal scholars' criticism of digital piracy is often tempered with an understanding of the complexity of the situation, and with good reason. For one, the evidence of digital piracy's negative effect on the sale of content is inconclusive (Liebowitz 2006; Oberholzier and Strumpf 2007). While industry organizations like the RIAA blame piracy for declining sales, Oberholzer and Strumpf suggest a number of alternative factors: "poor macroeconomic conditions, a reduction in the number of album releases, growing competition from other forms of entertainment such as video games and DVDs … , a reduction in music variety … , and possibly a consumer backlash against record industry tactics" (2007: 24). Supporting this thesis, Lessig notes that the unauthorized downloading of copyrighted content does not necessarily displace sales: users might download content they would not otherwise buy, download content that is out-of-print or otherwise unavailable for purchase, or download content in such a way that leads to a future purchase (2004: 68). As Lessig asks, "How much has society gained from p2p sharing? What are the efficiencies? What is the content that otherwise would be unavailable?" (2004: 73). Furthermore, scholars have pointed out that musicians are often poorly compensated by record labels, instead earning their income from live performances (Alderman 2001: 52; Oberholzier and Strumpf 2007: 25). For many musicians, piracy may actually be beneficial, helping to attract larger audiences to performances. Finally, it is important to remember that peer-to-peer networks are also used legally to reproduce and distribute content, contributing to the vibrancy of the public domain.

There are other reasons to be concerned about the methods used by the entertainment industry to curtail digital piracy—reasons not related to copyright, the public domain, or the remuneration of authors. In particular, scholars have expressed concerns about the connection between anti-piracy initiatives and the innovation of methods of surveillance and policing. As legal scholar Sonia Katyal writes, "Today, the seemingly intractable problem of digital piracy has led to the creation of massive offensives—criminal, civil, and international—spearheaded by private intellectual property owners. Private companies routinely join forces with law enforcement officials to investigate and prosecute individuals for trafficking in pirated materials" (2005: 266). Lessig too notes that "the technologies of the Internet are open to snoops as well as sharers, and the snoops are increasingly good at tracking down the identity of those who violate the rules" (2004: 160). This vulnerability is characteristic not only of the Web, as Lessig argues (161), but—to a lesser extent—of peer-to-peer networks, the users of which can also be identified. As Katyal notes, "Following the DMCA, the Napster court established a set of directives for [Internet Service Providers] to follow in addressing the infringing activities of their users" (2005: 273).

Interrogating the means used by the entertainment industry to curtail digital piracy is important; however, it is the ends of digital piracy that I want to draw into question. What are these ends? For the legal scholars discussed, piracy occasions new opportunities for investment and innovation. While they do not condone "stealing" content, neither do they dwell on this form of piracy, because, I suspect, they sincerely believe it to be a temporary trend that will be overcome through the market. As Lessig wrote in 2004: "Today, file sharing is addictive. In ten years, it won't be. It is addictive today because it is the easiest way to gain access to a broad range of content. It won't be the easiest way to get access to a broad range of content in ten years" (297).

Lessig makes an important point. Consider, for example, his prescient claim that the Internet as would soon be "as ubiquitous as the best cell-phone service, where with the flip of a device, you are connected" (298). When this ubiquity finally comes to pass, Lessig writes,

> it will be easier to connect to services that give you access to content than it will be to download and store content on the many devices you will have for playing

> content. It will be easier, in other words, to subscribe than it will be to be a database manager, as everyone in the download-sharing world of Napster-like technologies essentially is. (298)

While I agree that the success of peer-to-peer networks created the impetus for the sort of technological and market innovation Lessig alludes to, I think that writing in 2004 he did not (or could not) see that piracy would set into motion a much broader transformation, fundamentally altering how economies of cultural content work. This is not a question of the ability of content providers to compete with peer-to-peer networks, as Lessig suggests, but of content providers' and other business interests' ability to adapt to a social and economic environment fundamentally transformed by peer-to-peer networks.

In this chapter I will begin to theorize this transformation by locating its roots in the basic mechanics of digital network technologies. As I have noted, content providers assumed the Internet to be an economic threat even before the advent of peer-to-peer networks; they understood something about the Internet's latent economic potential. The first step in explicating how peer-to-peer networks transform economies of cultural production is to analyze this economic potential—what it is and where it comes from. To do this, I will discuss two contrasting perspectives. The first belongs to *Wired* magazine co-founder Kevin Kelly, who understands the technologies in question in a way that few if any political-economists or social theorists have. The second belongs to the scholarship of Karl Marx, which understands the production of economic value in a way that few technology savants have. In this discussion, I aim to draw from the insights of each perspective while remaining open to questions not addressed by either, particularly questions about transmission and value which I will examine in subsequent chapters.

Ultimately I will argue that the economic potential of the Internet is a function of the materiality of data. In economic terms, data is a non-rivalrous resource—its consumption by one user does not preclude or inhibit its consumption by other users. Unlike commodities, which are transferred from buyer to seller, usually in exchange for money, data is rarely given up when it is transmitted; the uploader of a digital file still possesses that file after it has been transmitted. For this reason, the more times a file is transmitted, the greater the number of copies of it that exist. This quality of data, what I will refer to as its viral character, enacts a fundamental break from the economic logic of commodity exchange, setting the stage for a transformation of economies of culture, a transformation catalyzed by peer-to-peer networks.

The Internet as a technology of production

In contemporary social and political-economic analysis, the Internet has largely been understood as a technology of communication. For example, scholars of globalization (Castells 1996; Thompson 2003), have examined the ways in which corporations, economic organizations, and financial institutions have used the Internet to establish and maintain relationships with customers and clients, conduct financial transactions, and coordinate geographically dispersed activity. In this work, the Internet has been conceptualized as a tool used to connect users with each other. While this approach has illuminated the ways in which the Internet facilitates production, it has not captured the productivity of the Internet in the way that a factory assembly line, for example, is productive. Theorizing the Internet as a technology of production is necessary, however, to account for the transformation of cultural economies catalyzed by peer-to-peer networks.

Kevin Kelly, co-founder of *Wired* magazine, offers a useful point of entry to begin examining the Internet as a technology of production. While not an academic scholar, Kelly's knowledge of the materiality of digital network technologies has led him to question the political economy of digital networks in a way not done by legal scholars or scholars of political economy. Kelly argues that the Internet is a fundamentally different kind of machine than the machines of industrial capitalism. He writes, "The internet is a copy machine …. Unlike the mass-produced reproductions of the machine age, these copies are not just cheap, they are free" (2008).[15] Kelly is referring to the fact that data must be copied many times as it travels through the Internet from sender to receiver. While users do not pay for these copies in any direct way, and while they may be unaware that copies are being made, copying is central to the successful transmission of data through the Internet.

Following this characterization of the Internet as a free copy machine, Kelly asks, "How does one make money selling free copies?" With this question, Kelly's argument shifts focus from the copies made on data's journey from sender to receiver, to the initial instance of copying—the moment when a sender copies a file in order to transmit it through the Internet. Focusing on this initial moment of copying solidifies the connection

[15] Kelly is not, of course, the first cultural critic to theorize the political economy of the copy. Beginning with Walter Benjamin's essay "The Work of Art in the Age of Mechanical Reproduction," scholars have long wrestled with this issue. While Benjamin's essay is notable as one of the first scholarly treatments of the copy as well for its departure from the work of some of his Frankfurt School contemporaries, I will not discuss it here as it is concerned more with the politics of reproduction than the economics.

Kelly has intimated between the Internet and the reproduction technologies of industrial capitalism, casting the Internet as the latest in a long series of reproduction technologies whose tendency is to produce ever-cheaper copies.

Situated at the tail end of this history, the Internet appears to reproduce valuable cultural content for free. As philosopher C. George Caffentzis reminds us, however, such fantasies of something-for-nothing suffer from flawed logic reminiscent of the alchemists in the seventeenth century: “For by increasing the supply of gold all that a successful alchemical industry would do is to decrease the relative price of gold while increasing the general price level. Far from realizing their visions of infinite wealth, the alchemists would destroy the very ideal they premised their vision on” (1997: 38). Devaluation is precisely the problem Kelly locates in the proliferation of free copies through the Internet, leading him to propose that the Internet is undermining the established economic order. He argues that the U.S. economy has been built on wealth accumulated through the sale of precious copies. As with gold or any other precious substance, once copies can be reproduced for free they are no longer precious and therefore lose value.

In order for the U.S. economy to continue to accumulate wealth, Kelly reasons, businesses will need to sell something other than copies. It is not simply that businesses need to find something new to sell because copies are no longer profitable, but that the devaluation of copies prompts the valuation of certain other qualities. As Kelly explains, “When copies are super abundant, they become worthless. When copies are super abundant, stuff which can’t be copied becomes scarce and valuable. When copies are free, you need to sell things which cannot be copied.” What are these qualities that cannot be copied and are thus made valuable by the superfluity of digital copies? Kelly calls them "generative values," defined as qualities or attributes "that must be generated, grown, cultivated, nurtured" and thus cannot be "copied, cloned, faked, replicated, counterfeited, or reproduced." He lists the following examples:

- immediacy [a copy that arrives quickly]
- personalization [a copy that can be customized]
- interpretation [instructions on how to use or understand a copy]
- authenticity [an officially sanctioned copy]
- accessibility [an instantly retrievable copy]
- embodiment [a means through which to watch, read, view, or listen to a copy]
- patronage [a copy that pays dividends to its author]
- findability [a copy that cuts through the glut of available content]

According to Kelly, these qualities add economic value to copies whose abundance has rendered them valueless.

A simple analogy helps to clarify Kelly's point: much like the Internet is characterized by a surfeit of digital copies, the Earth contains an abundance of water. Even when water is free and potable, however, it can still be privatized and sold. Why would a consumer pay for potable water if he could acquire it for free? There are many possible reasons: perhaps he prefers the taste of bottled water, prefers to drink from a bottle, or prefers water to be cold; perhaps he believes an act of terrorism might compromise the public water supply, or perhaps it is more convenient to purchase a bottle of water than it is to locate a free source. It is not simply that these generative qualities (to use Kelly's term) add value to water, but that they become water's primary source of value in the context of its ubiquity. Similarly, once digital copies are ubiquitous, generative qualities become their primary source of value.

Underlying Kelly's argument is the neo-classical economic principle that scarcity is a commodity's primary source of value. As David Harvey (2008) has argued, Marx's critique of the classical economists (i.e. their failure to consider the social dimensions of value's production) led them to abandon a labor theory of value and to postulate neo-classical marginal theories of value. Departing from classical economic theory, neo-classical economists typically attribute the economic value of commodities to some combination of utility and scarcity, returning in a sense to pre-classical physiocratic notions of value. Kelly's argument, which suggests that the economic value of commodities is a function of their scarcity, is crafted in this mold. While Kelly clearly understands how digital network technologies challenge the economic status quo, his analysis nonetheless suffers from the same flaw Marx identified in classical and pre-classical economic analyses: the obfuscation of value's social dimension. Revisiting Marx's theory of value will help to illuminate this social dimension, and, ultimately, to theorize the form of value produced when data is transmitted through the Internet.

Marx on value

In his analysis of capitalism, Marx differentiates between price and value in order to explicate value's social dimension. While he acknowledges that the price of a commodity rises and falls in relation to supply and demand, Marx reasons that these fluctuations in price do not necessarily correspond to a fluctuation in a commodity's value. In other words, the price of a commodity does not reflect or represent its value unless supply and demand are at equilibrium. Instead, the value of a commodity reflects the amount of socially-necessary labor-time crystallized in it through the labor process.[16] This is not to say that the value of a commodity cannot fluctuate as does its price. Despite Marx's description of value as crystallized labor-time (which might lead one to think of value as a physical, immutable quality), labor-time is always accompanied by the modifier "socially necessary" in Marx's analysis and is thus vulnerable to any transformation (such as technological innovation) which alters average rates of production. In other words, fluctuations of value are a product of the social conditions under which any given commodity is produced, not the abundance or scarcity of that commodity. From this perspective, the devaluation of over-abundant digital copies might be understood as a function of how little human labor is required to reproduce data; digital copies have lost all value because their reproduction requires almost no human labor.

The importance of the concepts of socialized human labor and labor-time in Marx's analysis of capitalism is difficult to overstate. They subtend his analysis of the

[16] Marx defines socially-necessary labor time as "the labour-time required to produce any use-value under the conditions of production normal for any given society and with the average degree of skill and intensity of labor prevalent in that society."

production of surplus-value—a feat that eluded other classical economists—and, through this analysis, his theorization of the exploitation of labor. Marx is harshly critical of accounts that look elsewhere to explain the production of value, especially those that look to machinery. In Marx's analysis, machinery does not and cannot produce value. As cultural critic Richard Dienst argues, machinery assumes two roles in Marx's texts: it transfers value crystallized in it (through human labor) "incrementally back into the products it helps to make, until it has no more value to dispense" and it "exerts a social force on the labor process that cannot simply be quantified" (1994: 47). So while Kelly suggests that technology is the means through which scarcity/value are produced, eradicated (through ubiquity), and found anew (through generative qualities), from a Marxist perspective technological advances affect the production of value only insofar as they alter social conditions of human labor.

At the heart of these diverging accounts is the question of what produces value: is it labor, scarcity, or something else? Before I can offer an answer to this question, there is another, more fundamental question that needs to be addressed: the question of what can have value. After all, if something cannot have value, what sense is there in questioning where its value comes from? In other words, before we can ask where data's value come from, we must ask whether it is possible for data to have value, and if so, how this value manifests. In the section that follows, I will argue that data exhibits a fundamentally different materiality than those things (i.e. commodities) that we typically think of as vessels of value, drawing into question data's ability to contain, crystallize, or otherwise yield value.

The materiality of data

David Harvey (1989: 1) notes that Marx struggled for many years in his preparatory writings for *Capital* to identify the best starting point for his argument. Marx could have started his analysis of capitalism with an interrogation of labor or money, but he chose instead to dissect the commodity form. Harvey writes that Marx chose to begin with the commodity form because of its "common denominator" appeal, i.e. its centrality to everyday life and to the inner-workings of capitalism. For these same reasons, I will ground my reexamination of value in the context of digital network technologies in an interrogation of the materiality of data. As the commodity is materially and economically central to industrial production, so too is data to what we might call digital network production.

In certain ways, data is materially similar to the commodity form. Like commodities, digital files are solid and singular objects: "zeroes and ones" inscribed into media such as the magnetic tape of a hard drive or the electromagnetic frequencies that carry data wirelessly. As with commodities, data occupies physical space and can be made to move through this space. And as with the exchange of commodities, the transmission of data occurs over time, however imperceptibly small the increments of time may be. While these points may seem obvious, they are important to note as scholars interested in the social and political-economic aspects of digital networks often characterize data as immaterial. In his discussion of copyright, Lessig, for example, writes, “The law turns the intangible into property” (2004: 84). Digital network activist John Perry Barlow similarly notes, “Legal concepts of property, expression, identity, movement and context do not apply to us. They are based on matter. There is no matter here” (as quoted in Katyal 2005: 241).

These characterizations of data as immaterial misunderstand data’s peculiar materiality, for although data is solid and singular, it exhibits one other quality that distinguishes it from the commodity form: it is what we might call “self-consciously” informational.[17] While all matter is informational, scientifically speaking, data distills information from matter, prioritizing its informational substrate in order to make data’s transmission as efficient as possible.[18] Whereas a commodity can only assume a singular form, data can multiply and vary forms while preserving its informational integrity. In this way data is both single and multiple. Upon request, a single digital file inscribed into the magnetic tape of a hard drive can become two digital files, one of which remains with the duplicator while the other can be sent to a receiver in the form of electrons or radio waves or pulses of light. As with the transmission of a virus, the transmission of data collapses reproduction and distribution, allowing that which is transmitted to be both passed on and retained. And as with the transmission of a virus, the more users that

[17] It is ironic that copyright scholars often characterize information as immaterial, as the very notion of copyright implies a material understanding of information (before information is theorized as such). As Thomas Jefferson famously remarked about cultural content: “Its peculiar character, too, is that no one possesses the less, because every other possesses the whole of it. He who receives an idea from me, receives instruction himself without lessening mine; as he who lights his taper at mine, receives light without darkening me” (as quoted in Vaidhyanathan, 2004: 24).
[18] For an in-depth definition and description of information from a scientific perspective, see Chapter Six and also Terranova 2004.

download a file, the more copies of it there are, and the greater the likelihood that one of these copies can be located and downloaded.

The question still remains: do easily reproduced, non-rivalrous digital files have value and if so what form does it take? To anyone who has purchased content online, this question might seem silly. Paying to download an album of music online, for example, appears to involve the same process as purchasing an album from a retail store. In both cases, the consumer relinquishes his money in exchange for a copy of the album he wants. Does it really matter whether that album is reproduced in a factory and shipped to a retail store where it sits on a shelf until a consumer buys it or whether it is stored on a hard drive and reproduced on-demand at the moment he pays for it? Is not the latter simply a more efficient version of the former? According to this logic, if a compact disc has value, then a digital copy also has value.

While data can be made to behave as any other cultural commodity, its viral character resists this treatment at every turn. As Stewart Brand famously proclaimed at the first Hackers' Conference, "Information wants to be free." Like wood wants to be cut with the grain, data wants to replicate and to spread. In his explication of Deleuze's critique of hylomorphism, John Protevi uses Deleuze's concept of "implicit forms" to describe this quality of matter. Protevi writes, "The form must be seen as suggested by the matter rather than as the pure product of the mind of the architect" (2001: 7). This is not to say that matter cannot assume a form contrary to its inclination, as when data is made to behave as a commodity. However, such forms are clunky, provisional, difficult to establish and maintain, and require too much scaffolding. Case in point: even Apple, the most successful peddler of songs and movies online, does not collect a profit from its commodification of data (for reasons I will examine in Chapter Five). So while a digital file can have value as if it were a commodity, this value does not successfully function, systemically speaking, in the way that the value of commodities does.

To be successful, cultural economies online have to cut with the grain of data, taking advantage of its viral character. Just as exchange value is native to economies of rivalrous commodities, digital networks produce an endemic form of value rooted in data's non-rivalrous, viral character, a form of value I will theorize in subsequent chapters. Content providers must learn how to work with this form of value, or else—as may likely be the case—die trying. As I will illustrate in Chapter Five, this has not been easy. Their world has been turned upside down by peer-to-peer networks. What was their business—the sale of content in commodity form—has become their poison, for no sooner is one MP3 sold than a million copies are reproduced and distributed for free through peer-to-peer networks. Of course, cultural content has always had a viral character of sorts. Copyright was established to reign in this character, managing the spread of cultural content so that it could yield dividends for authors while encouraging productivity in the future. However, because of the extreme facility with which data can be reproduced through the Internet, digital network technologies threaten the ability of copyright to do these things—a threat that was mostly kept at bay until 1999, when Napster was released.

In light of digital network technologies' independence from the commodity form (in terms of economies of culture), one might ask: is an analysis of capital or capitalism possible in the absence of the commodity form? This is as much a conceptual challenge as it a rhetorical one, as Marx's analysis of capital is structured in such a way that makes it difficult to alter any of his concepts, let alone a central one. Jonathan Beller succinctly summarizes this problem in his description of the rhetorical structure of the *Grundrisse*. Beller writes:

> One cannot understand the commodity-form without understanding the entire process of exchange. One cannot understand exchange without understanding circulation and production. One cannot understand circulation and production without understanding wage labor and surplus labor-time. One cannot understand these without understanding the falling rate of profit and so on until one can see the grand functioning of all aspects of Marx's great mimetic model with each mutually interactive, dialectical concept spinning into and from the others, mutually defined. (1998: 80)

Of course for Marx the interlocking of these concepts is not simply a rhetorical issue (if it is a rhetorical issue at all for Marx), but is the problem of capitalism itself. In other words, Marx's concepts are inseparably interlocked because he understood capitalism itself as a totalizing system.

Given the all-encompassing character of Marx's analysis, it is difficult though not impossible to analyze capitalism from a Marxist perspective in the absence of one or more of his central concepts. As Patricia Clough has argued, it is possible to conceive of capitalism(s) (Rajan 2006) in "nonsystemic systemic terms," that is as a system which is not totalized (2000: 106). Whereas a systemic analysis of capitalism makes it nearly impossible to alter any of Marx's concepts without producing logical disarray, a nonsystemic systemic view makes possible analyses of capitalism which incorporate incongruous or even contradictory elements. From a nonsystemic systemic perspective, digital network technologies need not fit into an all-encompassing account of capitalism, such as Marx provides. In other words, we need not prioritize the commodity form in order to theorize how peer-to-peer networks and digital network technologies' transform economies of cultural production. Neither must we abandon capitalism as an organizing concept. Instead, our effort is best spent on theorizing how disparate elements come together as capitalism shifts over time, which circumstances and conditions bring these elements together, in what concatenations, why, and for how long.

The Internet in Marxist cultural criticism

The task of theorizing this shift should fall to Marxist cultural critics. Beginning with the Frankfurt School, Marxist cultural critics have long examined the relation of cultural production to value production, applying and adapting Marx's social and political-economic analysis to economies of culture. As Marxist cultural criticism has changed over the years in response to technological shifts such as the advent of television (e.g. Dienst 1994), as well as to feminist (e.g. Haraway 1991) and post-structuralist (e.g. Deleuze 1987) critiques of the human subject, it has yielded important insights into economies of cultural production, many of which remain relevant in the context of digital network technologies. Contributing to this history, several Marxist cultural critics have recently offered ways to think about how digital network technologies fit into contemporary capitalism. However, I will argue that these latest accounts struggle to make sense of digital networks' attenuation of the commodity form, often resulting in an ill-fitting idealism invested in digital networks' libratory potential.

Tiziana Terranova (2004) has argued that the Internet intensifies and mutates the economic and cultural logic of capitalism. Knowledgeable about the nitty-gritty of information theory and sensitive to its implications for social theory, Terranova is careful not to reduce the Internet to yet another machination of capital against labor. Nevertheless, her argument remains grounded in an affirmation of the commodity form, as when she writes (in response to the postmodern intuition that commodities on the Internet are immaterial and over-abundant), "The commodity does not disappear as such; it rather becomes increasingly ephemeral, its duration becomes compressed, it becomes more of a process than a finished product" (90). Ultimately, this leads her to conclude that human labor—in this case the labor of designers and programmers—is the source of value produced through the Internet (a position I will later critique).

Nick Dyer-Witheford has gone slightly further than Terranova in questioning how "informational goods" resist a commodity form. Writing before the advent of peer-to-peer networks, Dyer-Witheford presciently imagined their impact:

> Information society theorists have long pointed out that "ethereal goods" have qualities anomalous in a market economy: they can be used simultaneously by many people, be duplicated and transmitted cheaply and instantaneously, are not "consumed" or exhausted by use and may grow in use-value the more widely they are shared. These features have become increasingly problematic to those concerned with policing digital commodity transactions. For what has emerged in cyberspace are collectivities of users who, rather than being subordinated to the laws of commodification, are rather characterized by a persistent, indeed often gleefully overt, transgression of these rules. (1999: 440)

Reflecting on the possible implications of information's anomalous economic qualities, Dyer-Witheford theorizes two potential outcomes: either "a radical intensification of commodification" as through pay-per-view content, or "a fundamental attenuation of the commodity form" as through digital piracy (442). Such an attenuation, Dyer-Witheford muses, might result in the formation of a communications commons. Unlike the information commons advocated for by copyright scholars, which aims, in part, to support healthy economic markets, Dyer-Witheford imagines that a communications commons might help to produce an alternative to capitalism:

> A diverse communication commons provides the matrix for … cultural experimentation, while the free time made available by the reduction of work creates the condition for the widespread involvement in cultural production necessary to give the new networks vivacity. Moreover, the establishment of such a commons creates unprecedented opportunities for co-operative organization—not least in the sphere of social governance. (446)

In linking digital networks' attenuation of the commodity form with resistance to capitalism, Dyer-Witheford underestimates capitalism's ability to transform the challenge of commodity attenuation into an occasion for economic investment and development.

Like Dyer-Witheford, Michel Bauwens (2005) has high hopes for an information commons. Bauwens argues that peer-to-peer networks produce a new form of property, what he calls universal common property, that will be the foundation of this commons. Like Dyer-Witheford, Bauwens imagines that an information commons could help to produce what he describes as an "alternative to neo-liberal dominance":

> People would have more time to think about and participate in decisions about organizing life in association with others; where they would have access to a very wide variety of communication channels, with a very wide diversity of representations and images about different possibilities of being; where these channels served also as routes for a flow of participatory decision making about the production and distribution of goods—and also about the directions taken and not taken in technological development.

For these reasons, Bauwens concludes that the peer-to-peer movement "is fast becoming the equivalent of the socialist movement in the industrial age. It stands as a permanent alternative to the status quo, and the expression of the growth of a new social force: the knowledge workers." Like Dyer-Witheford, Bauwens thus misunderstands the political-economic ramifications of the "universal common property" produced through peer-to-peer networks.

The problem with these analyses is not that they fail to understand the Internet as a machine (as Patricia Clough has argued of critics of television), so much as they cannot account for what this machine does, what it produces. Whatever the reason for this flaw—intellectual force of habit, a desire for alternatives to capitalism—I do not think that Marxist cultural criticism is unsuited to the task of theorizing the transformation of cultural economies catalyzed by peer-to-peer networks. Rather, as I will argue in the following chapter, the task of theorizing this transformation can be well-served by picking up where Marxist cultural criticism of television left off.

Conclusion

To better understand how peer-to-peer networks catalyze a transformation of economies of culture, I have examined in this chapter the economic potential latent in digital network technologies—the potential actualized by peer-to-peer networks. This potential is rooted in data's non-rivalrous materiality, which exhibits what I have described as a viral character due to the facility with which it is reproduced and distributed. Unlike commodities, whose rivalrous character makes them well-suited for economic exchange, data's viral character makes it a poor fit for exchange. Accordingly, data yields a different form of value than exchange-value—a form I will theorize in subsequent chapters.

Having determined that data, like the commodity form, does indeed yield value, I will also return to consider the question of value's origin. In this chapter I referenced two opposing accounts of value's origin: Kelly's implicit account, which attributes value to commodities' scarcity, and Marx's explicit account, which attributes value to socialized human labor. Taken together, these accounts seem to suggest that one cannot have it both ways: either one accepts a labor theory of value and is confined to examining industrial conditions of production or one abandons this theory in order to make sense of what we might call digital conditions of production. In the chapter that follows I will begin to offer a resolution between these positions.

While digital networks produce an endemic form of value, it is not actualized until peer-to-peer networks circumvent the legal and technical obstacles that previously prevented the massive reproduction and distribution of copyrighted content online. In this way, the form of piracy condemned by legal scholars—the form that opts out of buying culture altogether—has also been the most economically innovative, transforming how cultural content yields value. In light of this transformation of economies of culture, any adverse economic effects peer-to-peer networks may have had on markets for cultural content are simply the growing pains of an industry in crisis. Put simply, just because peer-to-peer network are perceived to be bad for business, does not mean they undermine capitalism. We should pause before concluding, as some cultural critics have, that because peer-to-peer networks can be used to avoid paying for cultural content, they are resistant or oppositional to capitalism. Peer-to-peer networks do not resist the economic status quo, so much as they are helping to produce a new status quo.

Chapter Four: An Attention Theory of Value

In the previous chapter, I examined several notable attempts by Marxist cultural critics to theorize the political economy of the Internet. Before Marxist cultural critics wrote about the Internet, however, they wrote extensively about television. Given critics' high level of interest in television, it is interesting that the Internet has gone relatively unexamined. There are several possible explanations for critics' disinterest. Perhaps television was in the right academic place at the right time. When the Left questioned why social unrest had been fleeting or unsuccessful, television offered an explanation: ideological interpellation. Resistance, in turn, could be located in alternative readings of the dominant discourse reproduced through television. Or perhaps the Internet is simply assumed to operate like television, rendering additional academic attention unnecessary. Or, recalling Patricia Clough's argument that Marxist cultural critics did not easily address television as a machine, perhaps the Internet is too much a machine for Marxist cultural criticism, or maybe it is the wrong kind of machine.

Whatever the reason, there remains much to learn about the political economy of the Internet from what Marxist cultural critics have had to say about television, though this body of work has been largely overlooked by scholars of the Internet. In particular, I will focus, as Clough does in *Autoaffection*, on work by Richard Dienst and Jonathan Beller.[19] These scholars' work is instructive not simply because it offers a model of how to reconcile the contradictions that arise when one brings a Marxist perspective to bear on

---

[19] While the essay of Beller's I will use is about cinema, his argument about the value of attention is equally if not more applicable to television.

contemporary culture, but because of its insight into how television produces value—insight that helps to make sense of economies of culture online. Amending Marx's theory of value, Dienst and Beller argue that purposeful labor is not the only source of economic value; watching television can produce value, even in its passivity. Following Dienst and Beller, I will argue that the Internet produces value in a similar way in its capacity as a technology of production.

From television to the Internet

Beginning with the Frankfurt School, Marxist cultural critics have looked to technology to make sense of capitalism's persistence despite the impoverished working and living conditions of large segments of the global population. Over the years this critique of technology has sedimented, prompting scholars interested in resistance and opposition to capitalism to search elsewhere. For example, scholars like Stuart Hall and Frederic Jameson looked instead to the quintessentially human processes of meaning-making and interpretation in order to locate pockets of resistance, allowing them to circumvent questions of technology altogether.

This is not to say that technology is absent from contemporary Marxist cultural criticism. As Clough argues, in the 1970s critics were intrigued enough by television to once again address questions of technology (2000: 70). They did this, Clough argues, because television made the technical character of media and mediation difficult to continue to ignore; the televisual apparatus required Marxist cultural critics to supplement meaning- and interpretation-centered approaches with an examination of the machine itself. Would critics simply return to the technophobia of earlier eras? Clough argues that previous critiques of technology had lost some of their explanatory power, since television—unlike earlier technologies—does not aim to reach subjects (for example, through Althusserian ideological interpellation) as much as it undermines subject formation. As Clough writes, "In pointing to the transnationalization of capital and the globalization of teletechnology in the late twentieth century, television will trouble Marxist criticism and its treatment of the economic in terms of the subject-centered, nation-centric discourse of the ideological apparatus." Criticism could still exhibit an aversion to technology, of course, but not in the same way as it had in the past.

What does television produce, then, if not ideological fodder for the masses? To answer this question, Clough draws from the work of Richard Dienst who argues that television socializes viewing time through an economy of images, bringing viewing time into relations of exchange (2000: 97). Dienst's argument departs from previous paradigms of Marxist cultural analysis, which had been satisfied to examine television's content, its programming and commercials. Importantly, Dienst is more concerned with the act of watching television than he is with its content. In his analysis, images are conceptualized as units of value, independent of their content. As Clough notes:

> Dienst imagines the watching viewer as a worker at work, the work of watching. It is not, therefore, in reading images and then consuming advertised commodities that the viewer produces surplus value. The viewer produces surplus value when he or she watches, that is, when a unit of viewing time and television image, having already been capitalized, is used up. (2000: 98)

In other words, while watching television may feel to viewers like leisure, in fact television viewers are at work, "the work of watching."

To make this argument, Dienst cites a passage from *Capital* in which Marx proposes that capitalism places workers under social conditions that allow capitalists to harness and exploit their productive power, creating the illusion that capital is productive when in fact it is labor that is productive. Similarly, Dienst argues, television makes labor of our free time, the time we spend watching television. Television socially collects our free time, as capital collects workers' labor time, establishing conditions which allow television networks to harness the socially productive power of our free time, even while it appears as if television itself (not audiences' viewing power) is the source of this productivity. Aiding this illusion, television audiences relinquish their free time willingly, seemingly unaware of the productive power of their viewing. As Dienst writes in a footnote, "Hence the peculiar property of watching television is that time enters into a cycle of value without being treated as a commodity by those who spend it" (179).

In a similar vein, Jonathan Beller has argued that our capacity to view images has become a kind of labor power. While Beller focuses on cinema as opposed to television, the two theses he proposes are well suited to the televisual. He writes:

> (1) cinematic movement is an extension of capital circulation: the cinematic image develops out of the commodity-form; and
>
> (2) cinema becomes directly involved in the process of social production and reproduction by occupying human time and converting visual attention to

> labor-power—in short, the labor theory of value is a special case of what I call *the theory of the productive value of human attention*." (his italics, 1998: 77)

In Beller's analysis, it is attention in its general form that produces value, not simply the attention that accompanies willful labor. Value can be produced outside of contexts of work narrowly conceived. As Beller argues, "Technologies such as cinema and television are machines that take the assembly line out of the space of the factory and put it into the home and the theater and the brain itself, mining the body of the productive value of its time, occupying it on location" (92).

As I have noted, in order to explain how the passive labor of watching produces value, Dienst (and Beller) lean heavily upon Marx's labor theory of value. This debt to Marx is discussed in more detail in Dienst's analysis, which affirms Marx's conceptualization of value as a measure of socialized time, even if not labor time as Marx thought of it. According to this argument, capitalism socializes our time, whether it is the time spent laboring in a factory or the time spent watching television, and in so doing, establishes a common measure of value which can serve as the basis for exchange. This common measure, in turn, facilitates capitalism's extension into the most remote corners of life, such that leisure activities can produce value. As in Marx's explication of socialized labor time, the socialized time of watching cinema and television is real time, the time of human experience. This retention of the human cements a strong connection with Marx's labor theory of value.

With Dienst's and Beller's amendment to Marx's labor theory of value in mind, we might ask: how does an apparently free medium such as television extract value from its viewers? In his analysis of television scholarship, Dienst notes that scholars of television typically turn to advertising in order to explain the cost exacted from television audiences. Citing Nick Browne's essay on the political economy of television, Dienst writes, "Advertising images—because they participate directly in the production of consumption—are assumed to function one way, having direct and statistically available results, and all the other images are there to keep up the flow and to prop up the attention of viewers, vaguely reinforcing the sales pitch" (1994: 30). Put another way, television is thought to produce value by increasing commodity consumption through its advertisements.

Dienst takes issue with this argument in two ways: first, he questions that idea that "lines of cause [advertising] and effect [consumption] can be traced from one order to another," and second, in a Marxian move, he argues that causal analyses of advertising treat television as if it were subjective, episodic—a transaction between economic agents, rather than a system. While Dienst recognizes that advertising often pays for television programming, and that clients who hire advertisers believe that advertisements help to increase or at least maintain their business, he argues that television does not require advertising to sustain itself. Rather, advertising cashes in on time already socialized by television; advertising realizes television's investment in viewing time.

Audiences pay for television with their time, though they rarely experience the time they relinquish as valuable. Might the Internet work according to a similar economic logic? To answer this question we first have to consider the ways the Internet differs from television. Even if one accepts Dienst's critique of cause-and-effect accounts of television advertising, it is possible that a cause-and-effect explanation might be more elucidating for the Internet, given the differences between television advertising and Internet advertising. While it may be difficult to prove a causal connection (on a systemic level) between television advertisements and the consumption of the commodities advertised, perhaps such a link is easier to substantiate with the Internet, given the ways Internet advertisers have used the interactive nature of the Internet to their advantage.

For advertisers, the interactive nature of the Internet offers three primary advantages. First, Web ads solicit users' engagement. They invite users to play video clips, toggle sound on and off, make screens larger or smaller, play games, and follow links. Even when they simply force users to close irksome pop-up windows, Web ads command users' attention. Second, users interact with Web ads, but Web ads also interact with users. For example, Amazon.com (currently the largest online retailer in the world) informs users of products they may be interested in based on previous purchases. These recommendations are formulated in two ways: either through an algorithm which analyzes the products purchased by other users with similar consumption patterns ("Customers Who Bought This Item Also Bought"), or through user-generated lists of products that are likely to appeal to a consumer who has purchased or is interested in purchasing a certain product ("Top 20 Cat Care Books"). While television advertisements target demographics, Web advertisements—if we take the term "advertisement" broadly—can target an audience as small as one user. Third, Web ads can more effectively procure and document consumer follow-through. The Internet makes it possible for advertisers to walk users from advertisement to purchase, for example through a “click to buy” option. Increasingly, users employ the same technology to find out about new products as they do to purchase them. In this way, the Internet narrows the gap between each valuable second of users’ attention and a return on advertisers’ investment in viewing time.

This last point especially seems to challenge Dienst’s critique. If cause (advertisement) can be linked unquestionably to effect (consumption), then advertising becomes less of a guessing game and more of an empirical project of engineering. Transformed in this way, one would expect advertising on the Web to be more effective and for its efficacy to be easier to prove, drawing advertisers and their clients in droves to the Internet. At this point in time, however, this does not appear to be the case. In fact, even some of the most popular Internet sites have struggled to forge successful advertising-based business models. Consider, for example, the online video delivery service YouTube—one of the most popular content providers to emerge following the success of peer-to-peer networks. Launched in November of 2005, YouTube invites users to post their own video content and to view content posted by other users. In August of 2008, the New York Times reported that 13 hours of video are uploaded to YouTube every minute (Stelter). Another source reported that YouTube use accounted for approximately 10 percent of global Internet traffic in 1998 (Pehnelt 2008). Before it was acquired by Google in November of 2006, YouTube disclosed that its business model is based in advertising, which at the time brought in approximately 15 million dollars a month. Despite this revenue, the New York Times reported in February of 2009 that YouTube struggled to cash in on its impressively large audience—more than 100 million unique viewers in January of 2009 according to the online research group comScore (2009; Helft).

The difficulty with which a site as popular as YouTube supports itself through advertising should give us pause. Even if the Internet promises a changed, better game for advertisers, it remains unclear how these changes will affect content providers. Why has it been so difficult for a site like YouTube to prosper through advertising? Part of the difficulty undoubtedly lies in the relative newness of Internet advertising. Still in its infancy, Internet advertising is going through a period of adjustment as advertisers, their clients, and content providers experiment with and negotiate models to meet the financial needs of all parties involved. This is as much an economic issue as it as a technical issue. As business scholar Jeffrey Rayport notes:

> There were a variety of difficulties in implementing the advertising-driven model. For example, determining appropriate C.P.M. [cost per thousand page impressions] rates for Internet advertising (segmented according to banners, buttons and interstitials); measuring traffic with integrity (which included defining to everyone's satisfaction the meaning of hits, page views and unique users), and ultimately estimating the efficacy of such messaging (whether impressions or click-throughs). (1999)

Furthermore, Internet audiences appear to be more fickle than television audiences. They are less willing than television audiences to sit through several minutes of commercials, and fewer minutes of commercials means fewer advertising dollars for content providers (Robertson 2007). For all of these reasons, the Internet has not yet proved to be the “killer application” many advertisers thought it would be.

Because of the relative newness of Internet advertising, it is not yet possible to determine whether it will become the empirical engineering project I have intimated it might. The above difficulties suggest that there still remains a degree of indeterminacy with regards to connecting cause (advertisement) to effect (consumption). In light of these difficulties, we might conclude that Dienst's critique still stands; if television does not require advertising, neither—it seems—does the Internet. Like television advertisers, Internet advertisers simply cash in on time already socialized by the apparatus. However, there is an additional factor I have not yet considered, which has made it difficult for sites like YouTube to prosper financially. Regardless of whether the Internet eventually becomes advertising's "killer app," content providers' ability to harvest the value of users' attention is undercut by their operating costs, and in particular the cost of bandwidth. In the next chapter I will argue that the cost of bandwidth not only eats away at content providers' profits, but siphons these profits to Internet Service Providers (ISPs). More than this, though, the consumption of bandwidth has become central to another, different form of value produced through the Internet, a form of value that competes with the value produced through human attention: the value of transmitting data.

Conclusion

Defined broadly, capital is value that expands, as captured in Marx's M-C-M' formula. In order to make sense of this expansion of value, Marx distinguishes between labor-power and labor (1967: 167). This distinction is central to Marx's critique of capitalism, as it makes it possible for him to argue that laborers are exploited; since laborers are paid for their labor-power and not their actual labor, they can be tricked into relinquishing the surplus value of their labor. For Marx, exploited labor is thus the backbone of capital.

Dienst and Beller remain largely faithful to Marx's labor theory of value, amending it to include the sort of passive labor that watching television or cinema entails. Even in its passivity, this labor too produces value, they argue, value that can be made to expand. Looking to the human elements of television to account for the value produced through television, Dienst and Beller can also partake to a certain extent in the politics that this perspective affords, the politics of exploited labor. For just as factory laborers can be exploited, in Marx's sense of the term, so too can television audiences. Furthermore, viewers give up their value-rich viewing power willingly, seemingly unaware of this exploitation.

Insofar as Internet content is attended to in the same way as viewers attend to television or cinema, Dienst's and Beller's argument helps us to understand how the Internet produces value. However, as I will argue in the next chapter, the material and economic organization of the Internet is different from that of television. Because of this difference, the Internet introduces a new dynamic not present with television: the valuation of transmission. In order to make sense of this new dynamic, I will continue to draw from Marx's labor theory of value, though with some critical differences. In particular, I will propose that the strength of Marx's theory of value lies in its focus on the socialization of time, while I will draw into question the notion that only the time of human experience can be socialized.

Chapter Five: A Transmission Theory of Value

Information wants to be free. (Stewart Brand)

From piracy to profit

Despite the closing of Napster in July 2001, file-sharing was more popular than ever. The peer-to-peer networks that became popular in the wake of Napster were acquiring more users, and peer-to-peer traffic was consuming more Internet bandwidth. Free of the financial constraints that typically prevent consumers from purchasing CDs indiscriminately, users' libraries of digital audio files expanded exponentially. As users' libraries grew, so too did their desire for a portable device like the Walkman or Discman that would allow them to listen to their MP3s on the go. Furthermore, the idea of a portable digital audio player promised new and desirable features to consumers, most notably the capacity to store hundreds and even thousands of songs; no more bulky, cumbersome CD libraries, no more changing of discs or cassettes.

In October of 2001, Apple launched a new product, the iPod, which would allow its users to do these things. To be certain, the iPod was not the first portable digital audio player on the market, but for a number of reasons—its relatively small size, large storage capacity, intuitive user interface, freedom from copyright-restricting software, and stylish appearance—it quickly dominated and then expanded the market for these devices. As iPods grew increasingly popular, the tension between Apple and the music industry also grew. To the music industry, the synergy between the iPod and digital piracy was undeniable: if the iPod responded to a consumer desire for a portable digital audio platform, it quickly seemed to feedback to a desire for more digital audio files. How could one possibly expect to fill an iPod that could hold 10,000 songs without downloading at least a few through peer-to-peer networks? In the early days of the iPod, Apple responded to this implicit incentive to pirate by shipping iPods in a transparent plastic sleeve inscribed with the words “Do not steal music” in four languages.

As I have noted, while the iPod was the first popular portable MP3 player, it was not the first portable MP3 player to exist. The music industry’s hostility towards the iPod was preceded by its hostility towards the Rio, an ancestor of the iPod made by Diamond Multimedia. In October of 1998, the Recording Industry Association of America (RIAA) tried to prevent the Rio from being sold, arguing in court that the device violated the 1992 Audio Home Recording Act. In particular, the RIAA argued that the Rio was not simply a playback device but a recording device, and that as a recording device, the Rio did not adequately inhibit the unauthorized duplication of copyrighted material. This lawsuit was the first of a number of legal actions engineered by the RIAA to either eliminate the market for portable digital audio devices or else force device manufacturers to incorporate copyright protection measures.[20]

Considering content providers’ longstanding hostility towards digital methods of reproduction and distribution, it came as a surprise when in April of 2003, Apple announced that it had struck an agreement with some of the largest commercial record

[20] Further examples include the Inducing Infringement Act and the RIAA’s 2/2006 filing in response to the Digital Millennium Copyright Act.

labels and would soon launch a new service, the iTunes Music Store (iTMS) that would sell digital audio files. Despite several notable previous attempts at selling digital music files online, iTMS was “the first real success story,” as the New York Times wrote following the launch of the service (Strauss 2003). At 99 cents a song (and no subscription fee), three million songs were sold through iTMS in its first month. Five years later, Apple announced that more than five billion songs had been sold through iTMS.

Striking an agreement with the music industry was not easy for Apple, as they clashed over issues of pricing and security. Tellingly, Apple insisted on a relatively low price point, as its underlying strategy was not to make money from selling songs, but rather from selling iPods. In other words, Apple believed that the more songs it sold, the more people that would buy an iPod. As Apple Senior Vice President Phil Schiller put it bluntly, “The iPod makes money. The iTunes Music Store doesn't” (Fried 2003). Content providers, on the other hand, wanted not only a higher price point—their business was in selling music, not iPods—but a number of Digital Rights Management (DRM) restrictions that would prevent users from reproducing files indiscriminately. Apple opposed such restrictions, which it claimed would drive users to download songs for free through peer-to-peer networks rather than purchase them through iTMS.

While Apple does not publicly discuss the composition of its revenue, it has long held that most of the 29 cents it makes per song (Grover and Burrows 2007) goes to the physical operation of iTMS—i.e. to Internet bandwidth and infrastructure maintenance—leaving around 10 cents in profit according to PriceWaterhouseCoopers, suggesting that it is not possible to sell digital content as if it were a commodity and still earn enough profit to remain economically viable. The numbers simply do not work out; the price of content needs to be high enough to cover expenses, but low enough to prevent users from flocking to peer-to-peer networks. Of course content providers can sell data in order to sell other things, like profitable portable digital audio players, as Apple does (Leonard 2008). Consider, for example, the iPod Shuffle (3rd generation) launched in early 2009. Business Week reported that for each $79 unit, Apple pays approximately $21.77 for components, earning a 72% profit on the device (not counting the costs of labor) (Hesseldahl 2009). Furthermore, Apple sells a lot of these devices. In April of 2007, Apple announced that it had sold more than 100 million iPods. Two years after the 100 millionth iPod was sold, the New York Times reported that President Obama gave one as a gift to Queen Elizabeth (Cooper 2009).

Apple's business model is not set in stone. To remain profitable in constantly shifting social, economic, and technological circumstances, Apple is required to be flexible. For example, in January of 2009, Apple reached a new agreement with record labels. The labels had long fought for a variable pricing scheme, in which popular music would cost slightly more, say $1.29, while less popular music would cost slight less, say $.69. This pricing scheme had already been put into place by newer online music vendors such as Amazon and Wal-Mart. Apple finally agreed to variable pricing in exchange for the removal of DRM restrictions; a song purchased through iTunes can now be used or copied in any way its user sees fit. These negotiations are one example of how competing interests (record labels, retail vendors, device manufacturers, etc.) experiment with a number of variables—song and album pricing, subscription fees, DRM restrictions, the inclusion of advertising—to craft a business model that satisfies all the players involved.

Following the success of its music store, in October of 2005 Apple announced that iTMS would also begin to sell music videos, short films, and television shows in addition to songs. To be certain, Hollywood, like the music industry, was not an easy partner to negotiate with. As the record industry pushed for increased DRM restrictions, so too did the movie and television studios. As the record industry pushed for higher priced content, so too did the studios. Initially the iTunes Store (no longer iTMS but iTS) offered approximately 2,000 music videos, 6 short films, and episodes from a handful of television shows. "We're doing for video what we've done for music," Apple CEO Steve Jobs commented. "We're making it easy and affordable to purchase and download, play on your computer, and take with you on your iPod" (Apple 2005). By June of 2008, iTS offered approximately 20,000 television episodes and 2,000 movies, some of them in high definition. Furthermore, customers could also rent movies (the terms of which were another source of tension between Apple and the studios). Between movie sales and rentals, Apple customers consumed approximately 50,000 movies a day by June of 2008. Alongside its expanding catalog of content and menu of services, Apple also developed additional hardware and software to allow consumers to stream purchased content to their television screens (Apple TV) and home stereos (AirPort), presumably in order to continue to cash in on its investment in selling content.

In addition to selling songs, television shows, and movies through iTS, in 2008 Apple went one step further and began selling applications for its proprietary smartphone, the iPhone. In April of that year, Apple released a free software development kit which would allow independent programmers (whether individuals or corporations like AOL and eBay) to design applications for the iPhone. Three months later Apple announced that this development kit had been downloaded more than 250,000 times (2008b). Apple allowed programmers to set their own price (including free) for the applications they developed, with the agreement that programmers would be paid 70% of the revenue earned from the sale of their applications. In September of 2008, Apple announced that from its catalog of approximately 3,000 applications (most priced under $10 and more than 600 available for free), its customers had downloaded more than 100 million applications (2008a).

The overwhelming success of Apple's iTS would appear to invalidate my previous claim that data resists commodification at every turn as a function of what I referred to as its "viral character." Don't the billions of songs, movies, television shows, and applications sold through iTS suggest that data can be commodified with great success? Again, it is important to remember that Apple does not substantially profit from selling this content, but rather through selling devices, suggesting that in commodity form data fails to provide a return on its investment except in its capacity to promote other, more profitable sales. Furthermore, I argued that while data *can* be commodified, its viral character makes its reproduction difficult to control, catalyzing a form of value endemic to the Internet. Even so, it is striking that when given a choice between downloading music for free through a peer-to-peer network or paying for it, many users choose to pay. Perhaps Lessig was right. Perhaps the market opportunity exposed through peer-to-peer networks has finally been realized. Perhaps, as Lessig predicted, our desire for convenience has finally surpassed our desire for free content, and, as Kelly predicted, generative qualities have become valuable.

Even in the history of iTS sketched above, it is not difficult to identify examples of what Kelly refers to as generative qualities. iTS is seamlessly integrated into iTunes, Apple's proprietary software for organizing users' content libraries, including the libraries on their iPods, making it easy for users to locate and purchase desired content. The iTS catalog is impressively large. iTS began with approximately 200,000 songs in 2003, and grew to include over eight million songs by 2008, representing approximately an 85% share of the digital music market (Leonard 2008). The content offered through iTS is of guaranteed quality: no low quality files, no fake files, no interrupted downloads. For users concerned about getting sued by litigious content providers, the legality of iTS is attractive. And last but not least, the content sold through iTS is relatively restriction-free and reasonably priced.

Kelly (2009) has also offered another theory as to why users pay for thing they might otherwise acquire for free: they *want* to pay. As long as prices seem fair, Kelly reasons, people will gladly pay. He proposes that payment serves a number of important social and psychological functions for consumers: it is a sign of approval, a vote, an indication of allegiance with producers, and a way to feel supportive of and connected to them. The dynamic Kelly describes is reminiscent of what is often termed conspicuous consumption, though we might think of it more accurately as conspicuous exchange. If conspicuous consumption describes the act of ascribing social meaning to the public display or use of commodities, we might think of conspicuous exchange as the meaning we give to the act of purchasing of a commodity, preceding its use.

Despite its common-sense appeal, Kelly's argument seems to be unaware of those consumers for whom acts of exchange do not promise the laundry list of positive social and psychological side-effects he enumerates. Certainly not everyone parts with her wage on such easy terms, not to mention the social obstacles that prevent consumers from feeling connected to producers. There is a deeper flaw in his argument, though, which is that it characterizes payment as a choice made by the consumer, rather than as a systemic requirement for the production and circulation of value under capitalism. Whatever our reasons for paying, whether choice or obligation, capitalism, on a systemic level, requires us to pay. While not uninteresting, the question "why do we pay?" is misguided. Rather than searching for reasons users pay for things that they might otherwise acquire for free, it is more relevant to ask "what do users pay for?" To be clear, I do not mean "what do users want?"—what Marx referred to as use values (long before Kelly's "generative values")—but rather "what is the thing of value for which users exchange their money?"

The answer, I will argue, is not simply content, but bandwidth, defined as the capacity of a channel of communication to transmit data—its capacity to do the work of transmission. Like the factory worker has labor power, or the television audience has viewing power, I will conceptualize the Internet as having transmission power. Like labor power or viewing power, transmission power is commodified and can be bought and sold. Like labor power or viewing power, the value of transmission power is equal to the cost of its reproduction. Finally, like labor power or viewing power, transmission power can produce more value than it costs to reproduce. Put simply, I will propose a transmission theory of value. I will articulate this theory as an amendment to or expansion of Marx's labor theory of value, in a similar vein to the contributions of Dienst and Beller discussed in the previous chapter. As I have noted, Marx argues that value is human in origin. Dienst and Beller affirm the centrality of the human in their amendments to Marx's theory of value. Drawing inspiration from Patricia Clough's argument that the non-human is central to the political economy of television, I will depart from Marx, Dienst, and Beller, arguing that the value produced through the consumption of bandwidth is not specifically human in origin. While this might seem like a critique or refutation of Marx's theory of value, it is not. On one hand, I see the labor theory of value as applicable to the industrial mode of production Marx examined, while a transmission theory of value applies to what I have called the digital network mode of production. These two modes, I think, co-exist under capitalism. On the other hand, I will argue that the key concept of Marx's theory of value, the concept that distinguishes it from other theories of value, is the central role it gives to the socialization of time. While for Marx this socialized time was by definition human time, I will argue that the non-human time of the transmission of data is also socialized.

In the previous chapter I reviewed Dienst's and Beller's argument that viewers pay for television with their time, i.e. real time or human time. With the Internet too, I argued, users pay with their time, if not with several notable differences. However, Internet use does not fully occupy real time. That is to say, while videos and images are viewed on the Internet (as on television) in real time, audio is heard on the Internet (as on television) in real time, and text is read on the Internet (as on television) in real time, there is another domain of time—what I will call transmission-time—which need not be experienced moment-to-moment, if indeed it is a time of human experience at all. Despite its independence from real time, this new mode of time has been socialized, that is to say brought into a social context in which its average productivity can be calculated, allowing it to serve as a measure of value in the context of digital networks, much like socialized labor time does for industrial production.

This raises a new question: why does the Internet and not television socialize transmission time? Both the electromagnetic waves which carry television signals and the Internet bandwidth which carries data are limited-capacity channels of communication. Like pipelines that can only hold so much water, these channels can only accommodate the transmission of so much information at any given time. However, because of the way television is organized, with access to transmission restricted by a system of licensing, television gives rise to a different economy than does the Internet. Unlike television signals, which are not depleted with use (5,000 viewers do not "use up" more television than five viewers) the transmission of data through the Internet depletes its channel capacity (i.e. bandwidth); 5,000 users likely use up much more bandwidth than five users do. While the producers of television content and the broadcasters of television content have the same economic interest—to attract as big an audience as possible—Internet Service Providers (ISPs) want to keep usage down insofar as Internet users do not (yet) pay for increased use. As a result, the Internet is economically organized in such a way that the interests of content producers and the interests of ISPs are opposed. The business of providing content through the Internet is therefore fraught with a deep underlying conflict that does not exist in television, a conflict between attention and transmission.

The costs of transmission

Whether or not the business of online content providers is undermined by the reproduction and distribution of copyrighted content through peer-to-peer networks as industry organizations like the RIAA have claimed, there is another reason that profitability remains elusive to even the most successful online content providers: Internet bandwidth is expensive. As a report referenced in the Globe and Mail (Canada) determined, “Bandwidth costs associated with broadcasting over the Web, particularly in high-definition formats, remain considerably higher than the mass distribution offered by cable and satellite TV” (Robertson 2006). Though the cost of bandwidth drops each year, it remains too expensive for many content providers to turn a profit, whether through selling hits to advertisers, as YouTube does, or through selling content to users, as iTS does. Furthermore, many of the users who consume the costly bandwidth of free content providers like YouTube do not earn incomes high enough to interest major advertisers. Of the 1.6. billion people in the world with Internet access, more than half fall into this category (Stone and Helft 2009). In order to reduce their bandwidth bills, companies like YouTube and MySpace—a social networking site with 130 million members, approximately 45 percent of whom do not reside in the U.S.—have experimented with reducing the graphic resolution of their sites and disabling secondary functionalities in certain countries and at certain times. MySpace, for example, is currently testing out such measures in India, where it has approximately 760,000 users, few of whom are presumably of interest to major advertisers.

Such measures reveal a crucial difference between the economics of television transmission and the economics of data transmission. Unlike Internet bandwidth, which is costly, the bandwidth that carries television signals is relatively inexpensive, especially when television is transmitted aerially. For one, cable costs more than air. As economist Bruce M. Owen (1999) notes, the airwaves became the dominant method of transmitting and receiving television signals even though cable is a technically superior medium, because the electromagnetic spectrum is, in a sense, its own infrastructure. Of course transmitting television signals is not free: it requires the establishment and maintenance of a certain amount of infrastructure. However, these costs do not constitute a significant portion of television's operating costs, even for cable and satellite television, as noted above. Rather, television's primary costs are programming—i.e. producing content—and, crucially, the license to broadcast content over specific frequencies of the electromagnetic spectrum.

The system of issuing licenses to television broadcasters has its roots in the federal government's regulation of radio. When it first became possible to broadcast sound over the electromagnetic spectrum in the early 20th century, no license was required to broadcast; anybody with the proper equipment could broadcast at any frequency. As broadcasting grew in popularity, however, the government was called upon to regulate the airwaves to prevent different broadcasters from using the same frequency at the same time. The Radio Act of 1912 resolved this problem by requiring radio broadcasters to be licensed, making it possible to ban broadcasters from transmitting at certain frequencies. Broadcasting licenses were (and still are) issued by the government for free. However, for those not lucky enough to receive a rare license from the government, licenses could also be purchased legally from a license holder. This loophole in licensing prompted the development of a market for radio stations and their government-issued licenses shortly after the government exercised control over the electromagnetic spectrum. Licenses were considered valuable insofar as they delivered an audience—the audience accrued to a specific frequency over time—just as the value of a company is a function, in part, of the productivity of its employees. While broadcasters have long argued that they work to grow their audiences, gaining their trust and loyalty through carefully programmed content, it is hard to deny that this work was made easier by the scarcity of licenses offered. For example, when the Federal Communications Commission (FCC) initially divided up VHF for television, it designated 12 channels, enough channels, it thought, to meet market demand. What made these scarce licenses valuable was not their scarcity, per se, but the larger audience that each station was able to attract because it did not have to compete with 100 other stations; fewer pieces of the pie means bigger slices for each player.

The buying and selling of broadcasting licenses produced a somewhat problematic relationship between broadcasters and the government, since federal regulation of the airwaves is predicated, in part, on the idea that broadcasting should be carried out in the public interest, as reflected in the Communications Act of 1934 (which established the government's right to grant or deny licenses in the name of the public interest). This emphasis on the public interest begs the question: if licenses can be bought and sold on the market as if they were real estate (Streeter 1996: 230), how can the government pretend that licenses are distributed in such a way that serves the public interest? Explaining how this incongruity was resolved, Streeter explains:

> The price paid for stations, the argument goes, is none of our business …. In the *Seitz* case, for example, the FCC opined that 'our primary consideration, from the standpoint of public interest, deals not with the prevailing relationship between contract price and the items to be transferred, but rather with the qualifications of the proposed transferees and their ability to provide the public with an improved broadcast service.' (235)

This is not to say that the FCC is uninterested in the sale of licenses, especially when the hefty sums they command indicate that licenses are extremely valuable. In particular, Streeter argues, both Congress and the Federal Radio Commission were very concerned that if licenses were shown to be valuable they could be treated in court as private property, in which case property law might be used to thwart government regulation. For this reason, the Radio Act of 1927 contained a non-ownership clause, providing for "the use of such channels, but not the ownership thereof." Furthermore, Streeter notes, the FCC came up with a way to explain why licenses were sold for amounts far exceeding the tangible assets of a station: "The commission described the intangible assets in terms of 'earning capacity,' network affiliation contracts, the existence of established audience habits of listening to a station, and so forth—in terms of anything but the possession of a license" (237). Despite lingering concerns that broadcasting licenses could be treated as private property, Streeter notes that after 1949 the FCC essentially accepted that broadcasting licenses share some qualities in common with private property. At that point, the FCC's strategy shifted "from trying to *prohibit* 'ownership' of licenses to accepting the fact of ownership and trying to shape the character of station owners, through policies on diversity of ownership and control of broadcasting" (240).

As this abbreviated history suggests, broadcasting regulations, policies, and practices are continually shaped and reshaped by multiple interacting (or intra-acting) forces: economic, legal, technological, and social. While more thorough accounts of how these forces have shaped the history of broadcasting have been written,[21] the basic sketch I have drawn is sufficient to illustrate how government issued broadcasting licenses, in splitting up the viewing public into larger, more profitable segments, play a determining role in the economic organization of television. I will now turn to consider the factors that play a determining role in the economic organization of the Internet, in order to show why it is necessary to theorize a new form of producing value.

As many scholars have noted, the Internet in its infancy was not a commercial but rather a military venture. In these early years, National Science Foundation (NSF) funding was necessary to install and maintain the fiber-optic cable that comprises the "backbone" of the Internet (Owen 1999: 221). However, once the Internet became commercially viable in the early 90's, NSF funding ended and telephone (now telecommunications) companies took control of the Internet's backbone. As Owen explains:

> Thereafter, communication companies cooperated with one another in providing pieces of the network (transmission facilities, access points, routers), while industry committees and the Commercial Internet Exchange facilitated agreement on the interconnection standards. These companies are in business to make

[21] See Streeter 1996 or Owen 1999 for examples.

> money, and they are paid by those who want access to their facilities—chiefly large companies, universities, and Internet Service Providers (ISPs). (202)

Internet Service Providers, in turn, provide transmission and routing services to businesses and residences, typically in exchange for a monthly fee. Through ISPs, businesses and residences connect to the Internet's "last mile"—either telephone cable or cable television cable. As Economides explains, "Users connect to the Internet either by dialing their ISP, connecting through cable modems, residential DSL, or through corporate networks. Typically, routers and switches owned by the ISP send the caller's packets to a local Point of Presence (POP) of the Internet" (2005: 375).

In the early 90s, before the Web became popular, early ISPs such as Prodigy and Compuserve provided their customers with both Internet access and content (broadly defined). ISPs charged users for the time they spent connected to the Internet in the same way as telephone companies charge for telephone calls—what is called metered usage, "on-demand," "pay-per-view," "pay-as-you-go," etc. When Internet usage is metered, the more time a user spends online, the more he pays. America Online also followed a metered usage model, attracting content providers who were paid a portion of the revenue generated from the use of AOL. Eventually, however, AOL—threatened by the emergence of small, independent ISPs—would make popular an unlimited monthly subscription. As e-commerce scholar Jeffrey Rayport notes, "The very idea of selling content or metering usage suddenly went from viable and commercially attractive to insupportable and economically naive. After all, audiences are valuable — and charging for usage is a deterrent to use" (1999). In other words, a threshold had been passed. While users still had to pay for access (unlike access to network television which is free, at least superficially), this audience had become lucrative enough to advertisers to prompt a shift in how users are charged for access to the Internet.

As broadband Internet access has become the norm, unlimited access to the Internet has grown increasingly indispensable. No longer a novelty, Internet access has become a primary mechanism of coordinating social, economic, and political activity. According to M. A. Rappa (2004), once Internet access had become an ineluctable resource, it could be economically managed as if it were a utility like electricity, water, or telephone service: "Users consider it a high necessity; high reliability of service is critical; ease of use is a significant factor; the full utilization of capacity is limited; services are scalable (leading to economies of scale); and exclusive rights are granted for providing service in a given area." In the late 90s and early 00s, economically managing Internet access as if it were a utility allowed ISPs to strike a balance between expansion and profitability. During this period, the economic interests of content providers and ISPs briefly aligned. Unlimited Internet access steered users in droves to the Web for content, inspiring investments in content providers, though content was still relatively minimal in terms of data and thus did not flood the network with traffic. As a result, services like America Online, which bundled bandwidth and content much in the way that television does, became less popular; users no longer needed to pay for content they could get for free.

In the mid 2000's the relationship between content providers and ISPs began to strain as broadband access prompted the development of more data-intensive forms of content (such as video and audio), increasing many times over the quantities of data transmitted through the Internet and threatening the profitability of ISPs. As the New York Times reported in March of 2008, “For months there has been a rising chorus of alarm about the surging growth in the amount of data flying across the Internet” (Lohr 2008). The article cites a particularly striking statistic: “Last year, by one estimate, the video site YouTube, owned by Google, consumed as much bandwidth as the entire Internet did in 2000.” Such concerns about bandwidth shortages can be dated to an article published in the *Wall Street Journal*, “The Coming Exaflood” (an Exabyte is one billion gigabytes). In this article, reporter Bret Swanson writes, “Each year the original content on the world’s radio, cable and broadcast television channels adds up to about 75 petabytes of data—or, 10 to the 15^{th} power. If current estimates are correct, the two-year-old YouTube streams that much data in about *three months*” (Swanson 2007). Pointing to the increasing frequency with which very large quantities of data are transmitted—from high-definition television to remotely stored personal data—Swanson argues that Internet traffic is going to increase at rates that cannot be supported by current infrastructure.

Responding to increasing bandwidth consumption, ISPs have become dissatisfied in recent years with providing users with unlimited access for a flat fee, though this model served them well in the late 90s and early 00s. Whether guided by a perceived market opportunity or a sense of waning profitability, ISPs are once again interested in a tiered pricing model. However, instead of charging users for the time they spend connected to the Internet, as they did before, ISPs may require users to select bandwidth caps. For example, users may be asked to select a monthly bandwidth cap of 5, 10, 20, or 40 gigabytes per month, with an extra charge per gigabyte when users go over their cap.

At the time of writing, it is unclear whether these experiments will actually result in a pricing paradigm shift, or whether they will fail or else be modified.

It is important to note that not everyone has been convinced by ISPs and exaflood preachers that growing bandwidth consumption is a problem. An *Economist* article from December, 2008 found good reason to be skeptical of these claims: Internet traffic is not growing at the catastrophic rates predicted, and in fact may be decreasing ("Surviving the Exaflood"2008) . Furthermore, in 2007 and 2008 bandwidth capacity grew faster than did Internet traffic. As Economides also notes, “Bandwidth and equipment costs have decreased and continue to decrease. Hence, access to fiber capacity is unlikely to be an impediment to sellers wishing to upgrade their networks, or to new competitors wishing to enter the market” (2005: 386). *The Economist* cites Grant van Rooyen, Senior Vice President of Content Markets at Level 3, a company which “operates network backbones that carry around a quarter of the world’s internet [sic] traffic”: “This isn’t like building a toll-road with an inflexible infrastructure. In the network world, we are able to scale infrastructure and capacity in real time.” In other words, “when bunches of optical fibres are laid in the ground or on the seabed … not all of them are immediately used or ‘lit’. So the capacity of a link can be increased by lighting more fibres. Even when all the fibres are lit, capacity can be further increased by upgrading the equipment at each end of the fibre.” Of course, increasing the capacity of the Internet’s backbone does not make much of a difference if the “last mile” is not also upgraded. However, the article goes on to state, competition between ISPs has driven many of them to improve last mile infrastructure.

As I have illustrated, the debate about whether or not the Internet will tolerate increasing amounts of data often focuses on questions of Internet usage and infrastructure: does increased usage strain infrastructure? Can infrastructure be made to accommodate usage? Underlying these questions lurks a more explicitly political debate: how should federal policy encourage or discourage certain types of Internet investment and growth. This debate is about what has come to be called "net neutrality," after the term coined by Tim Wu (2003). Wu explains:

> The argument for network neutrality must be understood as a concrete expression of a system of belief about innovation .... Speaking very generally, adherents view the innovation process as a survival-of-the-fittest competition among developers of new technologies. They are suspicious of models of development that might vest control in any initial prospect-holder, private or public, who is expected to direct the optimal path of innovation, minimizing the excesses of innovative consumption.

Proponents of net neutrality want to protect and promote innovation through application and content development, though it may not be in the immediate economic interests of ISPs. They argue that ISPs should not be legally permitted to discriminate between types of data (apart from offering different tiers of service, e.g. dial-up, DSL, cable) as in the practice of packet filtering (slowing down the transmission of certain types of data), insofar as these practices undermine the process of competitive innovation.

As the net neutrality debate reveals, the tension between content providers and ISPs is not simply about logistics—bandwidth capacity and patterns of use—but about what have become irreconcilable economic interests. For alongside the value-rich attention users cede to the Internet—the hours spent surfing the Net, watching video online, periodically checking e-mail, refreshing websites—comes the value-draining consumption of bandwidth. Put simply, attention produces value for content providers and drains value from ISPs, while bandwidth drains value from content providers and produces value for ISPs.

There is at least one point, however, on which ISPs and content providers can agree: they are both staunch opponents of peer-to-peer networks. While the reasons (discussed in Chapter Three) that content providers oppose peer-to-peer networks are obvious, ISPs oppose peer-to-peer networks for more subtle reasons. Because content providers require much larger amounts of bandwidth than their users do, content providers typically pay much more for their Internet access, though this cost is ultimately passed on to users (whether users pay with money or time). In other words, when users pay for content, they essentially pay for bandwidth twice—they pay for their own bandwidth, and they pay for content providers' bandwidth. When content is uploaded/downloaded through peer-to-peer networks, however, ISPs are only paid once for the same amount of bandwidth consumed. Put another way, peer-to-peer networks allow users to bypass content providers, "cheating" ISPs out of the payment they would otherwise incur from a heavy uploader of content. For this reason, ISPs have been hostile to peer-to-peer activity.

Consider, for example, ISPs' hostility towards Skype. Launched in 2003 by the programmers responsible for Kazaa, one of the most popular post-Napseter peer-to-peer applications, Skype—a shortening of the phrase "sky peer-to-peer"—is an Internet telephony application that allows users to make telephone calls from their computers to other computers or, for a fee, land lines or cell phones. In the fourth quarter of 2008, Skype reported 405 million registered users and logged 2.6 billion minutes of calls. Impressively, eight percent of the international calls made in 2008 were made through Skype. Skype has been so successful, in part, because it utilizes peer-to-peer technologies which require few centralized resources and are therefore economical to operate. Put simply, Skype eliminates costs—including the cost of bandwidth—by distributing them throughout the network. ISPs, in turn, are forced to pick up the bill.

A transmission theory of value

The conflict which permeates economies of culture online between attention and bandwidth, a conflict which does not exist with television, exposes the inadequacy of an attention theory of value to fully account for the production of value online. To account for this production of value, we must also theorize the form of value whose production undermines the value of attention: the value produced through data's transmission. To do this, I will depart from Dienst's and Beller's attention theory of value.

Underlying Dienst's and Beller's theory is a particular reading of Marx, one that remains faithful to Marx's observation that labor power is bought and sold for less than it is worth, and that this bargain is what delivers surplus value to capital, even while the labor described by theorists of television is not the kind of purposeful labor that takes place in the factories of *Capital*. What makes it possible for Dienst and Beller to bridge this gap between purposeful labor and passive labor is that these labors both occupy real time—the time of human experience. While I find this amendment to Marx's labor theory of value useful in terms of theorizing how attention to the Internet produces value, I will argue that its human-centeredness makes it a poor fit for theorizing how the transmission of data produces value. In de-prioritizing the human, digital networks force us to ask: is the time of human experience the only mode of time that can be socialized, serving as a common measure of value, or can a non-human mode of time like the time of transmission be socialized?

Before I respond to this question, it is important to note that the non-human elements of digital networks do not break with so much as expand forms nascent in television. As Patricia Clough has argued, television forges novel connections between bodies and machines, eyeballs and screens. In Clough's analysis, humans do not simply use television; there can be no such binary relation. Rather, the borders between the two are blurred, forming what Clough (following Deleuze) characterizes as a machinic assemblage (2000: 99). For this reason, Clough is more hesitant than are Dienst and Beller to distinguish between human watching and televisual apparatus, as if the act of watching might be rescued from televisual conditioning. As she writes, "Television points to and produces itself in a network of a vast number of machinic assemblages, crisscrossing bodies—not just human bodies—producing surplus value, pleasures, and signs all on one plane" (2000: 99). Compelled by the materiality of her object of analysis and perhaps less interested in preserving a connection with Marx's labor theory of value, Clough has an easier time putting the human aside.

Like television (and cinema), digital networks draw into question the possibility of distinguishing between human and machine. Better stated, digital networks reveal the extent to which so-called human functions, such as hearing (as I will discuss in the following chapter), are what we might call a technical production, performance, or determination, revealing the limits of Marx's concepts of fixed and variable capital. If, as Beller argues (1998: 78), cinema marks a phase in capitalism's modification of the social, perceptual, and material, it seems likely that television and, most recently, the Internet mark subsequent phases in this modification. Clough's question, "What does [television] make and what does it make happen in collapsing the difference between production and reproduction, production and circulation, text and control?" appears prescient in light of this progression (2000: 76). If cinema and television collapse (re)production and circulation, as Clough suggests, then digital network technologies extend this collapse.

It is also important to note that there are modes of transmission which are begun through television and expanded through digital network technologies. For example, time-shifting, the recording of content so that it can be consumed at the user's convenience, describes a mode of transmission that can be traced back to the advent of the Video Cassette Recorder (VCR).[22] As Dienst writes:

> What the VCR makes possible, in fact, is the further ramification of televisual time by altering its speed, and in this sense it retools the televisual apparatus for a new economic cycle …. Television's new speeds, however, are both a matter of expanded individual choice and a new zone of fixed capital and image valorization. To use an orthodox Marxist expression, we are currently witnessing the development of relative modes of socializing time, based upon the absolute socialization already posited by the apparatus itself. (1994: 63)

[22] Of course, practices of time-shifting can be traced back at least to the earliest recordings of audio in the late 19th and early 20th century. However, it is not until the advent of the VCR that time-shifting is taken up into relations of transmission here theorized.

If the VCR allows television to be watched at the viewer's convenience, digital network technologies extend and transform this operation, facilitating and increasing user control over content, while also realizing the productive potential of this control, for example, through mining information about users' consumption habits.

Even with a VCR attached, television can only produce value through its occupation of real time. While the Internet too occupies real time—the time of surfing the Web, checking e-mail, instant messaging, and playing games—it also occupies a mode of time distinct from real time: the time of uploading and downloading data, the time of transmission. Simply put, transmission-time describes the time it takes to transfer data, the time between the moments of its request and arrival. Unlike the real time occupied by watching television or other forms of labor, transmission-time requires minimal human input. While it is possible to experience transmission, as when a downloading file is graphically depicted in the status bar of a Web browser, experience is tangential to data transfer; a user need not watch a website load or a downloading file accrete byte-by-byte on her hard drive in order for this transfer to occur. Data transfer can occur outside the experience of a user, in the background, in another window, or while the user is absent. Unlike real time, transmission-time can be multiple, as in the simultaneous downloading of multiple files. In these ways, data's transfer need not occupy any real time at all.

This is not to say that transmission-time is opposed to real time. Logistically speaking, the transfer of data can occupy both real time and transmission-time, as when a user watches a partially transferred video as it loads. Usually users experience this time as waiting: for a large file to upload or download, for a video or audio stream to buffer, for a heavily hit web server to respond to a request to view a particular page. When users wait for a file to download, their attention can be occupied by the transmission of data. Admittedly this is not usually a desirable form of attention. Whenever possible users avoid attending to waiting, letting data upload and download while they do something else.

While real time and transmission-time can coincide, their relationship is characteristically inverse; real time describes the occupation of human experience, while transmission-time describes the compression of human experience. If real time *lasts*, transmission-time *divests*. The human is not entirely absent from this compression of experience, participating in various ways: requesting data, receiving data, consuming data, demanding ever-greater quantities of data. In this way, transmission-time targets the human without exactly belonging to it in the way that real time does. As I will illustrate in the following chapter, relations of transmission do not target the human subject as much as they do bodily matter. In this way, digital network technologies bring back the body into theorizations of technology, culture, and economy, displacing the centrality of the subject in these fields.

As I have argued, once transmission-time is socialized—i.e. introduced into a social context in which its average productivity can be calculated—it serves as a measure of the value produced through transmission. What is calibrated and capitalized when transmission-time is socialized is not just viewing time and image (content), but transfer time with data. In particular, transmission-time is socialized through the calibration of current infrastructural technologies (how much data can physically be transferred, how fast, and at what cost), with business applications (what kind and quality of data one can get given current infrastructure, hardware, software, compression technologies, etc.), and user necessity, desire, and patience (what one can get for the money, how long one has to wait for a transfer given any legal risks risks, the wait time, the advertisements, etc., and the ultimate payoff). Where is this value produced through transmission made visible? Recall that in Dienst's analysis of television, the value of viewing power is harvested by television networks. Similarly, I propose that the value produced through the transmission of data is harvested by ISPs and, in turn, the companies that maintain the Internet's backbone.

The value harvested by ISPs creates a conflict that does not exist in television between attention and bandwidth. Because ISPs and content providers have decoupled, content providers must pay ISPs for the data they transmit, a cost which they ultimately pass on to users. This dynamic has resulted in a tug of war between ISPs and content providers for the value produced through the reproduction and distribution of cultural content through the Internet, especially when content is data-intensive. YouTube, for example, has not forged a successful business model despite its popularity, largely because any value it produces through the attention of its users is used to pay for its immense bandwidth costs; the value YouTube produces for its ISP (through transmitting data) outweighs the value it produces through attention. For this reason, content providers like YouTube are eager to adopt technologies that reduce their bandwidth consumption while ISPs are more interested in taking advantage of patterns of increased consumption to innovate their business model, as through tiered broadband pricing.

Unlike content providers, users are not typically interested in economizing their bandwidth consumption (at least until they have to select a monthly cap), though they are interested in increasing their upload and download speeds. Following Dienst's and Beller's analyses, one might argue that the purpose of increasing the speed of transmission would be to reduce the unproductive time of waiting and to increase the value-rich time of paying attention. Whereas the attention spent on activity (even passive television watching) produces value, the attention spent waiting is a waste of time. From this perspective, the purpose of decreasing transfer time would simply be to make users more productive; make them wait less so they can work more. While it is true that less waiting might mean more working, it is important to remember that waiting need not accompany the transmission of data, and even when it does, it is affiliated with the value produced through transmission. In other words, waiting can also be working.

There is another argument we might consider in explaining the drive to reduce transfer time: reducing transfer time does not simply allow users to get back to work (the work of watching), it also creates and transforms work (the work of the factory or office). For one, the drive to reduce transmission-time fuels what we might call industries of transmission, both indirectly through businesses that build computer parts and install and maintain infrastructure, and directly through ISPs, companies that write content-delivery software, etc. Furthermore, reduced transfer time has become central to businesses whose efficiency and competitive edge rely on quick and coordinated data transfers. While these points are valid, it is important to note that such arguments return to the concepts of human labor and the commodity form in order to explain how culture yields value through the Internet. Rather than using these concepts as the basis for my analysis, I have considered them instead as epiphenomena of an industrial mode of production. Put another way, it is important to examine digital networks on their own terms, not the terms of other (industrial, televisual, etc.) modes of production.

These factors—reduced wait time, the creation and streamlining of work—are not insignificant. However, now that Internet access is managed as a utility, the push to reduce transfer time is as much about the tension between content providers and ISPs as it is any of these factors. Put simply, content providers want to get the most bang for their data buck, reproducing the dynamic Marx describes in his explication of relative surplus value. Marx argues that by making labor more efficient, capitalists could temporarily gain a market advantage over competitors, until they too gained access to efficiencies. A similar reward awaits content providers who make good use of bandwidth, whether this good use is a function of the desirability of the content offered, or more simply its size in bytes. To explain the former, an attention theory of value is sufficient. With regards to the latter, however, a new theory is needed: a transmission theory of value.

Conclusion

Just as watching television realizes the value of socialized viewing-time, the transfer of data through the Internet realizes in addition the value of socialized transmission-time. And just as capitalists buy laborers' labor-power, and television networks buy television audiences' viewing-power, Internet users buy the Internet's transmission-power. However, unlike capitalists or television networks, users who buy the Internet's transmission-power do not collect the value realized when this transmission power is "used up"—when data is transferred. Rather, this value is collected by ISPs when content is consumed online, whether users pay for this content with their money (as through iTS) or with their attention (as through YouTube).

Because of the decoupling of ISPs from content providers, the value produced through data's transmission does not supplement the value produced through attending to content. Rather, the cost of bandwidth for online content providers has undermined their ability to profit from the value-rich attention their content attracts. A number of scholars have suggested possible solutions to this problem for content providers. Mark Pesce, for example, has imagined that peer-to-peer traffic might be used to generate revenue for television producers by subtly introducing brand logos (bugs) into the corner of the screen, capitalizing on what Pesce (2005) calls the most valuable and underutilized piece of real estate in the human universe. He proposes that content production companies work directly with advertisers, bypassing television networks altogether. Advertisers would pay for the production of television episodes, which would be branded with advertisers' logos and then introduced into peer-to-peer networks. In reproducing and distributing these programs through peer-to-peer networks, users would inadvertently also reproduce and distribute advertisers' branding. This solution will likely be less appealing to ISPs who, following this model, would not be paid for the extra bandwidth consumed by peer-to-peer traffic.

Whether or not this type of solution is viable remains to be seen. What is clear is that market advantages fall to those content providers who make the best, most economical use of bandwidth. In the next chapter I will take up what is perhaps the oldest method to economize bandwidth: the compression of data. I will examine one particular form of compression—perceptual coding—which removes information from digital files that is unlikely to rise above the threshold of perception, calling into question the human/machine divide central to Marx's labor theory of value, and suggesting a new role for the human body in relations of value in a digital network mode of production.

Chapter Six: Socializing the Non-human

> *If there is a question raised by the mere existence of digital sound technology, it is not a question of the impact of digital technology on sound culture. It is a question of what happened to the sonic and the digital that led to their mutual entanglement.* (Sterne 2003: 33)

Technologies often create visible seams in our lives when they are first introduced. These seams, experienced as novelty, diminish over time. The novelty of e-mail in the early 1990s, for example, eroded in a few short years, revealing what now seems like an ordinary convenience if not a burden. In time, e-mail allowed for other, newer technologies: Blackberries, iPhones, and Sidekicks designed, in part, to let users access their e-mail on the go. This compounding of technologies never seems to end: Blackberries build on e-mail which builds on networking which builds on computation which builds on electricity, and so on. In this way, technologies that appear straightforward or even simple—an impression advanced by increasingly intuitive user interfaces—often disguise complex strata of technological innovations.

Peer-to-peer networks are built on many technologies, most obviously Internet protocols and infrastructure, and computing. I will focus on one of the less obvious technologies upon which peer-to-peer networks are built: data compression. In particular, I will examine the compression of digital audio files. Put simply, without audio compression Napster never would have succeeded. Until recently, uncompressed audio files were too large to be transmitted efficiently through the Internet. It might take hours or even days to download a single uncompressed song. Audio compression technologies mitigate this problem by rendering audio files small enough to be uploaded and downloaded efficiently. Of course efficiency is relative. When Napster was released, it might take an hour to download a single MP3. This was considered efficient at the time, or at least tolerably inefficient given its inexpensiveness.

There are two primary methods used to selectively target and eliminate data in an audio file. The first method is general; it can be applied to many different kinds of data, not just audio data. Colloquially it is referred to as "zipping," after the early and popular ZIP compression protocol. Rooted in information theory (what is essentially the science of compressing data), this method targets and removes extraneous or redundant data in a file. Because the data removed by an uploader is later restored by a downloader, this type of compression is categorized as "lossless." The second method, categorized as "lossy," is specific to audio (and image/video) files. Rooted in information theory and psychoacoustics (the science of how sound is perceived), this method—called perceptual coding—targets and removes sounds which are likely to be inaudible to the average listener, and whose absence is thus likely to go unnoticed. Both these methods are necessary to reduce audio files to a size small enough to be transmitted efficiently through the Internet.

Beyond the historical connection between audio compression technologies and peer-to-peer networks, I will argue there is a deeper underlying political-economic connection. Not only do audio compression technologies make possible peer-to-peer networks by reducing the size of audio files for transmission, they participate in the socialization of what I have termed transmission-time. Recall that I argued that peer-to-peer networks actualize a form of value native to digital network technologies, what I described as the value of transmission. Taking cues from Richard Dienst, Jonathan Beller, and Patricia Clough, I theorized this form of value as made possible by the socialization of a mode of time characteristic of the Internet. In other words, if socialized labor-time is endemic to the industrial apparatus, and socialized viewing-time is endemic to the televisual apparatus, then socialized transmission-time is endemic to the digital network apparatus. However, whereas labor-time and viewing-time describe modes of time occupied by human activity, I conceptualized transmission-time as a non-human mode of time.

As I have pointed out, unlike labor-time or viewing-time, the concept of transmission-time poses a peculiar problem: is it possible to describe a non-human mode of time as socialized? When we say "socialized," don't we always mean socialized humans? In this chapter, I aim to unpack the process of socializing transmission-time, with particular attention to the apparent conflict between the decentering of the human in digital networks and the socialization of the mode of time endemic to digital networks. To this end, I will examine how perceptual audio compression technologies participate in the socialization of transmission-time. In particular, I will propose that they participate in two key ways: 1) by targeting an average listener, produced "biopolitically" through standardized testing and statistical instruments and 2) by making an economic variable of the technical quality of files—how much compression are consumers willing to accept?

How much are they willing to pay (in time or money) for content of varied technical qualities? How much costly bandwidth can content providers save by compressing content?

In examining how perceptual audio compression technologies participate in the socialization of transmission-time, I also aim to unpack the argument begun in the previous chapter that the value produced when data is transmitted through the Internet is not produced by human labor, whether the willful labor of factory production or the passive labor of watching or listening. To this end, I will review the intellectual history that underlies Marx's theory of value, with particular attention to the notion that only human laborers can create value. Drawing from Michel Foucault, I will argue that Marx's insistence on the separability of human from machine was problematic even at the time of his writing. However, whether or not this separation is viable for an industrial mode of production, I will argue that it is not viable for a digital mode of production. Indeed, what sense can this separation make in the context of technologies that, as Sterne (2006b) has argued, hear *for* us (or, better stated, *before* us)?

If this question makes it seem as if it is still possible to distinguish between human and machine, I will argue (following Foucault and Karen Barad) that the function performed by perceptual coders—i.e., hearing—is not simply human. Rather, hearing is a concept that organizes how we think about the bodily matter categorized as the ear. There are other ways we might think about this bodily matter; certainly there are other ways people have thought about in the past. From this perspective, it is not the human body that is imitated by code, but the understanding organized by the concept of hearing, which despite its origins in studies of human anatomy, does not depend on human bodily matter to be operational. This is not a question of cyborgs, of human-machine hybrids, but of a "biomediated" (to use Eugence Thacker's term) assemblage of human bodily matter, information theory, and statistical instruments. This assemblage does not displace the human laborer, producing value in his absence. Rather it has become a means through which the time of uploading and downloading of data can be socialized, yielding an exponentially greater return on content providers' investment in users' viewing-time.

Sound as information

Over the past several decades sound reproduction technologies have changed drastically. This change is marked by the growing predominance of digital formats—most notably compact discs and digital audio files—over analog formats such as vinyl records and cassette tapes. Digital technologies now suffuse the ways music is produced, stored, transported, and listened to. Music producers and engineers, musicians, manufacturing facilities, and consumers have adopted digital technologies, replacing reel-to-reel recorders, vinyl molds, and tape decks with their digital counterparts, presumably for the superior sonic accuracy with which digital technologies are said to capture, retain, and reproduce recorded sound. Upgrades from vinyl records to eight tracks to cassette tapes to compact discs have been invested in, engineered, marketed, and sold to consumers based on these formats' superior fidelities over older technologies, with each new format trumping its predecessor.

Unlike the sound on a record which is inscribed in its grooves or the sound on a cassette which is polarized on its magnetic tape, digital sound is coded as data in the form of zeroes and ones. As zeroes and ones, sound—like other forms of data—can be digitally compressed; it is digitization that makes possible compression, opening up the informational content of matter to measure. But what exactly does it mean that sound is informational? How can something as material as sound vibrations be linked to something like information, which is often presumed to be disembodied, intangible, and ephemeral. In order to answer these questions, I will join a number of scholars who have wrestled with confused and often contradictory uses of the term "information," searching for a definition that helps clarify the subtle and complex materiality of digital technologies.

The concept of information has been taken up by social and cultural studies primarily through examinations of immaterial labor and affect economies.[23] In this body of work, the term "information" is often used synonymously with "content" or "knowledge," and as such is understood to be immaterial. I will follow instead Tiziana Terranova and similar cultural theorists, employing what Terranova (2004: 9) refers to as "the modern scientific concept of information" most often associated with the experiments begun in the 1940's at Bell Laboratories and specifically with Claude Shannon's seminal paper, *A Mathematical Theory of Communication*. The experiments at Bell Laboratories mark the emergence of information theory from applied mathematics. While the genealogy of information theory transcends Shannon's work, as well as

[23] Here I am thinking of work by Frederic Jameson, Antonio Negri, Michael Hardt, Manuel Castels, Marc Uri Porat, and David Harvey.

crossing a number of other disciplines, it is with Shannon and the experiments at Bell Laboratories that information receives its first rigorous scientific treatment.

For Shannon and other early communication theorists, information posed a practical problem. As Terranova documents, Shannon's conception of information was "explictly subordinated to the technical demands of communication engineering" (2004: 12). From the beginning, information was posed as a problem of process—the process of transmitting enough data over a capacity-restricted and noise-producing channel so that a message could be accurately pieced together at the receiving end. In his seminal paper, Shannon defines information through it transmission, describing "five moments or components in the communication process: an information source, a transmitter, the message, the channel of communications and the receiver" (Terranova 2004: 13). The chief problem posed by information theory was how to ensure that a message would not become so distorted in its journey from sender to receiver as to render it incoherent.

Maintaining the integrity of transmitted data was not Shannon's only concern, however; he and his colleagues were searching for methods to transmit data as efficiently as possible. What is often considered to be Shannon's greatest contribution to information theory is a mathematical formula that determines the minimum amount of data needed to adequately transmit a signal from sender to receiver. This formula recognizes that the more "knowledge" a sender and receiver share about the patterns a message contains *before* its transmission, the less data that needs to be sent in order for a transmission to be successful. As Shannon's colleague and collaborator Warren Weaver explains, "The concept of information applies not to the individual messages (as the concept of meaning would), but rather to the situation as a whole, the unit information indicating that in this situation one has an amount of freedom of choice, in selecting a message, which it is convenient to regard as a standard or unit amount" (1964: 5). The standard unit of information—the "binary digit" or "bit" for short—is thus not a property of data but rather of data in transmission, or what information theorists call a signal.[24] As Eugene Thacker writes, "Information, while not an object or a thing, is nevertheless the constantly varying, quantitative value of a message or content at a given point within either the cybernetic system or the line of communication" (2003a: 83).

In crafting a mathematical formula for the measure of information, Shannon took advantage of a concept from statistical thermodynamics—the concept of entropy. Specifically, Shannon employed the mathematical expression of entropy formulated by Ludwig Boltzmann, a physicist working in the field of statistical mechanics at the turn of the 20th century. Boltzmann theorized that the most probable distribution of gas molecules in a closed chamber is the one in which the molecules are evenly dispersed. This is also, therefore, the distribution that can be made to do the least work (defined thermodynamically as a transfer of energy). In this way, Boltzmann correlated entropy with probability.

---

[24] These bits of situational information are not to be confused with the bits of file size, which indicate only how much space a given piece of data occupies. For example, a five megabyte MP3 contains a string of 41,943,040 zeroes and ones. However, some of these zeroes and ones may be redundant and therefore contain less information than their overall file size would appear to indicate.

Shannon's insight was to use Boltzmann's mathematical description of entropy to measure the information contained in a signal.[25] Shannon theorized that the less a receiver knows about a signal—that is, when a signal might contain *x* number of equally probable messages—the more information it contains. As Shannon's colleague J. R. Pierce writes, "The entropy of communication theory is a measure of the uncertainty as to what message, among many possible messages, a message source will actually produce on a given occasion" (1961: 202). This might seem counter-intuitive, because information is typically associated with certainty (i.e., the more information one has, the more certain she is). In Shannon's conceptualization of communicative situations, however, information is built upon uncertainty. When a receiver knows nothing about the message it is going to receive—that is, when all signals are equally probable— is when a signal contains the most information. As Charles Seife writes, "The more random—the less predictable—a stream of symbols is, the less redundant it is, and the more information it tends to carry per symbol" (2006: 73).

Conceptualizing communicative situations in terms of mathematical probabilities allowed Shannon and his colleagues to engineer techniques that take advantage of the statistical redundancy that most messages contain, maximizing the efficiency of transmission. Using the English language as an example, Weaver illustrates just how much extraneous information can be removed from a message while maintaining its essential information. He writes, "The redundancy of ordinary English, not considering

[25] The relation between the mathematical expression of information entropy and that of thermodynamic entropy is both more complex than I can describe here, as well as being the subject of some controversy. See Seife 2006.

statistical structure over greater distances than about eight letters, is roughly 50%. This means that when we write English half of what we write is determined by the structure of the language and half is chosen freely" (1964: 14). He elaborates, "For as the successive symbols are chosen, these choices are, at least from the point of view of the communication system, governed by probabilities; and in fact by probabilities which are not independent, but which, at any stage of the process, depend upon the preceding choices" (6). By incorporating these probabilities into a communication system's coding and transfer scheme, an engineer might save much needed channel capacity.

Digital v. analog

I suggested earlier that digital sound, unlike analog sound, is coded as data. To be clear, I should differentiate "data" from "information." Data is always informational, always part of a communicative situation, but information is not always digital. For this reason, analog audio signals are just as informational as digital signals. In other words, it is not the ontology of the signal, but rather that of the communicative context that calls forth an informational understanding. As Terranova argues (citing Frederich Kittler), "We could refer to the informationalization of culture as starting with the analog function of frequency, that is with the encoding of sound in the grooves of a gramophone record, where speech phonemes and musical intervals were recognized for the first time as complex frequency mixtures open to further mathematical analysis and manipulation" (2004: 8). If anything, continuous (analog) signals contain even more information, more uncertainty than their digital counterparts. As Pierce writes, “Since a continuous signal can assume an infinite number of different values at a sample point, we are led to assume that a continuous signal must have an entropy of an infinite number of bits per sample. This would be true if we required an absolutely accurate reproduction of the continuous signal” (1961: 131). However, Pierce continues, “signals are transmitted to be heard or seen.” Therefore, a continuous signal can be stripped of much of its information and remain coherent to the human eye or ear.

If analog signals also contain information, how can the analog be ontologically distinguished from the digital? This is not an easy question to answer, for while there has been much written about “the digital” in social and cultural studies, most scholars have not addressed the materiality of either digital or analog technologies. Indeed, it is often unclear what exactly scholars are referring to when they write about “the digital.” Is it the Internet, computation, information, zeroes and ones? Is it just technology, now? This nebulous web of connotations has not prevented scholars from either heralding digital technologies as libratory or lamenting their limitations. In this way, the materiality of digital technologies has been masked behind a separation between digital technologies and their social uses. Conceptualized as tools, technologies become defined by what they can do *for* users, instead of what they can do *to* users, or more to the point, what alternative configurations of matter they can assemble and what these configurations can do.

While the digital is often (and correctly) defined as being comprised of zeroes and ones, to fully account for the materiality of the digital we must go beyond zeroes and ones. Zeroes and ones are static moments, snapshots of an itinerant and transformative computational milieu. Confined to these static snapshots, theorizations of the digital often end in a human user for whom meaning must be reconstructed out of zeroes and ones, turning away from the indeterminacy of matter exposed by the digital. Brian Massumi, for example, has argued that "digitization is a numeric way of arraying alternative states so that they can be sequenced into a set of alternative routines. Step after ploddingly programmed step" (2002: 137). In contrast to the digital, Massumi associates the analog with openness and virtuality, an inexhaustible futurity that lies beyond the reach of the intelligible. He writes that the analog connotes "*process*, self-referenced to its own variations. It resembles nothing outside itself" (135). Massumi argues that the only connection between the digital and the virtual is through the analog, which brings the digital into the realm of human experience. He writes, "The digital always circuits into the analog. The digital, a form of inactuality, must be actualized. That is its quotient of openness" (138). Taking digital sound as an example of this circuiting, Massumi writes

> The sound is as analog as ever, at least on the playback end, and usually at the recording end as well (the exception being entirely synthesized music). It is only the coding of sound that is digital. The digital is sandwiched between an analog disappearance into code at the recording end and an analog appearance out of code at the listening end.

In Massumi's analysis, code thus exhibits a liminal ontology, dependent on the analog to bring it back to the realm of human experience. It is at this point in Massumi's argument that a separation is made between technology and social use, as the actualization of the digital occurs in relationship to a sensing subject, for example a "hypertext reader" who can "serially experience effects, accumulate them in an unprogrammed way, in a way that intensifies, creating resonances and interference patterns moving through the successive, linked appearances" (138).

In prioritizing the sensing subject, Massumi's notion that the analog disappears into code and reappears from code does not sufficiently account for the materiality of the analog and the digital, for they not only alter the experience of a sensing subject, but the very integrity of subject formation. In theorizing the analog's disappearance into and reappearance from code, Massumi's analysis precludes alternative understandings of the material configurations that digital and analog technologies produce. To be certain, these configurations are not strictly digital or analog but rather involve their intersection—the very moment mystified in Massumi's analysis. Upon further investigation, this intersection entails more than simply the disappearance/reappearance of the analog, because the analog that disappears is not the same analog that reappears. In taking a closer look at the materiality of the digital, I want to draw into question the supposition that technology becomes social only through human use and to suggest instead that the social operates on matter itself, in its measurement, not simply in its use. To do this I will examine the materiality of the digital in juxtaposition to the analog.

The most commonly articulated material distinction between the digital and the analog is the one that Massumi alludes to in his argument, namely that the digital is discrete and the analog continuous. The founding cybernetician Norbert Weiner also characterizes this distinction in terms of precision. As Terranova writes, "For Weiner, analogue machines, unlike digital machines, measure rather than count, and are therefore 'greatly limited in their precision,' because they operate 'on the basis of analogous connection between the measured quantities and the numerical quantities supposed to represent them' " (2004: 32). In contrast to analog machines, digital machines are as precise as the distinction between yes and no, zero and one. This precision is what enables the digital to produce "exact and yet mobile snapshots of material processes" (33). However, these snapshots lack the rich detail of the analog—they are precise but never fully accurate; in the interval between two digits, there is always more matter to be measured.

As a technique of precision, of counting, the digital opens up matter to informational measures in a way that analog measures cannot, though all matter, including analog signals, can be measured discretely on a quantum scale (Sterne 2006a). Except in the case of natively digital audio (as with software instruments, for example), the precision of the digital results from a process of "sampling" or "quantizing," that is, of taking discrete measurements of a continuous audio signal at regular intervals. To capture the rich quality of continuous audio signals, samples need to be both detailed and frequent. For example, to produce quantized audio for compact disc, samples are taken 44,100 times per second. Each of these samples has a resolution of 16 bits, meaning that each sample consists of a string of 16 binary digits (for example: 1001010001011010). At this resolution, there are 2^{16} or 65,536 possible combinations of zeroes and ones for each sample. With 44,100 samples per second, 16 bits per sample, and two channels for stereo separation, a CD contains 1,141,200 bits of data per second. While this quantity of data does not present a practical problem for encoding musical albums of average length on compact disc, it does present a practical problem for the transmission of audio files over the Internet given current bandwidth limitations. However, as I illustrated above, it is possible to find patterns among lengthy strings of data and to use those patterns to eliminate redundant bits. This is what information theory does, putting together sampling (quantization, digitization) with a mathematical tool, probability, that can be used to compress strings of bits. As long as the receiver of data is aware of the rules by which data is compressed prior to the act of transmission, the receiver can uncompress data following the act of transmission.

As in the Massumi passage referenced above, scholars and audio aficionados often dismiss digital sound as a reduction of the richness of continuous, analog sound. Drawing again from Karen Barad's argument, I want to suggest instead that the quantization process neither captures nor reduces an objective quality of sound waves. Rather, as Barad writes, objects have no "independent existence separate from the conditions of determinability specified by the apparatus" (2007: 127). In other words, she continues, "*the measurement apparatus is the condition of possibility for determinate meaning for the concept in question*" (her italics, 127). Simply put, measure is not reflective, but productive. Or in Foucauldian terms: knowledge and use are bound together; knowledge is always applied. What digital measures of sound produce, then, is economized sound whittled down to its bare informational "essence" to make its transmission as efficient as possible. Digitizing sound measures sound (vibrations) in a way that is already entangled with the production of value, given the economizing mission of information theory. As I will now illustrate, this economizing finds a welcome home not only in the digital files that travel from computer to computer through the Internet, but in the matter of the human body.

Psychoacoustics

A commodity is, in the first place, an object outside us. (Marx 1967)

The quest for an always better-sounding recording had been deeply institutionalized by the music technology industry when in the early 1970s Dieter Seitzer, a German scientist and engineer, grew interested in developing a way to transport music over telephone lines. Seitzer assembled a team to begin experimenting with audio compression. In many ways, this was not a new endeavor; data compression had long been a topic of conversation among information theorists and computer scientists, yielding a wide range of compression techniques based on the exploitation of statistical redundancies. But something new did emerge from Seitzer's group. One of his graduate students, Karlheinz Brandenburg, theorized that a digital audio file could be compressed beyond previous limits if its generative algorithm could take advantage of perceptual irrelevancies—that is, if it could remove those sounds which are physically present in an audio signal but not actually perceived by listeners. The goals of what has since become known as lossy digital audio compression ("lossy" because sound is permanently removed or lost in the process of compression) were established in the early years of research and experimentation. These goals were efficiency coupled with perceived fidelity (Brandenburg 1999). Eventually Brandenburg's research would lead to the advent of the Motion Pictures Expert Group-1 Audio Layer 3, or MP3 for short, the digital audio compression standard whose implementation was first popularized through Napster.

The production of lossy digital audio files through what is called "perceptual coding" is rooted in the science of psychoacoustics. While perceptual coding is a recent development, communications scholar Jonathan Sterne argues that the study of the perception of sound goes as far back as 1750, marking the beginning of a period he calls the Ensoniment. During this period, Sterne writes, "sound itself became an object and a domain of thought and practice, where it had previously been conceptualized in terms of particular idealized instances like voice or music. Hearing was reconstructed as a physiological process, a kind of receptivity and capacity based on physics, biology, and mechanics" (2003: 2). In part, Sterne dates this shift with the emergence of otology—the study of the ear and its diseases—in the late 18th and early 19th centuries. He writes, "When the ear became a discrete object of study, it became measurable. Specific quantities and qualities of the ear's shape and function could be isolated and measured" (51). In particular, Sterne focuses on the isolation of the ear's tympanic mechanism, which transduces sound vibrations in the air to neural impulses in the middle ear. Just as ears were literally excised from human corpses for the purpose of scientific study during this early period, "the tympanic functions could be abstracted from the ear, and the tympanic function itself could be actualized as a purely mechanical operation" (52). That is to say, once the tympanum was isolated and understood as a transducer, its function could be replicated by other, non-biological matter, such as the stylus on a phonograph.

Over the last century, psychoacoustic analyses of hearing have targeted a number of other significant mechanisms of hearing, resulting in increasingly complex and detailed psychoacoustic models and also opening up new domains of intervention. I will focus on one specific mechanism called “masking,” which has played a central role in the development of lossy digital audio technologies.

The American Standards Association defines masking as “the amount (or the process) by which the threshold of audibility for one sound is raised by the presence of another (masking) sound” (Lombardi). In other words, a sound at a certain frequency and volume can be rendered inaudible by the presence of another sound at a certain frequency and volume. This does not mean that the first sound disappears, only that it cannot be perceived. Psychoacoustician Albert S. Bregman compares this perceptual slight-of-hand to looking at a painting of a red dot. If the canvas is white, the eye perceives the dot. If the canvas is red, the eye cannot perceive the dot, even though it is there. As Bregman writes, “You can think of a masker as something that fills in the background in such a way that there is no longer any spectral shape defined against the white canvas of silence. The signal is still there, but it is camouflaged” (1990: 392). Technically, he describes this as “the loss of individuality of the neural consequences of the target sound, because there is no way of segregating it from the effects of the louder tone.”

Physiologically, masking occurs when sound waves desensitize the basilar membrane inside the ear (Carline, Edwards, and Coulton 2001). When sensitive hairs along the basilar membrane are stimulated by sounds of certain frequencies and volumes, these hairs lose the ability to register certain other sounds. As psychoacousticians Ted

Painter and Andreas Spanias explain, “Distinct regions in the cochlea (inner ear), each with a set of neural receptors, are ‘tuned’ to different frequency bands” (2000: 4). Accordingly, not all frequencies are masked equally: “Low frequencies displace the basilar membrane much more: the distance from stapes (one of the three bones in the middle ear) is about 30mm at 25 Hz compared to 20mm at 800 Hz” (Lombardi).

Mathematically precise measurements of the sonic conditions under which masking occurs made possible the development of psychoacoustic coders, defined as “multiband systems [that divide] up the spectrum in a fashion that mimics the critical bands of psychoacoustics” (Lombardi). This is one of the major technological achievements of contemporary psychoacoustics. For while sound had been compressed using Shannon’s theorem to maintain intelligibility in the face of noise (by exploiting redundancy), never before had sound been compressed using techniques that minimize perceptible differences in quality despite an actual reduction of data. An audio engineer explains, “By modeling human perception, albeit in an elemental way, perceptual coders can process signals in much the way humans do” (Lombardi). That is to say, perceptual coders can perceive in effect, performing (in part) the perceptual function that renders vibrations in the air into sound in the body. As Sterne argues, “Sound is a product of perception, not a thing ‘out there’—the only thing ‘out there’ is vibration, which the body organizes and stratifies into what we call sound” (2006b: 862).

While there is no singular technique used by all psychoacoustic coders to eliminate perceptually irrelevant data from audio files, they generally follow a similar formula. First, they segment signals into smaller units of time called “frames” which range from 2 to 50 milliseconds in duration. These frames are further decomposed (using what are called “parallel filter banks”) into frequency subbands, not unlike the way a prism separates light into its spectral components. Subbands are similar to the “critical band” of human hearing. Like neural receptors in the ear separate out analog sound into its component frequencies, so too do parallel filter banks. With an input signal segmented and decomposed in this way, psychoacoustic models are overlayed to determine and eliminate those bits of data which are likely to correspond to masked frequencies.

Despite the precision with which thresholds of perception are measured and described by psychoacoustic models, the psychoacoustic compression of data still entails some speculation. This speculation does not result from an inability to locate masked data, but rather from the cost of locating data, which can affect the speed of the encoder, and/or introduce noise into a signal. Software programmers perform a balancing act in engineering psychoacoustic coders that are careful (i.e., that do not introduce noise through excessive data elimination), that are not too slow, that can significantly reduce the size of an audio file, and that can be used on audio files that exhibit a wide range of frequency and volume distributions. Far from Massumi's characterization of the digital as a series of ploddingly programmed steps, the variability of encoding audio standards allows for a supple form of control that can be tailored around local conditions and needs. For example, a software engineer might design two very different encoders, one fast and noisy and the other slow and clean, while still meeting the standards defined for encoding MP3s. In this way, audio standards such as the MP3 straddle the line between precipitating local control and targeting a general population of listeners.

In order for the perceptual compression of audio data to go unnoticed by as many listeners as possible, the models of hearing it employs must effectively describe an average listener. This average listener is produced through standardized tests that measure a sample population's ability to perceive frequencies at certain volumes and in the presence of other frequencies (Yang, Kuo, and Kyriakakis 2005). The testing of a sample population typically proceeds as follows: first, a sample population is selected, usually from 10 to 20 listeners (possibly fewer if the listeners are "experts") (Vincent, Jafari, and Plumbley 2006). Second, listeners are familiarized with the criteria they are asked to evaluate. Third, each listener is placed in a thoroughly controlled environment where parameters such as the cubic volume and acoustic properties of the room, the placement of the listener, the type and position of speakers, the amount of background noise, and the listening materials are all controlled according to published standards. Finally, experiments are performed in which each listener is asked to evaluate listening materials according to parameters such as spatial impression, stereo impression, transparency, sound balance, timbre, and freedom from noise and distortions (Hoeg, Christensen, and Walker 1997). Once an adequate number of listeners have been tested in this way, their individual experiences can be compiled and calculated to describe an average listener—a listener that describes no one person yet targets us all.

This quantification, averaging, and delivery of the measured behaviors of bodily matter to code is not specific to psychoacoustics or perceptual coding. As Terranova writes, "The question of information was posed first of all in the context of statistics of 'populations' " (2004: 28). More to the point, the rise of statistics in the social sciences marks a political-economic turning point at which mechanisms of power begin to target populations. Michel Foucault coined the term "biopolitics" to theorize these mechanisms of power, which seek to regularize capacities both "below" the human body and "above" the human subject, at the scale of populations. As Clough writes, with biopolitics "the individual body is not so much the focus as is the species body and the regularities of the aggregate effects of individual bodies which institutes a politics of population" (2007: 25). Biopolitics targets "general biological processes," the administration of which occasion new methods of study: "forecasts, statistical estimates, and overall measures" (Foucault 2003: 246, 249).

While it is tempting to conceptualize psychoacoustic coding as imitating or replicating a natural, biological process, following Barad and Foucault I would like to suggest that this conceptualization underestimates the extent to which psychoacoustic models do not capture how hearing works, but rather *determine* (to use Barad's term) its form through measurement. This is not to say that our ears would disappear without the concept of "ear," but rather that the concept of the ear as a distinct thing with distinct properties shapes what scientists can know about it as well as what they can do with the knowledge. From this perspective, the production of knowledge is a form of politics, as it makes possible certain forms of intervention and excludes others. In the case of psychoacoustic modeling, these politics are biopolitics, gathering information from a sample population of listeners (or rather, their ears) in order to target an average listener. As I have argued, this biopolitical production makes possible the compression of data beyond previous limits, facilitating its transmission while conserving bandwidth. I will now turn to consider more closely the economic ramifications of psychoacoustics' determination of bodily matter and the form of compression it makes possible.

Human bodies, docile bodies, biomedia

> *Given the individual, the production of labour-power consists in his reproduction of himself or his maintenance.* (Marx 1967)

> *It is comforting, however, and a source of profound relief to think that man is only a recent invention, a figure not yet two centuries old, a new wrinkle in our knowledge, and that he will disappear again as soon as that knowledge has discovered a new form.* (Foucault 1994)

Designed to take advantage of psychoacoustic irrelevancies, the algorithms that produce lossy digital audio files target and eliminate those zeroes and ones that are likely to correspond to inaudible frequencies. As Sterne writes, the MP3 "decides for listeners what they need to hear and gives them only that," or more simply: "The mp3 plays its listener" (2006b: 866, 863). This leads Sterne to argue that technology contributes "a kind of surplus activity (if not quite labor) to make the system run" (866). Using Sterne's statements as a jumping off point, I will draw into question the applicability of Marx's treatment of humans and machines to a digital network mode of production. As I noted in the last chapter, the distinction between humans and machines was central to Marx's theory of value and by extension his analysis of capitalism. Rather than proposing a sea change in Marxist theory, however, I will argue that the perceptual compression of audio data suggests a new role for the human in productions of value: while human laborers do not produce the value created when data is transmitted through the Internet, human bodily matter nonetheless participates in the socialization of transmission-time, which serves as a measure of this value.

To be certain, Marx was not the first to suggest that human labor produces economic value. The theory that human labor produces value is most often associated with the classical economist Adam Smith who is thought to have been the first to suggest that value stems from processes of production rather than exchange.[26] However, as Foucault points out, "Adam Smith did not … invent labour as an economic concept … he does not even give it a new role to play" (1994: 222). Foucault continues, "But he does displace it: he maintains its function as a means of analyzing exchangeable wealth; but that analysis is no longer simply a way of expressing exchange in terms of need …; it reveals an irreducible, absolute unit of measurement" (223). For this reason, the labor theory of value is often associated with Smith; it was Smith that proposed that labor is the basis for the absolute measure of value, as that which produces value.

Smith's conceptualization of labor as the source of value departed from the physiocrats and the utilitarians—pre-classical economists who believed value to be a

[26] While Foucault argues that it was Smith who first used labor as an absolute measure of exchange value, he notes that it was Ricardo who first linked value to production in such a way that labor could become more than simply a tool of measurement. Foucault writes, "[Ricardo's] analysis is not the first to give labour an important place in the economic process; but it explodes the unity of that notion, and singles out in a radical fashion, for the first time, the worker's energy, toil, and time that are bought and sold, and the activity that is at the origin of the value of things" (1994: 253).

product of exchange (192). As Foucault explains, the physiocrats believed that "before exchange, there is nothing but that rare or abundant reality provided by nature; demand on the one hand and relinquishment on the other are alone capable of producing value" (192). For the utilitarians as well, value stems from exchange. Foucault cites the utilitarian Étienne Bonnot de Condillac: "To say that a thing has value is to say that it is, or that we esteem it, good for some use. The value of things is thus founded on their utility, or, what amounts to the same thing, on the use we can make of them" (196). Foucault concludes, "The body of fundamental propositions used is common to both [utilitarians and physiocrats]: all wealth springs from the land; the value of things is linked with exchange; money has value as the representation of the wealth in circulation; circulation should be as simple and as complete as possible" (199).

Like the classical economists who succeeded them, the physiocrats and utilitarians distinguished between wealth and value, proposing that nature produces wealth, which in turn could be made valuable through exchange (195). For the classical economists this distinction proved to be somewhat more problematic than it was for the physiocrats and utilitarians, owing to their proposition that labor (not exchange) produces value. How would they explain why nature produces wealth but labor produces value? Doesn't the weather do as much labor as any farmer in producing a season's crops? The same point might be argued of other non-human means by which wealth is produced. Doesn't the machinery of a factory do as much work as the laborers who operate it? For the classical economists, nature and technology thus posed a singular problem: the non-human production of wealth.

Foucault writes that in order to explain why nature and technology could produce wealth but not value, the classical economists distinguished between "*the worker's capacity to labor*" and "*labor actually done*" (his italics, 219). While nature and machines can *perform* work, the classical economists argued, they do not have a *capacity* for work. This distinction allowed the classical economists to justify their exclusion of non-human labor from their theory of value. But what exactly is this capacity to labor, and why can only humans have it? This is the million dollar question; unfortunately it is often answered with circular reasoning. For Marx, for example, the capacity to labor describes "the aggregate of those mental and physical capabilities existing in a human being, which he exercises whenever he produces a use-value of any description" (1967: 336). In other words, labor-power is defined by its embodiment in humans and humans are defined by their capacity to labor.

Distinguishing labor from labor-power served Marx's argument well, allowing him to theorize a temporal gap between the sale of labor-power and the act of labor, a gap in which Marx locates the alienation of laborers from the products of their labor. Because of this gap, Marx argued, the laborer can be tricked into selling his labor's capacity to produce value for a wage that is less than the value his labor will actually produce; the laborer gets only what he needs to survive while his employer collects the surplus. In this way, Marx's affirmation that labor-power is by definition a human quality allowed him to negate the non-human production of value while also motivating the organization of labor against the unjust extraction of surplus value by capitalists.

Marx's affirmation of the unity and coherence of the human body in his theory of value is curious given how contemporaneous understandings in biology—a field in which Marx was interested—drew this unity/coherence into question. As Foucault notes in *The Order of Things*, the study of biological functions in the life sciences at the end of the 18th century precipitated a breakdown of the opposition between the living and the mechanical. He locates the origins of this breakdown (in part) in a shift in thought—from taxonomies of being which focused on visible organs to life sciences that did not take for granted the visible similarities between organisms. He writes, "In contrast with the mere gaze, which by scanning organisms in their wholeness sees unfolding before it the teeming profusion of their differences, anatomy, by really cutting up bodies into patterns, by dividing them up into distinct portions, by fragmenting them in space, discloses the great resemblances that would otherwise have remained invisible" (1994: 269). For the life sciences, organizing the body and body parts in terms of functions thus served to "relate together totalities of elements without the slightest visible identity" (265). This identification of the commonalities between visibly different bodies might have suggested that Marx was right, that there is a unified, coherent human body. However, Foucault argues, what bodies held in common—their functions—suggested instead the extent to which they were mechanical. He concludes that by the end of the 18th century, life could not be easily distinguished from the mechanical (269).

In *Discipline and Punish*, Foucault uses the concept of docility to describe this breakdown. In contrast to Marx's concept of labor-power, which affirms the unity/coherence of the human body, Foucault's "docile body" avoids "treating the body, *en masse*, ‘wholesale,’ as if it were an indissociable unity” (1995: 137), with the underlying idea that modern techniques of power work the body “ ‘retail,’ individually; exercising upon it a subtle coercion, obtaining holds upon it at the level of the mechanism itself—movements, gestures, attitudes, rapidity; an infinitesimal power over the active body” (137). In producing docile bodies, modern techniques of power do not so much turn the body into a machine as they render legible (or determine, to use Barad’s term) its technical organization. Once the body’s technical organization is rendered legible, its functions can be contracted out to non-bodily matter. For example, as Sterne documents, once the ear’s tympanic function was isolated and studied, it could be reproduced in the stylus of a phonograph. Again, if this makes it seem as if machines are made to imitate bodies, I would like to reiterate that modern techniques of power render this distinction less practicable.

As techniques of docility emerge in the late 18^{th} century alongside shifts in biology (and, it should be noted, physics), new techniques of engaging bodily matter arise in the late 20^{th} century alongside the advent of information theory and related fields (e.g. perceptual coding). To theorize these techniques, I will turn to Eugene Thacker’s concept of biomedia, which—like Foucault’s “docility”— emphasizes “the technical reconditioning of the ‘biological’ ” while downplaying “ ‘technology’ as a tool” (2003b: 57). In this way, the concept of biomedia, like Foucault’s “docility,” avoids the human/machine distinction that often creeps into social analyses of technology. For example, Thacker distances “biomedia” from the concept of the posthuman, which despite its neologism, still conceptualizes technology as a tool or, at best, a prosthetic, preserving a boundary “between human and machine, biology and technology, nature and culture” (2003a: 77).

In contrast to the concept of the posthuman, Thacker’s “biomedia” stresses an informational understanding of the body. He argues that the informationalization of bodily matter does not reduce the body to data, but rather configures the body digitally (89). Information as “the source code for all matter” thus becomes more important than “any notion of materiality or substance” (86), much like the study of anatomy in the late 18th century prioritized the body’s “invisible” functions over its visible organs according to Foucault. Thacker thus concludes, “Information equals the body, which by extension implies that information equals biology and/or materiality, which leads from the contingency of the biological body to the emancipation of the biological body through the technical potential of informatics” (87).

The biomediated body, like the docile body, is technical from within. What distinguishes the biomediated body from the docile body is the scale at which informational measures target bodily matter, the character of this targeting, and crucially, the interventions it makes possible. “When the body is considered as essentially information,” Thacker writes, “this opens onto the possibility that the body may also be programmed and reprogrammed” (86). He argues that the informational body can be “improved, enhanced, or analyzed in further detail” (77). Thacker is especially interested in the interventions made by biotechnology firms. He writes, “The technologies in biotech are not simply objects or things, but rather liminal techniques for intervening in the body; they operate not mechanically (as does a prosthetic), externally (as does surgery), or through engineered foreign elements (as does gene therapy), but by harnessing biological (read: biological-as-natural) processes and directing them toward novel therapeutic ends" (93). In the case of perceptual coding—not traditionally considered a biotechnology, though a case could easily be made—these ends are not therapeutic so much as they are productive. Still, this falls in line with the general modus operandi of biotech firms. As Clough argues, "The development of biotechnology is central in making 'life itself' more productive. Or to put it another way, biotechnology puts the complexity of the pre-individual forces of non-organic life to work" (2007: 19).

Again, my purpose in drawing into question the coherent, unified human body at the center of Marx's theory of value with the concepts of docility and biomedia is not to prove his theory wrong, but rather to question its viability in the context of digital network technologies and, more specifically, the perceptual compression of audio data. As I argued in the previous chapter, the human-centeredness of Marx's labor theory of value makes it a poor fit to theorize how the transmission of data through the Internet produces value. But let's not throw out the baby with the bath water; the great insight of Marx's theory of value—its implication of the socialization of time in the production of value—remains critical in explaining how the transmission of data produces value. The human body (or bodily matter) has a new role to play in this production. The body is not the source of value, but rather through psychoacoustic coding participates in the socialization of time, making possible the compression of digital files so that they are small enough to transfer quickly through the Internet. In other words, the value of a unit of transmission is determined in part through the ability of code to "hear" before transmission occurs. The biopolitical, biomediated production of human bodily matter is central to this process, as it participates in the determination of the value of transmission.

Conclusion

Scholars of the peer-to-peer movement often credit the MP3 with inspiring Napster's development. The advent of peer-to-peer networks would not have been possible without the MP3 and techniques of psychoacoustic coding which made it possible to compress audio files to a size small enough to be reproduced and distributed through the Internet efficiently. While not discounting this historical connection, the argument of this chapter reveals a deeper and less obvious connection between psychoacoustic coding and peer-to-peer networks. If peer-to-peer networks made it possible (for the first time) to reproduce and distribute copyrighted content efficiently and with little legal risk, realizing the viral character of data and catalyzing the value of transmission, psychoacoustic coders participated from the beginning in socializing the time of transmission, determining its value.

Less obvious still is the relation between methods of compression and the transmission of data at the global level. While compression would seem to decrease Internet traffic, systemically it facilitates the reproduction and distribution of large files through the Internet, increasing traffic. In other words, compression decreases transfer times locally, while ultimately increasing transfer times globally. Methods of compression do not simply allow large files to be transmitted through the Internet, they make the Internet a desirable method of reproducing and distributing content, suggesting that on a systemic level when data is compressed, capital expands.

This dynamic should resonate with students of Marx, as he looked to technological development to explain the temporary devaluation of human labor. Because value is produced through socialized labor-time, Marx reasoned, new technologies (i.e. technologies which have not been adopted throughout society) yield more value from human labor. In the case of perceptual compression technologies, however, this dynamic is reversed. Because value is produced through the transmission of data and measured through socialized transmission-time, new technologies (such as psychoacoustic coders) which reduce transfer times yield more value from the transfer of data than the social average. In this way, the non-human produces value while bodily matter participates in the socialization of (non-human) time.

To be certain, this argument represents a departure from the ways technology is most often approached by scholars of the social. Typically, technology is examined in relation to human subjects. Some scholars focus on the effects of technological development on the (human) labor process. Some focus on how technologies are used more generally (by humans), shaping the character of our lives. And some focus on the social effects of technology on a systemic level—the cumulative effects of individual use. I have argued that in order to make sense of a digital mode of production, and more specifically of the transformation of economies of culture catalyzed by peer-to-peer networks, we have to move beyond this focus on the human, acknowledging and theorizing how the social operates "below" the human body, at the level of matter.

Bibliography

Aberer, K, LO Alima, A Ghodsi, S Girdzijauskas, S Haridi, and M Hauswirth. 2005. "The essence of P2P: A reference architecture for overlay networks." *P2P2005, The 5th IEEE International Conference on Peer-to-Peer Computing*.

Alderman, John. 2001. *Sonic Boom: Napster, MP3, and the New Pioneers of Music*. Cambridge: Perseus.

Androutsellis-Theotokis, S and D Spinellis. 2004. "A Survey of Peer-to-Peer Content Distribution Technologies." *ACM Computing Surveys* 36: 335-371.

Apple. 2005. "Apple Announces iTunes 6 With 2,000 Music Videos, Pixar Short Films & Hit TV Shows." October 12. Retrieved September 1, 2009 from http://www.apple.com/pr/library/2005/oct/12itunes.html.

—. 2007. "100 Million iPods Sold." April 9. Retrieved September 1, 2009 from http://www.apple.com/pr/library/2007/04/09ipod.html.

—. 2008a. "App Store Downloads Top 100 Million Worldwide." September 9. Retrieved September 1, 2009 from http://www.apple.com/pr/library/2008/09/09appstore.html.

—. 2008b. "iPhone SDK Downloads Top 250,000." June 9. Retrieved September 1, 2009 from http://www.apple.com/pr/library/2008/06/09iphone_sdk.html.

—. 2008c. "iTunes Store Top Music Retailer in the US." April 3. Retrieved September 1, 2009 from http://www.apple.com/pr/library/2008/04/03itunes.html.

—. 2008d. "iTunes Store Tops Over Five Billion Songs Sold." June 19. Retrieved September 1, 2009 from http://www.apple.com/pr/library/2008/06/19itunes.html.

Barad, Karen. 2007. *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*. Durham: Duke University Press.

Barkai, D. 2002. "Technologies for Sharing and Collaborating on the Net." *P2P01: First International Conference on Peer-to-Peer Computing*.

Bauwens, M. 2005. "The Political Economy of Peer Production." *Ctheory.net*. Retrieved September 1, 2009 from http://www.ctheory.net/articles.aspx?id=499.

Beller, J. 1998. "Capital/Cinema." in *Deleuze and Guattari: New Mappings in Politics/Philosophy/Culture*, edited by E. Kaufman and K. Heller. Minneapolis: University of Minnesota Press.

Brandenburg, Karlheinz. 1999. "MP3 and AAC Explained." *AES 17th International Conference on High Quality Audio Coding*.

Bregman, Albert S. 1990. *Auditory Scene Analysis: The Perceptual Organization of Sound*. Cambridge: MIT Press.

Caffentzis, C. George. 1997. "Why Machines Cannot Create Value; or, Marx's Theory of Machines." Pp. 29-56 in *Cutting Edge: Technology, Information Capitalism and Social Revolution*, edited by J. Davis, T. Hirsch, and M. Stack. London: Verso.

Carline, Dylan TF, Reuben Edwards, and Paul Coulton. 2001. "Psychoacoustic Properties of Multi-Channel Audio Signals." *2nd Annual Postgraduate Symposium on The Convergence of Telecommunications, Networking, and Broadcasting*.

Carter, Bill. 2009. "A New Ratings Low for ABC," in *Media Decoder*. Retrieved September 1, 2009 from http://mediadecoder.blogs.nytimes.com/2009/08/11/a-new-ratings-low-for-abc/?scp=2&sq=june%20television%20ratings&st=cse.

Castells, Manuel. 1996. *The Rise of the Network Society*. Malden: Blackwell Publishers.

Christakis, N. 2008. "Social Networks Are Like the Eye." *The Third Culture*. Retrieved September 1, 2009 from http://www.edge.org/3rd_culture/christakis08/christakis08_index.html.

Clough, Patricia Ticiento and Craig Willse. Forthcoming. "Human Security/National Security: Gender Branding and Population Racism." in *Beyond Biopolitics: Essays on the Governance of Life and Death*, edited by P. T. Clough and C. Wilse. Durham: Duke University Press.

Clough, Patricia Ticineto. 2000. *Autoaffection: Unconscious Thought in the Age of Teletechnology*. Minneapolis: University of Minnesota Press.

—. 2007. "The Affective Turn: Political Economy and the Biomediated Body." Unpublished Manuscript.

Clough, Patricia Ticineto, Greg Goldberg, Rachel Schiff, Aaron Weeks, and Craig Willse. 2007. "Notes towards a theory of affect-itself." *Ephemera: Theory and Politics in Organization* 7: 60–77.

Cohen, Bram. 2003. "Incentives Build Robustness in BitTorrent." May 22. Retrieved September 1, 2009 from http://www.bittorrent.org/bittorrentecon.pdf.

comScore. 2009. "YouTube Surpasses 100 Million U.S. Viewers for the First Time." Retrieved September 1, 2009 from http://www.comscore.com/press/release.asp?press=2741.

Cooper, Helene. 2009. "Obamas Give Queen Elizabeth an iPod." *The New York Times*, April 2. Retrieved September 1, 2009 from http://www.nytimes.com/2009/04/02/world/europe/02ipod.html?_r=1.

Currah, A. 2007. "Managing Creativity: The Tensions Between Commodities and Gifts in a Digital Networked Environment." *Economy & Society*: 467-494.

Deleuze, G. 1987. *A Thousand Plateaus*. Translated by B. Massumi. Minneapolis: University of Minnesota Press.

Dienst, R. 1994. *Still Life in Real Time: Theory After Television*. Durham: Duke University Press.

Dyer-Witheford, N. 1999. *Cyber-Marx: Cycles and Circuits of Struggle in High Technology Capitalism*. Urbana Champaign: University of Illinois Press.

Economides, Nicholas. 2005. "The Economics of the Internet Backbone." in *Handbook of Telecommunications Economics*, vol. 2, edited by S. K. Majumdar, I. Vogelsand, and M. E. Cave. Amsterdam: Elsevier B.V.

Electronic Frontier Foundation. 2008. "RIAA v. The People: Five Years Later." Retrieved September 1, 2009 from http://www.eff.org/wp/riaa-v-people-years-later.

Erikkson, K. 2005. "On the Ontology of Networks." *Communication and Critical/Cultural Studies* 2: 305-323.

Foucault, Michel. 1994. *The Order of Things: An Archaeology of The Human Sciences*. Translated by Tavistock/Routledge. New York: Vintage Books.

—. 1995. *Discipline and Punish: The Birth of the Prison*. Translated by A. Sheridan: Vintage Books.

—. 2003. *Society Must Be Defended: Lectures at the College de France 1975-1976*. Translated by D. Macey: Vintage Picador.

Fried, Ina. 2003. "Will iTunes make Apple shine?," in *CNET news*. Retrieved September 1, 2009 from http://news.cnet.com/2100-1041-5092559.html?tag+nl.

Galloway, A. 2004. *Protocol: How Control Exists After Decentralization*. Cambridge: MIT Press.

Galloway, A and E Thacker. 2007. *The Exploit: A Theory of Networks*. Minneapolis: University of Minnesota Press.

Goldstein, Paul. 2003. *Copyright's Highway: From Gutenberg to the Celestial Jukebox*. Stanford: Stanford University Press.

Grover, Ronald and Peter Burrows. 2007. "Universal Music Takes on iTunes." *Business Week*. Retrieved September 1, 2009 from http://www.businessweek.com/magazine/content/07_43/b4055048.htm.

Haraway, D. 1991. "A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century." Pp. 149-181 in *Simians, Cyborgs and Women: The Reinvention of Nature*. New York: Routledge.

Harvey, D. 1989. *The Limits to Capital*. Chicago: The University of Chicago Press.

—. 2008. "Reading Marx's Capital," Retrieved September 1, 2009 from http://davidharvey.org.

Helft, Miguel. 2009. "YouTube Shares Revenue From Downloaded Videos," in *Bits*. Retrieved September 1, 2009 from http://bits.blogs.nytimes.com/2009/02/12/youtube-shares-revenue-from-downloaded-videos/.

Hesseldahl, Arik. 2009. "Deconstructing Apple's Tiny iPod Shuffle." *Business Week*, April 13. Retrieved September 1, 2009 from http://www.businessweek.com/technology/content/apr2009/tc20090410_507831.htm.

Hoeg, W, L Christensen, and R Walker. 1997. "Subjective Assessment of Audio Quality: The Means and Methods within the EBU." *EBU Technical Review*.

Jameson, Frederic. 2001. *Postmodernism, or, The Cultural Logic of Late Capitalism*. Durham: Duke University Press.

Katyal, SL. 2005. "Privacy vs. Piracy." *Yale Journal of Law and Technology*: 223-345.

Kelly, K. 2008. "Better Than Free," in *The Technium*. Retrieved September 1, 2009 from http://www.kk.org/thetechnium/archives/2008/01/better_than_fre.php.

Kelly, Kevin. 2009. "People Want To Pay," in *The Technium*. Retrieved September 1, 2009 from http://www.kk.org/thetechnium/archives/2008/08/people_want_to.php.

Kolata, G. 2007. "Find Yourself Packing It On? Blame Friends." *The New York Times*, July 26. Retrieved September 1, 2009 from http://www.nytimes.com/2007/07/26/health/26fat.html.

Kunzmann, G, R Nagel, T Hoßfeld, A Binzenhöfer, and K Eger. 2007. "Efficient Simulation of Large-Scale P2P Networks: Modeling Network Transmission Times." *15th EUROMICRO International Conference on Parallel, Distributed, and Network-Based Processing*.

Labaton, Stephen. 2008. "F.C.C. to Act on Delaying of Broadband Traffic." *The New York Times*, February 25. Retrieved September 1, 2009 from http://www.nytimes.com/2008/02/25/technology/25cnd-fcc.html.

Lash, Scott. 1990. *Sociology of Postmodernism*. New York: Routledge.

Latour, B. 2005. *Reassembling the Social: An Introduction to Actor-Network Theory*. New York: Oxford University Press.

Leonard, Devin. 2008. "Apple defeats music rate hike." *Fortune*. Retrieved September 1, 2009 from http://money.cnn.com/2008/10/02/technology/ituneswins.fortune/.

Lessig, L. 2004. *Free Culture: How Big Media Uses Technology and the Law to Lock Down Culture and Control Creativity*. New York: Penguin Press.

Liebowitz, Stan J. 2006. "File Sharing: Creative Destruction or Just Plain Destruction?" *The Journal of Law and Economics* 49: 1-28.

Lien, Y and H Xu. 2007. "A UDP Based Protocol for Distributed P2P File Sharing." *ISADS'07: Eighth International Symposium on Autonomous Decentralized Systems*.

Liu, Y, L Xiao, and LM Ni. 2007. "Building a Scalable Bipartite P2P Overlay Network." *IEEE Transactions on Parallel and Distributed System* 18: 1296-1306.

Lohr, Steve. 2008. "Video Road Hogs Stir Fear of Internet Traffic Jam." *The New York Times*, March 13. Retrieved Septemeber 1, 2009 from http://www.nytimes.com/2008/03/13/technology/13net.html.

Lombardi, V. "Masking and Perceptual Coding," Retrieved September 1, 2009 from http://minidisc.org/MaskingPaper.html.

Mariano, Gwendolyn. 2001. "Napster fans stretch across the border," in *CNET News*. Retrieved September 1, 2009 from http://news.cnet.com/Napster-fans-stretch-across-the-border/2100-1023_3-255378.html.

Marx, Karl. 1967. *Capital*, Vol. 1. Translated by S. Moore and E. Aveling. New York: International Publishers.

Massumi, B. 2007. "The Thinking-Feeling of What Happens: An Interview with Brian Massumi." in *Interact or Die*, edited by J. Brouwer and A. Mulder. Rotterdam: V2 Publishing.

Massumi, Brian. 2002. *Parables for the Virtual: Movement, Affect, Sensation*: Duke University Press.

Media Metrix. 2001. "Napster Service Continues Rapid Growth, Reports Jupiter Media Metrix."

Mediadefender.com. Retrieved September 1, 2009 from http://www.mediadefender.com/.

Newman, M, A-L Barabasi, and D Watts. 2006. "The Structure and Dynamics of Networks." Princeton: Princeton University Press.

Oberholzier, F and K Strumpf. 2007. "The Effect of File Sharing on Record Sales: An Empirical Analysis." *Journal of Political Economy*: 1-42.

Owen, Bruce M. 1999. *The Internet Challenge to Television*. Cambridge: Harvard Unitersity Press.

Painter, Ted and Andreas Spanias. 2000. "Perceptual Coding of Digital Audio." *Proceedings of the IEEE* 88: 451-515.

Pehnelt, Gernot. 2008. "The Economics of Net Neutrality Revisited." *Jena Economic Research Papers*.

Pesce, Mark. 2005. "Piracy is *Good*? How *Battlestar Gallactica* Killed Broadcast TV," in *Mindjack*. Retrieved September 1, 2009 from http://www.mindjack.com/feature/piracy051305.html.

Pierce, JR. 1961. *Symbols, Signals, and Noise: The Nature and Process of Communication*. New York: Harper Torchbooks.

Protevi, John. 2001. *Political Physics: Deleuze, Derrida, and the Body Politic*. New York: The Athlone Press.

Qiao, Y and FE Bustamante. 2005. "Elders Know Best – Handling Churn in Less Structured P2P Systems." *P2P2005, The 5th IEEE International Conference on Peer-to-Peer Computing*.

Rajan, KS. 2006. *Biocapital: The Constitution of Postgenomic Life*. Durham: Duke University Press.

Rappa, M. A. 2004. "The utility business model and the future of computing services." *IBM Systems Journal* 43: 32-42.

Rayport, Jeffrey F. 1999. "The truth about Internet business models." *Strategy & Business*.

Recording Industry Association of America. 2008. "2008 U.S. Manufacturers' Unit Shipments and Value Chart." Retrieved September 1, 2009 from http://www.riaa.com/keystatistics.php.

Robertson, Grant. 2006. "Web not seen surpplanting TV any time soon; Bandwidth costs pose major hurdle, consulting firm says." *The Globe and Mail (Canada)*, June 10.

—. 2007. "Broadband access not necessarily a vote for Web TV; Broadcasters mindful of higher user costs." *The Globe and Mail (Canada)*, April 2.

Safenet-inc.com. Retrieved September 1, 2009 from http://www.safenet-inc.com/.

Samuels Gibbs, Adrienne. 2009. "Exclusive: Vibe Closes Down," in *EbonyJet.com*. Retrieved September 1, 2009 from http://www.ebonyjet.com/culture/index2.aspx?id=13696.

Seife, Charles. 2006. *Decoding the Universe*. New York: Penguin Group.

Skype. 2008. "Skype Q4 Fast Facts 2008." Retrieved September 1, 2009 from http://ebayinkblog.com/wp-content/uploads/2009/01/skype-fast-facts-q4-08.pdf.

Stelter, Brian. 2008. "Some Media Companies Choose to Profit From Pirated YouTube Clips." *The New York Times*, August 15. Retrieved September 1, 2009 from http://www.nytimes.com/2008/08/16/technology/16tube.html.

Sterne, Jonathan. 2003. *The Audible Past: Cultural Origins of Sound Reproduction*. Durham: Duke University Press.

—. 2006a. "The Death and Life of Digital Audio." *Interdisciplinary Science Reviews* 21: 328-348.

—. 2006b. "The MP3 as Cultural Artifact." *New Media & Society* 8.

Stone, Brad. 2008. "BitTorrent Sacks Half its Staff," in *Bits*. Retrieved September 1, 2009 from http://bits.blogs.nytimes.com/2008/11/07/bittorrent-sacks-half-its-staff/.

Stone, Brad and Miguel Helft. 2009. "In Developing Countries, Web Grows Without Profits." *The New York Times*, April 26. Retrieved September 1, 2009 from http://www.nytimes.com/2009/04/27/technology/start-ups/27global.html.

Strauss, Neil. 2003. "Apple Finds a Route for Online Music Sales." *The New York Times*, May 29. Retrieved September 1, 2009 from http://www.nytimes.com/2003/05/29/arts/the-pop-life-apple-finds-a-route-for-online-music-sales.html.

Streeter, Thomas. 1996. *Selling the Air: A Critique of the Policy of Commercial Broadcasting in the United States*. Chicago: The University of Chicago Press.

Swanson, Bret. 2007. "The Coming Exaflood." *The Wall Street Journal*, January 20.

Tadros, Victor. 1998. "Between Governance and Discipline: The Law and Michel Foucault." *Oxford Journal of Legal Studies* 18: 75-103.

Terranova, Tiziana. 2004. *Network Culture: Politics for the Information Age*. Ann Arbor: Pluto Press.

Thacker, Eugene. 2003a. "Data Made Flesh: Biotechnology and the Discourse of the Posthuman." *Cultural Critique*: 72-97.

—. 2003b. "What Is Biomedia?" *Configurations* 11: 47-79.

The Economist. 2008. "Surviving the Exaflood." December 4. Retrieved September 1, 2009 from http://www.economist.com/sciencetechnology/tq/displayStory.cfm?story_id=12673221.

Thompson, G. 2003. *Between Hierarchies and Markets: The Logic and Limits of Network Organization*. Oxford: Oxford University Press.

Thrift, N. 2006. "Re-inventing Invention: New Tendencies in Capitalist Commodification." *Economy and Society* 35: 279-306.

Vaidhyanathan, S. 2001. *Copyrights and Copywrongs: The Rise of Intellectual Property and How It Threatens Creativity*. New York: NYU Press.

Vaidhyanathan, Siva. 2004. *The Anarchist in the Library: How the Clash Between Freedom and Control is Hacking the Real World and Crashing the System*. New York: Basic Books.

Vincent, Emmanuel, Maria G Jafari, and Mark D Plumbley. 2006. "Preliminary Guidelines for Subjective Evaluation of Audio Source Separation Algorithms." *Department of Electronic Engineering, Queen Mary, Univeristy of London*.

Wang, C and L Xiao. 2006. "An Effective P2P Search Scheme to Exploit File Sharing Heterogeneity." *IEEE Transactions on Parallel and Distributed Systems* 18: 145-157.

Weaver, Warren. 1964. "Some Recent Contributions to the Mathematical Theory of Communications." in *The Mathematical Theory of Communication*. Chicago: University of Illinois Press.

Wu, Tim. 2003. "Network Neutrality, Broadband Discrimination." *Journal of Telecommunications and High Technology Law* 2.

Yang, Dai Tracy, CC Jay Kuo, and Chris Kyriakakis. 2005. *High-Fidelity Multichannel Audio Coding*. New York: Hindawi Publishing.

Zeinalipour-Yazti, D, V Kalogeraki, and D Gunopulos. 2007. "pFusion: A P2P Architecture for Internet-Scale Content-Based Search and Retrieval." *IEEE Transactions on Parallel and Distributed Systems* 18: 804-817.