The Centripetal Network:
How the Internet Holds Itself
Together, and the Forces Tearing It
Apart

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Two forces are in tension as the Internet evolves. One pushes toward interconnected common platforms; the other pulls toward fragmentation and proprietary alternatives. Their interplay drives many of the contentious issues in cyberlaw, intellectual property, and telecommunications policy, including the fight over "network neutrality" for broadband providers, debates over global Internet governance, and battles over copyright online. These are more than just conflicts between incumbents and innovators, or between "openness" and "deregulation." The roots of these conflicts lie in the fundamental dynamics of interconnected networks.

Fortunately, there is an interdisciplinary literature on network properties, albeit one virtually unknown to legal scholars. The emerging field of network formation theory explains the pressures threatening to pull the Internet apart, and suggests responses. The Internet as we know it is surprisingly fragile. To continue the extraordinary outpouring of creativity and innovation that the Internet fosters, policy makers must protect its composite structure against both fragmentation and excessive concentration of power.

This paper, the first to apply network formation models to Internet law, shows how the Internet pulls itself together as a coherent whole. This very

343

process, however, creates and magnifies imbalances that encourage balkanization. By understanding how networks behave, governments and other legal decision makers can avoid unintended consequences and target their actions appropriately. A network-theoretic perspective holds great promise to inform the law and policy of the information economy.

TABLE OF CONTENTS

INTRODUCTION

"Sadly, it looks like the period in which the Internet functions seamlessly is over."[1] — *Vint Cerf*

Two forces are in tension as the Internet evolves. One pushes toward interconnected common platforms; the other pulls toward fragmentation and proprietary alternatives. The interplay of these forces drives many of the contentious issues in cyberlaw, intellectual property, and telecommunications policy. These issues include the fight over "network neutrality"[2] for broadband providers, debates over global Internet governance, and battles over online copyright protection. These are more than just conflicts between incumbents and innovators, or between "openness" and "deregulation." The roots of these battles lie in the fundamental dynamics of interconnected networks. Fortunately, there is an interdisciplinary literature on network properties, albeit one virtually unknown to legal scholars.[3] The emerging field of network formation theory explains the pressures threatening to pull the Internet apart and suggests responses.[4] The Internet as we know it is surprisingly fragile.[5] To continue the extraordinary creativity and innovation that the Internet has and

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[1] Rana Foroohar, *The Internet Splits Up*, NEWSWEEK INT'L, May 15, 2006, at 38, *available at* http://www.newsweek.com/id/47643. Vint Cerf, co-creator of the core Internet protocol, is often called the "Father of the Internet."

[2] *See* Kevin Werbach, *Only Connect*, 22 BERKELEY TECH. L.J. 1234, 1269-70; Tim Wu, *Network Neutrality, Broadband Discrimination*, 2 J. ON TELECOMM. & HIGH TECH. 141, 143 (2003) [hereinafter Wu, *Network Neutrality*]; Tim Wu, *The Broadband Debate, A User's Guide*, 3 J. ON TELECOMM. & HIGH TECH. 69, 86 (2004); Christopher S. Yoo, *Beyond Network Neutrality*, 19 HARV. J.L. & TECH. 1, 37-39 (2005) [hereinafter Yoo, *Beyond Network Neutrality*]; Christopher S. Yoo, *Network Neutrality and the Economics of Congestion*, 94 GEO. L.J. 1847, 1900-04 (2006) [hereinafter Yoo, *Economics of Congestion*]. *See infra* note 167.

[3] *See* Katherine J. Strandburg et al., *Law and the Science of Networks: An Overview and an Application to the "Patent Explosion,"* 21 BERKELEY TECH. L.J. 1293, 1295 n.6 (2006) ("The application of network science to law is in its infancy.").

[4] *See infra* Part III.

[5] *See infra* Part II.

continues to foster, policy makers must protect its composite structure[6] against both fragmentation and excessive concentration of power.

Network formation theory helps explain the pressures around network integration that promote such beneficial interconnection on the Internet and the countervailing forces at work today.[7] A new branch in the broader field of network science, network formation theory models what happens as networks add and remove connections. Among other things, network formation theory shows that, as networks develop, they create new dominant nodes within the interconnected environment.[8] As the network's hubs grow increasingly powerful, they accumulate a growing share of value. This creates two sources of tension. Those in the hubs see the opportunity to become more proprietary, and those outside the hubs worry that the hubs will dominate them. Both tendencies produce reactions that mitigate the network's connectivity and all the value it creates.[9]

Network formation theory provides new insights for important legal and policy issues. For instance, China's efforts to develop its own Internet addressing systems represent a potential threat to the basic functioning of the Internet.[10] Moreover, the greatest danger that telephone and cable companies may pose to the Internet is not their discriminatory treatment of certain online content, but their consolidation of Internet backbone infrastructure.[11] Furthermore, overzealous extension of online copyright protection threatens not only independent content creators, but also the massive constellation of businesses built on top of Internet search engines. Policy makers must appreciate these risks and the dangers that common platforms create when they become restrictive monopolies.[12]

Understanding Internet development through the lens of network formation theory also contributes to the larger project of network law. In light of the growing economic and social significance of the Internet, skirmishes between network operators, content providers, users, equipment manufacturers, and governments have exploded

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[6] *See infra* Part I.B.

[7] *See generally* Matthew O. Jackson, *The Stability and Efficiency of Economic and Social Networks*, *in* ADVANCES IN ECONOMIC DESIGN 319 (S. Koray & M. Sertel eds., 2003) (summarizing the findings of network formation theory).

[8] *See infra* Part III.

[9] *See infra* Part III.C.

[10] *See infra* Part II.A.3.

[11] Backbones are the Internet's long-distance links between local access networks. *See infra* Part II.B.2.

[12] For a discussion of information platforms and their legal significance, see *infra* Part IV.C.1.

along a variety of legal fronts. Traditional notions of property rights or competition policy are ill suited for this new environment.[13] Yet efforts to develop novel legal frameworks for cyberspace have largely failed on both descriptive and normative grounds.[14]

Network science, with its rigorous grounding in both abstract mathematics and empirical studies, can provide the basis for a new approach to cyberspace law. Until now, although a few findings of network science researchers have received attention in legal scholarship, the network formation theories detailed here have not.[15] This article begins the process of applying network formation theory to Internet law and policy.

Part I outlines the structure of the Internet and the tensions it experiences between pressures toward centralization and decentralization. Part II provides four major case studies of Internet fragmentation: addressing and governance, backbone interconnection, network neutrality, and content reuse. Part III explores how network formation theory and other findings from network science explain these developments. Part IV uses the teachings of network formation theory to analyze the history and development of the Internet. It then suggests an approach for Internet law based on network formation principles.

I.   THE FATE OF THE INTERNET

A.   *Centralizing and Decentralizing Forces*

Like the railroad system or the electric power grid, the Internet is a collection of independent networks that coordinate their actions, forming what appears to be a seamless collective. This structure allows all users, application creators, and content providers to leverage the full power of the global inter-network.[16] The Internet fosters innovation by eliminating transaction costs, enabling new services to

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[13]   *See infra* Part IV.C.1.

[14]   In other words, these new approaches neither described the actual behavior of private and governmental actors on the Internet nor offered sufficient guidance for policy makers. *See* JACK GOLDSMITH & TIM WU, WHO CONTROLS THE INTERNET? ILLUSIONS OF A BORDERLESS WORLD 142 (2006).

[15]   As of this writing, the sole reference in the LEXIS U.S. Law Review database to the extensive network formation writings of Stanford professor Matthew O. Jackson, a leading scholar in the field, is a footnote disclaiming the authors' intent to address this body of research. *See infra* note 231. The phrase "network formation theory" does not appear in the database.

[16]   *See infra* Part IV.B.

emerge.[17]   Today, however, centrifugal[18] forces of dissolution are ascendant.[19] The growing potential for balkanization[20] poses grave threats to the Internet as an engine of innovation, economic growth, and creative expression.

The Internet thrives because its powerful inward-pulling, or "centripetal,"[21] forces promote interconnection and federation at every layer of functionality.[22] The very name, "Internet," is short for "inter-network." The Internet is a compound system that manifests itself as a single entity. When President George W. Bush declared during a 2004 debate with John Kerry that, "I hear rumors on the Internets that we're going to have a draft," his use of the plural form was widely viewed as a gaffe.[23] It is not obvious, however, why there is only one Internet, and not many Internets.

The Internet pulls together heterogeneous parts and turns them into a seemingly uniform whole. Devices, applications, and network links may have different capabilities. Users may choose to purchase different levels of access but these are local variations within the Internet environment, not choices among competing Internets.[24]

The existence of one unified Internet creates tremendous benefits because the network experiences what economists call increasing returns to scale.[25]   More users, network operators, device manufacturers, service providers, and content creators sharing a common environment produce a virtuous circle of exponentially

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[17]   *See infra* Part II.C.

[18]   *See infra* note 21.

[19]   *See infra* Part II.

[20]   As used in this paper, "balkanization" means dissolution into distinct and potentially hostile sub-units. No connection to the geographical region of the Balkan Mountains in Eastern Europe or the geopolitical history of that part of the world is implied.

[21]   The terms "centripetal" and "centrifugal" are used generically in this paper to describe inward-pulling and out-pulling forces. The terms come from Newtonian physics, but are not intended to refer to any specific physical phenomenon. *See* LAWRENCE S. LERNER, PHYSICS FOR SCIENTISTS AND ENGINEERS 129-30 (1996) (defining centripetal and centrifugal force).

[22]   *See infra* Part I.B. As used in this paper, "interconnection" is the linkage of two networks. "Federation" is a deeper integration into a single virtual network.

[23]   James Harding, *A Draw Is as Good as a Win for Bush's Relieved Supporters*, FIN. TIMES, Oct. 11, 2004, at 7.

[24]   *See infra* Part IV.A.

[25]   *See infra* Part IV.B; *see also* W. BRIAN ARTHUR, INCREASING RETURNS AND PATH DEPENDENCE IN THE ECONOMY 1-4 (1994) (describing concept of increasing returns); George Gilder, *Metcalfe's Law and Legacy*, FORBES ASAP, Sept. 13, 1993, at S158 (explaining significance of increasing returns for telecommunications).

greater value (both economic and social).[26] Each user can access more resources (or other users) and each provider can reach more customers in a federated environment. To take just a few examples, any user can exchange email with more than a billion other global Internet users; entrepreneurs can launch services like eBay or YouTube on top of the network and quickly turn them into multi-billion dollar businesses; and Google can index billions of pages to both organize the world's information and power a phenomenally profitable and targeted advertising business.

There are other significant benefits to the Internet's federated structure. Common networks facilitate innovation independent of the infrastructure platform, which can create significantly more value than the network itself.[27] In other words, a company such as Amazon.com need not worry about how its customers access the network. It can deploy new services and features without making special arrangements with network operators.   Furthermore, open platforms promote democratic values of individual expression and empowerment.[28] Finally, interconnected networks may foster economic growth by unleashing the diversity of human communication.[29]

Nonetheless, the absence of alternative Internets is not a foregone conclusion. Many analogous platforms are balkanized in ways the Internet is not. There are multiple stock markets, even though these are networked exchanges like the Internet. Any telephone can call any other, but in the United States, a mobile phone from one carrier usually cannot be used to subscribe to another carrier. There are two competing formats for high-definition DVD players, despite the

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[26] Network operators such as AT&T and Comcast operate physical networks that carry communications or data traffic. Device manufacturers build end-user devices such as personal computers, mobile phones, and iPods. Service providers, as used in this paper, are companies such as Google, eBay, and Amazon.com, which deliver functionality to customers using the Internet.

[27] *See* Brett Frischmann, *An Economic Theory of Infrastructure and Commons Management*, 89 MINN. L. REV. 917, 937 (2005) (noting that commons management principle "catalyzes innovation through the creation of and experimentation with new uses").

[28] *See* Yochai Benkler, *From Consumers to Users: Shifting the Deeper Structures of Regulation Toward Sustainable Commons and User Access*, 52 FED. COMM. L.J. 561, 579 (2000) (promoting commons as more "effective means than traditional structural media regulation of securing robust democratic discourse and individual expressive freedom").

[29] *See* Susan Crawford, *The Internet and the Project of Communications Law*, 55 UCLA L. REV. 359, 387-90 (2007) ("Our national economic policy . . . should be closely tied to communications policy that facilitates the interactive, group-forming attributes of the Internet.").

obvious benefits of standardization.[30]   Even in the history of digital information networks, the Internet's uniformity is the exception, rather than the rule. It took years for the dominant consumer online services such as AOL and Compuserve to even offer fully interoperable email, for example.[31]

How did the Internet achieve its open, composite structure? The answer is not obvious. The Internet has no master control element that decides where information flows.[32]   Instead, individual routers and networks pass along packets of data between their origin and destination. Moreover, the Internet is both global and, in most of the world, a creature of the private sector.[33]   Though it traces its roots to American military and government research networks, today's commercial Internet is not a government-built system.[34]   Nor is it a pervasively regulated network like the public switched telephone network[35] or virtually every other major communications network.[36] External mandates cannot explain the Internet's universality.

Remarkably, for all the complexity and the rapid changes in their constituent technologies, the networks and systems that combine to form the Internet do so largely voluntarily. The Internet pulls *itself* together. This behavior — coordination without a coordinator, competitive advantage without proprietary dominance — has enabled

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[30]   Sarah McBride & Phred Dvorak, *Studios Strike HD-DVD Deals for Holiday 2005*, WALL ST. J., Nov. 29, 2004, at B1. In this case, Sony's Blu-ray format eventually triumphed over the competing HD-DVD format.   *See* Martin Fackler, *Toshiba Acknowledges Defeat as Blu-ray Wins Format Battle*, N.Y. TIMES, Feb. 20, 2008, at C2.

[31]   *See* Mark Lemley & David McGowan, *Legal Implications of Network Economic Effects*, 86 CAL. L. REV. 479, 552 (1998) ("Each of these computer networks was largely incompatible with the others, with the result that joining a bulletin board allowed you to communicate only with other members of that bulletin board. Interconnection protocols, beginning with Usenet and SMTP, allowed messages to be transferred between different groups of networked computers.").

[32]   *See* Kevin Werbach, *Digital Tornado: The Internet and Telecommunications Policy* 20 (FCC Office of Plans & Policy, Working Paper No. 29, 1997), *available at* http://www.fcc.gov/Bureaus/OPP/working_papers/oppwp29pdf.html   (describing governance and management of Internet).

[33]   China is an obvious counter-example to private control of the Internet. *See infra* Part II.A.3.

[34]   *See generally* KATIE HAFNER & MATTHEW LYON, WHERE WIZARDS STAY UP LATE: THE ORIGINS OF THE INTERNET (1996) (detailing history of Internet); JOHN NAUGHTON, A BRIEF HISTORY OF THE FUTURE: THE ORIGINS OF THE INTERNET (1999) (discussing same).

[35]   The public switched telephone network refers to the global publicly accessible telephone system. HARRY NEWTON, NEWTON'S TELECOM DICTIONARY 736 (22d ed. 2006).

[36]   The Federal Communications Commission imposes extensive regulatory obligations on telephone networks, pursuant to the Communications Act. 47 U.S.C. §§ 151-615(b) (2000).

many of the Internet's great achievements. Despite this, the interconnected Internet faces significant challenges, as the next section explains.

B.   The Network at War with Itself

Although the Internet has held together remarkably well, its composite architecture creates significant challenges. Deeply rooted tensions become significant when a network becomes as economically and socially significant as the Internet is today. Seemingly contradictory tendencies toward both centralization and decentralization are producing an array of conflicts that current legal frameworks do not adequately address.[37]

At one level, the Internet is fundamentally democratizing and decentralizing. It empowers anyone to launch a new application and allows users to express themselves freely.[38] In business, the Internet allows firms to globalize their operations and facilitates efficient collaboration among distributed employees, partners, contractors, and customers.[39] In media, the Internet allows creators to deliver programming through a mesh of peer-to-peer servers,[40] rather than a central archive. Further, the Internet empowers users to exchange content directly rather than rely on traditional commercial distribution chains.[41] In countless other areas, the Internet sweeps away traditional gatekeepers and places productive capacity in the hands of individuals.[42]

Simultaneously, however, the Internet establishes new dominant centers to replace the old proprietary ones. Google is a high-profile example. In just a few years, Google has become an online colossus, dominating Internet search and advertising.[43] Google is also

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[37]   *See infra* Part II.

[38]   *See infra* Part IV.B.2.

[39]   *See generally* JOHN HAGEL & JOHN SEELY BROWN, THE ONLY SUSTAINABLE EDGE: WHY BUSINESS STRATEGY DEPENDS ON PRODUCTIVE FRICTION AND DYNAMIC SPECIALIZATION (2005) (describing business potential of pervasive global networks).

[40]   Peer-to-peer means that computers connect to each other as peers, rather than through a hierarchical arrangement. *See* Nelson Minar et al., *A Network of Peers: Peer-to-Peer Models Through the History of the Internet*, *in* PEER-TO-PEER: HARNESSING THE POWER OF DISRUPTIVE TECHNOLOGIES 3, 3-4 (Andy Oram ed., 2001).

[41]   *See* Yochai Benkler, *Freedom in the Commons: Towards a Political Economy of Information*, 52 DUKE L.J. 1245, 1246-47 (2003); Dan Hunter & F. Gregory Lastowka, *Amateur-to-Amateur*, 46 WM. & MARY L. REV. 951, 1003-06 (2004).

[42]   *See* YOCHAI BENKLER, THE WEALTH OF NETWORKS: HOW SOCIAL PRODUCTION TRANSFORMS MARKETS AND FREEDOM 32 (2006).

[43]   *See* Sarah Arnott, *Discontent Flares Over Google's 'Dominance,'* THE INDEP., June

threatening large and entrenched traditional media businesses by capturing viewers these businesses once controlled. Unlike Microsoft in the operating system market, Google owns no proprietary gateways.[44] Its users are free to choose another search engine, and Google's primary function is to send those users away to other sites. Yet Google continues to increase its revenue, profits, and market share despite the best efforts of powerful competitors such as Microsoft and Yahoo!.[45]

Across the board, whether it be YouTube in online video sharing, eBay in auctions, or Facebook and MySpace in social networking, the leading Internet players may be new, but they dominate their markets at least as much as Wal-Mart or Intel dominate theirs.[46] The world may be flat, to use Thomas Friedman's memorable phrase,[47] but the Internet is in many ways highly hierarchical, and increasingly concentrated.[48]

The hardware and software infrastructure of the Internet is experiencing similar consolidation. The major players in the Internet economy, including Google, Microsoft, and Yahoo!, are constructing massive central data centers that integrate connectivity, applications, and content to deliver increasingly sophisticated services across the global Internet.[49] To meet the fantastic processing and storage

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16, 2008, http://www.independent.co.uk/news/business/news/discontent-flares-over-googles-dominance-847920.html; Jim Kerstetter, *Hitwise Provides More Proof of Google's Search Dominance*, CNET, Aug. 12, 2008, http://news.cnet.com/8301-1023_3-10015300-93.html.

[44] Because Microsoft owns the Windows operating system, it controls the application programming interfaces that developers use to build software running on Windows-based personal computers. *See* United States v. Microsoft Corp., 253 F.3d 34, 61-62 (D.C. Cir. 2001) (discussing how Microsoft used its control over Windows to harm competition).

[45] Eric Bangeman, *18-month Beatdown: Google Search Crushing Microsoft, Yahoo*, ARS TECHNICA, Aug. 13, 2008, http://arstechnica.com/news.ars/post/20080813-18-month-beatdown-google-search-crushing-microsoft-yahoo.html.

[46] *See, e.g.*, News Release, The Nielson Company, The "500 Million" Club (July 2, 2008)   (http://blog.nielsen.com/nielsenwire/wp-content/uploads/2008/07/report.pdf) (demonstrating dominance in U.K.).

[47] *See generally* THOMAS FRIEDMAN, THE WORLD IS FLAT: A BRIEF HISTORY OF THE TWENTY-FIRST CENTURY (2005) (explaining how globalization creates a "flat" world with a level playing field).

[48] *See* Eli Noam, The Internet: Still Wide Open and Competitive?, Paper Presented at the Telecommunications Policy Research Conference 4 fig.1 (Sept. 2003), *available at* http://web.si.umich.edu/tprc/papers/2003/200/noam_TPRC2003.pdf (finding that "the Internet sector's overall concentration has never been low").

[49] *See generally* George Gilder, *The Information Factories*, WIRED, Oct. 2006, http://www.wired.com/wired/archive/14.10/cloudware_pr.html   (describing   how

demands of today's network applications, Internet-based providers are effectively building virtual supercomputers from thousands of coordinated machines. Constructing this infrastructure requires both significant capital and sophisticated expertise in integrating systems. Internet application infrastructure is making the same shift that electric power generation did at the end of the nineteenth century.[50] Central utilities are replacing local production.[51]

The juxtaposition of decentralizing and centralizing forces produces conflicts. Powerful new centers threaten other participants, even when they don't explicitly manipulate the terms of their offerings to cement their dominance. That threat in turn, encourages those smaller participants to create their own balkanized enclaves. The very success of the network of networks produces the seeds of its failure.[52] This basic storyline describes a diverse set of major business, legal, and political developments across all segments of the Internet economy. Part II examines four of these fault lines in detail.

II.   THE PATH TO BALKANIZATION

For most of its commercial history, the Internet exerted a powerful centripetal force.[53] The Internet pulled networks together into peering and transit relationships,[54] linked hundreds of millions of devices into

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Internet creates new centralized "cloud computing" infrastructure in data centers).

    [50] *See* NICHOLAS CARR, THE BIG SWITCH: REWIRING THE WORLD, FROM EDISON TO GOOGLE 12 (2008).

    [51] In the 19th century, companies operated their own local electricity generation facilities, typically powered by water wheels. Large centralized power plants replaced these local facilities because they were much more efficient. The Internet equivalent is the shift from individual service or content providers maintaining their own server computers to a "cloud computing" model in which massive central data centers provide shared capacity for many providers. *See id.* at 9-11.

    [52] This story is not unique to the Internet. The tendency of networks to promote both centralization and decentralization of power and wealth has been observed in other contexts, most notably the sociology of urbanization and globalization. *See* Ithiel de Sola Pool, *Communications Technology and Land Use*, 451 ANNALS AM. ACAD. POL. & SOC. SCI. 1, 2 (1980); Saskia Sassen, *Locating Cities on Global Circuits*, 14 ENV'T & URBANIZATION 13, 15 (2002) (describing "dynamic of simultaneous geographic dispersal and concentration"); Kazys Varnelis, *The Centripetal City: Telecommunications, the Internet, and the Shaping of the Modern Urban Environment*, CABINET MAG., Spring 2004, *available at* http://varnelis.net/articles/centripetal_city (explaining how Internet produces both centralization and decentralization in urban environment).

    [53] *See infra* Part IV.A. Because the Internet is a network of networks, it is both the origin and the subject of these forces.

    [54] *See* Michael Kende, *The Digital Handshake: Connecting Internet Backbones*, 11

common address spaces, established universal application platforms divorced from the infrastructure underneath, and brought content into accessible pools.[55] This pressure for uniform connectivity, however, also sowed the seeds of a countervailing reaction.

At every layer of network functionality, the ties that have traditionally bound the Internet into a universal, richly connected whole are weakening.[56] This Part analyzes four major developments: private address and governance spaces, peering archipelagos, proprietary application-integrated broadband networks, and islands of protected content.[57] While each of these trends has received some attention, the pattern behind them has not. Each phenomenon involves a different set of players and a different aspect of the Internet. Some appear arcane and technical, while others seem like typical conflicts between competing companies. The connection, however, is clear. From the physical infrastructure that delivers data across the globe to the content-based services that drive advertising and transactions, the Internet is becoming a less uniform, less universal place.

A. Internet Governance: Operational Balkanization

The clearest example of creeping Internet fragmentation involves the area broadly described as governance — the policies and practices that knit the global internetwork together. The Internet famously has no central government.[58] Also, because the Internet operates across national boundaries, sovereign nations have difficulty subjecting it to their mandates. The governance of the Internet, in practice, involves the arrangements through which systems and sites join the network, as well as the policies that individual governments impose on Internet

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COMMLAW CONSPECTUS 45, 45 (2003).

[55] *See infra* Part II.A-D.

[56] The Internet is a layered system, with separable levels of functionality sitting on top of one another. *See* Kevin Werbach, *A Layered Model for Internet Policy*, 1 J. ON TELECOMM. & HIGH TECH. L. 37, 57-64 (2002) (describing four vertical layers of internet as physical, logical, applications, and content). *See generally* Kevin Werbach, *Breaking the Ice: Rethinking Telecommunications Law for the Digital Age*, 4 J. ON TELECOMM. & HIGH TECH. L. 59 (2005) [hereinafter Werbach, *Breaking the Ice*] (expanding on layered model).

[57] *See infra* Part II.A-D.

[58] "We reject: kings, presidents and voting. We believe in: rough consensus and running code." David D. Clark, An Input/Output Architecture for Virtual Memory Computer Systems (Jan. 1, 1974) (Ph.D. dissertation), *reprinted in* M.I.T. Project MAC Technical Report 117, at (1974), *available at* http://publications.csail.mit.edu/lcs/pubs/pdf/MIT-LCS-TR-117.pdf.

providers operating within their jurisdiction.[59]   In both areas, governments are attempting to carve out fiefdoms in which proprietary rules apply.

This process has been underway for some time.[60]   The current developments however, are different than the traditional governmental efforts to regulate Internet activity that affects their citizens or occurs within their borders. The changes to Internet governance mechanisms involve technical alterations to the Internet itself. When an Internet user in France and a Web-based services provider headquartered in California are forced to comply with French law, they may be prohibited from entering into a transaction, such as sale of Nazi memorabilia, that other Internet participants would be free to conduct.[61] Yet they are still connecting to the same Internet, and benefiting from its universality. Thus, there will not *be* a single Internet if the structure of Internet addressing and governance changes.

The major examples of Internet governance balkanization are fragmentation of the address space and governmental efforts to impose localized legal rules. This section first describes, in Subpart 1, how Internet addressing operates. Subpart 2 then describes the potential breakdown of a unitary address space, principally due to battles over international character sets.   Subpart 3 details China's efforts to dominate the future Internet through control over the next-generation Internet addressing protocol.   Finally, Subpart 4 explains how governments are imposing local content rules and other restrictions that further fragment the Internet.

1.   Internet addressing

The most active battlefield of Internet governance is the domain name system ("DNS").   The DNS is the crucial link between the machine-readable addresses of Internet-connected network nodes and their human-readable identities.[62] For example, a domain name such as "ebay.com" means nothing to the routers that direct Internet traffic

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[59]   *See* GOLDSMITH & WU, *supra* note 14, at 37-40.

[60]   *See id.*

[61]   *See id.* at 1-2.

[62]   *See generally* ELLEN RONY & PETER RONY, THE DOMAIN NAME HANDBOOK (1998) (providing comprehensive and practical history of policies, protocols, principles, controversies, and initiatives with DNS); Jon Postel, Network Working Group, *RFC 1591: Domain Name System Structure and Delegation* (Mar. 1994), ftp://ftp.isi.edu/in-notes/rfc1591.txt (providing information on structure of names in DNS and on administration of domains).

but everything to the users looking for the auction site.[63] In addition to this operational function, the DNS plays a key role in integrating the Internet. The universal DNS database, with generic top-level domain names[64] independent of physical geography, helps to bind the World Wide Web into a single global platform.[65]

The DNS is a distributed addressing database.[66] When a user sends a request for an Internet address, such as a web page query or an email message to a destination, that user's Internet service provider ("ISP") queries its domain name server for the Internet Protocol ("IP") address associated with that name. The ISP's local domain name server pulls content regularly from one of thirteen global "root servers." So long as all ISPs point to the canonical root servers, every domain name represents a unique point on the Internet.[67] However, an ISP could choose to point to a different DNS directory. If an ISP did so, its users might go to an entirely different website when they typed an address such as Whitehouse.gov or AOL.com.[68] Users would have no way of knowing because the redirection would be seamless. Thus, what holds the logical layer of the Internet together is the voluntary agreement of ISPs to point to the same root servers.

The Internet grew out of the NSFNet, managed by the U.S. National Science Foundation ("NSF"). The DNS infrastructure in turn was established under an NSF contract.[69] Network Solutions Inc. ("NSI"), a small networking company, won the original contract to build and maintain the DNS registry.[70] In the mid-1990s, the NSF allowed NSI to

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[63] For a description of how the DNS functions, see *infra* note 66 and accompanying text.

[64] A generic top-level domain name ("gTLD"), such as .com, .biz, or .museum, has no necessary connection to a physical location. By contrast, a country-code domain name, such as .uk or .jp, is associated with a sovereign nation. The most significant gTLDs are .com, .net, and .org. *See* Postel, *supra* note 62, at 1-3.

[65] *See* Christopher Rhoads, *Endangered Domain*, WALL ST. J., Jan. 19, 2006, at A1 (explaining how domain name system holds Internet together, and identifying various balkanization threats).

[66] Paul Vixie, *DNS Complexity*, ACM QUEUE, Apr. 2007, at 24, *available at* http://www.acmqueue.com/modules.php?name=Content&pa=showpage&pid=481&page=1 (calling DNS "a distributed, coherent, reliable, autonomous, hierarchical database, the first and only one of its kind").

[67] *See id.*

[68] *See* RONY & RONY, *supra* note 62, at 64-75.

[69] *See* Jay P. Kesan & Rajiv C. Shah, *Fool Us Once Shame on You — Fool Us Twice Shame on Us: What We Can Learn From the Privatizations of the Internet Backbone Network and the Domain Name System*, 79 WASH. U. L.Q. 89, 170-71 (2001).

[70] *See* Network Solutions, Company History, http://about-networksolutions.com/corporate-history.php (last visited Nov. 12, 2008).

begin charging for domain name registrations, migrating the system to a privately funded enterprise.[71] An explosion of registrations generated capital that allowed for massive expansion of the capacity of the DNS. However, private control of this increasingly important resource was tantamount to a government-granted monopoly at the center of the Internet infrastructure.[72] Meanwhile, pressure grew for the addition of new generic top-level domain names, such as .com, and conflicts over the intersection of domain names and trademarks escalated.

Subsequently, in 1998 the U.S. government helped create the Internet Corporation for Assigned Names and Numbers ("ICANN") as the administrative and policy overseer for the DNS.[73] At the same time, the U.S. Department of Commerce negotiated a new arrangement with NSI to allow competition in domain name registration.[74] ICANN is a unique, quasi-private entity. Formally constituted as a California non-profit corporation, it actually operates as a global governance entity with a Byzantine structure that incorporates representation from various private, non-governmental, and governmental entities.[75]

During the reformation of DNS management in the mid-1990s, there were serious efforts to set up alternative roots.[76] Even Jon Postel, the engineer who historically oversaw DNS policy, engaged in a "technical

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[71] *See* Answers.com, Network Solutions, LLC, http://www.answers.com/topic/network-solutions (last visited Nov. 12, 2008).

[72] NSI was eventually acquired by SAIC, a large defense contractor, and subsequently by Verisign. *See* David Diamond, *Whose Internet is it Anyway?*, WIRED, Apr. 1998, at 172; SAIC, Growth of the Company: FY 2000, http://www.saic.com/about/timeline/ 2000.html (last visited Nov. 6, 2008).

[73] *See* MILTON MUELLER, RULING THE ROOT: INTERNET GOVERNANCE AND THE TAMING OF CYBERSPACE 163 (2002); A. Michael Froomkin, *Wrong Turn in Cyberspace: Using ICANN to Route Around the APA and the Constitution*, 50 DUKE L.J. 17, 24 (2000); Kesan & Shah, *supra* note 69, at 174; Jonathan Weinberg, *ICANN and the Problem of Legitimacy*, 50 DUKE L.J. 187, 209-12 (2000).

[74] *See* Department of Commerce & Network Solutions, Inc., Amendment No. 11 to NCR-09218742, http://www.ntia.doc.gov/ntiahome/domainname/proposals/docnsi100698.htm (last visited Oct. 31, 2008).

[75] *See* Froomkin, *supra* note 73, at 71.

[76] An alternative root is a parallel root server that an Internet access provider can use instead of the official root system to determine the Internet protocol address associated with a domain name. *See* Will A. Foster et al., *Who Governs the Internet?*, COMM. ACM, Aug. 1997, at 15, 19, (discussing concerns about efforts to create "an alternate set of root-level domain name servers"); Weinberg, *supra* note 73, at 198; Jonathan Zittrain, *ICANN: Between the Public and the Private — Comments Before Congress*, 14 BERKELEY TECH. L.J. 1071 n.58 (1999); Open Root Server Confederation, http://www.open-rsc.org/ (last visited Oct. 31, 2008); *Rogue Domains Revolt*, CNET NEWS.COM, Mar. 4, 1997, http://news.com.com/2100-1023-275957.html?tag=rn.

experiment" to redirect the root servers, apparently to show that he could.[77] The creation of ICANN and its arrangements with NSI and other root server operators ended these efforts at the time. There are new scenarios on the horizon, however, under which the unity of the DNS may crumble.

2. Address fragmentation

One threat to the DNS lies in private address spaces. The DNS is the addressing system for the dominant applications at the dawn of the commercial Internet: email, file transfers, and the Web. All of these key off of domain names. Many newer applications, however, use their own addresses. The largest instant messaging ("IM") networks have over 100 million users, reachable through names the IM operator assigns privately.[78] Skype's voice over Internet protocol ("VOIP") service also has over 100 million users.[79] Similarly, social networking services such as MySpace, Hi5, and Facebook have massive user bases.[80] These services' users are not reachable through their universal email address; rather, the sender must know their private address on the service.

Private addresses are nothing new. IM services have been around since the mid-1990s.[81] What has changed is the prevalence of these applications and their growing share of Internet usage. This is especially true for younger Internet users. There is no sinister plot here. Application providers are making a voluntary decision to create their own addressing schemes, and users are making voluntary choices to adopt those applications. Yet the end result is a movement toward fragmentation of the Internet.

Another, and perhaps more direct, possibility for fragmentation in Internet addressing arises from language. At one level, the language of

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[77] *See* Froomkin, *supra* note 73, at 46.

[78] *See* Werbach, *Breaking the Ice*, *supra* note 56, at 88.

[79] Edward Cone, *Harnessing the Power of Networks*, CIO INSIGHT, Aug. 1, 2008, http://www.cioinsight.com/c/a/Books/Harnessing-the-Power-of-Networks/.

[80] A social networking service provides information and applications based around a "social graph" — a map of relationships between friends or business associates. *See Social Networking Increases Across Globe, Facebook Tops Popularity Chart*, TECHSHOUT, Aug. 13, 2008, http://www.techshout.com/internet/2008/13/social-networking-increases-across-globe-facebook-tops-popularity-chart/.

[81] The FCC discussed the history and significance of instant messaging in its order reviewing the merger of AOL and Time-Warner. *See In Re* Applications for Consent to the Transfer of Control of Licenses and Section 214 Authorizations by Time Warner Inc. and America Online, Inc., Transferors, to AOL Time Warner, Inc., Transferee, 16 F.C.C.R. 6547, 6603 paras. 128-45 (mem. op. & order).

the Internet is the language of its users. When Americans and other English speakers dominated Internet and World Wide Web usage, most of the content online was in English. Today, when Europeans and Asians significantly outnumber Americans online, content in other languages is an increasingly larger share of the total.[82] English however, is built into the DNS because the DNS grew out of an American system.

As evidence that the DNS grew out of an American system, generic top-level domain names, for example, are shortened versions of English words: for example, .com for commercial, .org for organization, and .net for network. More significantly, the character set used for Internet addresses is ASCII, a standard designed for English and other languages based on the Roman alphabet.[83] An address in Arabic or Russian, to say nothing of idiographic languages such as Mandarin and Japanese, must be transliterated into ASCII. An Internet user speaking one of these languages cannot simply type in or read a website address as an English or French speaker can because they use a different character set than the network.

The way to overcome this limitation is to adopt mechanisms in the DNS that accept Unicode, a broader standard than ASCII, which can support the world's main languages.[84] Unfortunately, implementation of such internationalized domain names ("IDNs") is not simple, and there are several different options for doing so. For example, IDNs must co-exist with the existing ASCII domain names. This means that some ASCII names that overlap with common Unicode strings[85] in some languages will take users to unexpected places. A Korean speaker might see one site after typing in a domain name, while a German speaker would see an entirely different site after typing in the Roman character equivalent of the same domain name. Effectively this would mean that different languages would create their own parallel domain name systems.[86] There might still be a single

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[82] *See Future of Non-English Internet*, DIGITAL LEARNING MAG., Feb., 2008, at 33, *available at* http://www.digitallearning.in/articles/article-details.asp?articleid=1718&typ=THE%20FOYER.

[83] ASCII has more characters than English, but many fewer than would be necessary for all the world's major languages. Geoff Huston, *Internationalizing the Internet*, THE ISP COLUMN, Dec. 2006, http://www.potaroo.net/ispcol/2006-12/idn.html.

[84] *See* THE UNICODE CONSORTIUM, THE UNICODE STANDARD: WORLDWIDE CHARACTER ENCODING, VERSION 1.0, at 1 (1991).

[85] A string is an arbitrary series of characters.

[86] *See* Geoff Huston, *Addressing the Future of the Internet*, ISP COLUMN, Feb. 2007, http://www.potaroo.net/ispcol/2007-02/address-paper.html; Huston, *supra* note 83.

governance regime, but to users the result would be identical to a situation in which each character set had its own parallel root servers.

ICANN has been working to implement IDNs for several years. However, progress towards an agreement has been slow, dissatisfying representatives of many countries.[87] Ineffective implementation of ICANN-approved IDNs could have significant negative consequences for the Internet, and could actually lead to the balkanization that the changes are supposed to avert. In particular, countries could adopt their own IDNs without waiting for ICANN.[88] When the governments pressured ICANN to implement IDNs quickly, ICANN chair Paul Twomey expressed concern: "The Internet is like a fifteen story building, and with international domain names what we're trying to do is change the bricks in the basement . . . . [W]e have to make sure that if we change the system, the rest is all going to work."[89]

A 2006 report that China was creating its own parallel root system proved to be a misunderstanding.[90] The report however, could easily have been accurate. ICANN began implementing IDNs in early 2008 even though open policy questions persisted.[91] Operators of some top-level domains are not waiting. Neustar, the ICANN-approved registry for the .biz generic top-level domain name, launched IDNs in March 2007.[92] Although such initiatives do not necessarily conflict with

[87] Michael Geist, *China and the Break-Up of the Net*, BBC NEWS.COM, Mar. 7, 2006, http://news.bbc.co.uk/2/hi/technology/4779660.stm.

[88] *See* Carolyn Duffy Marsan, *Native Language Domains Threaten 'Net*, NETWORK WORLD, Mar. 27, 2006, http://www.networkworld.com/news/2006/032706-icann-internationalized-domain-names.html ("The issue of IDNs threatens to undermine the Internet itself, which is based on a shared namespace that originates in a single root."); Dugie Standeford, *ICANN Urged to Speed Up IDNs to Prevent Dangerous "Breakaway" TLDs*, WASH. INTERNET DAILY, Mar. 29, 2006. There have also been efforts to use alternate private naming systems on top of the DNS. *See* Leslie Walker, *Web Shortcuts Become Key Issue*, WASH. POST, Apr. 20, 2000, at E1; James Niccolai, *Dutch Company Starts New Internet Address System*, INFOWORLD, Nov. 28, 2005, http://www.infoworld.com/archives/emailPrint.jsp?R=printThis&A=/article/05/11/28/HNnewaddresssystem_1.html.

[89] Asher Moses, *Web Chief Warns of Domain Name Chaos*, SYDNEY MORNING HERALD, Nov. 21, 2006, http://www.smh.com.au/news/web/web-chief-warns-of-domain-name-chaos/2006/11/21/1163871392720.html.

[90] *See* BR Staff Writer, *China Splits from the Internet? Probably Not*, COMPUTER BUS. REV., Mar. 1, 2006, http://www.cbronline.com/comment/china_splits_from_the_internet_probably_not.

[91] *See* Press Release, Internet Corp. for Assigned Names and Numbers, IDN TLD Allocation Implementation Processes (Aug. 20, 2008) (http://www.icann.org/en/announcements/announcement-20aug08-en.htm); Larry Seltzer, *The Era of Whatever*, EWEEK.COM, June 26, 2008, http://www.eweek.com/c/a/Security/The-Era-of-Whatever/.

[92] *See* Press Release, NeuStar, Inc., NeuStar Launches Chinese and Japanese

2008] The Centripetal Network 361

ICANN's efforts, they raise the possibility of different portions of the DNS having different internationalization patterns. Multiple inconsistent implementations of IDNs could turn into a form of fragmentation, or at least segmentation, of the Net.

Alphanumeric domain names are not the only Internet addresses at risk of fragmentation. A similar threat is arising around IP numbers, the unique numeric addresses that routers use to identify each machine connected to the Internet.

3. China's IPv6 strategy

When the current version of the Internet protocol, IPv4, was defined in 1979, the Internet was still a noncommercial network for a relatively small number of research and government computers.[93] The Internet's protocol designers adopted a 32-bit address space, allowing for roughly four billion unique network hosts. At the time, that seemed like a nearly inexhaustible number.[94]

As the Internet grew, however, the address space gradually became congested. Because addresses are hierarchical and assigned in blocks to networks, not every available address is available for use.[95] Massive blocks of addresses were assigned early on to networks and organizations that did not actually need them. Moreover, the Internet no longer just connected personal computers, but also incorporated mobile phones, sensors, and other devices.[96] Growing Internet adoption has accelerated the time horizon before all available IPv4 addresses are distributed. Although various measures have been taken to reduce the usage of IP addresses, current estimates are that IPv4 addresses will be exhausted in 2011 or 2012.[97]

The Internet Engineering Task Force ("IETF"), which defines Internet standards, responded to the impending addressing shortage,

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Language Domain Names in .BIZ TLD (Mar. 22, 2007) (http://phx.corporate-ir.net/phoenix.zhtml?c=189420&p=irol-newsArticle_print&ID=977185&highlight=).

[93] *See* Information Sciences Institute, *Internet Protocol* (Aug. 1979), http://www.networksorcery.com/enp/ien/ien111.txt.

[94] *See id.*

[95] *See* William Jackson, *Government Moves to IPv6 One Step at a Time*, GOV'T COMPUTER NEWS, Dec. 11, 2000, http://www.gcn.com/print/vol19_no34/3391-1.html (stating that IPv4 address allocation is only five percent efficient).

[96] *See* Kevin Werbach, *Sensors and Sensibilities*, 28 CARDOZO L. REV. 2321, 2324 (2007).

[97] *See* Dugie Standeford, *Enhanced Cooperation in Key Policy Areas Said to Show ICANN Works*, WASH. INTERNET DAILY, July 2, 2007 (quoting ICANN Chairman Vint Cerf's estimate of IPv4 exhaustion date); Neal Weinberg, *IPv6 D-Day Is Coming up Fast*, NETWORK WORLD, June 28, 2007, http://www.networkworld.com/news/2007/062807-ipv6-deadline.html (stating ARIN head John Curran's estimate of 2011 exhaustion date).

and to other limitations in IPv4 such as security, by developing a new protocol, IPv6.[98] IPv6 was adopted in 1995 as the official replacement for IPv4.[99] IPv6 provides 128-bit address space, enough for more than 10^{38} unique hosts — more than the total number of atoms on the surface of the planet.[100]

Despite the advantages of IPv6, adoption over the past decade has been spotty. The costs of updating every network-connected device are substantial.[101] Companies and network operators see no revenue gains associated with these costs because from the outside the network operates the same as it did before. Furthermore, the IETF has no authority to mandate protocol adoption. Assuming a private group or regulator could somehow require a transition and shut off IPv4-based equipment, such a step would produce massive disruption and outcry. So, while software and hardware sold today almost universally supports IPv6 as an option, few major networks are fully updated to IPv6.[102] As a result, IPv4 address exhaustion is a real possibility.[103]

The shortage of IPv4 addresses is felt most acutely in China, which had negligible Internet usage a decade ago, but is experiencing

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[98] S. Deering et al., Network Working Group, *Internet Protocol Version 6 (IPv6) Specification* (Dec. 1998), http://www.ietf.org/rfc/rfc2460.txt; IPv6:   The Next Generation!, Information Page, http://www.ipv6.org/ (last visited Oct. 31, 2008).

[99] Ben Worthen, *Internet Strategy: China's Next Generation Internet*, CIO MAG., July 15, 2006, www.cio.com/article/22985.

[100] Kevin Murphy, *Internet Addresses Drying up Fast*, COMPUTERWIRE, May 22, 2007,   www.computerwire.com/industries/research/?pid=8508BA51-4FCC-47E9-AEE7-FAAFF18AC8F1.

[101] *See* Weinberg, *supra* note 97.

[102] For example, both Microsoft and Apple's current operating systems natively support IPv6.

[103] *See* Ben Arnoldy, *For Online Users, a Looming Shortage of IP Addresses*, CHRISTIAN SCI. MONITOR, Aug. 3, 2007, http://www.csmonitor.com/2007/0803/p02s01-ussc.html?page=2; IPv4 Address Report, http://www.potaroo.net/tools/ipv4/index.html (last visited Nov. 12, 2008). ARIN, which assigns IP addresses for North America, felt the need to issue its August 1 statement to express its opposition to efforts that have already begun to create a secondary market for increasingly scarce IPv4 addresses. Statement of ARIN's Board of Trustees Regarding Future Internet Address Policy in the ARIN Region 1 (Aug. 1, 2007) (http://www.arin.net/media/200701August_ Statement.pdf); *see also* Posting of John Curran to NANOG Mailing List, http://www.merit.edu/mail.archives/nanog/msg01712.html   (July   24,   2007) ("Continuation of the ISP industry is predicated on enabling IPv6 for public-facing sites over the next few years."). *See generally* Raymond A. Plzak & Stephen M. Ryan, Legal and Policy Aspects of Internet Number Resources, Presented to VI Computer Law World Conference (Sept. 6, 2006), http://www.law.ed.ac.uk/ahrc/complaw/docs/ ARIN.pdf (explaining "the need for a consistent legal and public policy approach to critical management issues regarding '[I]nternet number resources,' which include Internet Protocol ('IP') addresses").

massive growth in connectivity. More than a quarter of all worldwide IPv4 addresses are assigned in the United States even though it represents a significantly smaller share of the global Internet user base.[104] In fact, even though China now has as many Internet users as the United States, it controls only about sixty million IP addresses, the same as Stanford University.[105]

China's national government seized on the Internet as an important priority for technological leadership in the twenty-first century. As a result, China has been aggressively funding development of the Chinese Internet industry. China has made IPv6 deployment a centerpiece of this national Internet policy.[106] It is building China's Next Generation Internet, an all-IPv6 high-speed Internet platform.[107] The Chinese government has already invested $200 million directly in the effort, supplemented with indirect expenditures by telecommunications companies and research organizations.[108]

By allowing every network-connected device to have its own address, IPv6 could facilitate a new generation of Internet-based applications, especially those involving smart devices beyond the personal computer. China also linked IPv6 deployment to its hosting of the 2008 Olympic Games.[109] China is betting that, by leading the world in IPv6 deployment, it will gain a head start on development of the new applications and services that take advantage of IPv6. China believes this process will be analogous to the way the United States had a significant head start in building the applications that define today's Internet.[110]

IPv6 itself is a non-proprietary standard issued by the IETF.[111] However, there would be many opportunities for a country that dominated implementation of IPv6 to dictate standards and practical

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[104] *See* NO. RESOURCE ORG., INTERNET NUMBER RESOURCE REPORT, http://www.nro. net/documents/presentations/jointstats.v1.0608.pdf (citing to IPv4 Global Unicast Address Assignments, http://www.iana.org/assignments/ipv4-address-space/) (last visited Nov. 12, 2008).

[105] *See* Worthen, *supra* note 99.

[106] *See* David Kirkpatrick, *Experts Say U.S. Must Act on Internet*, FORTUNE MAG., Nov. 6, 2006, *available at* http://money.cnn.com/2006/11/03/technology/fastforward_ ipv6 _networking.fortune; Robert Cringely, *The $200 Billion Lunch: We're Switching to IPv6, Dontcha Know, and It Might Be Worth It*, THE PULPIT, Nov. 2, 2006, http://www.pbs.org/cringely/pulpit/2006/pulpit_20061102_001174.html.

[107] *See* Worthen, *supra* note 99.

[108] *See id.*

[109] *See id.*

[110] *See id.*

[111] *See* sources cited *supra* note 98.

implementation of services. Companies will build products to meet market demand. If the Chinese implementation of IPv6 represents the biggest market, vendors will make equipment to support it.

The world got a taste of what this scenario could look like with the development of new mobile phone standards when China developed its own proprietary protocol, called TD-SCDMA.[112] Vendors had to decide whether to develop products to the proprietary Chinese standard, even though it may not have been efficient to do so. A 2006 survey of 1,000 Internet experts by network equipment manufacturer Juniper Networks found that eighty-six percent of respondents worried that slow adoption of IPv6 would hurt U.S. competitiveness.[113] More worrisome, fifty-eight percent thought it could imperil the stability of the Internet in the United States.[114]

Damage to U.S. competitiveness is only one dimension of the threat from aggressive Chinese implementation of IPv6. A world in which some countries build on IPv6, while others continue to maintain IPv4 networks, is one in which the address space of the Net is no longer universal. Management issues across the boundaries of these two blocks may become more complex, especially if they divide along geopolitical boundaries. Investment in enhancements on one platform may not redound to the full benefit of the other if those enhancements either depend on or work around the local addressing environment.

As significant as these technical and market challenges are, they are not the only danger of Internet fragmentation arising from the addressing system. Control over Internet addressing is also a political question.

4.   The politics of balkanization

The DNS and its associated components are the closest things the Internet has to central control points. Shut down any website, or even any Internet backbone network, and while there might be significant disruption, the Internet as we know it would continue to function.[115]

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[112] TD-SCDMA stands for time division synchronous code division multiple access. It is a variant of the code division multiple access ("CDMA") technologies in other third-generation wireless standards. *See* Frederick Yeung, *Beijing Has Much at Stake on 3G Plan*, S. CHINA MORNING POST, Jan. 7, 2008, at 5.

[113] *See* Press Release, Juniper Networks, IPv6 Transition Will Impact 30 Percent of U.S. Government IT Purchasing Decisions in 2007 According to IPv6 Government Action Study (Nov. 6, 2006) (http://www.juniper.net/company/presscenter/pr/2006/pr-061106.html).

[114] *See id.*

[115] Because each Internet router independently forwards packets along the best

Shut down the DNS root servers, and the Internet would effectively go dark.[116] Moreover, the DNS is also the mechanism by which individuals, organizations, and networks take concrete, public steps to join the Internet. A user can connect to the Internet simply by opening a private account with any access provider. However, a website seeking to become publicly accessible must register its domain name somewhere so that it goes into the central registry and root servers.[117] The DNS therefore is the logical place to locate any regulatory or contractual obligations on Internet sites.

Many governments chafe at what they perceive to be the excessive level of U.S. dominance of the Internet. Their concerns include dissatisfaction with ICANN, a belief that Internet governance issues should be addressed through an established international organization such as the United Nations, and the desire of developing countries to address the global digital divide.[118]

These concerns coalesced in a U.N. effort called the World Summit on Information Society ("WSIS").[119] In 2003 and 2005, WSIS held two meetings to address key issues of global Internet governance. Throughout the process, the United States, while endorsing the broad concept of the meeting, strongly resisted pressure to turn over ICANN's governance function to an international body. After a great deal of debate, representatives at the second WSIS meeting agreed to create a new group to carry forward its work — the Internet Governance Forum ("IGF").[120] At the time, U.S. representatives expressed satisfaction that the IGF was a discussion forum rather than an agency with any power to adopt rules, and would not supersede the existing authority vested in ICANN.[121]

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route to its destination, traffic is automatically routed along new paths when one network fails.

[116] More precisely, there would be no updates, since ISPs would still have the static links in their cached copies of DNS.

[117] *See* MUELLER, *supra* note 73, at 5-7.

[118] *See* Joan Engebretson, *Rooted in Controversy*, TELEPHONY, Nov. 20, 2006, at 28, 31, *available at* http://telephonyonline.com/mag/telecom_rooted_controversy/ index.html; Jonathan Krim, *U.S. May Face World at Internet Governance Summit*, WASH. POST, Oct. 13, 2005, at D05; Frederick Kempe, *How the Web Was Run*, WALL ST. J. ONLINE, Oct. 25, 2005, *available at* http://www.wgig.org/news/Thinking%20Global .pdf. The issues didn't involve the war, but the climate made more desire for international solutions.

[119] *See* World Summit on the Information Society, Basic Information: About WSIS, http://www.itu.int/wsis/basic/about.html (last visited Aug. 18, 2008).

[120] *See* Internet   Governance   Forum,   About   This   Web   Site, http://www.intgovforum.org/about.htm (last visited Nov. 12, 2008).

[121] *See* Declan McCullagh, *US Endorses Internet Governance Forum*, ZDNET, Nov.

It remains to be seen whether the IGF will satisfy both the forces for and against an intergovernmental Internet governance mechanism. If the IGF fails, countries may simply go their own way, balkanizing the Internet.[122] Such balkanization would not necessarily involve a series of completely parallel networks. Recall that the DNS functions through the voluntary decisions of ISPs to point to the canonical root servers. If operators in some countries chose to point to non-ICANN root servers, these databases may be almost completely identical to the current ones, at least initially. Users would therefore not see anything different until the breakaway network began to adopt different DNS mappings. Recently, a group based in Germany, calling itself the Open Root Server Network, established its own parallel root system to protest the U.S. invasions of Iraq and Afghanistan.[123] Though largely symbolic, this effort shows how simple it would be to split the Internet. If the concerns that gave rise to the WSIS meeting are not resolved in the coming years, there may be more serious efforts, backed by governments from around the globe, to set up a parallel root system.

Already, those countries wishing to control what Internet content their citizens can access, most notably China, are taking matters into their own hands and creating a semi-balkanized Internet. China has created a ring of gateways at the points where Internet backbones pass into the country, deploying filtering servers that block or redirect certain content deemed politically or otherwise inappropriate. This "Great Firewall of China" can be circumvented by clever technical mechanisms, but the average Chinese Web user sees what the government deems appropriate.[124]

China is the most prominent, but by no means the only, country adopting pervasive Internet censorship. In fact, Internet censorship is proliferating around the world.[125] Governments seeking fine-grained

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16, 2005, http://news.zdnet.co.uk/internet/0,1000000097,39237279,00.htm.

[122] *See* Darren Waters, *Warning over "Broken Up" Internet*, BBC NEWS, Oct. 12, 2006, http://news.bbc.co.uk/2/hi/technology/6037345.stm.

[123] *See* Foroohar, *supra* note 1, at 39.

[124] *See* Lawrence Lessig & Paul Resnick, *Zoning Speech on the Internet: A Legal and Technical Model*, 98 MICH. L. REV. 395, 396 (1999); Christopher Stevenson, Note, *Breaching the Great Firewall: China's Internet Censorship and the Quest for Freedom of Expression in a Connected World*, 30 B.C. INT'L & COMP. L. REV. 531, 556-57 (2007); Germie Barme & Sang Ye, *The Great Firewall of China*, WIRED, June 1997, at 176.

[125] *See* Mark Anderson, *A Sneak Peek at a Fractured Web*, WIRED NEWS, Nov. 13, 2006, http://www.wired.com/science/discoveries/news/2006/11/72104. *See generally* ACCESS DENIED: THE PRACTICE AND POLICY OF GLOBAL INTERNET FILTERING 155-432 (Ronald Deibert et al. eds., 2007) (analyzing Internet filtering practices in over three dozen countries); Nart Villeneuve, *The Filtering Matrix: Integrated Mechanisms of Information Control and the Demarcation of Borders in Cyberspace*, FIRST MONDAY, May

controls on what speech passes across the network may find common ground with network operators seeking fine-grained control over applications and content as a way of enhancing revenues.   These governments may also make common cause with individuals seeking to exclude malware and what they perceive to be inappropriate.[126]

As a legal matter, governments are entitled to determine what Internet content their citizens can access, just as they can determine what books they read or what television shows they can view.[127]   The thorny disputes over Internet jurisdiction involve situations where one country seeks to apply its laws to individuals or companies located somewhere else.[128]   There is no question today that governments have the technical wherewithal to, at a minimum, make it significantly more difficult for their citizens to access information on the Internet.[129]   The danger lies in Internet content controls becoming not just local actions on the part of individual governments, but challenges to the structure and universality of the Internet itself. Those challenges are even more apparent in the next area of potential fragmentation: the physical infrastructure that carries network traffic.

B.   *Network Infrastructure: Service Balkanization*

The physical networks that deliver Internet data across the world are also susceptible to balkanization.   These "backbone" networks were the initial adopters of the interconnectivity that produced the composite Internet.[130]   In fact, the primary function of the Internet protocol is to enable independent data networks to federate into a single meta-network. Today, however, the primary considerations for the Internet's constituent networks are not technical, but economic.

1996,   http://firstmonday.org/htbin/cgiwrap/bin/ojs/index.php/fm/article/view/1307/ 1227 (Last visited Nov. 19, 2008) ("Increasingly, states are adopting practices aimed at regulating and controlling the Internet as it passes through their borders.").

[126] *See* John G. Palfrey, Jr. & Robert Rogoyski, *The Move to the Middle: The Enduring Threat of "Harmful" Speech to Network Neutrality*, 21 WASH U. J.L. & POL'Y 31, 42-53 (2006); Jonathan L. Zittrain, *The Generative Internet*, 119 HARV. L. REV. 1974, 2013 (2006).

[127]   This is not a judgment that censorship is good. It most certainly is not. But it exists.

[128]   *See* GOLDSMITH & WU, *supra* note 14, at 143-45; Joel R. Reidenberg, *Technology and Internet Jurisdiction*, 153 U. PA. L. REV. 1951, 1953 (2005).

[129]   *See* GOLDSMITH & WU, *supra* note 14, at 66-85.

[130]   An Internet service provider ("ISP") or Internet access provider, such as Earthlink or Time Warner Cable, offers service directly to an end-user or company. A backbone provider, such as Level 3 Communications, offers service between ISPs. Some companies such as Verizon and AT&T provide both functions. *See* Werbach, *supra* note 32, at 13.

The business relationships between Internet backbone networks determine the basic connectivity patterns of the network. As with addressing and governance, fragmentation is beginning to replace universality. Subpart 1 of this section explains how Internet backbone interconnection operates, and Subpart 2 explains how the system that allowed for relatively seamless connectivity is breaking down.

  1.   Terms of network interconnection

Until the early 1990s, there was only one Internet backbone — the NSFNet, operated by the National Science Foundation.[131] Regional educational and governmental networks connected through this backbone to hand off traffic. When the NSF decided to exit from the business of managing the Internet, it did not simply privatize the central NSFNet. Instead, the NSF decreed that, at the same time the Internet was commercialized, the backbone would become competitive.[132] To this aim, the NSF funded the creation of Network Access Points ("NAPs") for exchange of traffic and required the privatized NSFNet backbone to connect to them.[133] At these neutral, multi-lateral exchange points, new backbones could interconnect to exchange traffic without restriction.

Within a few years, the NAPs became congested and diminished in significance relative to a new set of private inter-backbone relationships and third-party interconnection mechanisms.[134] The contractual relationships between backbones took two primary forms: peering and transit.[135] In a peering relationship, the networks exchange traffic without any financial settlement. The assumption is that the networks gain roughly equal benefits from the relationship, and therefore metering and billing for traffic passing in each direction merely adds complexity and transaction costs to the relationship.[136] Conversely, in a transit relationship, one network pays the other for the service of delivering packets.[137]

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[131]   *See id.*

[132]   *See* Brett M. Frischmann, *Privatization and Commercialization of the Internet Infrastructure: Rethinking Market Intervention into Government and Government Intervention into the Market*, 2 COLUM. SCI. & TECH. L. REV. 1, 19-24 (2001); Kesan & Shah, *supra* note 69, at 111-16.

[133]   *See* Kesan & Shah, *supra* note 69, at 169-70.

[134]   *See* Werbach, *supra* note 2, at 1252-53.

[135]   Kende, *supra* note 54, at 45.

[136]   *Id.*

[137]   *Id.*

The Federal Communications Commission ("FCC") has never attempted to regulate the financial relationships between the networks that make up the Internet.[138] Thus, there is no standard rule for which inter-network relationships are subject to peering and which to transit. Nor is there any standard definition of what pricing arrangement applies when the parties agree to a positive charge in a transit situation.

Backbone interconnection is an economic decision. Networks handing off traffic to each other have customers that benefit from the exchange. However, the relative benefits and costs of the exchange to each network may vary depending on the circumstances.[139] Customers of a small network gain more from reaching a big network, for example. Therefore, the economically efficient pricing regime may involve a positive charge from one network to the other. Moreover, many network interconnection situations involve a "build vs. buy" decision. Peering requires each network to construct infrastructure to a common point or points.[140] Transit is a service that networks can purchase from others. Each network must weigh the relative benefits of extending its own infrastructure to carry the traffic in question to its destination, versus relying on another network to do so.[141]

By distinguishing peering from transit, while treating the boundary line as an evolving negotiation between market participants and allowing significant flexibility in transit pricing arrangement, the Internet economic model optimally addresses the full range of networks. By allowing any network of sufficient size and scope to become a top-tier "peer" with others, and still allowing smaller networks to reap the benefits of ubiquitous connectivity, these economic arrangements helped facilitate all the innovation that took place on top of the infrastructure. Nonetheless, the peering system is under strain, as the next subpart explains.

2.   Fearing for peering

Disputes have flared up many times between networks that disagree about whether both parties are entitled to free traffic exchange.[142] The

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[138]   *See* Werbach, *supra* note 2, at 1255.

[139]   *See* Adam Candeub, *Network Interconnection and Takings*, 54 SYRACUSE L. REV. 369, 404-09 (2004).

[140]   This is inherent in the nature of peering. If each party were not responsible for constructing infrastructure to the meet point, one network would have to pay the other to do so.

[141]   *See* Candeub, *supra* note 139, at 404-09.

[142]   *See, e.g.*, Kesan & Shah, *supra* note 69, at 112-13 (identifying difficulties in backbone market); Jonathan Angel, *Toll Lanes on the Information Superhighway*,

most visible   peering dispute occurred in 2005 between backbone operators Cogent and Level 3.[143] Level 3 terminated its then-existing peering agreement with Cogent. Level 3 argued that because Cogent originated significantly more traffic than it received, the relationship was more expensive for Level 3. Because Level 3 terminated more of the traffic, it had to invest more in its own infrastructure. Therefore, Level 3 claimed, Cogent was more appropriately classified as a paying transit customer.[144] Cogent insisted that it should still be entitled to settlement-free peering with Level 3. When negotiations failed, Level 3 severed the links between the two networks.   This caused connectivity outages for customers of both networks.[145] Eventually, amid threads of government intervention, Level 3 re-established the link. The companies ultimately negotiated an agreement, although its terms were confidential.[146]

The Cogent-Level 3 dispute was an isolated occurrence affecting a small subset of Internet users.[147]   Changes in the backbone market, however, could break down the traditional peering equilibrium.   The centripetal dynamics at the physical layer of the Internet operate effectively because there has been no truly dominant backbone.[148] However, the possibilities for new arrangements are more acute today.[149]

NETWORK, Feb. 1, 2000, at 27 (describing conflicts between Internet backbones); Denise Pappalardo, *When Private Peering Arrangements Go Bad*, NETWORK WORLD, June 11, 2001, at 8 (discussing failures of private peering arrangements); Neil Weinberg, *Backbone Bullies*, FORBES, June 12, 2000, at 236 (describing exercise of market power by backbones); *see also* Joan Engebretson, *Level 3: Whiner or Visionary*, TELEPHONY, May 25, 1998, at 7 (describing MCI-WorldCom's refusal to peer with Level 3); John J. Keller, *Level 3 Assails the WorldCom-MCI Deal*, WALL ST. J., May 20, 1998, at B10.

[143] *See* Stacy Cowley, *Level 3, Cogent Call Time Out on Peering Spat*, IDG NEWS SERVICE, Oct. 10, 2005, http://www.infoworld.com/article/05/10/10/HNlevel3cogent _1.html?P-TO-P.

[144] *See* Level 3 Issues Statement Concerning Internet Peering and Cogent Communications, PR NEWSWIRE, Oct. 7, 2005, http://www.prnewswire.com/cgi-bin/stories.pl?ACCT=104&STORY=/www/story/10-07-2005/0004164041.

[145] The exact impact was difficult to gauge, because most users can reach virtually any point on the Internet through more than one backbone. More pervasive peering disputes, or disputes between the very largest backbones, would have more significant consequences.

[146] *See* Cowley, *supra* note 143.

[147] There have undoubtedly been other significant peering disputes, but because these negotiations and contractual terms are almost always confidential, few examples are public.

[148] The equilibrium of many competitive backbones avoids the network effects problem that allows one network to dominate. *See infra* Part IV.B.

[149] *See* Robert Frieden, *Without Public Peer: The Potential Regulatory and Universal Service Consequences of Internet Balkanization*, 3 VA. J.L. & TECH. 8, 30-34 (1998).

Consider one such scenario. AT&T and Verizon are the dominant Internet backbones. They are among the largest backbones in terms of traffic and geographic coverage. More importantly, they are the only large backbones to also control last-mile connectivity[150] in significant parts of the country, and to have large numbers of retail broadband subscribers. Verizon and AT&T might establish a peering relationship with one another and refuse to offer such peering to other backbones. The cable industry is poised to do something similar for its VOIP services.[151]

Such a move by Verizon and AT&T would likely push other major backbones, such as Level 3 and Qwest, to partner or be acquired by competitors of the two dominant backbones. For example, Comcast already has an arrangement with Level 3 to lease significant quantities of dark fiber, which provides additional capacity that can be "lit" at a later date. Comcast individually, or the major cable operators collectively, or the cable operators and Sprint Nextel, which are in an alliance for wireless broadband, could purchase one or more of these major backbones. Google and Microsoft, both of which have grand ambitions and vast assets through their market capitalization, would also be in the mix as potential acquirers.

If such a scenario came to pass, the Internet backbone could evolve away from the current uneven but relatively stable market structure, in which large backbones have an advantage over smaller players but where universal connectivity is preserved through market forces.[152] The new backbone ecosystem would be dominated by, in all likelihood, two to three independent "archipelagos" involving a combination of backbone, last-mile, and content/information service assets.

In contrast to the status quo, these archipelagos probably would not provide seamless connectivity to one another. Especially if information service, content providers, or both, were in the ownership mix, backbones would look for ways to provide preferential transport to their partners. A Verizon DSL customer would, in all likelihood,

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[150] The last mile is the final run of network wiring (or wireless signal) from a network operator's office to a house or business.

[151] *See* Carol Wilson, *VON: Cable Close to National VOIP Peering*, TELEPHONY ONLINE, May 21, 2007, http://telephonyonline.com/voip/technology/cable_voip_ peering_032107/.

[152] In reviewing the market structure of the backbone in connection with Verizon's acquisition of MCI, the FCC concluded that, "[s]o long as there is 'rough equality' among backbone providers, each has an incentive to peer with the others to provide universal connectivity to the Internet." *See In re* Verizon Communications Inc. & MCI, Inc. Applications for Approval of Transfer of Control, 20 F.C.C.R. 18433, 18496 para. 118 (2005) (mem. op. & order).

still be able to reach Google's website because customers would demand such access and regulators would probably mandate it. However, the quality of access, and the menu of offerings available to customers, would vary depending on their choice of access provider. The environment would look similar to the online services ecosystem in the late 1980s, just prior to the explosion of the commercial Internet.[153]   The archipelagos would provide interconnectivity for established applications where it was expected, such as email, but would vie to use exclusivity or price/product discrimination for new services, content, and applications.

Concern over Internet backbones failing to peer with one another, resulting in a balkanized Internet, is not unprecedented. In the early days of the commercial Internet, when the UUNet backbone achieved a degree of market power, it set about trying to pressure other backbones into less advantageous interconnection agreements.[154] In the late 1990s, there were significant disputes about peering policies, which led to predictions than the Internet would fragment.[155] In various FCC and Department of Justice merger review proceedings at the time, competitiveness of the backbone was a major issue.   Sprint and WorldCom abandoned their proposed merger largely because the Department of Justice announced its intention to block the combination for promoting excessive consolidation of the Internet backbone.[156]

The difference today is that the largest backbones are also the dominant access providers. They have the ability to leverage their monopoly control over the "last mile" to a particular user into the more competitive backbone market. Moreover, they are major providers of voice and video services that Internet-based alternatives such as Skype and YouTube might threaten. Even if no player has market power in the backbone market itself, incentives to preserve peering, and the broader linkage it promotes across the physical layer, are diminishing.

Recently, another threat to backbone interconnectivity has emerged in the form of patents on methods to interconnect VOIP services with the public telephone networks. Several companies, beginning with Verizon, successfully sued Vonage, the leading independent, equipment-based VOIP provider, for infringing on VOIP

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[153] For example, email was not fully interoperable among online services such as Compuserve and Prodigy for some time. *See supra* note 31 and accompanying text.

[154] *See* Frieden, *supra* note 149, at 10 n.15; Kende, *supra* note 54, at 47-48.

[155] *See* sources cited *supra* note 154.

[156] *See* Complaint at 9-11, United States v. WorldCom, No. 00-CV-1526 (D.D.C. June 26, 2000), *available at* http://www.usdoj.gov/atr/cases/f5000/5051.pdf.

interconnection patents.[157] The bulk of the patents were for interconnection techniques.[158] The possibility that interconnection on the Internet will no longer be a matter of technical sufficiency and business agreement, but rather require negotiation with a group of intellectual property right-holders, adds a frightening new dimension to the backbone balkanization equation. With voice traffic increasingly migrating to VOIP, even for incumbent operators, the patent overhang becomes substantial. Controversial suits against Microsoft, Research in Motion, and eBay have illustrated the extreme confusion and disruption that patent litigation can generate.[159] When the patent is the means for interconnecting participants in the network, the threat is even more severe.

The foundations of the universal interconnected Internet are thus not as stable as they may seem. The same pattern is emerging at higher levels of functionality. Above the physical layer of network backbones and the logical layer of addressing are the applications such as the World Wide Web and email that users interact with directly. These are subject to their own balkanizing forces, in the form of efforts to violate the application neutrality of the network.

C. Network Neutrality and Application Balkanization

A core design feature of the Internet is that it is not limited to providing a particular application or class of application. In the words of renowned Internet engineer David Clark, it is "oblivious" to the uses of the network.[160] Any service that can be encapsulated into the

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[157] *See* Verizon Servs. Corp. v. Vonage Holdings Corp., 503 F.3d 1295, 1311 (E.D. Va. 2007); Leslie Cauley, *Vonage Chief Stays Sunny About the Future*, USA TODAY, Jan. 28, 2008, at B4; Olga Kharif, *Collecting on an Old Phone Bill*, BUSINESS WEEK, Mar. 26, 2007, at 13; Michael Orey, *A Higher Hurdle for Inventors*, BUSINESS WEEK, May 14, 2007, at 38; Carol Wilson, *The Patent Problem*, TELEPHONY ONLINE, Apr. 9, 2007, http://telephonyonline.com/regulatory/commentary/telecom_patent_problem/.

[158] *See* Danny Adams, *VoIPers Gain Interconnection Rights, Lose Patent Suit*, IP BUSINESS, Apr. 1, 2007, http://www.ipbusinessmag.com/articles.php?issue_id=24 &article_id=94.

[159] *See, e.g.*, *U.S. BlackBerry Users in Confusion, as the Fight Goes on*, 24X7 UPDATES, Feb. 25, 2006, http://www.24x7updates.com/FullStory-News-U_S_BlackBerry _Users_ in_confusion _as_the_fight_goes_on-ID-200929.html (last visited Nov. 12, 2008).

[160] DAVID CLARK ET AL., NEW ARCH: FUTURE GENERATION INTERNET ARCHITECTURE 22 (2003), *available at* http://www.isi.edu/newarch/iDOCS/final.finalreport.pdf; *see also* Bernard Aboba & Elwyn Davies, Internet Eng'g Task Force, *Reflections on Internet Transparency* (July 2007) (Request for Comments No. 4924), http://tools.ietf.org/rfc/ rfc4924.txt.

TCP/IP protocol stack can be delivered over the network.[161]   This makes the Internet very different from platforms, such as the public switched telephone network, which are highly optimized for one kind of service.[162]   The telephone network does an excellent job of delivering reliable, good-quality voice phone calls, but its suitability for other applications is limited. The Internet promotes innovation because the network itself is not optimized for one service and is flexible enough to support unanticipated applications.[163] Because the Internet knows nothing about applications, it can serve as a universal platform to connect all of them.

Today, the Internet's indifference to applications is breaking down. Retail broadband access in the United States is largely a duopoly, with major cable and telephone companies dominating the market.[164] Two companies — AT&T and Verizon — control the lion's share of the nationwide DSL access market; a small number of cable operators, led by Comcast and Time Warner, are their primary competitors.[165] Further, the FCC classified both DSL and cable modem access as "information services," meaning that network operators are not subject to requirements that they share their networks with competitors.[166]

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[161] TCP/IP stands for transmission control protocol / Internet protocol. It is the standard format for the packets of digital information that traverse the Internet.

[162] There are some optimizations (e.g. more file transfer than real-time services) implicit in the protocol design, based on assumption of the engineers at the time. However, such tradeoffs are necessary in any engineered system.   The Internet protocols may express an implicit bias for certain applications, but they in no way preclude other applications, nor do they prevent network operators, service providers, and equipment vendors from devising clever techniques to circumvent the limitations in the protocol.

[163] *See* J. Kempf & R. Austein, Internet Eng'g Task Force, *The Rise of the Middle and the Future of End-to-End: Reflections on the Evolution of the Internet Architecture* (Mar. 2004) (Request for Comments No. 3724), http://tools.ietf.org/rfc/rfc3724.txt.

[164] *See* Charles H. Ferguson, The Broadband Problem: Anatomy of a Market Failure and a Policy Dilemma 132 (2004); Rob Pegoraro, *Broadband Is Too Important to Be Left to Cable-Phone Duopoly*, Wash. Post, Aug. 14, 2005, at F07.

[165] A few independent providers such as Earthlink remain active, but their share of the market is small, and they depend on reselling incumbent services. *See* Alex Goldman, *Top 23 U.S. ISPs by Subscriber: Q2 2008*, ISP-Planet, Aug. 29, 2008, http://www.isp-planet.com/research/rankings/usa.html.

[166] *See In re* Inquiry Concerning High-Speed Access to the Internet over Cable and Other Facilities, 17 F.C.C.R. 4798, 4819 (2002) (declaratory ruling and notice of proposed rulemaking) (concerning cable modem service); *In re* Appropriate Framework for Broadband Access to the Internet over Wireline Facilities, 17 F.C.C.R. 3019, 3019 (2002) (notice of proposed rulemaking) (concerning DSL service); Werbach, *supra* note 2, at 1268.

In this environment, incumbent broadband providers could discriminate against unaffiliated providers of Internet applications and content.[167] Advocates of "network neutrality" urge the government to adopt rules prohibiting network operators from engaging in such discrimination.[168] These advocates argue that, without enforceable network neutrality mandates, the network owners will dampen innovation in the application and content markets.[169] The operators and their supporters respond that they have no incentive to engage in such practices and that neutrality mandates would constrain their own incentives to innovate and deploy new broadband services.[170]

There is an unappreciated danger in the fight. A non-neutral Internet is also a non-uniform Internet. If network operators begin cutting special deals with content and application providers, the capabilities a user enjoys will increasingly depend on which access provider they use. Baseline Internet connectivity will still be universally available, but users will be choosing a set of capabilities tied to their access mechanism.

In opposition to network neutrality mandates, Christopher Yoo argues that there is a choice between promoting network neutrality and what he calls network diversity — an environment in which networks make different choices about architecture, pricing, and services.[171] Yoo attacks network neutrality mandates on the grounds that they flatten such distinctions, and thereby reduce incentives for novel competitive entry in the broadband market.[172] As an analogy, Yoo points to the NFL Sunday Ticket offering on the DirecTV direct

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[167] *See* sources cited *supra* note 2.

[168] *See* Petition for Declaratory Ruling at 3, *In re* the Petition of Free Press et al. for Declaratory Ruling that Degrading an Internet Application Violates the FCC's Internet Policy Statement and Does Not Meet an Exception for 'Reasonable Network Management,' No. 07-52 (FCC Nov. 1, 2007), *available at* http://fjallfoss.fcc.gov /prod/ecfs/retrieve.cgi?Native_or_pdf=pdf&id_document=6519810275; Wu, *Network Neutrality*, *supra* note 2, at 8; Ex Parte Submission in CS Docket No. 02-52 from Timothy Wu, Professor of Law, Univ. of Va., and Lawrence Lessig, Professor of Law, Stanford Univ., to Marlene H. Dortch, Sec'y, FCC 12-15 (Aug. 22, 2003) http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=65146 83884 [hereinafter Wu & Lessig, *Ex Parte*].

[169] *See* Wu & Lessig, *Ex Parte*, *supra* note 168, at 12-15.

[170] *See* Yoo, *Beyond Network Neutrality*, *supra* note 2, at 52; Yoo, *Economics of Congestion*, *supra* note 2, at 1887-89.

[171] Yoo, *Beyond Network Neutrality*, *supra* note 2, at 18-19.

[172] Yoo's claim is that policy-makers should be most concerned about broadband competition, because it addresses the ultimate problem, and therefore the network neutrality tradeoff isn't worth it. *See id.* at 9.

broadcast satellite service.[173]   This exclusive football package encouraged many sports fans to select DirecTV over cable, increasing the competitiveness of the multi-channel video programming market.

Whether or not Yoo is correct that the benefits of network diversity are superior to those of network neutrality, there is an important aspect of his analysis that bears highlighting. The more "diverse" a new entrant's business model, the more it will diverge from the universal connectivity model of the established Internet. A network diversity principle would open the door for greater divergence from the experience of a single, uniform Internet. This may be a worthwhile tradeoff, or there may be enough other constraints to prevent networks from straying too far from neutrality. However, it is impossible to be certain.

Variation among access providers is not the only trend that may cause the Internet to balkanize as an application platform. Content and application providers may seek similar special deals with operators in situations where they feel they have leverage. For example, ESPN, the cable sports programmer, offers a slate of special online content through ESPN360.com, which is only available to customers of broadband access providers that pay ESPN a supplemental fee.[174] The result is similar to what would happen if some broadband providers blocked the ESPN service, but in this case it is ESPN's desirable content that drives the business relationship. There is nothing fundamentally improper in ESPN or any other content provider holding out for such a payment. Network neutrality proponents would distinguish the ESPN 360 arrangement on the grounds that ESPN lacks the market power or control over expensive physical infrastructure that might allow network operators to abuse their position.   The result, however, is to move closer to an environment that lacks the universality of today's Internet.

In the future, the underpinnings of the application-indifferent Internet are likely to break down further. The rapid growth of online video distribution is causing network operators to consider deploying "deep packet inspection" capabilities to differentiate their treatment of traffic on an application-by-application basis.[175] Video files are so much larger than other forms of Internet content that they already make up a substantial portion of global Internet traffic, and a

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[173] *See id.* at 32.

[174] *See* George Ou, *Is ESPN Committing Reverse Net Neutrality?*, ZDNET, June 21, 2006, http://blogs.zdnet.com/Ou/?p=251.

[175] *See* Andrew Parker, Chief Technology Officer, The Truer Picture of Peer-to-Peer Filesharing at the CacheLogic Presentation 12 (July 2, 2004) (on file with author).

substantial majority of the bits flowing over many broadband access networks.[176]

Therefore, access providers seeking to differentiate video traffic and charge differently for it, either to end-users or to content providers, can reasonably argue that they are simply making an efficient economic move.[177] Much like firms practicing price discrimination in other industries, access providers will argue that if the relatively small number of heavy video users pay more, most users will pay less.[178] Some broadband providers are cutting off or throttling back heavy users or file-sharing applications that they claim are monopolizing network bandwidth.[179]

For wireless Internet access, most network operators already cap "unlimited" plans and charge special fees for applications such as live streaming TV and ringtone downloads.[180] The wireless industry has a unique history, regulatory status, and technical issues. Until recently, the "wireless Internet" was something of a misnomer. Now, with devices such as the Apple iPhone promising a full Web experience and third-generation wireless networks delivering near-broadband speeds, the two worlds are converging. If the result is something closer to the wireless model, it will represent a significant shift in how users experience the Internet.

D. *Digital Copyright: Information Balkanization*

The final links holding the Internet together arise at the content layer, based on a set of legal constructs. Specifically, content pulls itself together on the Internet through the widespread exploitation of a grey area in intellectual property law. That grey area may soon divide into black and white boundaries. If it does, the foundation for many Internet services that today are taken for granted, such as search engines, may disappear.

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[176] *See* Kevin Werbach, *The Implications of Video P2P on Network Usage*, *in* VIDEO PEER TO PEER 97, 101 (Eli M. Noam & Lorenzo Maria Pupillo eds., 2008).

[177] Yoo, *Economics of Congestion*, *supra* note 2, at 1864.

[178] In economics, price discrimination has no derogatory connotation. The idea is simply that firms can sometimes maximize total welfare by charging some customers more than others. *See generally* CARL SHAPIRO & HAL VARIAN, INFORMATION RULES: A STRATEGIC GUIDE TO THE NETWORK ECONOMY (1998) (arguing that classic economic principles still offer strategic value in technological marketplace).

[179] *See* Declan McCullagh, *BitTorrent Firms: Comcast Throttling Is Anticompetitive*, CNET, Feb. 14, 2008, http://news.cnet.com/8301-13578_3-9872464-38.html.

[180] *See* Tim Wu*, Wireless Carterfone*, 1 INT'L J. COMM. 389, 405-06 (2007).

This section elucidates, in Subpart 1, how intellectual property rules define the connective tissue of the Internet at the content layer. Subpart 2 explains how litigation challenges threaten this connective tissue.

1. Linkage at the content layer

The content passing across the Internet is, like any other fixed expression of ideas, entitled to intellectual property protection. The text of a Web page, or digital material such as books, songs, and television shows stored on file servers, are all subject to the infringement prohibitions of copyright law. All property rights serve to distinguish one person's assets, with their associated bundle of rights, from others' assets.[181] Drawing such boundaries produces tremendous benefits by unlocking the potential for investment and innovation associated with both tangible and intangible assets.[182]

Yet the benefits of legal enforcement of property rights come at a cost. Property rights necessarily limit the freedom of non-owners.[183] The dangers from over-aggressive enforcement of property rights are especially great for intangible goods such as intellectual property, which are otherwise economically nonrival.[184] Without copyright protection, for example, everyone could have a copy of a song or a piece of software, without exhausting the resource. Of course, such an arrangement would likely eliminate the economic incentive to create the resource, which is why some intellectual property protections are necessary. However, too stringent a regime can have spillover effects on innovation, and can produce a "tragedy of the anti-commons" in which too many fragmented owners prevent effective use of the resource.[185]

Intellectual property on the Internet has been an active legal battleground.[186]   To date however, there have been few overt

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[181] *See* JOSEPH WILLIAM SINGER, ENTITLEMENT: THE PARADOXES OF PROPERTY 6 (2000); Kevin Werbach, *Supercommons: Toward a Unified Theory of Wireless Communication*, 82 TEX. L. REV. 863, 918 (2004) ("The question, therefore, is how to draw the boundaries.").

[182] *See* Harold Demsetz, *Toward a Theory of Property Rights*, 57 AM. ECON. REV. 347, 350 (1967).

[183] *See* Werbach, *supra* note 181, at 885; *see also* LAWRENCE LESSIG, THE FUTURE OF IDEAS: THE FATE OF THE COMMONS IN A CONNECTED WORLD 168 (2001), *available at* http://thefutureofideas.s3.amazonaws.com/lessig_FOI.pdf.

[184] *See* LESSIG, *supra* note 183, at 237.

[185] *See* Dan Burk, *The Trouble with Trespass,* 4 J. SMALL & EMERGING BUS. L. 27, 49 (2000); Dan Hunter, *Cyberspace as Place, and the Tragedy of the Digital Anticommons*, 91 CAL. L. REV. 439, 509-13 (2003); Mark A. Lemley & Brett M. Frischmann, *Spillovers*, 107 COLUM. L. REV. 257, 281 (2007).

[186] *See* LESSIG, *supra* note 183, at 207-09; *see, e.g.*, A & M Records, Inc. v. Napster,

controversies over unauthorized reuse of online content. Search engines index, copy, and redisplay millions of pieces of copyrighted content every day without permission.[187] Internet service providers and application providers host and aggregate information they do not own, and that in some cases infringes on the rights of content owners.

Search engine indexing is perhaps the best example of accepted content reuse online. We take it for granted that search engines such as Google, Ask.com and Yahoo! can index sites on the World Wide Web.[188] Search engines are now so ingrained as the starting points for use of the Internet, and content reuse is so central to search engines, that the idea of their operation as a copyright violation at first is perplexing. However, what most search engines do is, for their own economic benefit and without receiving any affirmative authorization, copy, store, and redisplay copyrighted content of other authors.[189]

All major Internet search engines use the same basic approach. They send out "spiders" — automated programs that follow hyperlinks from page to page on the web — recording information about those pages as they go along. Among other things, the spiders copy the text of the page into the search engine's database, typically in a compressed format to speed retrieval.[190] Some search engines, most notably Google, also keep a full readable copy of most sites in their local database, allowing users to retrieve the page from the search engine's cache rather than from the origin site itself.[191]

Search engines therefore do many things that seem to constitute, at first glance, copyright infringement.[192] Yet there has been little legal

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Inc., 239 F.3d 1004 (9th Cir. 2001) (finding Napster file-sharing service guilty of contributory copyright infringement); *see also* Metro-Goldwyn-Mayer Studios Inc. v. Grokster, Ltd., 545 U.S. 913, 931-41 (2005) (refining *Napster*'s theory for secondary copyright liability).

[187] *See* Siva Vaidyanathan, *Copryight Jungle*, COLUM. JOURNALISM REV., Sept.-Oct. 2006, at 42, 44, *available at* http://works.bepress.com/cgi/viewcontent.cgi?article=1012 &context=james_grimmelmann ("One of the least understood concepts of Google's business is that it copies everything.").

[188] *See* James Grimmelman, *The Structure of Search Engine Law*, 93 IOWA L. REV. 1, 6 (2007).

[189] *See id.* at 27-28.

[190] *See id.* at 7-8.

[191] *See* Perfect 10, Inc. v. Amazon.com, Inc., 508 F.3d 1146, 1156 n.3 (9th Cir. 2007) ("Google's cache saves copies of a large number of webpages so that Google's search engine can efficiently organize and index these webpages.").

[192] *See* DAVID L. HAYES, ADVANCED COPYRIGHT ISSUES ON THE INTERNET 15 (2004), *available at* http://www.fenwick.com/docstore/355/Advanced_Copyright_02-29-04.pdf; Grimmelman, *supra* note 188, at 27-28.

scrutiny of their behavior. Only a handful of cases have parsed whether a search engine may be engaging in a copyright violation.[193]

As a practical matter, content reuse is prevalent online because it benefits content owners. Search engines are the starting points for most Internet users. If something isn't listed in a search engine, it effectively does not exist. The search engines pass off users to the origin sites once they return their results, so allowing a search engine to index a page doesn't prevent the content owner from monetizing that same page through advertisements or other means. If pressed, search engines could advance three primary legal theories to defend their indexing of online content: fair use, implied license, and statutory safe harbors.

Fair use is a well established and statutorily grounded, yet notoriously vague, aspect of copyright law. It allows re-use of copyrighted material under circumstances, such as educational applications, parodies, and *de minimis* copying, where the balance of equities favors the copier over the exclusion.[194] Search engines typically display only a small excerpt of the indexed page, with a link to the original site. However, this is not always the case. Google caches and makes available the full text of most pages in its search index, and its book search service stores the full text of a book.[195] An alternative hypothesis is that websites have tacitly and collectively authorized search engines to copy and index their pages, under the legal theory of implied license.[196] Perhaps content providers would be entitled to stop search engines and other online service providers from using their content, but they simply have not. Under an implied license theory, the content owners' silence, with awareness about the scope of copying, is tantamount to a limited waiver of their intellectual property rights.[197]

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[193] *See* Parker v. Google, Inc., 422 F. Supp. 2d 492 , 494-95 (E.D. Pa. 2006), *aff'd*, 242 F. App'x 833, 837 (3d Cir. 2007) (per curiam); Field v. Google, Inc., 412 F. Supp. 2d 1106, 1124 (D. Nev. 2006). In both cases, the courts declined to impose liability on Google.

[194] *See* 17 U.S.C. § 107 (1976) (defining statutory elements of fair use); Harper & Row, Publishers, Inc. v. Nation Enters., 471 U.S. 539, 560-61 (1985). *See generally* WILLIAM F. PATRY, THE FAIR USE PRIVILEGE IN COPYRIGHT LAW (1985) (describing fair use).

[195] *See* Hannibal Travis, *Google Book Search and Fair Use: iTunes for Authors, or Napster for Books?*, 61 U. MIAMI L. REV. 87, 131-33 (2006); John S. Sieman, Comment, *Using the Implied License To Inject Common Sense into Digital Copyright*, 85 N.C. L. REV. 885, 906-09 (2007).

[196] *See* Sieman, *supra* note 195, at 921-23.

[197] *See id.*

The final theory for content re-use is that it is protected under the legal safe harbors established under the Telecommunications Act of 1996 ("Telecom Act")[198] or the Digital Millennium Copyright Act ("DMCA").[199] Section 230 of the Telecom Act immunizes ISPs from liability for content that merely resides on their networks.[200] Section 512 of the DMCA incorporates a more complex safe harbor regime, in which service providers must take down allegedly infringing materials upon notice from copyright holders in order to qualify.[201]

Though most Internet users and service providers take widespread online content reuse for granted, its foundations remain shaky. Pending litigation may produce a dramatic change in the environment.

2.   Breakdown of voluntary content reuse

Content owners are beginning to chafe at the ways that search engines and online service providers make use of their content.[202] Moreover, online services are pushing the boundaries of copyright law in new ways, making content owners uncomfortable that they will lose control and revenues. YouTube and other video sharing sites have exploded in popularity in recent years, with YouTube agreeing to sell itself to Google for over $1.5 billion less than two years after its launch.[203]

Unlike Napster and other peer-to-peer file-sharing services, who argued they had no control over the content flowing across their networks, YouTube is a traditional central storage site, which hosts all videos available to its users.[204] YouTube's defense to copyright

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[198]   Telecommunications Act of 1996, Pub. L. No. 104-104, 110 Stat. 56 (codified in scattered sections of 47 U.S.C.).

[199]   17 U.S.C. § 512(a)-(d), (j) (2000).

[200]   47 U.S.C. § 230 (1996). This provision was incorporated into the legislation to counterbalance the Communications Decency Act ("CDA") provisions, which made it illegal to post indecent material on the Internet.   The CDA was declared unconstitutional, but the safe harbor provisions, and their associated language about the value of an unfettered Internet, remained in the statute. *See generally* Reno v. ACLU, 521 U.S. 844 (1997) (invalidating § 223(a)(1) and § 223(d) of CDA).

[201]   *See* Mark A. Lemley, *Rationalizing Internet Safe Harbors*, 6 J. ON TELECOMM. & HIGH TECH. L. 101, 103-04 (2007).

[202]   *See also* David Lazarus, *Pay-to-Play is One Way to Help Save Newspapers*, SFGATE.COM, Mar. 14, 2007, http://www.sfgate.com/cgi-bin/article.cgi?file=/c/a/2007/03/14/BUG4COKGDU1.DTL.

[203]   Sara Kehaulani, *Google Gambles on Web Video*, WASH. POST, Oct. 6, 2006, at A01, *available at* http://www.washingtonpost.com/wp-dyn/content/article/2006/10/09/AR2006100900546.html.

[204]   *See* Seagrumn Smith, *From Napster to Kazaa: The Battle over Peer-to-Peer Filesharing Goes International*, DUKE L. & TECH. REV., Mar. 2003, at 1, 1-3, *available at* http://www.law.duke.edu/journals/dltr/articles/2003dltr0008.html.

infringement is squarely based on the DMCA safe harbor provisions.[205] Some content owners are not satisfied that YouTube does all it could do to prevent infringing material from appearing on its site or to remove such material once it's there. As a result, content owners have begun filing suit. Viacom's lawsuit, seeking over $1 billion in damages from YouTube, is a high-profile test of YouTube's claims.[206]

Google's Book Search service has also raised the issue of Internet content reuse. Google has launched a massive project to digitally scan books and make them searchable through its search engine.[207] Google's project, in partnership with major university libraries, includes two components. The first component involves scanning books that are in the public domain, primarily older works that are no longer covered by copyright protection. The more controversial part of the program involves scanning books that are still under copyright.[208] For these works, Google places a complete copy of the scanned book in its database. It indexes that material, so that a user can search on anything within the book. However, Google does not display the entire book, as it does for the public-domain material. It provides a small snippet of content around the search term, and a few excerpts from the original book.[209]

Google claims that it is providing a service to both readers and publishers by making it easier to find books.[210] From a legal perspective, Google argues that its actions are protected by fair use and by the DMCA's safe harbor provisions.[211] The publishing industry sees it differently. Google requires publishers to opt out of including their copyrighted works in the Book Search database, rather than gaining affirmative approval from each publisher for inclusion of a work. In opposition to this procedure, the Author's Guild and the Association of American Publishers filed copyright infringement suits against Google in 2005.[212]

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[205] *See* Amanda Bronstad, *Video Web Sites Download a Defense*, NAT'L L.J., Oct. 2006, http://www.law.com/jsp/article.jsp?id=1162375515690.

[206] *See* Nate Anderson, *Viacom Sues YouTube for "Brazen" Copyright Infringement*, ARS TECHNICA, Mar. 13, 2007, http://arstechnica.com/news.ars/post/20070313-viacom-sues-youtube-for-copyright-infringement.html.

[207] *See* Google Book Search, Legal Analysis, http://books.google.com/googlebooks/legal.html (last visited Nov. 12, 2008).

[208] *See* Travis, *supra* note 195, at 95-99.

[209] Google also provides links to where the original book can be obtained. *Id.* at 131.

[210] Eric Schmidt, *Books of Revelation*, WALL ST. J., Oct. 18, 2005, at A18.

[211] *See* Travis, *supra* note 195, at 126-39 (analyzing Google's fair use claims).

[212] *See* Complaint at 2, McGraw Hill Co. v. Google, Inc., No. 05 Civ. 8881 (S.D.N.Y. Oct. 19, 2005), *available at* http://www.scribd.com/doc/2692021/The-

In launching its Book Search service, Google is betting that it will prevail in the copyright litigation. If Google loses, the impact could go well beyond one company and one service. A precedent requiring affirmative consent from copyright holders before indexing protected content would throw into question the more common practice of indexing Web content.

Congress originally created the DMCA and Telecom Act safe harbor provisions to protect ISPs and online services, which necessarily stored user-generated content.[213] A safe harbor approach made sense because it would have been unreasonable to require access providers to vet every piece of content one of their users placed on their servers. Google Book Search is a somewhat different situation. In *Metro-Goldwyn-Mayer Studios Inc. v. Grokster, Ltd.*, the Supreme Court ultimately imposed liability on a peer-to-peer file-sharing service, even though the service had the "substantial non-infringing uses" that would ordinarily be a shield against secondary liability.[214] A similar decision in the Google Book Search or YouTube litigation could add devastating uncertainty to the entire Internet content economy.

Google may be doing the right thing, and it may win the Book Search case. However, Internet content re-use is now subject to high-profile scrutiny and a direct legal challenge. The content linkages that Internet users and businesses take for granted are in jeopardy. There will be other lawsuits, and other efforts to erect barriers around information on the Internet. As with governance, backbone interconnection, and network neutrality, the pressure is building to break down the pervasive connectivity that made the Internet what it is today.

Why is the Internet fragmenting now? There are many answers and many contributing factors. Every development described in the previous section has its own specific causes. Yet standing behind these local factors is a deeper, more universal reason for the current pattern: the fundamental dynamics of interconnected networks.

McGrawHill-Companies-Inc-et-al-v-Google-Inc-Document-No-1?ga_related_doc=1; Complaint at 2, Author's Guild v. Google, Inc., No. 05 Civ. 8136 (S.D.N.Y. Sept. 20, 2005), *available at* http://www.scribd.com/doc/2691192/The-Authoraposs-Guild-et-al-v-Google-Inc-Document-No-1.

[213] *See* Alicia L. Wright, *Newsgroups Float into Safe Harbor, and Copyright Holders Are Sunk*, DUKE L. & TECH. REV., Nov. 2006, at 1, 13-14, *available at* http://www.law.duke.edu/journals/dltr/articles/2006dltr0019.html.

[214] 545 U.S. 913, 948 (2005). The "substantial non-infringing use" test arose from the celebrated Sony Betamax case, in which the Supreme Court refused to ban the video cassette recorder because it had non-infringing as well as infringing applications. *See* Sony Corp. of Am. v. Universal City Studios, Inc., 464 U.S. 417, 456 (1984).

III.   NETWORK FORMATION DYNAMICS

All networks share characteristic properties, which researchers have only recently begun to study closely. A branch of network science known as network formation theory suggests exactly the pattern of fragmentation unfolding on the Internet today. As some inter-network components — the U.S.-dominated addressing system, large backbones, broadband access providers, and Google, for example — achieve disproportionate power, they provoke countervailing efforts toward balkanization. The simulations, models, and empirical research of network scientists, applied to the Internet, can aid in understanding these Internet developments and in developing appropriate responses.

Network formation theory demonstrates that interconnected networks such as the Internet can grow quickly but also dissolve quickly. The greatest threat to continued stability is the network itself. Growing networks of independent, economically motivated actors are inherently unstable.[215] If they become stable, they are most likely configured inefficiently.[216] Both outcomes pose threats to the continued vibrancy of the Internet.

This Part introduces the science of networks and its implications for the future of the Internet. Subpart A summarizes the key elements of network science. Subpart B delves into the extension of network science — network formation theory — that is most relevant to the issues of Internet balkanization. Finally, Subpart C ties in two other key findings of network science — the "small-worlds" effect and scale-free distributions — which are consistent with the network formation results.

A.   A New Science

Networks are ubiquitous in modern society, as well as in the physical and biological world.[217] In formal terms, a network is a collection of nodes tied together with links.[218] In the airline industry,

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[215]   *See infra* Part III.B.3.

[216]   *See infra* Part III.B.3.

[217]   *See generally* MARK BUCHANAN, NEXUS: SMALL WORLDS AND THE GROUNDBREAKING SCIENCE OF NETWORKS (2002) (explaining network theory); DUNCAN J. WATTS, SIX DEGREES: THE SCIENCE OF A CONNECTED AGE (2003) (same).

[218]   The formal modeling of networks uses a branch of mathematics called graph theory. *See* Daniel F. Spulber & Christopher Yoo, *On the Regulation of Networks as Complex Systems: A Graph Theory Approach*, 99 NW. U. L. REV. 1687, 1695-99 (2005). The terms "edges" and "vertices" are used interchangeably with "nodes" and "links." *Id.* at 1693 n.17.

airports are the nodes and routes between them are the links. In a social setting, the nodes may be the individuals, and the links their relationships: friendship, sexual contacts, or business partners. In the Internet infrastructure, for example, the routers are the nodes and the data lines are the links. On the Web, the web pages are the nodes and the hyperlinked pointers between them are the links.[219] It is no coincidence that as communications, information, energy, logistics, and transportation networks have spread across the globe, network structures have assumed greater importance in society.[220]

Network science studies the generic properties of these and other networks. It draws upon several disciplines, including statistical physics, sociology, applied mathematics, biology, complexity theory, economics, and computer science.[221] Despite its broad area of inquiry and youth as a coherent field, network science has produced many impressive results.[222] One of network science's leading practitioners labels it "the science of the connected age."[223] Insights from network science are starting to be applied to legal questions.[224] In recent years, scholars have utilized network science to analyze business models for electronic commerce,[225] pricing regulation for unbundled telecommunications network elements,[226] the patent system,[227] privacy,[228] and Internet security.[229] Network science is also beginning

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[219] *See* Réka Albert et al., *Diameter of the World Wide Web*, 401 NATURE 130, 130 (1999) (analyzing network structure of Web).

[220] *See* MANUEL CASTELLS, THE RISE OF THE NETWORK SOCIETY 1 (2d ed. 2000).

[221] The boundaries of these various disciplines are not universally accepted. In particular, scholars differ on whether network science is a sub-discipline of complexity theory, or the reverse, and use a variety of terms to refer to both fields. Adding to the confusion, some of the literature uses the terms "network science" or "network theory" to describe what this paper treats as sub-domains of the larger field, particularly the economic scholarship around network effects. In this paper, I use the term "network science" to address those disciplines concerned with the behavior of complex, evolving, networked systems.

[222] *See generally* BUCHANAN, *supra* note 217 (summarizing significant findings of network theory); WATTS, *supra* note 217 (explaining same).

[223] That is the subtitle of Watts's book, *Six Degrees. See* WATTS, *supra* note 217; *see also* M.E.J. Newman, *The Structure and Function of Complex Networks*, 45 SIAM REV. 167, 180-96 (2003) (describing common properties of networks).

[224] *See* Strandburg, *supra* note 3, at 1295 n.6 (noting relative paucity but significant richness of legal scholarship using tools from network science).

[225] *See generally* CHRIS ANDERSON, THE LONG TAIL: WHY THE FUTURE OF BUSINESS IS SELLING LESS OF MORE (2006) (showing how "power law" distributions, concept from network theory, appear commonly in e-commerce markets).

[226] *See* Spulber & Yoo, *supra* note 218, at 1707.

[227] *See* Strandburg, *supra* note 3, at 1318-19.

[228] Lior Jacob Strahilevitz, *A Social Networks Theory of Privacy*, 72 U. CHI. L. REV.

to show up in the analysis of information and communications policy questions.[230]

Network science covers a great deal of ground. One branch in particular helps to explain the balkanization dynamics described in Part II. That branch is known as network formation theory.

B.   *Network Formation Theory*

1.   In general

Networks can be seen as either exogenous or endogenous factors to the behavior being studied. If exogenous, the network is taken as a given, and the question is what participants in that network are likely to do. This is the stance of most communications and Internet law scholarship.[231] Looking only at what happens once networks exist is a valuable simplifying assumption. Yet in the real world, participants also decide whether to form networks, or to form new links within those networks. For example, people evaluate whether to become friends with each other and Internet backbones evaluate whether to peer.

A full picture of network behavior must therefore consider networks as endogenous factors as well. In other words, networks both produce and are produced by a collection of interactions. There is a branch of network science called network formation that treats networks

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919, 946-47 (2005).

[229] *See* Réka Albert et al., *Error and Attack Tolerance of Complex Networks*, 406 NATURE 378, 380-82 (2000). *But see* David Alderson & Walter Willinger, *A Contrasting Look at Self-Organization in the Internet and Next-Generation Communications Networks*, IEEE COMM., July 2005, at 94, 96 (noting that descriptions of Internet structure based on statistical physics fail to capture properties derived from its actually engineering design).

[230] *See generally* David G. Post & David R. Johnson, *"Chaos Prevailing On Every Continent": Towards a New Theory of Decentralized Decision-Making in Complex Systems*, 73 CHI.-KENT L. REV. 1055 (1998) (using complexity theory, cousin of network science, to address Internet governance questions); Mark Cooper, Making the Connection: Using Network Theory to Explain the Link Between Open Digital Platforms and Innovation (Mar. 24, 2004) (unpublished manuscript, http://cyberlaw.stanford.edu/blogs/cooper/archives/network%20theory.pdf) (applying network theory to telecommunications policy).

[231] Daniel Spulber and Christopher Yoo, in their graph-theoretic analysis of telecommunications interconnection pricing, expressly limit their consideration to what they call "managed" networks, as opposed to the "spontaneous" networks that form endogenously, even though they acknowledge that "the latter type may ultimately become the more important way to analyze communications technologies." *See* Spulber & Yoo, *supra* note 218, at 1693 n.16. Intriguingly, their rationale for this limitation is "the dominance of a handful of infrastructure providers." *Id.*

endogenously.[232]   Network formation theory is a newer field of scholarship than network science generally. As such, there are many questions it has yet to tackle in both the theoretical and empirical cases.[233]   Therefore, application of network formation theory to concrete questions of Internet law and governance must necessarily be preliminary and tentative.

Nonetheless, the major findings of network formation provide significant insights regarding the future of the Internet.[234] In addition to modeling the feedback effects that participants exert on the network itself, network formation expressly considers network structure.[235] Different structures have important consequences, such as the ease of reaching another user on the network and the power of highly connected nodes on the network.[236]

There are two broad classes of network formation models.[237] One set, based on the mathematical domain of graph theory, treats link formation as essentially random. This first set seeks to explain how observed properties in real-world networks could develop through network growth dynamics.[238] The other models, employing game-theoretic techniques from economics, treat link formation as a strategic decision of individual, self-interested agents.[239]   These

[232]   *See* Matthew O. Jackson, *A Survey of Models of Network Formation: Stability and Efficiency*, *in* GROUP FORMATION IN ECONOMICS: NETWORKS, CLUBS AND COALITIONS 11, 25-26 (Gabrielle Demange & Myrna Wooders eds., 2005), *available at* http://www.stanford.edu/~jacksonm/netsurv.pdf; Matthew O. Jackson, *Network Formation*, *in* 5 THE NEW PALGRAVE DICTIONARY OF ECONOMICS 906, 907 (Steven N. Durlauf & Lawrence E. Blumem eds., 2d ed. 2008) [hereinafter Jackson, *Network Formation*].

[233]   *See* Jackson, *supra* note 7, at 319 ("[W]e are only beginning to develop theoretical models that are useful in a systematic analysis of how such network structures form and what their characteristics are likely to be.").

[234]   *See* ROMUALDO PASTOR-SATORRAS & ALESSANDRO VESPINGANI, EVOLUTION AND STRUCTURE OF THE INTERNET: A STATISTICAL PHYSICS APPROACH 84 (2004) ("In recent years we have witnessed a change of perspective in the theoretical study of complex networks that shifts the modeling focus from the reproduction of the network's *structure* to the modeling of its *evolution*. This new approach is the outcome of the realization that most complex networks — the Internet being only one of the most important examples — are the result of a growth process.")

[235]   *See* Jackson, *supra* note 7, at 319.

[236]   *See generally* WATTS, *supra* note 217 (detailing dynamics of different types of networks).

[237]   *See* Matthew O. Jackson, *The Economics of Social Networks*, *in* 1 ADVANCES IN ECONOMICS AND ECONOMETRICS: THEORY AND APPLICATIONS, NINTH WORLD CONGRESS, at 1, 11 (Richard Blundell et al. eds., 2006).

[238]   *See infra* Part III.B.2.

[239]   *See infra* Part III.B.3.

economic models can measure the relative social welfare benefits of different network structures, and can better explain why those outcomes emerge.[240] The economic models, however, come up short in describing how networks progress through the formation process and what they will look like at the end of the process. Despite the limitations of each method, taken together, the two approaches paint a rich picture of network formation.[241] The combination of these methods forms a set of tools and techniques for evaluating normative questions about Internet evolution.

2. Random network formation

The seminal early work in network formation, by Paul Erdős and Alfred Rényi in the 1950s, modeled networks as what are called "random graphs": sets of nodes between which links were randomly added.[242] Erdős and Rényi found that these random graphs experienced a "phase transition" as the density of links increased relative to the number of nodes.[243] At that point, the networks rapidly shifted from collections of small, discrete components to a single "giant component," which incorporated the vast majority of the nodes.[244] In other words, networks with enough links tend towards interconnection.[245] They pull themselves together.

The random graph studies show that the key factor in whether networks come together is not their size, but their connectivity.[246] The more connections there are between participants on the network, the

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[240] *See* Jackson, *supra* note 237, at 20-33.

[241] The approaches are not in conflict; they are different means of evaluating network formation. The scholars developing random and strategic network formation models were generally unaware of each other until recently. One of the signal developments in the emergence of network formation as a distinct branch of network theory is the appreciation of the complementary nature of the two approaches. *See id.*

[242] *See generally* DOUGLAS B. WEST, INTRODUCTION TO GRAPH THEORY (2d ed. 2001) (describing graph theory); Paul Erdős & Alfred Rényi, *On Random Graphs,* 6 PUBLICATIONES MATHEMATICAE 290 (1959) (modeling random graphs).

[243] The number of links per node is called the degree of that node. *See* Jackson, *supra* note 237, at 3-4. The phase transition in a random graph network occurs when the average degree of the network exceeds one. *See id.* at 13.

[244] *See id.* at 13.

[245] These models do not take into account the ownership structures of the component networks. As noted in the previous section, the outcome in the real world may either be a single dominant network operator, or a constellation of interconnected providers. *See* Lemley & McGowen, *supra* note 31, at 549-50; *infra* text accompanying note 331.

[246] *See* Jackson, *supra* note 237, at 13-14.

more likely it is that those participants will share a common platform.[247] In the real world, network links do not simply appear arbitrarily; they have a cost. If links are cheaper to establish, there will be more of them, which therefore makes an interconnected platform more likely.

This has, in fact, been the case. Researcher Tom Vest engaged in a large study of "autonomous network" data measuring the degree of connectivity on the Internet.[248] He found that the key variable explaining the rate of Internet penetration worldwide is the availability and pricing of telecommunications circuits.[249] Similar examples can be adduced at other layers. In content, for example, the fact that search engines need not negotiate and pay a market clearing price to incorporate online content into their indexes allows those indexes to cover a large percentage of the publicly accessible Web, rather than just selected portions of it.[250]

The point here is not just the obvious one that cheaper links mean more links, but that cheaper links are more likely to produce a universally interconnected platform. The reverse is also true. As links become more expensive, and thus rarer, the network may experience a phase transition in reverse. Instead of connectivity decaying gradually, the network may quickly switch from one in which the bulk of users can communicate to one in which most users are trapped in discrete sub-networks.[251] Thus, network science sounds the cautionary alarm that networks may balkanize more rapidly and more extensively than would be expected.

3. Strategic network formation

The limitation of the random-graph models of network formation is that they do not examine *why* links form. They simply assume a random process, or some arbitrary algorithm. An alternate and complementary approach, grounded in economic theory, begins with the recognition that the participants in networks are self-interested actors.[252] These actors are focused on maximizing their own welfare,

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[247] *See id.*

[248] Telephone Interview with Tom Vest, Senior Economist & Policy Analyst, Coop. Ass'n for Internet Data Analysis (Sept. 12, 2006).

[249] *See id.*

[250] Because search engines operate by sending out spiders that crawl the Web through its links, content that is not connected to other portions of the network may be "invisible" to them.

[251] *See* Jackson, *supra* note 237, at 14-15.

[252] *See id.* at 20-33.

not the aggregate behavior of the network. Their decisions, far from being random, reflect strategic tradeoffs based on the environment they see around them.[253] Such situations are the domain of game theory.

Game theory is an area of economics that studies strategic interactions between independent actors (called "agents") by modeling them as games.[254] Consider a group of agents, who may be individuals, companies, or other actors, that are potentially part of a network. Each agent must decide whether to form a link between its node and those of other agents.[255] The agent decides whether to form the link by evaluating the relative costs and benefits of establishing the link. If two agents find that the benefits of connecting exceed the costs, they will do so.

Agents benefit not only from their own links, but from the ability to reach others on the network with whom they are not directly connected. For example, Internet users benefit from the peering relationships between one ISP's backbone and other backbones, even though users are not part of those negotiations. A user's ability to locate documents on the Web increases when someone else creates a link to it. This is because the link increases the likelihood that a search engine spider will find a given document and because search engines will utilize that link structure to match that document with the user's query.[256] The potential disconnect between the private calculus of agents, who selfishly act based on their own cost-benefit calculations, and the real welfare calculus for those agents, which depends on collective behavior, is a central subject for game theory.[257] The balkanization of the Internet is an example of just such behavior.[258]

A burgeoning body of game-theoretic literature seeks to model how the collective behavior of self-interested network nodes produces global network structures.[259] Agents are given cost-benefit functions

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[253] *See id.*

[254] *See generally* DREW FUDENBERG & JEAN TIROLE, GAME THEORY (1991) (describing game theory). Game theory is the field in which John Nash, the subject of the book and movie, *A Beautiful Mind*, won the Nobel Prize. The Nash Equilibrium is the point in any game where no agent would benefit by altering its strategy.

[255] For simplicity, this discussion, and the earlier discussion of graph theory, uses examples of "non-directed" graphs, in which both sides must agree to form a link. There are also "directed" graphs, such as the network of citations among academic papers. Citations flow in only one direction; the cited paper has no say in the decision.

[256] *See supra* Part II.D.

[257] This is an example of the famous "prisoner's dilemma," in which two agents will fail to cooperate, even though doing so would make them both better off.

[258] *See supra* Part II.

[259] *See* Matthew O. Jackson & Asher Wolinsky, *A Strategic Model of Social and Economic*

for linking with other nodes, which can incorporate not only the direct benefit to the connected nodes, but the indirect network effects that propagate out to other nodes.[260]   These models reveal the equilibrium points that networks may evolve toward as their participants employ various strategies to maximize their own welfare.

A key dimension of network formation models is pairwise stability, which was introduced by Matthew Jackson and Asher Wolinsky.[261] A network is considered pairwise stable if no node would be better off by severing one of its links, and no two nodes would benefit from adding a new link between them.[262] For example, an Internet backbone must constantly decide whether to add additional peering points with other backbones, or to eliminate existing connections. It will weigh the costs and benefits of each decision. Given a particular scenario, there may be no pairwise stable network equilibrium. If there are one or more pairwise stable outcomes, the models show that those network structures will likely emerge.[263]

A different criterion for evaluating networks is their efficiency — the extent to which networks maximize aggregate utility for their participants. From an economic standpoint, the goals of law and public policy are to maximize social welfare. A network configuration that makes a few nodes better off, but most nodes worse off, is undesirable.[264]   Highly concentrated networks, in which one node dominates, are also unlikely to be efficient unless the value to the central node is so enormous that it exceeds the cost to the other nodes.

To express the two technical terms colloquially, efficient networks are the networks we want while stable networks are those we are likely to get. The key question is: When are stable networks also efficient, and vice versa?   Unfortunately, the strategic network formation models

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Networks, 71 J. ECON. THEORY 44, 45-48 (1996); Jackson, *supra* note 7, at 319-20.

[260] *See, e.g.*, Jackson & Wolinsky, *supra* note 259 (modeling network stability and efficiency using this approach).   The network formation models use the generic concept of nodes.   They apply to collections of networks deciding whether to federate and to individual users or companies determining whether to join a network.

[261] *See id.* at 47-48.

[262] *See* Jackson, *Network Formation*, *supra* note 232, at 27-28; Jackson & Wolinsky, *supra* note 259, at 51; Jackson, *supra* note 7, at 336. As a somewhat stylized concept, pairwise stability only gives an indication of the robustness of a network. It does not mean that the network will no longer evolve, or that it will not disintegrate. *See* Jackson, *supra* note 7, at 336.

[263] *See* Jackson & Wolinsky, *supra* note 259, at 45 ("This analysis is designed to give us some predictions concerning which networks are likely to form . . . .").

[264] For simplicity, this example assumes that the harm or benefit to each node is the same.

show that efficiency and pairwise stability are often at odds.[265] Stable networks may not be efficient, and efficient networks may not be stable. One reason for this apparent tension is network effects.[266] Decisions to form or sever links produce significant externalities,[267] meaning that individual nodes may not accurately perceive the overall costs and benefits to the network.[268] A second reason is that networks with a few highly connected hubs may be efficient, but the less-connected nodes will then have incentives to connect directly, undermining the disproportionate power of the hubs.[269]

Another class of strategic network formation models uses the engineering concept of optimization rather than purely game-theoretic approaches.[270] Under a highly optimized tolerance ("HOT") model, network nodes seek the optimal balance between conflicting incentives to minimize cost and maximize value for the network as a whole.[271] Cost is an important constraint in the real world, where some links are more expensive to construct than others. A link across a large physical distance may be too costly to build, even though it would significantly improve the connectivity of a given node. In the HOT model, nodes balance a cost constraint (minimizing the physical distance to other connected nodes), against a value constraint (shortening the number of hops to the central network hubs). The magnitude of both the cost and value variables will lead the network to evolve into a more or less centrally clustered structure.

The network formation studies offer a rich and multi-dimensional picture of how networks grow and develop. Intriguingly, their findings are consistent with two other major insights of network science — small worlds and scale-free distributions. Adding these concepts provides an even clearer picture of how and why networks such as the Internet come together and then fragment.

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[265] *See* Jackson & Wolinsky, *supra* note 259, at 59-60.

[266] *See infra* Part IV.B.1.

[267] An externality is a cost or benefit from an action that the actor itself does not naturally perceive or take into account when choosing to act or refrain from acting. *See* WATTS, *supra* note 217, at 211. Pollution from factories is a classic negative externality.

[268] *See* Jackson, *supra* note 7, at 319.

[269] *See id.* at 349-50. This is essentially the scale-free dynamics described below.

[270] *See* Alderson & Willinger, *supra* note 229, at 96.

[271] *See* J.M. Carlson & John Doyle, *Highly Optimized Tolerance: A Mechanism for Power Laws in Designed Systems*, 60 PHYSICAL REV. E 1412, 1423-26 (1999) [hereinafter Carlson & Doyle, *Mechanism for Power*]; J.M. Carlson & John Doyle, *Highly Optimized Tolerance: Robustness and Design in Complex Systems*, 84 PHYSICAL REV. LETTERS 2529, 2529 (2000) [hereinafter Carlson & Doyle, *Robustness and Design*].

C. Disproportionate Power: Small Worlds and Scale-Free Dynamics

Among the most notable discoveries of network science are two surprising properties of many networks: "small-worlds" behavior and scale-free patterns. Each has significant legal and policy implications. Specifically, small worlds and scale-free distributions although expressing different concepts, both mean that some nodes or clusters of the network can attain disproportionate power merely through natural network processes. These insights are consistent with the findings of network formation theory that networks may reach an equilibrium with a small number of dominant hubs. They further illustrate how some actors in an environment such as the Internet can take advantage of inter-connectivity to produce an environment that ultimately undermines the network.

1.   It *is* a small world after all

The small-worlds phenomenon is embodied in the famous concept of "six degrees of separation," immortalized in a popular play and movie of the same name.[272] The original concept came from an experiment that psychologist Stanley Milgram conducted in the 1960s.[273] Milgram asked a group of people to send a letter to someone they knew, who could in turn pass it along to a particular unknown recipient in another state. It took approximately six steps on average for the letters that were received at the final destination. Given the population and geographical dispersion of the United States, this was a shockingly small number.[274] Similar findings appear in a wide variety of networks. For example, there are an average of less than four links between any two actors (treating co-starring in a movie as a link),[275]

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[272]   *See generally* JOHN GUARE, SIX DEGREES OF SEPARATION (1992).

[273]   Stanley Milgram, *The Small World Problem*, PSYCHOL. TODAY, May 1967, at 60, 60-68 (1967).

[274]   Contrary to popular belief, Milgram's experiment did not prove that there are only six degrees of separation between any two people. For example, only letters that arrived at the destination were counted. Three-fourths never got there. *See* Judith S. Kleinfeld, *The Small World Problem*, SOC'Y, Jan.-Feb. 2002, at 61, 62-64. The significance of Milgram's work is that it showed the presence of short paths through the network, in the days before computer simulations could demonstrate such behavior formally.

[275]   *See* Duncan J. Watts & Steven H. Strogatz, *Collective Dynamics of "Small World" Networks*, 393 NATURE 440, 441 tbl.1 (1998). A humorous parlor game called Six Degrees of Kevin Bacon takes advantage of this fact to trace the relationship of any actor through a chain of co-stars to Kevin Bacon. WATTS, *supra* note 217, at 93-95.

and only about three hyperlinks on average between documents in a sampling of 50 million World Wide Web pages.[276]

In the 1990s, network scientists, most prominently Duncan Watts,[277] generalized and explained the operation of the small-worlds phenomenon. The diameter of a network — the average number of links between any two arbitrary nodes — tends to grow much more slowly than the number of nodes. In other words, two users on a big network can reach each other without traversing many more links than they would on a small network.[278] In a famous paper, Watts and Steven Strogatz showed how a simple network with only local connections between adjacent nodes (and therefore a large diameter between distant nodes) could turn into a small world through the random insertion of a few "shortcut" connections.[279] A small number of long-distance links transforms the connectivity patterns of the network.

From a network formation perspective, the small-worlds phenomena can be explained as a strategic equilibrium among network participants.[280] Most links are local. Long-distance links are costly to create and usually involve weaker connections. Long-distance links are therefore rare. Once established, however, long-distance links are a source of significant value-creation because they dramatically shorten paths across the entire network.[281] Viewed another way, the long-distance links control valuable assets, not because they are bottlenecks in the traditional market power sense, but because they reduce the effective network diameter for everyone else. Those who control such network shortcuts, whether address

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[276] *See* Lada Adamic, *The Small World Web*, 1696 LECTURE NOTES COMPUTER SCI. 443, 444 (1999), *available at* http://www.springerlink.com/content/4fjgx8c7m92nqe05/fulltext.pdf.

[277] *See generally* WATTS, *supra* note 217 (elaborating on small-worlds phenomenon).

[278] In addition to being small worlds, social networks also tend to be highly clustered. This means that if one node in a linked pair connects to a different node, the second node in the pair is likely to as well, forming a triangular structure. The coexistence of small worlds and clustering is surprising. The former suggests that there are many long-distance "shortcuts" across the network, while the latter implies that nodes are densely interconnected with their close neighbors. The Watts-Strogatz model showed theoretically how such network properties could emerge simultaneously. *See* Watts & Strogatz, *supra* note 275, at 441.

[279] *See id.*

[280] *See* Jackson, *supra* note 237, at 27-28.

[281] This work parallels the findings of sociologists and management scholars, such as Ronald Burt of the University of Chicago, who study the effects of social capital in business. *See generally* RONALD BURT, STRUCTURAL HOLES: THE SOCIAL STRUCTURE OF COMPETITION (1992) (illustrating value of long-distance links in business).

databases that facilitate connections to distant websites or the search engines that send users to the distant reaches of the Web, are in an enviable economic position.

Moreover, the entire Internet is a collection of long-distance links between discrete, locally connected networks.[282]   Although the Internet appears to be smooth and featureless, it is actually a group of islands with links between them. There are fewer of those links than one might imagine, and their importance to the network as a whole is greater than it appears.

2.   Scale-free networks: the rich get richer

Network science's second prominent finding is scale-free dynamics. Researchers, including Albert-László Barabási, developed the theory of scale-free networks based on the observation that in many networks, some nodes are vastly more connected than others.[283] For example, the most connected pages on the Web, the most connected electric power substations in the Western United States, and the most active protein in the metabolism of yeasts are all orders of magnitude more connected than the average node in those networks.[284] Put another way, the frequency of different connectivity levels of nodes (formally known as the degree of those nodes) is not a bell curve (Gaussian) distribution in which medium levels of connectivity are most common and high or low connectivity is relatively uncommon. It is instead a power-law distribution, meaning that each degree of connectivity is exponentially more rare.[285] This produces a distribution curve with a narrow, tall "head" and a long, fat "tail." A tiny number of nodes have massive numbers of links, and very many nodes have few or no links.

The scale-free pattern arises from a phenomenon known as preferential attachment.[286] When new nodes join the network, they do not connect randomly to other nodes.[287]   They are more likely to

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[282]   *See supra* Part II.B.

[283]   *See generally* ALBERT-LÁSZLÓ BARABÁSI, LINKED: HOW EVERYTHING IS CONNECTED TO EVERYTHING ELSE AND WHAT IT MEANS (2002) (describing major findings of network science).

[284]   *See* Newman, *supra* note 223, at 187.

[285]   The term "scale-free" arises from the fact that no level of connectivity is typical for the network. The function for describing the curve is exponential. Represented graphically, the "long tail" curve has a head that is extremely high and narrow, but a tail that is extremely long and flat.

[286]   *See generally* BARABÁSI, *supra* note 283 (discussing preferential attachment and related concepts).

[287]   Hence, the basic Erdős-Rényi random graph model fails to account for

connect to nodes that are already well connected. For example, a new link on the Web is more likely to point to an already-popular site because those are the sites most people are familiar with and find interesting. When new Internet users ask their friends what search engine to use, they are most likely to tell them to use Google. When a new network backbone seeks a peering relationship, it is more likely to first approach the largest, best connected existing network.

Both the physical routers making up the Internet and the links connecting web pages exhibit a scale-free structure.[288] Network theorists have concluded from this that the Internet is both more stable and more vulnerable than previously thought.[289] It is more stable because the vast majority of nodes are relatively unimportant and can be knocked out without significant effects on network-wide connectivity. Conversely, it is more vulnerable because a few key nodes are so densely connected that a coordinated attack on them would quickly break up the network.[290] Consistent with the network formation analysis, the Internet turns out to be both robust and at risk at the same time.[291]

The scale-free dynamics of the Internet are dangerous because those participants that are not at the top of the power-law curve may choose balkanization over losing out to the most connected node.[292] Remember that, as the network formation literature demonstrated, the shift from a network that offers near-universal connectivity to disconnected islands can be abrupt.[293] Just as a small-world network is unusually dependent on its few "shortcut" links, a scale-free network is unusually dependent on its dominant nodes.[294]

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significant properties in observed real-world networks. *See* Erdős & Rényi, *supra* note 242, at 290-97. Modifications to the random graph model can, however, produce scale-free behavior.

[288] *See id.*

[289] *See* Andres Guadamuz, *Scale-Free Law: Network Science and Copyright*, 70 ALB. L. REV. 1297, 1304 (2008).

[290] *See* Albert, *supra* note 229, at 380-81. *But see* Andrei Broder et al., *Graph Structure in the Web*, 33 COMPUTER NETWORKS 309, 309-10 (2000) (offering more nuanced picture of large scale structure of Web); Cooper, *supra* note 230, at 24.

[291] *See* Jackson, *supra* note 237, at 12; *supra* Part III.B.2.

[292] That appears to be what is happening in several of the case studies above. *See supra* Part II.

[293] *See supra* Part III.B.2. In scale-free networks, other aspects of network structure influence the likelihood of a phase transition between lightly connected and highly connected networks, as compared to random graphs where the relative number of links to nodes is the primary variable. *See* Newman, *supra* note 223, at 225-28.

[294] Random network formation models can be modified to incorporate preferential attachment, and thereby produce scale-free networks. *See* Jackson, *supra* note 237, at

Sociologist Saskia Sassen makes an analogous point in her analysis of cities and globalization.[295]   Even as production is increasingly distributed around the globe, she notes, management functions and their associated support services become increasingly centralized in a few highly concentrated "global cities."[296]   This creates risks of catastrophic failure, especially as poorly connected regions fail to reap the promised benefits of global connectivity. Sassen points out that cyberspace, being embedded in the larger dynamics of society, is not immune from these forces.[297]   Thus, the countervailing pressures of centralization and decentralization within society also operate directly on the Internet. Sassen's analysis illustrates how universal system dynamics can have tremendous real-world consequences.   The Internet is not immune from the tensions of globalization. Its fate may be an illustration of them.

As this Part has shown, theoretical models of networks tell a story that is entirely consistent with the general dynamic of a network at war with itself outlined in Part I, and the stories of Internet balkanization in practice in Part II. The remaining question is what, if anything, should be done about this trend.

IV.   ONE NETWORK OR MANY?

The choice facing policy makers today is whether to allow the Internet to fragment, or to reinforce the norms that helped to pull it together.   The dynamics of network formation, small worlds, and scale-free structures will produce a more balkanized environment unless external regulatory forces are brought to bear. An examination

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16-17. The strategic network formation models have a more difficult time accounting for this phenomenon. They treat link formation as an economic weighing of costs and benefits, rather than a decision shaped by previous behavior.

[295] *See* Sassen, *supra* note 52, at 21 ("[W]hile regionally oriented firms need not negotiate the complexities of international borders and the regulations of different countries, they are still faced with a regionally dispersed network of operations that requires centralized control and servicing.").

[296] *See generally* SASKIA SASSEN, THE GLOBAL CITY (2001) (explaining concept of global cities); Sassen, *supra* note 52, at 15 ("This dynamic of simultaneous geographic dispersal and concentration is one of the key elements in the organizational architecture of the global economic system.").

[297] Saskia Sassen, *The Topoi of E-Space: Global Cities and Global Value Chains*, *in* SARAI READER 01:   THE PUBLIC DOMAIN 24, 24-25 (2001), *available at* http://www.sarai.net/publications/readers/01-the-public-domain (follow "The Topoi of E Space: Global cities and global value chains – Saskia Sassen – 24" hyperlink); *cf.* Julie Cohen, *Cyberspace and/or Space*, 107 COLUM. L. REV. 210, 212-13 (2007) (describing interrelationship of cyberspace and physical space).

of the Internet's history shows that open federation of disparate systems creates innumerable benefits. Network effects, a fundamental concept that has been incorporated into network science, sharpens the explanation of why the composite structure of the Internet creates value that independent networks could not.[298]

Regulators, legislators, and courts should promote the continued integration of networks and systems into the interoperable Internet. Historical examples, such as the privatization of the Internet backbone, show that government can simultaneously facilitate both interconnection and competition. Federation and uniformity are not the best answer in every situation, but the modeling techniques of network science provide a rich toolkit to assess the implications of different network structures.

This Part suggests some guidelines to aid policy makers in mapping network science to network law and regulation. Subpart A offers an historical and technical picture of how the Internet became such as unifying force, illustrating the role of conscious design. Subpart B explains the economics of network effects, and how they further explain the benefits of a federated Internet. Finally, Subpart C offers some initial thoughts for translating these concepts into prospective policy decisions.

A.   *How the Internet Came Together*

1.   The ends as the means

One of the central lessons of network science is that the same collection of actors will produce different results based on the way their connections are wired.[299] In other words, the characteristics of networks strongly influence their ultimate utility.[300] The Internet and the public switched telephone network ("PSTN") use the same physical infrastructure. However, their economic and social outputs are very different, for example, because their connections are structured differently. The PSTN is a "circuit-switched" network in which powerful phone company switches control the flow of

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[298]   *See infra* Part IV.B.1.

[299]   *See generally* Yannis Ioannides, *Random Graphs and Social Networks: An Economics Perspective* (Tufts Dep't of Econ., Working Paper No. 518, 2006) (explaining how network science improves on overly simplistic economic models that merely aggregate individuals); *supra* Part III.

[300]   *See* WATTS, *supra* note 217, at 244 ("The structure of the network can have as great an influence on the success or failure of an innovation as the inherent appeal of the innovation itself.").

information.   The Internet is a "packet-switched" network, which decentralizes traffic management to the real-time decisions of individual routers.[301]

The dominant project of cyberlaw is to parse the implications of the Internet's structural rules or "code."[302]   Legal scholars seeking to explain the Internet's dynamism as a unified platform have emphasized a particular structural factor: the so-called "end-to-end" model.[303] An end-to-end network is one that pushes control out to the endpoints.[304] The network focuses on moving bits from one place to another, without considering what those bits contain.   Any edge device, such as a computer or mobile phone, can add a new application, and those edge devices are solely responsible for factors such as reliability and security that ensure the success of that application.   Because innovations do not require the consent or updating of the network core, those innovations can be deployed more quickly.[305] As edge devices become more powerful, which they do as computing power improves over time, their enhancements can immediately be joined to the network.   So, new services such as Google, Skype, Hotmail, Facebook, and Amazon.com can catch on and grow rapidly, generating significantly more social and economic benefits than in a network like the PSTN, where central control nodes must approve new features.[306]

The end-to-end model emphasizes only one side of the equation — the edges. The Internet gives extraordinary power to its endpoints, but it also embodies linkages between those endpoints, and between

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[301] A packet-switched network routes individual packets, which are small chunks of data, while a circuit-switched network keeps open the same circuit for an entire call. *See* Werbach, *supra* note 32, at 17. The distinction between packet and circuit switching is one of many structural differences between the Internet and the PSTN. *See id.*

[302] *See* LAWRENCE LESSIG, CODE AND OTHER LAWS OF CYBERSPACE 107-108 (1999).

[303] The classic statement of the end-to-end model was a 1981 paper by computer scientists Jerome Saltzer, David Clark, and David Reed. *See* Jerome Saltzer et al., *End-to-End Arguments in System Design*, 2 ACM TRANSACTIONS ON COMPUTER SYS. 277, 278 (1984). Its implications for innovation were later famously explained in the work of David Isenberg and Lawrence Lessig. *See* LESSIG, *supra* note 183, at 34-35; Mark Lemley & Lawrence Lessig, *The End of End-to-End: Preserving the Architecture of the Internet in the Broadband Era*, 48 UCLA L. REV. 925, 931 (2001); David Isenberg, *The Rise of the Stupid Network*, COMPUTER TELEPHONY, Aug. 1997, at 16, 16.

[304] *See* Saltzer et al., *supra* note 303, at 278.

[305] *See* Lemley & Lessig, *supra* note 303, at 930-31.

[306] *See id.* at 931; Zittrain, *supra* note 126, at 2021-22. Zittrain argues that, absent intervention, the edge devices on the Internet will increasingly be locked-down, special-purpose devices, rather than the general-purpose computers that generate innovation. *See* Zittrain, *supra* note 126, at 1977-78, 2002.

aggregations of systems that connect into a composite network. The fact that the edges of the network define the applications say nothing about how those edges are wired together. An endpoint can offer a brilliant innovation, but such innovation will be of no value if other endpoints cannot access it, or cannot access it easily.[307] Something more than the end-to-end principle must explain how the Internet holds together.

2. Connected by design

Like any network, the Internet is, to a great extent, a product of the design parameters under which it was created.[308] While the end-to-end model accurately describes the orientation of the engineers who designed the Internet, it was a retroactive explanation of the network's architecture, rather than a guideline for its design.[309] The actual development of the Internet focused not on the edges, but on the links.

Histories of the Internet typically trace its ancestry from broad concepts such as packet switching, developed by Paul Baran, to the first implementation in the ARPANet of the U.S. Department of Defense, to the civilian NSFNet, to its commercialization and privatization into the Internet we know today.[310] While not inaccurate, such a timeline de-emphasizes the key shift in moving from the ARPANet to the Internet: the emphasis on internetworking. The ARPANet was a single, integrated network. The NSFNet, and the fully private Internet that succeeded it, were collections of interconnected but separately managed networks.

For those who created it, the Internet had one paramount objective: it was designed to transport packets of data transparently across a network of networks.[311] It is hard to imagine today, when the Internet

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[307] The "ease" of access may involve several dimensions, including cost, speed, and reliability.

[308] *See generally* Varnelis, *supra* note 52 (discussing design parameters of Internet).

[309] The Saltzer, Clark, and Reed paper that articulated the end-to-end principle was published nearly a decade after the basic Internet protocols were adopted. *See* Saltzer et al., *supra* note 303, at 278.

[310] *See* Werbach, *supra* note 32, at 13-16; *supra* text accompanying note 33.

[311] *See* David Clark, *The Design Philosophy of the DARPA Internet Protocols,* ACM SIGCOMM COMPUTER COMM. REV., Aug. 1988, at 106, 106, *available at* www.cs.princeton.edu/~jrex/teaching/spring2005/reading/clark88.pdf. It would, of course, be an oversimplification to label interconnectivity the sole purpose of the Internet. Other goals, such as robustness, supporting a wide range of possible applications, demonstrating the feasibility of wide-area packet networking, and supporting research applications, were also significant. Moreover, the Internet we know today developed through an evolutionary process, involving many contributors.

is synonymous with data connectivity, but there were already research and academic networks before the Internet came about. The difference was that these networks were typically limited to local systems or specific services.[312] The Internet was designed to break down those boundaries.

The Internet protocol was designed to be lightweight enough to ride on top of any available network infrastructure.[313] Other protocols and their implementations followed "Postel's Law," named after Jon Postel, one of the key members of the Internet engineering community.[314] Postel's dictate, in order to enhance cooperation among separately managed networks, was to "be conservative in what you do, be liberal in what you accept from others."[315] Most of the other technical innovations that allow the Internet to function, such as the ingenious congestion management schemes that operate without central regulatory mechanisms and the distributed databases supporting the DNS, were developed for internetworking. Even the end-to-end approach, now emphasized primarily for its effects on innovation, had its roots in internetworking. In an end-to-end network, connectivity does not depend on enhancements baked into a particular network. Edge devices are free to communicate and establish new applications, regardless of what network infrastructure they sit on.

Significant consequences flow from the fact that interconnectivity, and not some other objective, is the baseline goal embedded in the Internet's architecture. The Internet is a complex, engineered system, and such systems necessarily involve tradeoffs.[316] Had the Internet

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However, effective internetworking was the most significant design element of the system. *See id.* at 106-10.

[312] The shift from local, purpose-specific networking parallels the shift in the computing world from single-function devices such as calculators and word processors to general purpose personal computers. *Cf.* Zittrain, *supra* note 126, at 1975-76.

[313] *See* G. Keith Cambron, *The Next Generation Network and Why We'll Never See It*, COMM. MAG., Oct. 2006, at 8, 10 ("IP's greatest contribution is its ability to switch information across diverse networks, independent of the underlying technology; the greatest legacy of IP is the universal acceptance of the address scheme and message structure.").

[314] *See* Jon Postel, Info. Scis. Inst., *Transmission Control Protocol: DARPA Internet Program Protocol Specification*, at ii (Sept. 1981) (Request for Comments No. 793), http://www.faqs.org/rfcs/rfc793.html (last visited Oct. 31, 2008). Postel also supervised the assignment of Internet addresses.

[315] *Id.* at 13.

[316] *See* Alderson & Willinger, *supra* note 229, at 94. The HOT models of network development demonstrate how tradeoffs between competing incentives in networks can produce instabilities and shape network performance. *See* Carlson & Doyle, *Mechanism for Power*, *supra* note 271, at 1424; Carlson & Doyle, *Robustness and*

been designed primarily to ensure reliability, security, or effective billing of real-time voice communications traffic, it would have turned out quite differently.[317] In particular, designs for internetworking have to create both incentives and the opportunities for isolated systems to come together.

Describing the Internet in these terms runs counter to the tenor of most cyberlaw scholarship. Because the end-to-end model focuses on the network's edges, it can over-emphasize the degrees of freedom those edges enjoy.[318] Moreover, perspectives that generalize about edges of "the Internet" miss how those edges are themselves embedded in component networks that are tightly interconnected.

B. *Federated Network Effects*

1. Bigger is better

The clearest reason why an interconnected, federated architecture creates so much value on the Internet is the phenomenon of network effects.[319] Though it is consistent with network formation theory, the economic concept of network effects predates the development of network science.[320] The basic idea is that participants on the network benefit from the presence of other participants. To take a simple example, my friend's decision to purchase a mobile phone also benefits me, because I can now call her more easily. In economic terms, there is a positive externality to her decisions to join the network. A bigger network is thus more valuable, independent of any scale or scope economies for its creators.

Design, *supra* note 271, at 2529.

[317] Under those circumstances, the Internet would have looked like the public switched telephone network.

[318] Zittrain's "generativity" model acknowledges that network edges may no longer be so unconstrained. *See* Zittrain, *supra* note 126, at 1995-96. However, his perspective still concentrates on the behavior of the edge devices, rather than the network links that tie them to networks, and networks to each other.

[319] *See* Lemley & McGowan, *supra* note 31, at 483 ("'Network effects' refers to a group of theories clustered around the question whether and to what extent standard economic theory must be altered in cases in which 'the utility that a user derives from consumption of a good increases with the number of other agents consuming the good.'").

[320] The foundational work on network effects in information industries was performed in the 1980s. *See* ARTHUR, *supra* note 25, at 1-4; Michael L. Katz & Carl Shapiro, *Network Externalities, Competition, and Compatibility*, 75 AM. ECON. REV. 424, 424 (1985); *see also* SHAPIRO & VARIAN, *supra* note 178, at 173-225 (detailing economic implications of "positive feedback" in network industries).

One consequence of network effects is that the network becomes more valuable as it grows. A bigger network gives users access to more other users, and to more content or services that can be delivered through the network. This principle means that growth and interconnectivity magnify the social welfare benefits of the Internet. In this environment, the benefit to each user grows with additional users. A group of distinct networks, such as the consumer online services that were prevalent immediately before the rise of the Internet, may in aggregate connect the same number of users. However, each user will have access to a smaller universe of other users, or of services on the network platform. The overall utility of this network configuration will be inferior to the Internet, which connects all users.[321]

These network effects also suggest that, even absent anti-competitive behavior, network industries may tend toward concentration. New entrants may find it difficult to catch an early market leader, because the larger network is inherently more valuable to users. Network effects have been used to explain how AT&T gained a commanding advantage in the early days of telephone service over smaller independent telephone companies, how Microsoft built and preserved a monopoly in personal computer operating systems, and how social networking site MySpace achieved a dominant market position, even facing high-profile competitors.[322]

2. Benefits of federation

In a 1998 article, Mark Lemley and David McGowan surveyed the implications of network effects for various areas of the law.[323] They concluded that, although network effects offer significant insights in fields such as antitrust, intellectual property, and communications law, courts and regulators often apply the concept carelessly or incorrectly.[324] In adversarial legal processes, partisans are incentivized to stretch the postulates of network effects theory to match their desired outcomes, sometimes beyond what the theory can justify.[325] Moreover, network effects themselves are often indeterminate. In real-

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[321] The issue is not just the scale and scope efficiencies of larger networks. These are questions of supply-side economies, which classical economics has long considered. Network effects is a demand-side phenomenon. *See* Lemley & McGowan, *supra* note 31, at 484.

[322] *See id.* at 549-51.

[323] *See id.*

[324] *See id.* at 609-11.

[325] *See id.* at 562.

world situations, their implications depend more on the particular dynamics of the relevant industry than on the general principles of the formal model.[326] Lemley and McGowan therefore urged a cautious approach to incorporating network effects into the law, adopting the least sweeping rule consistent with the theory.[327]

There has been significant legal and economic scholarship on the implications of network effects for telecommunications and the Internet.[328] As Lemley and McGowan explain, network effects do not necessarily mean that the largest player will dominate potential competitors.[329] In a networked system such as the Internet, network effects push toward a single universal platform.[330] However, that need not be a monopoly network controlled by a single provider. When compatible standards allow networks to interconnect and federate, a single internetwork such as the Internet or today's multi-provider telecommunications market is an equally valid configuration.[331] The durability of the Internet backbone market as a relatively competitive environment is testament to the fact that the rich do not always get richer.

In other words, the network effects literature suggests that, in a networked environment such as the Internet, there are powerful incentives toward either of two potential market structures: a single dominant firm, or an interconnected environment of many firms using common standards. The Internet has primarily, but not exclusively, followed the latter path. As explained above, the network was from the beginning designed for standardized interconnection, and for many years it was operated under cultural and economic conditions that reinforced that structure.[332] For applications, the common standards of the Web and the separation of applications from

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[326] *See id.* at 609-11. This parallels the criticism leveled by Spulber and Yoo. They point out that the primary variable determining the magnitude of network effects — the size of the network — is often too coarse to be useful for policy determinations. As they note, the structure of networks, which graph theory models, may be more significant than their size in many cases. *See* Spulber & Yoo, *supra* note 218, at 1690-92.

[327] *See* Lemley & McGowan, *supra* note 31, at 593.

[328] *See id.* at 546-61.

[329] *See id.* at 506.

[330] *See id.*

[331] *See id.* at 549.

[332] The exception was the NSFNet backbone, through which all traffic flowed. The NSFNet privatization process replaced that central hub with the mesh of competing backbones that characterizes the Internet today. *See generally* Kesan & Shah, *supra* note 69 (describing privatization process).

connectivity create an environment of easy entry.[333] However, other aspects of the network are more centralized. For example, consolidation of power in the Internet backbone has raised antitrust concerns.[334] And the Internet addressing system points back to central "root servers" managed by one company under an agreement with the U.S. Department of Commerce.[335]

The victory of the interconnected outcomes over the centralized ones was always contingent on historical, regulatory, economic, and cultural factors. The economics of network effects therefore provide a basis for understanding both the power of the composite Internet, as well as its fragility. With that in mind, policy makers can begin to formulate effective responses to the Internet's creeping balkanization.

C. Network Science Meets Network Law

This subpart develops some initial ideas for linking the insights in the prior Parts with normative policy making. Subpart 1 explains the challenge the policy makers face in the interconnected Internet environment. Subpart 2 shows how government action and inaction played a role in many of the stories of federation and balkanization described in Part II. Subpart 3 highlights some early efforts to apply network models directly to policy-relevant questions.

1. The challenge for law

Traditional legal approaches struggle to explain the fissures emerging on the Internet today because they are not sensitive enough to the underlying network structures. The primary legal construct for addressing concentrations of power is antitrust law. Antitrust enforcement and analogous administrative regulation have been used in some high-profile cases involving networked industries, such as the effort to break up Microsoft.[336] As the Microsoft case demonstrated,

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[333] One of the reasons the Web triumphed was that a competing application platform unwisely attempted to exert centralized control. The University of Minnesota tried to impose licensing fees based on its copyrights in Gopher, a popular Internet navigation service in the early 1990s. That scared away many sites from adopting it. *See* Posting of Yen & Minnesota Gopher Team, yen@boombox.micro.umn.edu, to pacs-l@uhupvm1.uh. edu, review@msen.com, com-priv@uu.psi.com (Mar. 11, 1993, 15:08:26 CST) (http://www.mirrorservice.org/sites/boombox.micro.umn.edu/pub/gopher/gopher-software-licensing-policy.ancient).

[334] *See* Complaint at 9-11, United States v. WorldCom, No. 00-CV-1526 (D.D.C. June 26, 2000), *available at* http://www.usdoj.gov/atr/cases/f5000/5051.pdf.

[335] *See supra* Part II.A.

[336] *See supra* note 44.

however, the application of traditional antitrust concepts becomes extremely challenging in a networked environment.[337] The problem is magnified on the Internet, which is not one networked platform but many platforms tied together in a complex federation. Moreover, antitrust is designed to break up firms, not pull them closer together. Yet, as discussed above, the great value of the Internet lies in its penchant for connecting systems into common platforms.[338] Mandated fragmentation may reduce market power, as traditionally conceived, but it would only magnify the balkanization of the Internet.

Similarly, traditional notions of property rights fail to capture the Internet environment. The Internet is chock full of private property, from the servers that host its data to the patents that protect particular algorithms. Yet no one owns the Internet. Again, it is the network of networks that emerges from the voluntary integration of largely private resources. The Internet is a commons, which produces value and even facilitates market interactions through the absence of exclusive property rights.[339]

When these paradigms collide, the result is legal uncertainty. Book publishers alarmed at Google's new Book Search service are correct that Google stores full-text copies of their copyrighted works on its servers.[340] At the same time, Google is correct that it is providing a new mechanism for discovery of books, just as it facilitates discovery of several billion other copyrighted documents on the Web. The courts will resolve this and other disputes with the tools at hand, but the absence of network-centric frameworks is a significant handicap.

In a networked environment, location and connectivity within the network matter. A more secure foundation for Internet law must start with the recognition that the Internet is a composite networked environment.

2.   Defining the government role

Network science provides more than just useful analogies to aid in resolution of Internet-related legal disputes. It offers new tools to

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[337]   *See* Joseph Farrell & Philip J. Weiser, *Modularity, Vertical Integration, and Open Access Policies: Towards a Convergence of Antitrust and Regulation in the Internet Age*, 17 HARV. J.L. & TECH. 85, 89 (2003) (describing challenges facing antitrust in networked "platform" environments, and proposing new framework based on "internalizing complementary efficiencies").

[338]   *See supra* Part II.A.

[339]   *See* LESSIG, *supra* note 183, at 26. *See generally* Frischmann, *supra* note 27 (analyzing economic implications of commons for Internet infrastructure regulation).

[340]   *See* Travis, *supra* note 195, at 131-39.

assess policy alternatives for some of the most significant issues in the information economy.[341]   The Internet *is* a network. It is within the class of phenomena that network science studies. The only difference is that science is fundamentally descriptive, whereas law is normative. Network science observes the patterns of networks in nature and tries to explain how and why they behave as they do. Law evaluates the success of networks in achieving normative goals, and then considers how their performance might be improved. That process, however, can still benefit from a clear understanding of how networks operate.

The project of marrying network science with Internet law is at the early stages. Even on its own terms, network formation theory has only begun to incorporate many attributes of real-world networks into its models. Its explanatory or normative value will depend greatly on the particular issues under consideration. A closer look at several of the case studies in Part II shows that public policy often has a significant impact.   Reviewing these examples provides a few generalizations about how network science can inform decision making on significant Internet law and policy questions.

A key lesson of network science is that the structure of network interactions can be extremely important.[342]   The same set of actors may produce different outcomes depending on the dynamics of their network relationships. By precluding some linkages, strengthening or weakening others, and mandating others, both governmental and non-governmental regulators mediated the potential excesses of the centralizing Internet.

The NSF's Internet commercialization and privatization effort was deliberately structured to ensure competition among multiple interconnected backbones.[343]   By funding the creation of network access points ("NAPs") and forcing the privatized NSFNet backbone to connect to them, the NSF prevented the most powerful backbone from leveraging network effects to cement its dominance.[344]   The default requirement of multilateral peering at the NAPs provided a baseline around which networks could establish more sophisticated private relationships. After the NSF exited the stage, the Department of Justice and FCC, and more recently the competition policy arm of the   European   Union,   became   the   primary   watchdogs   of

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[341]   *See supra* Part III.

[342]   *See* Jackson, *supra* note 7, at 319.

[343]   *See* Rajiv C. Shah & Jay P. Kesan, *The Privatization of the Internet's Backbone Network*, 51 J. BROAD. & ELEC. MEDIA 93, 95-96, 100, *available at* http://findarticles.com/p/articles/mi_m6836/is_/ai_n25007515.

[344]   *See* Kesan & Shah, *supra* note 69, at 111-16.

competitiveness in the backbone market. Through divestiture requirements and occasional outright prohibitions on mergers, these government entities helped to preserve a backbone environment that is both competitive and well connected.[345]

Government took a similarly assertive, although less visible, role in holding together the other layers of the Internet. In addressing, the private governance mechanisms of Jon Postel's Internet Assigned Numbers Authority were for many years sufficient for universal adoption of a common platform. Once those consensual institutions broke down, the Department of Commerce and ICANN took on the mantle of Internet governance. Despite ICANN's many failings, breakaway efforts and movements to wrest control over the root servers have so far been unsuccessful.

At the application layer, the neutral Internet, in which access providers did not interfere with applications and content on their networks, grew out of a series of FCC decisions to limit the power of network operators. Finally, in content, the safe harbors of the DMCA and Telecom Act provided cover for practices such as search engine indexing of Web content. These provisions could not have been written with the intention of addressing the kinds of content sharing that sprung up after they were adopted. Nonetheless, they are becoming increasingly significant in the legal calculus for major new Internet-based services such as YouTube and Google Book Search.[346] The statutory safe harbors, along with the broader fair use exception to copyright liability, provide breathing space for online content aggregation services that might otherwise run afoul of copyright silos.

Government has not always been a positive force. The NSI monopoly over generic top-level domain name registration was entirely a creation of the NSF. The tensions and uncertainties in copyright law and its application to online services like Google Book Search result from a combination of action and inaction by both the legislative and judicial branches of government. The potential balkanization of IPv6 implementation juxtaposes two governances systems. The IETF is inclusive but weak in its attempts to push a universal transition to IPv6, while the top-down Chinese IPv6 effort is ruthlessly effective. Most of the stories described above in Part II

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[345] *See* Michael Kende, *The Digital Handshake: Connecting Internet Backbones* 18-20 (FCC Office of Plans & Policy, Working Paper No. 32, Sept. 2000), *available at* http://www.fcc.gov/Bureaus/OPP/working_papers/oppwp32.pdf.

[346] *See* Tim Wu, *Does YouTube Really Have Legal Problems?*, SLATE, Oct. 26, 2006, http://slate.com/id/2152264.

about the breakdown of the composite Internet involve governments or governmental institutions as at least contributing factors.

3.   Early analytical work

There have been some efforts to analyze issues relevant to Internet policy using network formation theory techniques, albeit not with a legal focus. These have predominantly been in the area of peering.[347] For example, researchers developed a strategic network formation model for the decisions of Internet backbone networks about whether to peer with one another directly or through a public exchange point.[348] The model showed how network operators would seek to differentiate their service quality and engage in price discrimination to maximize revenues, while end-users would prefer a more undifferentiated environment.[349] This mirrors the kinds of conflicts actually emerging among Internet backbones.

The differentiated services outcome that backbone operators favor is not necessarily the wrong one from a public policy perspective; the question is whether the overall benefits (in terms of service innovation and investment in network capacity) exceed the costs (in terms of increased costs for users). A more refined model would recognize that physical-layer interconnection also influences application-layer opportunities, because application and service providers connect to backbones as well. Again, network formation theory will not offer a clear-cut suggestion for every Internet policy question. As the scientific field matures, however, it will offer increasingly valuable guidance about the likely consequences of intervention into Internet markets.

D.   Guidelines for Policy Makers

As a threshold matter, regulators must appreciate what about the Internet they can and cannot control. Nodes in networks benefit not only from their direct connections, but from the number and structure of indirect relationships as well. Individuals and entire networks will react to any external stimuli in the form of regulatory impositions.

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[347] *See generally* Alessio D'Ignazio & Emanuele Giovannetti, *From Exogenous to Endogenous Economic Networks: Internet Applications*, 20 J. ECON. SURVS. 757 (2006); W.B. Norton, *The Art of Peering: The Peering Playbook*, http://www.blogg.ch/uploads/ peering-playbook.pdf (describing business dynamics of peering decisions).

[348] *See* Narine Badasyan & Subhadip Chakrabarti, *Private Peering Among Internet Backbone Providers* 2-5 (Wash. Univ. in St. Louis, Series on Indus. Org., Econ. Working Paper Archive, No. 0301002, 2003).

[349] *See id.* at 21-22.

The results may be unpredictable, even harmful.[350] Achieving a defined policy outcome may not be nearly as simple as it seems.

Governments can play two primary positive roles in the evolution of the Internet ecosystem: catalyzing network formation, and moderating the forces that push towards excessive concentration of power. The first thing governments can do is to promote the growth of networks themselves. Government action can reduce both the internal costs of adding links to a network and the external costs of linking networks together.[351] The DARPA and NSF initiatives to fund what ultimately became the Internet are canonical examples. Today, with the commercial sector so heavily engaged in the Internet, such direct support is unnecessary. However, there is room for additional investment in basic research on the foundations of networks at all layers. Moreover, with only a limited number of broadband competitors, FCC policies geared towards formation of new network platforms could have a significant impact.[352]

The second government function is to prevent networks from becoming their own worst enemies. Complex adaptive systems are characterized by "tipping points," where change suddenly accelerates and becomes difficult to stop.[353] The phase transitions in network growth[354] and the potential "lock-in" effects of network effects[355] are examples of this pattern. At certain key moments, aspects of the Internet may tip toward either concentration of power or interconnected competition, or even toward the sub-optimal outcome of unconnected islands. This is the story of peering archipelagos, IPv6 balkanization, DNS fragmentation, network neutrality vs. diversity, and islands of copyright protection, which are detailed above in Part II.A-D.

Networks do not necessarily tend towards the overall state that is the most efficient, welfare maximizing, or socially beneficial.[356] Network

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[350] *See* Spulber & Yoo, *supra* note 218, at 1713-16 (criticizing FCC's interconnection pricing rules for incumbent telephone companies through graph-theoretic analysis).

[351] *See* Jackson, *supra* note 237, at 13-14; *supra* Part III.B.2.

[352] Such policies would have more than just economic benefits. As Susan Crawford explains in a recent paper, communications policy should emphasize the broader opportunities of additional human communication. *See* Crawford, *supra* note 29, at 364-65.

[353] *See* MALCOLM GLADWELL, THE TIPPING POINT: HOW LITTLE THINGS CAN MAKE A BIG DIFFERENCE 12 (2000).

[354] *See* Jackson, *supra* note 237, at 12-15.

[355] *See* Lemley & McGowan, *supra* note 31, at 501, 522.

[356] *See generally* Jackson & Wolinsky, *supra* note 259 (using game-theoretic techniques to analyze network formation, and distinguishing network stability from

structures on the Internet are the product of strategic decisions by many independent agents, who focus on their own perceived interests rather than those of society. In general, such decentralized, market processes produce remarkably good results, for both economic efficiency and for normative measures of individual welfare.[357]

On the other hand, market systems can go off the rails. They can produce inequality, excessive swings in the business cycle, durable monopolies, or other undesirable results. A small example is the desire of telephone companies to impose per-minute charges on dial-up ISPs in the mid-1990s.[358] Had the FCC granted this request, the resultant dampening of Internet growth would have far exceeded the costs of the switch upgrades the phone companies ultimately adopted. The phone companies themselves would have suffered, because they would not have enjoyed the increased demand for second lines, data circuits, and eventually broadband connections for Internet access. Fortunately, the FCC declined to act on the requests.

In general, government policies that promote cheaper access to network links, encourage standardization, and restrain excessive concentrations of power at any layer of the network, may help restrain the inherent pressures for the Internet to either over-centralize or balkanize. As the discussion of network science demonstrated, factors such as the density of links relative to the number of nodes, the cost of links, and the overall size of the network strongly influence the path that the network will take. Much work remains to map these general concepts to practical choices in specific regulatory proceedings. However, these guidelines provide a solid baseline for policy making grounded in fundamental network dynamics.

CONCLUSION

The story of the Internet is still being written. Though the federation of distinct networks and the resulting aggregation of power in new hubs were often design goals, in practice they emerged from the complex interactions of independent actors. Thoughtful policy decisions may help preserve the better attributes of an open, interconnected network platform, but there are no guarantees. A fragmented Internet would forfeit many of the positive network effects

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network efficiency).

[357] *See generally* FRIEDRICH HAYEK, THE ROAD TO SERFDOM (1944) (explaining superiority of decentralized market-based economies over centralized socialist approaches).

[358] *See* Werbach, *supra* note 32, at 48-51.

that have driven extraordinary growth in innovation over the past decade. Uniformity, however, also imposes costs. Some balkanization of the Internet may create space for experimentation and incentives for new kinds of innovation. The potential value of such developments should be weighed against the potential costs and uncertainties inherent in such a course. Network science can help policy makers make better choices for the future of the world's most important information and communications platform.