WOULD YOU LIKE YOUR INTERNET WITH OR WITHOUT VIDEO?

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Abstract

According to Cisco's Visual Networking Index *forecast, "consumer Internet video traffic will be 85% of consumer Internet traffic in 2020, up from 76% in 2015," and the majority of this traffic will be entertainment*-oriented *video.*[1] *Many might view this as the (near) realization of the promised convergence of digital broadband delivery platforms that has been coming since first generation broadband services started becoming available in the mid-1990s. A question we should ask is whether this is the Internet we want. Even if one concludes that the marriage between entertainment media and the Internet is a foregone conclusion, it is worthwhile to consider what this may mean for the design, regulation, and economics of the Internet.*

In this Article, we critically examine the proposition that the conventional wisdom that convergence toward "everything over IP," or even stronger, "everything over the Internet," is efficient, inevitable, or desirable may be wrong. Convergence means different things in technical, economic, and policy terms. Building a single network that is optimized for 80% entertainment video traffic might disadvantage other services. Moreover, the economics of media entertainment are distinct from, and potentially in conflict with, the economics motivating many of the usage cases most often cited as justification for viewing the Internet as an essential infrastructure. Finally, separately managing the traffic for Internet and video services may be advantageous in addressing regulatory agenda items such as performance measurement, set-top boxes, universal service, online video distributor reclassification, and Internet interconnection. While most of the traffic may share the same physical (principally, wired) conduit into homes, it may be more efficient and flexible to segregate traffic into multiple logically distinct networks; and doing so may facilitate technical, market, and regulatory management of the shared resources.

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1. CISCO, VNI COMPLETE FORECAST HIGHLIGHTS 3 (2016), http://www.cisco.com/c/dam/m/en_us/solutions/service-provider/vni-forecast-highlights/pdf/North_America_2020_Forecast_Highlights.pdf.

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I. INTRODUCTION

According to Cisco's Visual Networking Index (VNI) forecast, "consumer Internet video traffic will be 85% of consumer Internet traffic in 2020, up from 76% in 2015," and the majority of this traffic will be entertainment-oriented video.[2] Many might view this as the (near) realization of the promised convergence of digital broadband delivery platforms that has been coming since first generation broadband services started becoming available in the mid-1990s. A question we should ask is whether this is the Internet we want. Should we assume that our video, voice, or other services will inevitably come to us over a single Internet connection, and is such convergence desirable? How might the design, economics, and regulatory policy for the Internet diverge if this video traffic were not part of the Internet's future?

This Article engages these questions and addresses the deeper, underlying question of what should be the optimal convergence path for our digital communications infrastructure, at least with respect to our last-mile access services. Convergence means different things in technical, economic, and policy terms. At the technical level, convergence requires us to provision our IP access networks to handle a mix of traffic that is heavily weighted toward video that is mostly one-way, cacheable, and associated with large-size files.[3] At the business/industry level, most of this traffic is supported by the economics of media entertainment.[4] Media entertainment, competing for consumer attention and leisure expenditures, is an important contributor to economic activity, but the supply/demand concerns are distinct from and, in many cases, only distantly related to other sectors of the economy (e.g., healthcare, government, energy, transportation) that are critical to the growth of our smart, information and communications technology (ICT)-connected economy.[5] The balance of non-media entertainment traffic that is associated with everything else—while smaller in aggregate volume—is more heterogeneous with respect to its requirements for connectivity, message size, and delivery specifications (i.e., routing, data rates, and quality-of-service requirements).[6] Finally, with respect to communications policy, convergence

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2. *Id.*; *see also* CISCO, CISCO VISUAL NETWORKING INDEX: FORECAST AND METHODOLOGY, 2015–2020 (June 6, 2016) [hereinafter CISCO VNI], http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/complete-white-paper-c11-481360.pdf. These percentages are for North America. CISCO VNI, *supra*. The corresponding global shares of traffic that will be Internet video in 2015 and 2020 are 70% and 82% respectively. *Id.* This includes both fixed and mobile video; and ambient video (nanny cams, pet cams, and home security cams), but excludes video conferencing/chat and multimedia gaming, which are included in other categories. *Id.*

3. Margaret Rouse, *Network Convergence*, TECHTARGET (Apr. 2008), http://searchconverged infrastructure.techtarget.com/definition/network-convergence/.

4. *Growth in Time Spent with Media Is Slowing?*, EMARKETER (June 6, 2016), http://www.emarketer.com/Article/Growth-Time-Spent-with-Media-Slowing/1014042.

5. *See, e.g.*, *Entertainment Industry*, ENCYCLOPEDIA.COM, http://www.encyclopedia.com/social-sciences-and-law/economics-business-and-labor/businesses-and-occupations/entertainment-0 (last visited Feb. 27, 2017) (providing an entertainment industry overview and detailing important characteristics of the market).

6. *See generally Real-Time Traffic over Wireless LAN Solution Reference Network Design Guide*, CISCO, http://www.cisco.com/c/en/us/td/docs/solutions/Enterprise/Mobility/RToWLAN/CCVP_BK_R7805F20_00_rtowlan-srnd/CCVP_BK_R7805F20_00_rtowlan-srnd_chapter_01.html (last visited Feb. 27, 2017)

requires us to address the challenge of transitioning from a world of separate regulatory rule sets for broadcast (television/mass media), telephone (PSTN), and Internet (which is in the midst of transitioning from mostly deregulated to partially regulated).[7] Each of these rule sets has sector-specific concerns with little obvious overlap.

In this Article, we critically examine the proposition that the conventional wisdom that convergence toward "everything over IP," or even stronger, "everything over the Internet," is efficient, inevitable, or desirable may be wrong. We explore ways in which building a single network that is optimized for 80% video traffic might disadvantage other services, as well as limit options for efficient video distribution. Relying on entertainment industry economics to drive broadband investment may be convenient, or even necessary, but may not best serve to promote the Internet uses that are most often cited as justifications for regarding the Internet as an essential basic infrastructure for the economy.[8] A world in which most of the Internet traffic is *not* entertainment video may deliver greater choice of content, more industry/market structure flexibility, and more competition than a world of converged Internet traffic flows. Finally, separately managing the traffic for Internet and entertainment video services may be advantageous in addressing regulatory agenda items such as performance measurement, set-top boxes, universal service, online video distributor (OVD) reclassification, and Internet interconnection. While most of the traffic may share the same physical (principally, wired) conduit into homes, it may be more efficient and flexible to segregate traffic into multiple logically distinct networks; and doing so may facilitate technical, market, and regulatory management of the shared resources.

The balance of this Article is organized into five parts. In Part II, we further elaborate the motivation and focus of this Article, explaining the various senses in which we plan to examine the convergence question, which we undertake in the following three parts. In Part III, we discuss prospects for technical convergence, discussing whether separating entertainment video traffic from Internet traffic, which will include everything else that is not the entertainment video stream, might change how we design, provision, and manage broadband access networks. In Part IV, we address the implications of relying on entertainment industry economics to drive broadband investment and the potential tensions that may pose for other anticipated—and generally regarded as more economically productive—uses of the Internet. In Part V, we focus on the regulatory challenges posed by convergence and discuss ways in

(explaining connection capacities).

7. Rebecca R. Ruiz & Steve Lohr, *F.C.C. Approves Net Neutrality Rules, Classifying Broadband Internet Service as a Utility*, N.Y. TIMES (Feb. 26, 2015), https://www.nytimes.com/2015/02/27/technology/net-neutrality-fcc-vote-internet-utility.html.

8. We recognize that trying to predict the future of the Internet may be a fool's errand. However, in light of the fact that entertainment video with distinct traffic characteristics accounts for the dominant share of Internet broadband access traffic today, and it is certainly possible that this will continue to be true into the foreseeable future, we believe it is worthwhile considering how this might be impacting the architecture, market economics, and regulatory policy for the Internet.

which these challenges might be ameliorated by delaying convergence at the regulatory level (even if convergence at the technical and economic levels is largely regarded as a fait accompli). We also sketch out one possible regulatory model for managing the traffic separately. Part VI concludes with summary thoughts.

II. BACKGROUND NOTES

In the following two Sections, we provide additional context to motivate our approach to the issues discussed herein. First, we explain how we view this work relating to current policy debates over the regulation of Internet traffic management practices that is commonly referred to as "network neutrality." Second, we discuss additional preconceptions or questions readers may have about how we have chosen to frame the issues. Our goal here is to suggest a fresh look at important issues, including the forces driving the evolution of the Internet and convergence of our communications networks toward a common IP-based technical platform, while recognizing that those issues are neither wholly new nor previously unaddressed. However, our interest here is more with the ideas than with tracing the intellectual and regulatory history of particular concepts.

A. Network Neutrality

The origin of the term "network neutrality" is usually credited to Tim Wu, from a paper originally written in 2002.[9] That paper addressed the potential threat to an open Internet as an innovation platform supported on top of the broadband access networks provided by Internet service providers (ISPs).[10] Over time, in subsequent scholarship by Professor Wu and numerous others—both proponents and opponents of network neutrality policies—the concept of "network neutrality" has evolved into a set of regulatory principles, or rules, targeted at ISPs, which seek to establish reasonable traffic management principles intended to prevent undesirable discrimination by broadband providers.[11] For example, according to Tim Wu, "Network neutrality is best defined as a network design principle. The idea is that a maximally useful public information network aspires to treat all content, sites, and platforms equally."[12]

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9. Tim Wu, *Network Neutrality, Broadband Discrimination*, 2 J. ON TELECOMM. & HIGH TECH. L. 141 (2003).

10. *Id.*

11. Marguerite Reardon, *FCC and Net Neutrality: What You Really Need to Know*, CNET (Feb. 7, 2015, 5:00 AM), https://www.cnet.com/news/fcc-and-net-neutrality-what-you-really-need-to-know/.

12. Tim Wu, *Network Neutrality FAQ*, TIMWU.ORG, http://www.timwu.org/network_neutrality.html (last visited Feb. 27, 2017). Professor Wu traces the origins of the debate to earlier work by Lemley and Lessig concerned with protecting the end-to-end nature of the Internet. *Id.* For a snapshot of the diverse views surrounding network neutrality, see *Special Issue on Network Neutrality*, 1 INT'L J. COMM. 377–716 (William H. Lehr et al. eds., 2007) [hereinafter *IJOC Special Issue*], http://ijoc.org/ojs/index.php/ijoc/issue/view/1. The special issue includes sixteen papers from Bauer, Frieden, Jordan, Lehr, Sicker, Wu, Yoo, and a number of other scholars who have been engaged in the ongoing debate over the pros and cons of network neutrality regulations.

The core motivation for regulatory policies to ensure network neutrality arises from the presumption that last-mile access providers have market power that they might seek to leverage to discriminate against traffic from content sites or applications, or against devices coming from unaffiliated, competing sources.[13] At the same time that the Internet was rising in importance and raising the potential that it would replace the public switched telephone network (PSTN) as our principle platform for basic electronic communications infrastructure, policymakers in the Federal Communications Commission (FCC) and elsewhere were considering what sort of regulation, if any, might be appropriate for the Internet.[14] In 2005, the FCC, under then-Commissioner Michael Powell, adopted a set of four principles intended to guide its policies for protecting an open Internet:

> (1) consumers are entitled to access the lawful Internet content of their choice; (2) consumers are entitled to run applications and services of their choice, subject to the needs of law enforcement; (3) consumers are entitled to connect their choice of legal devices that do not harm the network; and (4) consumers are entitled to competition among network providers, application and service providers, and content providers.[15]

The goal of these regulatory policies was to establish a regulatory framework for protecting consumer choice, competition, and innovation in the applications, content, and services that made use of the last-mile broadband access services provided by ISPs.[16] In addition to Tim Wu, a range of academics, including Barbara van Schewick, Susan Crawford, Lawrence Lessig, and Mark Lemley have argued in favor of network neutrality policies,[17] while other academics, including Christopher Yoo, Hal Singer, Robert Litan, and Adam Thierer have been opposed to such policies.[18] Among industry

13. Robert C. Atkinson, *Network Neutrality Overview*, at 2 (9th Annual Telecom, Cable, and Wireless Conf., 2007), http://www.citi.columbia.edu/aboutus/Atkinson_Net_Neutrality.pdf. An ISP's incentives to discriminate against unaffiliated content and application providers rely on a presumption of ISP market power. *Id.* at 21. Much of the debate over network neutrality focuses on the extent to which ISPs may have market power, the incentives to misuse any market power they may have, and actual evidence of such behavior. We do not wish to engage in those important but distracting questions here.

14. For a discussion of issues arising from the transition from the PSTN to the broadband Internet, see William Lehr et al., *Measuring Internet Performance when Broadband Is the New PSTN*, 3 J. INFO. POL'Y 411 (2013).

15. Press release, FCC, FCC Adopts Policy Statement (Aug. 5, 2005), https://apps.fcc.gov/edocs_public/attachmatch/DOC-260435A1.pdf. For the policy statement, see Appropriate Framework for Broadband Access to the Internet over Wireline Facilities, Policy Statement, 20 FCC Rcd. 14986 (2005), https://apps.fcc.gov/edocs_public/attachmatch/FCC-05-151A1.pdf.

16. Atkinson, *supra* note 13, at 1.

17. *See IJOC Special Issue*, *supra* note 12; *see also, e.g.*, Susan P. Crawford, *The Internet and the Project of Communications Law*, 55 UCLA L. REV. 359 (2007); Mark A. Lemley & Lawrence Lessig, *The End of End-to-End: Preserving the Architecture of the Internet in the Broadband Era*, 48 UCLA L. REV. 925 (2001); Barbara van Schewick, *Towards an Economic Framework for Network Neutrality Regulation*, 5 J. ON TELECOMM. & HIGH TECH. L. 329 (2007).

18. Christopher S. Yoo, *Beyond Network Neutrality*, 19 HARV. J.L. & TECH. 1 (2005); Robert E. Litan & Hal J. Singer, *Unintended Consequences of Net Neutrality Regulation*, 5 J. ON TELECOMM. & HIGH TECH. L. 533 (2007); Adam Thierer, *Are "Dumb Pipe" Mandates Smart Public Policy? Vertical Integration, Net Neutrality, and the Network Layers Model*, *in* NET NEUTRALITY OR NET NEUTERING: SHOULD BROADBAND INTERNET SERVICES BE REGULATED? 73 (Thomas M. Lenard & Randolph J. May eds., 2006); *see also*

stakeholders, providers of applications and content such as Google, Microsoft, and Netflix have been generally supportive of network neutrality regulations, while ISPs like AT&T, Comcast, and Verizon have generally opposed such rules.[19]

In 2010, the FCC issued its first attempt at framing rules to regulate network neutrality.[20] This order was challenged and substantially struck down by the D.C. Circuit Court of Appeals, which concluded that the FCC's claim to asserting jurisdiction to regulate broadband was inappropriate.[21] In response, the FCC reclassified broadband Internet access service (BIAS) as a Title II telecommunications service subject to common carrier regulation under the Communications Act of 1934.[22] Over this same period, a number of regulatory authorities in other countries were crafting analogous frameworks to protect network neutrality. Examples of such efforts include the European Union,[23] Brazil,[24] and India.[25] Although the specifics differ, they share a desire to protect unfettered access of users, application and content providers, and devices to non-discriminatory access to the Internet, enforced via restrictions on the network management and commercial practices that ISPs may employ.[26] Some of the key issues that are addressed include: (1) defining the scope of the rules; and (2) determining what constitutes "reasonable" network management practices.[27] With respect to scope, the rules typically apply only to ISPs, and not to the application and content providers that are also key players in the Internet ecosystem; and with respect to network management, the rules generally limit throttling, blocking, or prioritizing traffic in a discriminatory

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William J. Baumol et al., *Economists' Statement on Network Neutrality Policy* (AEI-Brookings Joint Ctr. Working Paper No. RP07-08, 2007), http://ssrn.com/paper=976889 (signed statement of seventeen economists arguing that their "basic concern is that most proposals aimed at implementing net neutrality are likely to do more harm than good").

19. Atkinson, *supra* note 13, at 4.

20. Preserving the Open Internet, Report and Order, 25 FCC Rcd. 17905 (2010), https://apps.fcc.gov/edocs_public/attachmatch/FCC-10-201A1.pdf.

21. Verizon v. FCC, 740 F.3d 623, 658 (D.C. Cir. 2014).

22. Protecting and Promoting the Open Internet, Report and Order on Remand, Declaratory Ruling, and Order, 30 FCC Rcd. 5601 (2015) [hereinafter Open Internet Order], https://apps.fcc.gov/edocs_public/attachmatch/FCC-15-24A1_Rcd.pdf.

23. *See, e.g.*, BODY OF EURO. REG. FOR ELEC. COMMC'NS (BEREC), BEREC GUIDELINES ON THE IMPLEMENTATION BY NATIONAL REGULATORS OF EUROPEAN NET NEUTRALITY RULES (Aug. 2016) [hereinafter BEREC GUIDELINES], http://berec.europa.eu/eng/document_register/subject_matter/berec/download/0/6160-berec-guidelines-on-the-implementation-b_0.pdf (setting forth guidelines for implementing Article 5(3) of the European Parliament Regulation 2015/2120 drafted November 25, 2015, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R2120&from=en).

24. For example, in 2014, Brazil adopted its "Marco Civil," a statute guaranteeing consumer rights to access the Internet, and issued a presidential decree establishing a network neutrality framework in 2016. Ademir Pereira, *Network Neutrality in Brazil: The Recently Enacted Presidential Decree Consolidates Meaningful Rules*, CTR. FOR INTERNET & SOC'Y (July 21, 2016, 10:32 AM), http://cyberlaw.stanford.edu/blog/2016/07/network-neutrality-brazil-recently-enacted-presidential-decree-consolidates-meaningful.

25. As of January 2017, India is in the midst of designing its regulatory framework to protect network neutrality. *See* TELECOM REG. AUTH. OF INDIA, CONSULTATION PAPER ON NET NEUTRALITY 2 (Jan. 4, 2017), http://www.trai.gov.in/sites/default/files/CP_NetNeutrality2017_01_04.pdf (outlining consultation process "to proceed towards the formulation of final views on policy or regulatory interventions, where required, on the subject of [net neutrality]").

26. *See, e.g.*, *id.*; BEREC GUIDELINES, *supra* note 23; Pereira, *supra* note 24.

27. *See* Pereira, *supra* note 24 (detailing Brazil's net neutrality policies); *see also* TELECOM REG. AUTH. OF INDIA, *supra* note 25 (describing India's approach to consultation and net neutrality approaches).

manner, and restrict practices that cannot be justified on technical grounds as needed to preserve the safety of the network, to address peak period congestion, or to maintain an acceptable quality of service.[28] Some key questions associated with the scope of the rules that arise relate to the services that are covered and those that may be exempt, but may be simultaneously offered by the ISPs and share resources with the Internet access services that are subject to the rules.[29] The exempt or differently regulated services have sometimes been referred to as "specialized services" and may include things such as enterprise virtual private network (VPN), Voice over IP (VoIP), or other services.[30]

The policy debates over network neutrality continue in the United States and abroad, and all aspects of the framework remain contentious, including whether any such regulation is needed, and if so, what would constitute the best policy model. In the United States, the FCC's Open Internet Order was established under Chairman Wheeler with a pro–network neutrality president in office.[31] President Trump has nominated Ajit Pai as the in-coming FCC chairman, who has been an outspoken critic of the Open Internet Order, so it is uncertain where policy will go in the future.[32]

While we recognize the relevance of these debates for our Article, we have chosen to distance ourselves from the focus on network neutrality for multiple reasons. First, network neutrality is first and foremost a policy response focused on broadband Internet access, with economic and technical implications for the larger communications ecosystem. Our intent is to be broader than "broadband," "Internet access," or "policy." Whereas the network neutrality debates proceed as a linear progression from policy to economics to technology, our goal is to consider each of these perspectives independently and on an equal footing to see what insights may emerge. We view network neutrality as a related concept, rather than as the principal focus. Second, the signal-to-noise ratio in the network neutrality wars has grown quite low as the volume of articles and press focusing on the issue has grown in volume and the positions of various contributors have hardened. We believe a more oblique approach to the network neutrality issues may actually be more beneficial in leading stakeholders toward workable solutions. When discussing/presenting this work, the connection to network neutrality discussions is usually obvious to our audiences, but we have found they are much more attentive to the discussion when not centrally framed around

28. *See, e.g.*, Pereira, *supra* note 24; TELECOM REG. AUTH. OF INDIA, *supra* note 25.

29. *See* Pereira, *supra* note 24 (explaining Brazil's approach to regulating ISPs and other services).

30. FCC, BROADBAND CONNECTIVITY COMPETITION POLICY 64–65 (June 2007), https://www.ftc.gov/sites/default/files/documents/reports/broadband-connectivity-competition-policy/v070000report.pdf.

31. April Glaser, *Net Neutrality Faces Extinction Under Trump*, RECODE (Dec. 12, 2016, 12:33 PM), http://www.recode.net/2016/12/12/13919952/net-neutrality-fcc-rosenworcel-trump-senate.

32. *See* Alina Selyukh, *Trump's Telecom Chief Is Ajit Pai, Critic of Net Neutrality Rules*, NPR (Jan. 23, 2017, 5:24 PM), http://www.npr.org/sections/thetwo-way/2017/01/23/510844936/trumps-telecom-chief-is-ajit-pai-critic-of-net-neutrality-rules (stating Pai has indicated plans to revisit net neutrality rules); Open Internet Order, *supra* note 22, at 5921 (dissenting statement of Comm'r Ajit Pai) (stating that if the Open Internet Order "manages to survive judicial review, these will be the consequences: higher broadband prices, slower speeds, less broadband deployment, less innovation, and fewer options for American consumers").

network neutrality, which often brings along sloppy characterizations of the issues at hand, framed to appeal to a Twitter audience. Third, we see our perspective as providing input more directly to the reconsideration of the Communications Act, and the overdue rewrite of its several titles that might result.

While we purposely avoid positioning this work as another network neutrality article, it is useful to provide context on how our analysis relates to network neutrality. We take a contrarian perspective by stating that the very thing driving much of the network neutrality debate[33]—removing entertainment video traffic from broadband Internet access and delivering it to end users via a separate IP service—would shift the debate in beneficial ways. By explicitly removing the dominant traffic type from the mix (arguably what a network neutrality proponent would say is overt traffic differentiation), we are recasting the argument.

The network neutrality debate commonly focuses on the value of innovation and the value of differentiation. The value of innovation considers where and how value is created in different parts of the ecosystem.[34] For example, whether what matters is innovation/investment in applications/ content that makes use of the Internet (a position often espoused by proponents of strong network neutrality regulation), or innovation/investment in the infrastructure that comprises the Internet (a position often espoused by opponents of strong network neutrality regulation). In this Article, we argue that these are not mutually exclusive and that separating the services into different "pipes" could have a net gain for both. In a paper where Professors Yoo (against) and Wu (for) debate the merits of network neutrality, Yoo argues that competition in networks (diversity) leads to important innovation; which Wu disputes, principally on the basis that last-mile broadband access remains a natural monopoly.[35] While nicely presenting the basic tension between competition and innovation in Internet services, the paper also highlights principles that motivated our proposal.[36] We see the need to differentiate traffic but also see that by removing video, the traffic composition changes in a

33. We assert that video is driving the debate, since it is Netflix, YouTube, and other video-intensive companies serving as the strongest proponents and most outspoken advocates of network neutrality.

34. Jarkko Pellikka & Timo Ali-Vehmas, *Managing Innovation Ecosystems to Create and Capture Value in ICT Industries*, 6 TECH. INNOVATION MGMT. REV. 17, 18 (2016).

35. *See* Tim Wu & Christopher Yoo, *Keeping the Internet Neutral?: Tim Wu and Christopher Yoo Debate*, 59 FED. COMM. L.J. 575 (2007). Yoo states:

> I am not convinced that deviations from network neutrality will necessarily harm consumers and innovation. On the contrary, competition and innovation might be better served if policymakers embraced a "network diversity" principle that would allow different network owners to pursue different approaches to routing traffic.
>
> Simply put, deviations from network neutrality may represent nothing more than network owners' attempts to satisfy the increasingly intense and heterogeneous demands imposed by end-users.

Id. at 575–76. Wu, however, points out the problems of a competitive last mile:

> Arguably, as a "solution" to the last-mile problem, allowing discrimination is both costly and ineffective. Its costs are large potential costs to the application market. And the idea that it will somehow solve the economic problems of the last mile strikes me as unlikely at best. So you risk the health of the applications market, and really, all for what?

Id. at 587.

36. *See generally id.*

way that could then allow other non-video services to have a better framework in which to grow and innovate. Rather than taking a position on whether it is the innovation in network infrastructure or in the content and applications that is more important, we wish to focus on the importance of both types of innovation and the potential issues that arise when entertainment converges with other, (hopefully) more productive uses of communications infrastructure.

Furthermore, even if one's central concern is protecting innovation by content and application providers, it is unclear whether limiting network management options by ISPs offers the best strategy. Professors Jamison and Hauge contend that diversified services may benefit innovation in content and applications because new entrants may need the differentiated services that ISPs might offer, but which large incumbents like Google or Netflix can self-provision.[37] The large incumbents may prefer a world of dumb "network neutral" pipes, since that may make it harder for the next Google or Netflix to challenge their market preeminence.[38] In this Article, we argue that the capabilities to implement fine-grained traffic management of IP networks is a key feature of modern networks that has the potential to offer significant benefits for the Internet and for the efficient use of broadband access platforms; hence, "dumb pipes" make little sense.

Another key issue that is touched upon here, and as part of the network neutrality debate, is the role of vertical integration by ISPs into content or applications, and what that implies for ISP incentives to leverage any market power they may have to discriminate against non-affiliated content or application providers. For example, Professor Speta argues that triple-play platform providers such as Comcast (providing broadband, telephone, and entertainment video services) present complicated problems when they integrate into content services (i.e., the NBC-Comcast merger), concluding that standalone non-discrimination rules applied to a single service—broadband Internet access—would be ineffective.[39] Speta's concerns are consistent with

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37. Mark A. Jamison & Janice A. Hauge, *Getting What You Pay for: Analyzing the Net Neutrality Debate* (Working Paper, 2008), https://ssrn.com/abstract=1081690. According to Jamison and Hauge:

> We find that the claims of the net neutrality advocates do not hold when network providers keep their commitment to not degrade service. Specifically, we find that offering premium service stimulates innovation on the edges of the network because lower-value content sites are better able to compete with higher-value sites with the availability of the premium service.

Id. at 20. In another paper, they conclude:

> It is commonplace for sellers of goods and services to enhance the value of their products by paying extra for premium delivery service. For example, package delivery services such as Federal Express and the US Postal Service offer shippers a variety of delivery speeds and insurance programs. Web content providers such as Yahoo! and MSN Live Earth can purchase web-enhancing services from companies such as Akamai to speed the delivery of their web content to customers.

Mark A. Jamison & Janice A. Hauge, *Dumbing Down the Net: A Further Look at the Net Neutrality Debate*, *in* INTERNET POLICY AND ECONOMICS 57, 57 (2009).

38. *See* Steve Forbes, *Net Neutrality: A Web of Deceit*, REUTERS (June 9, 2014), http://blogs.reuters.com/great-debate/2014/06/09/net-neutrality-a-web-of-deceit/ (arguing that net neutrality will benefit only a select powerful few to the detriment of startups).

39. James B. Speta, *Supervising Managed Services*, 60 DUKE L.J. 1715, 1758–59 (2011) ("The Comcast-NBC transaction highlights a reality of multipurpose, converged platforms that has been all too absent from the network neutrality debate in recent years. . . . Discrimination strategies designed to enhance revenues have long been important in both content and distribution markets, as demonstrated by widespread

the perspective we take here—regulation of the broadband access pipe needs to be considered in conjunction with regulation of the Internet if the goal is to preserve an open Internet as a platform for innovation.

Hopefully, this brief introduction to the network neutrality debates provides sufficient orientation and allows us, in the balance of this Article, to engage that debate tangentially, as to go deeper into these issues would warrant a separate article in its own right.

B. Convergence and Working Assumptions

Anyone following developments in broadband or media entertainment might well ask whether the convergence of broadband and entertainment video is a foregone conclusion. Both mobile and fixed broadband service providers have been expanding their capacity to handle streaming video from services like Netflix, YouTube, and Hulu—and a host of others.[40] According to Sandvine, as of December 2015, 70% of peak Internet traffic consisted of real-time streaming entertainment, up significantly from the 13% share reported for 2008.[41] The proliferation of multiple screens per user and per household capable of accessing Internet-delivered programming anywhere,[42] the expanding selection of programming available in multiple quality formats (SD, HD, and ultraHD),[43] and the vertical integration of programming and

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and widely accepted windowing, tiering, and bundling strategies. If nondiscrimination regulation forbids those sorts of strategies, then carriers will have the incentive to restrict the Internet-access channel or to shift content and services to managed portions of the platform, in which case the effectiveness of nondiscrimination rules would be severely compromised.").

40. Most of the traditional programming providers are launching services to access video content online over mobile and fixed platforms. Web-based and/or application (usually mobile) streaming is available from most broadcasters of over-the-air and pay-per-view programming (NBC, CBS, ABC, Fox, Comedy Central, ESPN, HBO, Showtime) and from most providers of broadband access services (Xfinity for Comcast, FiOS TV for Verizon), as well as from a host of alternative and/or user-generated streaming sources (YouTube, Twitch, Meerkat, Periscope, BitTorrent). Although these sources also provide streaming news and other programming that some might not identify as "entertainment," most of this includes entertainment programming.

41. Sandvine reported that real-time entertainment traffic accounted for the following shares of peak traffic: 12.6% (2008), 26.6% (2009), and 70.4% (2015). SANDVINE, GLOBAL INTERNET PHENOMENA: AFRICA, MIDDLE EAST & NORTH AMERICA 2 fig.1 (Dec. 2015) [hereinafter SANDVINE—INTERNET PHENOMENA], https://www.sandvine.com/downloads/general/global-internet-phenomena/2015/global-internet-phenomena-africa-middle-east-and-north-america.pdf; SANDVINE, 2009 GLOBAL BROADBAND PHENOMENA 2 (Oct. 2009) [hereinafter SANDVINE—BROADBAND PHENOMENA], https://newmediagr.files.wordpress.com/2009/11/2009 global_broadband_phenomena_exec_sum.pdf. Real-time entertainment traffic includes streaming video and audio entertainment, but the bulk of the traffic is video.

42. The iPhone inaugurated the consumer smartphone revolution in 2007, and big screen LCD televisions that cost north of $4,000 were costing less than $2,000 by 2005. *See* David Goldman, *Flat-Screen TV Prices to Plunge for Holiday Season*, CNN MONEY (Sept. 25, 2010, 8:45 AM), http://money.cnn.com/2010/09/23/technology/lcd_tv_prices/ (listing average prices of 32-inch LCD televisions). Increasingly, households have and are using multiple devices to consume video content. A 2015 Accenture survey found 40% of consumers owned a tablet, laptop/desktop, *and* a smartphone; 16% also owned a connected television; and 89% accessed long-form video content over the Internet. ACCENTURE, DIGITAL VIDEO AND THE CONNECTED CONSUMER 6, 8 (2015), https://www.accenture.com/t20150523T021027__w__/us-en/_acnmedia/Accenture/Conversion-Assets/Microsites/Documents17/Accenture-Digital-Video-Connected-Consumer.pdf.

43. The resolution at the high end continues to increase, with a growing volume of programming available in HD (high definition) or ultra HD (4K) formats. At the same time, expanded options for SD (standard definition) and other lower-quality (lower-resolution) format programming (e.g., animation, user-generated content) is being made available. Many popular programs are available in multiple formats to

broadband service providers[44] are all trends that have been in evidence for years. Collectively, these and related trends have contributed to the rapid growth of the entertainment video traffic that has induced broadband providers to expand capacity and increase per-subscriber data rates.[45] Whereas much of the discussion touting the Internet's importance as essential infrastructure has focused on the role of the Internet in enabling "Smart X" (where X can be replaced with energy grids, homes, cities, healthcare, supply chains, education, etc.),[46] most of the traffic growth has been from video entertainment.[47]

Although entertainment video already comprises the dominant source of traffic on our broadband networks, and market trends and strategic plans by key value chain participants are propelling us further in that direction, it is worthwhile to consider what a counterfactual world might look like: one in which the Internet carried the *other 20%* of non-entertainment video traffic; and the 80% of the traffic that comprises entertainment video were delivered to homes via a separate access network service.[48]

Our focus here will be on the "last-mile" access networks that provide fixed communication services (Internet, video, and telephone) to consumer households—the so-called "eyeball" networks operated by AT&T, Charter, Comcast, and Verizon[49]—because these have been the principal focus of communications policy concerns and remain the principal Internet "on ramps" for most consumer households.[50] In focusing on fixed access networks, we are

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accommodate different subscriber equipment needs and viewing contexts.

44. The announcement that Comcast is acquiring DreamWorks and that the FCC is expected to approve the AT&T-DirectTV merger are just two recent examples. *See* Ian Olgeirson, *OTT Integration with Multichannel Packages Amasses Gains*, SNL (Jan. 12, 2016, 6:13 PM), https://www.snl.com/InteractiveX/Article.aspx?cdid=A-35020212-15157. The Comcast-NBC merger was consummated in 2011. Moreover, as of January 2016, SNL Kagan reports that 20% of multichannel video program distributors (MVPDs) are now providing access to over-the-top Internet video content (e.g., Netflix, YouTube) as part of their regular video offers. *Id.*

45. *See* Sean Michael Kerner, *U.S. Broadband Speeds Accelerate*, ENTER. NETWORKING PLANET (Jan. 4, 2016), http://www.enterprisenetworkingplanet.com/netsp/u.s-broadband-speeds-accelerate.html (providing summary of the state of high-speed networking). Peak and average data rates for fixed and mobile services have increased year to year. For example, the FCC reported that the average rate was 31 Mbps in September 2014, up from 10 Mbps in 2011. *Id.* This is significantly higher than the Akamai estimated average data rate in the United States of 12.6 Mbps. *See* AKAMAI, STATE OF THE INTERNET: Q3 2015 REPORT 26 (Dec. 2015), https://www.akamai.com/us/en/multimedia/documents/report/q3-2015-soti-connectivity-final.pdf.

46. The National Broadband Plan touting the importance of broadband for the nation's future has chapters devoted to discussing the role of broadband in healthcare, education, energy, and the environment; in promoting economic opportunity and civic engagement; and in enhancing government performance and public safety. Although it mentions "entertainment" as a common consumer use, it does not emphasize this as a key reason for why the nation needs a national broadband plan. *See* FCC, *Connecting America: The National Broadband Plan* (Mar. 16, 2010) [hereinafter *National Broadband Plan*], https://transition.fcc.gov/national-broadband-plan/national-broadband-plan.pdf.

47. DELOITTE, DIGITAL MEDIA: RISE OF ON-DEMAND CONTENT (2015), https://www2.deloitte.com/content/dam/Deloitte/in/Documents/technology-media-telecommunications/in-tmt-rise-of-on-demand-content.pdf.

48. These shares are based on the VNI forecast cited earlier. *See* CISCO VNI, *supra* note 2.

49. There are also many smaller broadband access providers that collectively provide services using a variety of network technologies, including fiber to the home (FTTH), hybrid fiber coaxial (HFC), all types of digital subscriber lines (xDSL), and wireless (terrestrial and satellite).

50. In so doing, we are mostly ignoring the network services, including Internet services, provided to businesses, government, and anchor institutions (e.g., libraries, schools) that typically share much of the local network infrastructure and collectively account for significant (mostly non-entertainment) Internet traffic. We

already accepting a significant degree of convergence, at least at the physical layer or with respect to much of the network and business facilities that will be shared by the Internet and such other services as may be delivered over these last-mile networks.[51] (Mobile broadband, although growing rapidly still accounts for only a small share of total Internet traffic[52] and for most subscribers remains a complement to fixed broadband service.[53])

Furthermore, we recognize that the "other 20%" is an approximate estimate of the traffic that is not comprised of entertainment video. First, some of the entertainment video may be downloaded as files from online stores (e.g., iTunes or Amazon) or via file-sharing applications like BitTorrent (that include a large share of copyright infringing media) and may not be appropriately identified as video entertainment or separately identifiable in the relevant data sources.[54] Second, video traffic may be associated with many non-entertainment applications (such as video conferencing and surveillance/ monitoring) or integrated into interactive multimedia applications.[55] Third, the category "entertainment video" includes content targeted at many different audiences and purposes such as news, educational videos, and home movies

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are also mostly ignoring those portions of the Internet that are upstream of the access networks (in the Internet "cloud") or downstream (part of the consumer's home network).

51. We note that, for the foreseeable future, there will be multiple facilities-based network infrastructures capable of serving entertainment video to broadband households (i.e., offering competitive alternatives to whatever is available over a household's broadband Internet access service). For most households, this will include at a minimum the legacy incumbent local exchange carriers (ILECs) and cable company multiservice networks, as well as multiple mobile networks. There are also single-service network alternatives such as direct broadcast satellites and over-the-air television. Obviously, these networks are not fully independent (e.g., when the mobile and fixed networks are owned by the same provider), and they offer different user-quality experiences. Although the implications of multimodal competition in delivery platforms is of great interest to policymakers, we will not focus on those issues here beyond noting that one argument in favor of delivering entertainment video via the Internet is precisely because of the potential for the Internet to serve as a "spanning layer" to support interoperability across these different entertainment video infrastructures.

52. According to Cisco VNI, in 2015, global IP traffic was 72.5 EB (exabyte) per month. Of that, 5% was mobile; 81% was consumer; and 40% was consumer IP video. CISCO VNI, *supra* note 2, at 10, 14.

53. Fixed broadband access services with Wi-Fi handle much of the mobile data traffic already; and with the trend toward smaller wireless cells (driven in part by spectrum scarcity), wired infrastructure is increasingly important for backhauling traffic in local distribution networks. *See* William Lehr & Miquel Oliver, *Small Cells and the Mobile Broadband Ecosystem* (25th Euro. Regional ITS Conf., 2014), http://econ papers.repec.org/paper/zbwitse14/101406.htm; John M. Chapin & William H. Lehr, *Mobile Broadband Growth, Spectrum Scarcity, and Sustainable Competition* (39th Research Conf. on Commc'n, Info. & Internet Policy, 2011), http://ssrn.com/abstract=1992423. Regarding the point that fixed and mobile broadband are more likely to be complements for most subscribers, see John B. Horrigan, *Smartphones and Home Broadband Subscriptions: Substitutes, Complements, or Something Else?* (draft INTX workshop, May 2016) (on file with authors); William Lehr, *Mobile Broadband and Implications for Broadband Competition and Adoption* (Broadband for Am., 2009), http://ssrn.com/abstract=2446011.

54. All available traffic and share estimates are imprecise due to data availability issues. The Cisco VNI, although widely cited, relies on a plethora of assumptions to develop its aggregate estimates. It is unclear how the Cisco VNI treats file sharing or purchases of digital media files from online vendors like iTunes. In any case, some of those files are likely to be encrypted and not identifiable as video. The estimates from Sandvine, Akamai, and some of the other sources cited herein focus on real-time streaming of entertainment media, which includes audio. *See* SANDVINE—INTERNET PHENOMENA, *supra* note 41; SANDVINE—BROADBAND PHENOMENA, *supra* note 41; AKAMAI, *supra* note 45. Although music files comprise a significant share of the file counts, the files are typically much smaller, and video remains the dominant form of traffic. CISCO VNI, *supra* note 2.

55. Although as noted before, the Cisco VNI estimates exclude video conferencing and multimedia gaming from the estimates of Internet video. CISCO VNI, *supra* note 2.

(user-generated content not intended for mass-audience distribution)—as well as what might more generally be regarded as traditional leisure-time entertainment video. As we shall explain further in Part IV, distinguishing between entertainment video or Internet uses and non-entertainment uses (education, job-search, eCommerce, or Smart-X uses) is inherently ambiguous.[56]

Our focus is on this latter class of video traffic which we believe comprises the bulk of the video traffic today and is likely to continue to do so in at least the near to midterm future. This is the traffic that is presently delivered to consumers as linear "television-like" or video-on-demand services as part of the video program offerings that comprise one leg of the triple-play bundle of services (Internet, telephone, and video) sold by the eyeball network operators.[57] We recognize that with the rise of "new media," definitions of what constitutes video entertainment are changing.[58] This is perhaps most evident with respect to the user-generated content that is often produced with smartphone cameras and webcams, and is distributed via services like Periscope, YouTube, Vine, and Snapchat.[59] A lot of this is shorter-form content or involves real-time broadcasting from diverse locations.[60] The ways in which it is produced, distributed, and consumed challenge traditional notions of television or entertainment video. Those developments notwithstanding, we believe that more traditionally produced types of video entertainment will continue to comprise a significant share of traffic; and in some cases, the new media channels are themselves becoming portals for access to legacy-format content.[61]

Our goal is not to precisely estimate the share of total traffic that is comprised of this type of entertainment video. Rather, it is to characterize in general terms what a future might look like where a very significant share of the traffic (upwards of two-thirds in volume) is not carried as part of the broadband Internet service but is delivered to homes over a logically (and capacity-isolated) separate access network. In most cases, we expect that the video services may be provided over the same physical infrastructure, as is the case today in cable- and telephone-based access network architectures, which begs the question of how separate the networks may actually be.

With Internet quality-of-service (QoS) technologies (e.g., DiffServ or

56. For example, whether having three channels showing basketball, football, and fishing provides more diversity than three different football games depends on how one assesses diversity.

57. By "television-like" services we mean programming that may be delivered as linear programming (in which the viewer receives a stream of content that is organized into a sequenced "channel" that may be recorded to facilitate time switching but is otherwise not decomposable by the user in real time) or video-on-demand (where the user can select the particular video content to view). One justification for moving from traditional television to Internet-based delivery of television programming is to better enable video-on-demand.

58. NATALIE KLYM, MIT, THE AMBIGUITY OF DISRUPTION: DISCOVERING THE FUTURE OF VIDEO CONTENT 13–18 (Sept. 2015), http://cfp.mit.edu/Ambiguity%20of%20Disruption%20Klym%20Sept%202015.pdf.

59. *See, e.g.*, *id.* at 1 (discussing the rise of the latest social media smartphone applications).

60. *Id.* at 18.

61. For example, YouTube and other new media outlets are now offering channel programming that is not materially different from watching traditional television channels from a user-experience perspective.

MPLS) and with modern cable modem technologies (e.g., DOCSIS3.x),[62] it is feasible to prioritize packets and allow multiple types and flows of traffic to share the same physical network infrastructure, while allowing the traffic to be segregated into separately managed flows, or equivalently, logically separate networks. These technologies may be configured to allocate underlying network resources to share capacity between the logical flows in a variety of ways.[63] For example, capacity may be shared among logical flows dynamically on a real-time basis; or alternatively, the flows may be allocated hard capacity assignments, mimicking what would happen if the traffic were segregated onto separate physical networks.[64] While we will discuss the implications of capacity sharing, for much of the discussion it will be useful to imagine that the traffic is logically and capacity separated on distinct IP networks, one of which will carry the "other 20%" of broadband Internet traffic and one that will carry the entertainment video in the access network.[65]

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62. There are multiple QoS mechanisms available on the Internet, and all of the modern broadband technologies have expanded capabilities to allow more fine-grained and flexible resource assignment to support QoS requirements for diverse traffic types, including video. For an explanation of DiffServ (short for Differentiated Services), see *Differentiated Services*, MICROSOFT, https://msdn.microsoft.com/en-us/library/windows/desktop/aa373439(v=vs.85).aspx (last visited Feb. 27, 2017). For an explanation of MPLS (short for Multi-Protocol Label Switching), see *MPLS FAQ for Beginners*, CISCO, http://www.cisco.com/c/en/us/support/docs/multiprotocol-label-switching-mpls/mpls/4649-mpls-faq-4649.html (last updated May 2, 2016); Richard A. Steenbergen, *MPLS for Dummies*, NANOG, https://www.nanog.org/meetings/nanog49/presentations/Sunday/mpls-nanog49.pdf (last visited Feb. 27, 2017). For more information about DOCSIS, see *Search Results for DOCSIS*, CABLELABS, http://www.cablelabs.com/?s=DOCSIS (last visited Feb. 27, 2017). DOCSIS (short for Data Over Cable Service Interface Specification) is a group of standardized technologies developed by CableLabs to support digital services over cable modem networks. *See DOCSIS® 3.1*, CABLELABS, http://www.cablelabs.com/innovations/docsis3-1/ (last visited Feb. 27, 2017). The most recent standard, DOCSIS 3.1, provides a host of features to enable fine-grained, dynamic, and flexible control of IP-based services over the hybrid coaxial-fiber-based networks operated by cable providers. *Id.* For a discussion of how these will significantly increase the capacity and capabilities of cable-based broadband access networks to deliver increasing volumes of broadband traffic that includes lots of entertainment video, see David P. Reed, *Trends in Cable Network Economics: Implications for the Open Internet* (44th Research Conf. on Commc'n, Info. & Internet Policy, 2016), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2758731. Similar capabilities are available with other broadband access network technologies such as FiOS and very-high-bit-rate digital subscriber line (VDSL). For further discussion of these QoS mechanisms, see BROADBAND INTERNET TECH. ADVISORY GRP., DIFFERENTIATED TREATMENT OF INTERNET TRAFFIC (Oct. 2015) [hereinafter INTERNET TRAFFIC], http://www.bitag.org/documents/BITAG_-_Differentiated_Treatment_of_Internet_Traffic.pdf; BROADBAND INTERNET TECH. ADVISORY GRP., REAL-TIME NETWORK MANAGEMENT OF INTERNET CONGESTION (Oct. 2013), http://www.bitag.org/documents/BITAG_-_Congestion_Management_Report.pdf.

63. *See generally* INTERNET TRAFFIC, *supra* note 62, at 2; Reed, *supra* note 62 (discussing how these new technologies will affect the allocation of capacity).

64. In segregating broadband traffic into IP flows that are associated with the Internet service and other services (e.g., specialized services) that may or may not be subject to regulatory constraints, there is the risk that ISPs may seek to shift broadband platform resources (e.g., bandwidth allocations) from one IP flow to another to avoid regulatory constraints such as network neutrality rules applicable solely to the Internet service. This is an obvious risk that needs to be considered but may be addressed in multiple ways. One way is to establish minimum quality standards for the Internet service or adopt rules restricting the allocation of broadband capacity. Many of the network neutrality proposals include language and provisions that seek to address this challenge. A full discussion of these options, while directly of concern to the network neutrality debates, is beyond the scope of what we can undertake here. Suffice it to say that the technical capabilities provide a wide range of technical options for granular, dynamic traffic management that at one end could be based on hard, capacity isolation of services and at the other end support per-packet resource allocation.

65. As we will explain further below, if any resources are shared (wires, IP routing, back-office support, conduit, etc.), it is generally not feasible to fully separate decision making about the networks at the technical, economic, or policy level (by nature of the sharing). *See, e.g.*, Günter Knieps & Volker Stocker,

From an economic-demand perspective, asking the question of what might be different if entertainment video traffic is separate from Internet traffic might strike some as either uninteresting or foolish. One might argue that attempts to forecast future Internet traffic requirements is a fool's errand because of the inability to predict what tomorrow's "killer application" may be. Not very long ago, we thought peer-to-peer (P2P) services like Napster and BitTorrent would dominate traffic flows, resulting in much more symmetric two-way flows.[66] Although today (asymmetric) streaming entertainment video is the dominant traffic type, in the future, the traffic of some new application may become dominant.[67] Much of the economic benefit of the Internet as a "general purpose technology" (GPT)[68] stems from its ability to support traffic with diverse QoS requirements that are well represented by video traffic, which may span a broad range of requirements (e.g., in terms of data rates, latency, megabytes, or direction of flows).[69] We accept that the future remains uncertain and recognize that a key component of the Internet's value proposition is to be a GPT; nevertheless, we think it is also reasonable to accept that entertainment video will likely continue to be the dominant traffic driver in the near to medium term *and* the convergence of video entertainment and the Internet may bias the direction of the Internet's design away from being a GPT.

Another potential critique of the focus of this Article is that the marriage between entertainment and the Internet is a practical necessity since consumers desire entertainment. Infrastructure investment is being driven by market demand. Indeed, most of the investment that underpins the Internet was undertaken to satisfy the demand for ubiquitously available telephone and cable television services—not Internet access.[70] Providing an Internet that mostly delivers entertainment video today allows us to build a highly capable broadband network that could not be sustained from an investment perspective without this traffic. One might fully accept this argument and still find the question we address in this Article interesting—if only as a thought experiment. On the other hand, the implicit explanation that convergence is a necessary byproduct of market evolution because that has been the case in prior generations of telecommunications infrastructure investment is hardly

Price and QoS Differentiation in All-IP Networks, 3 INT'L J. MGMT. & NETWORK ECON. 317 (2016).

66. Rebecca Giblin, *Physical World Assumptions and Software World Realities (and Why There Are More P2P Software Providers than Ever Before)*, 35 COLUM. J.L. & ARTS 57, 94–97 (2011).

67. Of course, if it is just another form of entertainment like gaming or entertainment-based virtual reality, the network requirements may change substantially, while the economic implications may change much less.

68. *See* PHILIPPE AGHION ET AL., GENERAL PURPOSE TECHNOLOGIES AND ECONOMIC GROWTH (Elhanan Helpman ed., 1998) (explaining GPT-driven economic growth and developments of available frameworks).

69. Video comes in many formats and may differ widely in terms of its cache-ability (e.g., real-time sports or breaking news versus movies). The rise of interactive media and user-generated content, as well as non-entertainment-based applications requiring video, such as video-conferencing and video-monitoring services, may require support for symmetric and dynamic routing control.

70. Nick Wingfield, *Finally Breaking Up the Cable Bundles*, N.Y. TIMES (May 28, 2014), https://www.nytimes.com/2014/05/29/technology/personaltech/finally-breaking-up-the-cable-bundles.html?_r=0.

conclusive. We might determine that the social benefits of deploying the Internet we want could warrant supporting its investment with public funds if the only alternative is to rely on entertainment industry revenues. Alternatively, we might conclude that having entertainment revenues fund a significant share of broadband investment does not require convergence and may be consistent with managing entertainment and Internet traffic separately.

Finally, it is worth noting that we view this Article as an exploratory effort. We are not personally persuaded yet that convergence does not offer the most suitable result, but we are uncomfortable with what we view as the under-examined presumption that it is desirable or inevitable. Even if we ultimately conclude that a different future might be more desirable, we recognize the potential infeasibility of realizing a better future in light of real-world practicalities.

In subsequent Sections, we paint a picture of how the world might be different from a technical, economic, and policy perspective if Internet traffic were separate from the entertainment video traffic. That discussion is followed by consideration of possible options for how one might actually accomplish the separation if desired, and some of the issues that would need to be addressed. We conclude with a summary and discussion of future research directions.

III. TECHNICAL

In this Part, we consider a number of technical questions relating to the role of video over broadband Internet access service. We start by providing some background on video services and then look at trends in video services over broadband access. Our goal here is to characterize the (roughly) 80% of access traffic that is entertainment video, and the "other 20%" that includes everything else. We then look at the traffic running over a sampling of broadband access links, and consider what these links might look like if you were to remove the video traffic. This includes considering the impact of these video services on the access link, and the role that network architecture plays. We then close with a brief summary of the technical analysis.

A. Background

We start this Section by discussing what we mean by video. Video on the Internet constitutes a broad range of services, where the basic uses include video for communications, sensing/monitoring, and entertainment. Table 1 summarizes our qualitative characterization of these three main categories of video traffic:

(1) Communications: Video conferencing is a key application that calls for bandwidth that supports symmetric, any-to-any real-time connectivity, and might in the future have patterns analogous to telephone calling. This category may also include groupware applications like WebEx, which provide collaborative, online, multimedia work platforms. It may include gaming, which can be a mix of characteristics, depending on the nature of the game. While communications video does demand considerable bandwidth (on the

order of 0.5 to 10 Mbps), as we describe in more detail in Section III.B, at this point it represents much less than 1% of the traffic on access networks.[71]

(2) Sensing/Monitoring: Video monitoring cameras, which includes webcams,[72] are likely to present a wide range of traffic types that may mix cacheable and real-time content (e.g., traffic and security cameras).

Unlike the communications uses, much of this traffic may be asymmetric and flowing upstream (in the opposite direction from most of the legacy entertainment media).[73] Additionally, for many sensing applications, it may be possible to significantly vary resolution requirements and real-time access to peak resources.[74] Once again, while sensing applications could represent considerable bandwidth in the future, today webcams and monitoring camera traffic represents less than 2% of traffic on access networks.[75] With the rise of the Internet of things (IoT), this category could grow significantly, but is unlikely to exceed 5% of access traffic over the next five years.[76]

(3) Entertainment: Television and long-form programming (movies) comprise the bulk of entertainment media traffic and the vast majority of this is currently still delivered and consumed via non-IP networks.[77] The entertainment-based IP video we are concerned about here includes the above

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71. The implications for provisioning requirements are significant in light of the requirement to support symmetric, real-time, any-to-any traffic. The "any-to-any" implies that the capacity has to exist everywhere (and in a converged mobile/fixed world, that really may mean everywhere and not just for every possible fixed location). As one moves beyond the portion of the network that is not shared among end users (a portion of the last mile), calling behavior will determine opportunities for sharing resources, and the limits to multiplexing. For example, the Erlang distribution found wide application for provisioning legacy telephone networks (e.g., predicting the number of switching ports needed to provide a targeted level of non-blocking telephone calls, and for allocating network costs to services. However, the Erlang model was disrupted when the rise of dial-up Internet access resulted in much longer holding times for calls. It is unclear whether a new "Erlang" model for traffic is feasible or desirable in a world with video conferencing and where the "telephone call" communications abstraction has expanded to encompass such a wide range of applications and services (from real-time to voicemail, from SMS to high definition, and multi-party video conferencing). Additionally, while real-time communication applications limit the potential to cache traffic to economize on peak capacity resources, the desire to record for later playback or review implies that video conferencing, as well as other applications like sports television that require real-time resources, may also have demand for caching support. Whether such storage should be provided depends on the content-delivery strategy, and many possible options are feasible and/or desirable, depending on the nature of the content. For a further discussion of the diversity of content delivery network (CDN) strategies, see Volker Stocker et al., *Content May Be King, but (Peering) Location Matters: A Progress Report on the Evolution of Content Delivery in the Internet* (27th Euro. Regional ITS Conf., 2016), https://people.csail.mit.edu/gsmaragd/publications/ITS2016/.

72. Many webcams are not actively monitored, which begs the question as to their purpose and the value of the traffic they generate. They may actually be monitoring something that is potentially of interest (home security, fish tank) or they may be on in lieu of setting up a video conference call.

73. Of course, in a future world of machine-to-machine automation, it is likely that automated communications may inextricably blend the functionality and the traffic for communications and sensing applications.

74. Many sensing applications are interruptible, depending on what the goal of the sensing is. Time-lapse video recording is often adequate, and real-time access to the recorded video may not be necessary.

75. CISCO, THE ZETTABYTE ERA: TRENDS AND ANALYSIS 29 (June 2016), http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/vni-hyperconnectivity-wp.pdf.

76. Cisco forecasts that machine-to-machine (M2M) connections will rise to represent 46% of total connections, but the traffic will account for only 3% of traffic by 2020 (and only a portion of this will be video). *Id.* at 5 fig.2, 6 fig.3.

77. Most cable, direct broadcast satellite, and terrestrial over-the-air television services are not IP-based today, although this is rapidly changing. Additionally, non-networked entertainment media consumption remains significant (e.g., DVDs, movie theaters).

types of content but is broadly construed to include entertainment content that is (1) commercial, as well as user-generated (e.g., YouTube); (2) offered by program aggregators (e.g., Netflix, Comcast), as well as specialty networks (e.g., HBO, ESPN); and (3) offered as linear television (where the channelization of programming and timing is set by the programmer and video on demand (VOD), so that the timing/selection of when a show is viewed is determined by the viewer). Entertainment video includes programming with an array of variable characteristics such as: long- or short-form programming; delivery-time sensitive (e.g., sports, live performances, and breaking news) and long-term cacheable (e.g., movies); content available in several resolutions; content subject to varying digital rights management (DRM) treatments; and content that may be delivered via IP or the Internet in multiple ways. Delivery methods include streaming from either VOD or subscription services (e.g., Netflix, Hulu, Xfinity), or downloading bulk files[78] at faster-than-real-time transmission rates (e.g., iTunes downloads).[79] From a traffic characterization perspective, this traffic tends to be asymmetric (mostly downstream, requiring only limited upstream capabilities)[80] and mostly cacheable.

78. This class of traffic presents a difficult challenge for our analysis since it may be difficult to distinguish from other types of file downloads, which we expect to remain an important component of the "other 20%" traffic. If there were a separate IP service for delivering entertainment video, it is plausible that this might also prove attractive for these sorts of bulk downloads of entertainment video, as we discuss further below.

79. For the most part, we will ignore new media applications like Periscope or live video–sharing applications being supported by a growing number of social networking services like Facebook, Twitter, and others. While traffic from these services is growing in importance, full consideration of the implications of such traffic is beyond the scope of this Article, and it is unclear how or to what extent such traffic represents a new form of traffic or legacy traffic shifting (or being replicated) in new streams (e.g., when a Periscope subscriber re-broadcasts entertainment video available via other services); and if it is a new form of traffic, how does it impact demand for legacy entertainment?

80. VOD requires an uplink channel for interactivity to select programming, but that could be provided via a distinct and separate network from the network used to deliver the video (e.g., when one orders goods by telephone or the Internet that are delivered via UPS). User-generated content needs one upstream channel to upload the content (for each item), but most of the end-user traffic remains downstream to multiple users downloading content for viewing. For individual pieces of content, the distribution is very fat-tailed (a small number of YouTube videos account for a disproportionate share of the traffic). Real-time streaming of user-generated content (e.g., via Periscope) is an exception.

Table 1. Qualitative Characterization of Video Traffic Types

	Communications	Sensing	Entertainment Video
Traffic direction (predominant)	Symmetric.	Asymmetric (upstream).	Asymmetric (downstream).
Real-time required?	Yes, but also may have demand for cacheable.	Variable, lots may be interruptible.	No mostly, sports/ breaking news an exception; new media sometimes.
Bandwidth required? —Total (MB)	Mixed, but generally moderate. Communication applications may be more tolerant generally of lower resolution.	Low generally, but could be variable depending on sensing application.	Mixed, but generally larger. Video files can be quite large, but resolution mixed and short-form files may be small. Trend toward higher resolution, which is important for entertainment applications.
—Upstream rate	High, since inherently two-way.	High, since inherently one-way upstream.	Low, since inherently one-way downstream. Gaming different.
—Downstream rate	High, since inherently two-way.	Low, since inherently one-way upstream.	High, since inherently one-way downstream.
Cacheable?	No, but caching needed if recording/ playback capability supported.	Variable. Most is cacheable, but some is real-time. Edge caching for latency-intolerant apps may be important.	Yes. Mostly cacheable, but some may also require real-time resources.
Interconnection?	High, since any-to-any.	Depends where cached.	Depends where cached.
Routing?	Any-to-any, including many-to-many.	Mixed, but classic may be many-to-one (lots of sensors talk to aggregate collector) or mesh (IoT).	Broadcast. Sources are fewer than destinations (i.e., viewers).
Wireless (5G) support?	Not necessary, but nice to have.	Yes. Ubiquitous coverage and mobility likely to be important.	Less important than for communications.

In this Article's thought experiment, we are not assuming that all entertainment video traffic will be eliminated from the Internet (or, excluded from the "other 20%"). First, as we have already noted, drawing the boundaries between what constitutes entertainment, communications, or other types of traffic is not easy, and may become less so with the emergence of new forms of entertainment media. Highly interactive entertainment media may have very different traffic patterns than the sort of legacy television/movie-like entertainment video that is dominant today.[81] Second, because the Internet will still support large file downloads (e.g., for updating software or databases, or backing up files), and because many of those files may be video (e.g., iTunes/Amazon rental or purchase downloads), a significant volume of traffic may still be entertainment video. Third, the Internet may be used to support limited interactivity for video control purposes (e.g., basic VOD and VCR functionality for fast-forward, rewind, program selection, and billing). However, those control functions could be handled via a gateway that would communicate with the entertainment video distribution network, if the entertainment and other Internet traffic were indeed to be separated. Furthermore, were entertainment video to be carried via a logically separate IP distribution network or service, that service might also prove attractive for other types of traffic that shares the general features of video traffic (e.g., software downloads).

B. Traffic Trends

In this Section, we discuss how the character of video traffic has been changing as a consequence of changes in traffic composition, program resolution, and the types of video available.

1. Video Trends: Traffic, Growth, and Resolution

Data from Sandvine's Global Internet Phenomena Report found the following: (1) entertainment traffic (streaming video and audio) accounted for over 70% of downstream peak traffic on fixed-access networks; (2) this is twice as much compared to just five years ago; (3) traffic sources include major video services such as Netflix (33%), YouTube (17%), and Amazon Video (4%); and (4) BitTorrent traffic, which is declining, is now at 5% of total peak traffic.[82]

A variety of factors have contributed to producing this increase in video traffic, including increased consumption of higher-resolution video and increased time per subscriber viewing Internet video. Today, the average

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81. This may also include user-generated media, which also presents a more difficult challenge with respect to differentiating entertainment traffic from other sources of traffic, and with respect to its technical characterization.

82. SANDVINE, 2016 GLOBAL INTERNET PHENOMENA: LATIN AMERICA & NORTH AMERICA 4–5, 7 (Oct. 2016), https://www.sandvine.com/downloads/general/global-internet-phenomena/2016/global-internet-phenomena-report-latin-america-and-north-america.pdf. The share of entertainment video on mobile networks is lower but growing rapidly, and during the first half of 2016 exceeded 35%. *Id.* at 7.

consumer is spending more time watching Internet video compared to just four years ago.[83] Part of this increase is attributable to the growing use of mobile devices (smartphones, tablets) for accessing video both in the home and outside of the home. The proliferation of higher-resolution devices, lower (quality-adjusted) pricing for viewing devices, and the expansion of Internet programming options have all contributed to the growth in online viewing.[84] While entertainment video viewing via the Internet has grown rapidly, it appears to have had only a relatively modest impact on legacy television viewing, with most Internet video viewers also subscribing to legacy television services, and with only limited evidence of cord cutting thus far.[85]

When considering the impact of video traffic on the access network, it is important to recognize the data demands of higher-resolution video streams. Video streams are moving from standard-definition television (SDTV) at 1 Mbps to 3.7 Mbps depending on compression,[86] to high-definition television (HDTV) at 3 Mbps to 20 Mbps, and even to ultra-high-definition television (UHDTV) at 20 Mbps to 320 Mbps.[87] It is expected that HDTV and UHDTV content will increase over the next five years and SDTV will decrease.[88] The result is a growth in the overall traffic, but largely in the downstream direction.[89]

2. Traffic Types/Categories

Having characterized what we mean by entertainment video, we turn to characterizing the traffic. Convergence requires us to provision our IP access networks to handle a mix of traffic that is heavily weighted toward video, which is mostly one-way, cacheable, and associated with large-size files. As we just described, the balance of non-media entertainment traffic that is

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83. eMarketer reports that the average time watching video has grown from 0:47 (2012) to 1:08 (2016) hrs:mins per day, while legacy television watching has fallen from 4:38 (2012) to 4:05 (2016) hrs:mins per day. *See Growth in Time Spent with Media Is Slowing*, EMARKETER (June 6, 2016), http://www.emarketer.com/Article/Growth-Time-Spent-with-Media-Slowing/1014042.

84. *See* CISCO VNI, *supra* note 2 (detailing patterns of growth in media consumption formats).

85. The data on Internet video viewing substituting for legacy viewing is mixed. Nielsen seems to show a significant shift from legacy to Internet viewing, especially among younger audiences; however, other studies indicate that Internet viewing is complementing traditional viewing. *See* J.C. Lupis, *Traditional TV Viewing: What a Difference 5 Years Makes*, MOBILUTION.IO (July 5, 2016), https://mobilution.io/traditional-tv-viewing-what-a-difference-5-years-makes/; BARRY KIEFL, CAN. MEDIA RESEARCH INC., TRENDS IN TV AND INTERNET USE: THE IMPACT OF INTERNET TV ON CANADIAN PROGRAMMING (July 2011), http://www.omdc.on.ca/Assets/Research/Research+Reports/Trends+in+TV+and+Internet+Use/Trends+in+TV+and+Internet+Use_en.pdf. As legacy television providers shift programming to the Internet, however, the substitution effect is likely to become much larger. This will make it feasible to shift resources on fixed networks from delivering legacy television to delivering broadband Internet.

86. MPEG2, H.264, or HEVC compression technologies are commonly utilized, with HEVC being the most aggressive in terms of compression. *Understanding MPEG-2, MPEG-4, H.264, AVCHD and H.265*, WOLFCROW, http://wolfcrow.com/blog/understanding-mpeg-2-mpeg-4-h-264-avchd-and-h-265/ (last visited Feb. 27, 2017).

87. Nick Pino & Jon Porter, *4K TV and UHD: Everything You Need to Know About Ultra HD*, TECHRADAR (Jan. 24, 2017), http://www.techradar.com/news/television/ultra-hd-everything-you-need-to-know-about-4k-tv-1258884.

88. *Id.*

89. *See* SANDVINE, *supra* note 82, at 4 (reporting that on fixed networks, real-time entertainment accounted for 20% of upstream and 70% of downstream traffic in 2016).

associated with everything else, while smaller in aggregate volume, is more heterogeneous with respect to its requirements for connectivity, message size, and delivery specifications (routing, data rates, and QoS requirements). Table 2 summarizes our qualitative characterization of the two major streams of traffic.

Table 2. Entertainment Video Versus "Other 20%" Traffic Characterized

	Entertainment Video	"Other 20%"
Traffic direction (predominant)	Asymmetric (mostly downstream, limited upstream capacity needed).	Symmetric (two-way needed, but mixed traffic; heavier upstream capacity required).
Data rate (average, peak)	High peak (high resolution) and high average because video is transmission-resource intensive generally, and especially so for high resolution.	Lower but mixed. "Other 20%" includes all types of traffic (i.e., all non-video and non-entertainment video traffic).
Burstiness (ratio peak to average data rate)	Less. Entertainment media viewing tends to be relatively predictable with flash crowds possible.	More. Mixed traffic that may be event driven (require unpredictable bursts of data of variable size) or require low latency guarantees even during aggregate peak, requiring extra capacity headroom to manage.
Real-time, cache-ability	Not real-time. Most traffic is cacheable (even "live" can often be near-real-time, and time-shifting is common).	Mixed, some real-time and in-network storage may be needed solely to support disruption-tolerant networking.
Routing	"Broadcast"-like (but not always multicast since that does not support VOD). Fewer video sources (content providers) than viewers (destinations downstream). Hierarchical tree.	Any-to-any mesh, especially to support IoT.
Upstream	Low, since inherently one-way downstream.	High, since inherently two-way.
Wireless	Increasingly desired as mobile video fastest growing segment, but typically much lower resolution. Large displays typically wired.	Necessary, since ubiquitous coverage and mobility required for many key applications (e.g., consider public safety, IoT).

C. *Evolving the Network for Video*

The advent of video over the Internet is a relatively recent phenomenon[90] that required a number of earlier developments. Widespread adoption of broadband access was one of the necessary precursors for Internet video consumption to grow. Previously, the limited speeds and quality of dial-up access and the limited capabilities of consumer devices (personal computers with low-resolution monitors) resulted in a poor video experience via the Internet. Content providers who were unable to offer a compelling user experience via the Internet naturally focused on other distribution channels (principally legacy television and VOD). While the initial driver for broadband adoption was not video, but instead, the desire for faster web access and always-on connectivity, the higher data rates offered by broadband made it feasible to embed video clips in what had previously been mostly static web content.

Faster broadband data rates necessitated that network servers, routers, switches, and consumer device capabilities all be enhanced to support and take advantage of the higher data rates supported over broadband Internet access. Many of these improvements, while benefiting video, were not necessary solely for video, but contributed to enhancing the performance of all Internet applications, and made it feasible for video and other types of traffic to dynamically share network resources. Faster hardware processors, more capable software, and enhanced network services have all played a part in enhancing the overall Internet experience, and at the same time, made it feasible to offer an increasingly compelling Internet video experience. Because video traffic has been growing so rapidly,[91] it is hard to separate improvements that were motivated by the need to better support video that also benefit other types of traffic, from those that are more video specific (e.g., the proliferation of video coding/compression technologies). For example, improvements to the Hypertext Transport Protocol (HTTP) to support better encoding for dynamic content enhance the performance of both video and other non-video Web 2.0 applications.[92]

The rise of content distribution network (CDN) services that were developed as overlay network services on the Internet to identify how to optimally distribute content (both dynamic and static) provided new techniques and capabilities for distributing content of all types, including video.[93] The

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90. Alex Zambelli, *A History of Media Streaming and the Future of Connected TV*, GUARDIAN (Mar. 1, 2013, 5:00 AM), https://www.theguardian.com/media-network/media-network-blog/2013/mar/01/history-streaming-future-connected-tv.

91. CISCO VNI, *supra* note 2.

92. For example, legacy HTTP used store-and-forward encoding. More recent versions of HTTP support "chunked encoding," which enhances the user experience by allowing the browser to serve streaming content to the user without first knowing how large the file is to be served. *HTTP Gallery*, HTTPWATCH, https://www.httpwatch.com/httpgallery/chunked/ (last visited Feb. 27, 2017). This allows the end user to start the viewing experience sooner. The optimal chunk size depends on the application and may be different for entertainment video streaming and other Web 2.0 interactive content. *Id.*

93. *Content Distribution Network*, AKAMAI, https://www.akamai.com/us/en/resources/content-distribution-network.jsp (last visited Feb. 27, 2017).

introduction of CDN services has re-written the interconnection model for the vast majority of Internet traffic, making it feasible to reduce the costs of content distribution across the Internet cloud.[94]

Finally, end-user devices have improved significantly, with higher-resolution screens, faster processors and image processing hardware, and enhanced operating systems with application support for interactive and mobile network services. These enhancements have benefited all classes of applications, including video. Each of these developments, together with multicast (push and pull), enhanced congestion control (load balancing), and more granular support for QoS have brought us to the current state. Now, the broadband Internet is supporting increased volumes of both video and "other 20%" traffic, and generally offering enhanced capabilities for all types of applications (i.e., higher resolution, lower latency, better reliability, mobility, etc.).[95] Users are both streaming video and using interactive (delay-sensitive) communication services (including video conferencing) and other "cloud" services (e.g., eCommerce, IoT, file backups, social networking, etc.).[96] However, it is unclear whether this will continue if the entertainment media (that is currently mostly consumed over legacy channels) migrates to the Internet and the nascent applications that compete for resources (e.g., video conferencing, IoT) take off. It is worthwhile considering whether sustaining the trajectory of improvements and capacity expansion that has proved successful thus far will prove equally successful in the future (when total Internet traffic loads are potentially orders of magnitude larger); or whether an alternate architecture that segregates the traffic might prove superior.

When we look across the network, we can highlight the bottlenecks that video creates, and identify how the providers have responded. As mentioned, network and end devices have employed a diverse set of incremental fixes to address many of the problems that video presents. While these fixes do a fairly remarkable job, there are still gaps in terms of the user's quality of experience (QoE). There are features that will continue to challenge the current model. These challenges are exacerbated by a host of potential failures that occur across the video content distribution path, for example, publishing failures, CDN failures, server failures, peering and transit disputes and failures, ISP provisioning inadequacies, and end-host issues.[97]

So we have asked: has video traffic fundamentally changed the way that we are designing the Internet, and at what cost to other services? The first question, "Has video changed the design of the Internet?," is an easy one to

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94. *See* David Clark et al., *Interconnection in the Internet: The Policy Challenge* (39th Research Conf. on Commc'n, Info. & Internet Policy, 2011), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1992641; Stocker et al., *supra* note 71.

95. Dave Clark et al., *Overlay Networks and the Future of the Internet*, 63 COMM. & STRATEGIES 1, 3, 14 (2006).

96. *See* SANDVINE, *supra* note 82, at 4–5.

97. Balachander Krishnamurthy et al., *On the Use and Performance of Content Distribution Networks* (ACM SIGCOMM Internet Measurement Workshop, 2001), http://web2.research.att.com/export/sites/att_labs/people/Krishnamurthy_Balachander/papers/imw01-abcd.pdf; Wenjie Jiang et al., *Cooperative Content Distribution and Traffic Engineering in an ISP Network* (11th Int'l Joint Conf. on Measurement & Modeling of Comput. Sys., 2009), http://www.princeton.edu/~chiangm/te-cdn.pdf.

answer: yes, as discussed above. To answer the second question, "How might separating video content impact last mile design?," is a challenge, which partly requires us to speculate what remains in the "pipe" and which applications and traffic might benefit from this new non-video Internet connection. In answering this second question, non-video trends can inform a new model for characterizing the potential "other 20%" traffic.

D. Traffic Percentages and a Future Internet

In this Section, we review traffic measurements over current broadband access networks, and then use this analysis to describe what a future video-less link might look like.

1. Current Traffic Composition of Broadband Internet Access

To understand the impact of video on access networks, we measured the types of traffic running over a number of broadband access network connections.[98] The types of traffic were then classified into video, web, file sharing, gaming, voice, and "other data" (data that we could not easily identify).[99] We found (on average) the following traffic on these links:

- Video (65.1%)
- Web (17.5%)
- File sharing (8.6%)
- Gaming (1.1%)
- Voice (<0.1%)
- Other data (7.6%)

These measurements are in reasonable agreement with other recent studies.[100] It is notable that even at peak periods, the network connection was at most 60% of peak capacity, meaning that these networks were not under heavy constraints. As stated, after excluding video traffic that is highly asymmetric, what remains is web, file sharing, gaming, voice, and "other data." This remaining traffic mix is more symmetric and of a much lower data rate. Also remaining is a higher percentage of voice and gaming applications, which are less delay-tolerant and not cacheable. Therefore, in an access Internet without entertainment video, traffic flows are:

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98. We looked specifically at cable, DSL, and fiber connections. While we believe that wireless likely presents a unique set of challenges, we will not deeply explore wireless access in this Article beyond the following comments: There has been some recent work looking at the role of broadcast technologies such as ATSC 3.0 and the Long Term Evolution (LTE) broadcast effort, and the Evolved Multimedia Broadcast Multicast Services (eMBMS) standard. Each of these seeks to enable video services in a more efficient manner for wireless (or over-the-air) broadcast. Capacity limits made more sensitive by spectrum costs may present an interesting perspective here. Of course, there is unlicensed spectrum, but this too presents its own set of challenges. Also, in some ways video has had a history different from most wireline networks as a result of usage caps on cellular services. Lastly, how designers exploit cross-layer optimization may differ in a wireless scenario, where close coupling of the layers might be justified.

99. Note that among the nineteen connections that we measured, the only service that had highly variable percentages was gaming. We omit the details of the measure method, as this was more of an informal tool to help consider the impact of video on the network.

100. *See* SANDVINE, *supra* note 82, at 4; CISCO VNI, *supra* note 2.

- More heterogeneous
- Lower average data rate
- Burstier (peak/average higher)
- More symmetric (two-way)
- Less latency tolerant
- Less cacheable

We next used historic data to extrapolate a model of what a future (video included) traffic mix might look like based on the trends described above (higher-resolution video and more of it). We found that video could account for more than 85% of traffic, which is higher than many of the available capacities analysts are projecting. We conducted a similar extrapolation for non-video traffic and combined this with some usage scenarios described below. In this mix, the aforementioned differences of heterogeneity, data rate, delay sensitivity, and cacheability were all pronounced.

2. Usage Scenarios of the 20%

To aid in our predictions about future traffic demands of the "other 20%," we consider several likely usage scenarios. The goal is simply to think about a potential traffic mix for future non-video traffic. We consider several prototypical scenarios—IoT in the home, healthcare, and public safety—where the value proposition driving the need for advanced communications taps into a very different set of social goals and personal needs. Focusing on these scenarios facilitates our ability to hypothesize about non-entertainment applications that may (or may not) suffer in an Internet of mixed traffic. The three scenarios are as follows:

- *Case 1 Home IoT:* characterized by low bandwidth, variable latency, and constant (control signals) to arbitrary connectivity.[101]
- *Case 2 Healthcare:* characterized by need to support mobile, IoT, and video conferencing applications, low to high bandwidth, variable latency, and variable connectivity.[102]
- *Case 3 Public Safety:* characterized by need for ad hoc networking capability, low to high bandwidth, variable latency, and variable connectivity.[103]

It is clear that the needs for low to high bandwidth, variable latency, and variable connectivity differ from video. Consequently, it is reasonable to conclude that a network optimized for video characteristics may not serve the needs of these non-video services. Each of these cases stresses the need for a heterogeneous/reliable/robust infrastructure. These services would put an

101. *See generally* John M. Chapin & William H. Lehr, *SCADA for the Rest of Us: Unlicensed Bands Supporting Long-Range Communications* (38th Research Conf. on Commc'n, Info. & Internet Policy, 2010), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1988184.
102. *Id.*
103. *Id.*

emphasis on connectivity to a wider array of devices. It may even justify the need for multi-homing to provide robustness benefits against failure modes. These cases raise significantly different connectivity models compared to traditional video.

We recognize that while the above is speculative, the scenarios we consider represent oft-discussed usage cases that are frequently cited to justify the importance of the Internet as essential infrastructure. Moreover, each scenario presents traffic requirements that are substantially different from those presented by traditional video. We also recognize that a portion of the traffic, even for those applications, will include traditional video, so any model of the "other 20%" would need to take into account provisioning for that video.

3. *Video's Impact on Other Services*

Another major question we consider is whether the Internet is flexible enough to carry a majority of video traffic yet still retain characteristics necessary to ensure the growth of other services. Of course, we cannot know what future Internet traffic will look like, but we can consider several scenarios with a variety of traffic types. Another factor to consider is the burstiness of (non-video) data.

At the core, the network topology has flattened and become more densely connected. Less traffic has to be routed from lower-tier networks via Tier 1 providers, and more of the content is served from networks that are directly connected to access networks.[104] Much of this has been driven by the rise of video content and the need to minimize the traditional flow of this type of content across the Internet. The role of the traditional Tier 1 and Tier 2 backbone providers has diminished with the advent of more densely connected networks, the introduction of CDNs, and the growing importance of edge networks. The most significant point regarding the core is that traffic resides in CDNs and other servers closer to the consumer, and therefore less of the traffic needs to traverse the traditional backbone.[105] These changes have resulted in pressure on peering arrangements, and as a result, interconnection among the networks continues to evolve. Of course, at the edge of the network we see a better representation of what the consumer requests, in that video is traversing this link (unlike the CDN traffic cached at the edge).[106] It could be possible to cache some of this video content at the home and shift this download to off-peak periods. While we did not measure the traffic by type, sources have identified numbers in the range of 40% video and 60% other across backbone and edge networks.[107]

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104. Phillipa Gill et al., *The Flattening Internet Topology: Natural Evolution, Unsightly Barnacles or Contrived Collapse?*, *in* PASSIVE AND ACTIVE NETWORK MEASUREMENT 1, 8 (Mark Claypool & Steve Uhlig eds., 2008), http://pub.cs.sunysb.edu/~phillipa/papers/PAM08.pdf.

105. *See generally Content Delivery Network Explained*, GLOBALDOTS, http://www.globaldots.com/content-delivery-network-explained/ (last visited Feb. 27, 2017).

106. *Id.*

107. *See, e.g.*, ALCATEL-LUCENT, BELL LABS METRO NETWORK TRAFFIC GROWTH: AN ARCHITECTURE IMPACT STUDY (2013), http://www.tmcnet.com/tmc/whitepapers/documents/whitepapers/2013/9378-bell-labs-

Other questions of interest include: Does the source of the video matter? Will most of the entertainment content be coming from known providers in the entertainment industry or from random end points (e.g., be user generated)? YouTube has allowed everyone to become a production studio, where individuals can upload cacheable content to a server asynchronously.[108] Most of this does not become popular and may only matter to a small group of friends, whereas a small number (out of the total) can become very popular and result in flash crowds. We do not know precisely how Google (which owns YouTube) pushes popular content toward the edge, but we presume it is via a CDN mechanism for its most popular content. There are a range of CDN solutions that vary along multiple dimensions, including the volume of content the content providers need to distribute. For example, small video providers may be happy with just using the standard Internet, posting files to web servers and accepting that the QoE of users may be variable, whereas middle- to large-size commercial providers of video services may purchase CDN services from Akamai or other CDNs to lower distribution costs and ensure better QoE for their subscribers.[109] Meanwhile, the largest video distributors (e.g., YouTube or Netflix) are so large that they are undesirable customers for any commercial CDN and therefore need to self-provision their own CDN.[110] They do this by negotiating bilateral agreements and using deep-network caching with eyeball access networks.

Another interesting question is: when does capacity isolation become an issue? This arises when broadband platform resources (whether in terms of the raw radio frequency (RF) capacity on the wires or other network resources) need to be allocated between Internet and other services (which may or may not be other IP-based services). These other services have collectively been referred to as "specialized services" to signify that the traffic and how they are offered is distinct from the Internet.[111] These specialized services may be subject to different sets of regulation.[112]

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metro-network-traffic-growth-an-architecture.pdf; *see also, e.g.*, William B. Norton, *Video Internet: The Next Wave of Massive Disruption to the U.S. Peering Ecosystem (v1.7)*, DRPEERING INT'L, http://drpeering.net/white-papers/Video-Internet-The-Next-Wave-Of-Massive-Disruption-To-The-U.S.-Peering-Ecosystem.html (last visited Feb. 27, 2017); Vijay Kumar Adhikari et al., *YouTube Traffic Dynamics and Its Interplay with a Tier-1 ISP: An ISP Perspective* (10th ACM SIGCOMM Conf. on Internet Measurement, 2010), http://conferences.sigcomm.org/imc/2010/papers/p431.pdf.

108. Corey Anton, *Clocks, Synchronization, and the Fate of Leisure: A Brief Media Ecological History of Digital Technologies*, *in* THE CULTURE OF EFFICIENCY: TECHNOLOGY IN EVERYDAY LIFE 81 (Sharon Kleinman ed., 2009).

109. *See generally CDN Provider*, AKAMAI, https://www.akamai.com/us/en/resources/cdn-provider.jsp (last visited Feb. 27, 2017).

110. *See* Ben Lovejoy, *Apple Bringing More of Its Content Delivery In-House, Possible Preparation for Streaming TV*, 9TO5MAC (Feb. 10, 2016), https://9to5mac.com/2016/02/10/apple-cdn-akamai/ ("Apple's main CDN company, Akamai, has warned shareholders that it expects to see its combined revenue from Apple and Microsoft more than halved this year.").

111. *What Are Specialised Services and How Are They Relevant to the Regulation?*, BEREC, http://berec.europa.eu/eng/netneutrality/specialised_services/ (last visited Feb. 27, 2017).

112. As discussed before, the treatment of so-called "specialized services" has a direct bearing on the efficacy of network neutrality regulations applied to the Internet since such services may contend with the Internet for resources and ISPs with market power may seek to shift traffic to specialized services to avoid network neutrality regulations.

While the scope of this Article precludes rigorous examination, we can look at a number of characteristics of specialized services and consider what this might mean for the overall characteristics of the broadband pipe and the different ways in which resources might be allocated (e.g., volume of isolated capacity, traffic type, and trends).[113] A whole set of related questions to consider include: How might we determine or measure the impact of capacity isolation on the rest of the broadband pipe? Is there a time when such isolation is good for the rest of the pipe (peak periods)? Does capacity isolation appear to be hurting the performance of current Internet traffic? Is there a role for the end user in deciding how capacity is isolated? Is there a role for new technology (SDN, NFV)[114] for a future network design—one where the edge of the network can dynamically morph to adjust to demands? These are open research questions to be addressed by the network research and policy communities.

4. Differences of Voice and Video as Specialized Services

From one perspective, the case for segregating video traffic from the Internet shares similarities with the case for segregating voice traffic. Today, many of the largest ISPs offer voice services that are implemented as Voice over IP (VoIP) over managed IP networks that are logically separate from the broadband Internet access traffic.[115] This decision is often justified in order to enable providers to ensure adequate QoS for telephone services, and to facilitate the integration with emergency services (e911) and compliance with lawful intercept requirements (CALEA).[116] Because these VoIP services allow calls to and from legacy telephone customers connected to the public switched telecommunications network (PSTN), these are sometimes referred to as "interconnected VoIP" services.[117] In addition to such services, there are also VoIP applications and services that use their customers' broadband access service to carry voice packets. This includes services like Skype, Vonage, or Ooma.[118] These services compete with the carrier-provided VoIP services and

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113. While beyond this thought experiment, it may be possible to characterize networks that are "tree-like"—where a limited number of sources may distribute to a large number of destinations, inherently broadcast/multicast versus fully connected (any-to-any telephone)—and relate that to peak/multiplexing constraints and costs.

114. SDN refers to software-defined networking and NFV refers to network function virtualization. Both developments are examples of the softwarization of modern communication networks, which allows more granular, flexible, and dynamic resource assignment using software instead of hardware-based control. Moving the control of network functionality into software can also help reduce costs by enabling the de-localization of network functionality (facilitating the realization of scale and scope economies) and enabling commodity hardware to be substituted for specialty hardware.

115. Rahul Singh & Ritu Chauhan, *A Review Paper: Voice over Internet Protocol*, 3 INT'L J. ENHANCED RES. IN MGMT. & COMPUTER APPLICATIONS 15 (2014).

116. *Id.* The Communications Assistance for Law Enforcement Act (CALEA) was passed by Congress in 1994, which required telecommunications companies to design and modify their network architecture to ensure it allows law enforcement to conduct lawful electronic surveillance. *Communications Assistance for Law Enforcement Act*, FCC, https://www.fcc.gov/public-safety-and-homeland-security/policy-and-licensing-division/general/communications-assistance#block-menu-block-4 (last visited Feb. 27, 2017).

117. Singh & Chauhan, *supra* note 115.

118. *See* Rob Marvin & Michael Muchmore, *The Best VoIP Providers and Phone Services for 2017*,

thus are analogous to the situation being considered here, in which video entertainment traffic may be delivered to consumers via separate networks or via the Internet.

From a capacity perspective, the difference is that voice traffic requires far fewer bits and so consumes a relatively small share of capacity resources relative to video.[119] However, voice traffic is communications oriented and symmetric, and as such relies on the two-way communications functionality that characterizes much of the "other 20%" traffic and distinguishes it from entertainment video traffic. Moreover, from an economic and policy perspective, policymakers have long concluded that voice telephony services should be regarded as essential communications services,[120] whereas it is unclear whether access to entertainment television is regarded as having as much social importance. In summary, therefore, while it is plausible to argue that voice and video traffic should both be separated from broadband into separate network flows, we do not make such an argument here. The two cases are sufficiently different from a technical, economic, and policy perspective that each should be considered independently. However, consideration of the case for separating entertainment video traffic may prove useful in informing an investigation of how voice services might best be managed in the future (and vice versa).

E. Architecture

In this Section, we consider what convergence might look like and the implications of different network architecture choices. We ask how might we provision entertainment video over a separate network service, one that might share the same physical conduit, or even the same virtualized pipe. A simple way of considering this is to think of "specialized services," akin to the way IP video or carrier VoIP services are currently delivered, using logically distinct portions of the RF on the last mile. There are many ways that this separation could occur, and depending on the attention placed on maintaining the bandwidth and other performance characteristics of the non-video Internet connection, it might be little more than a traffic-shaping mechanism; or it might involve complex cross-layer optimization.

This happens today over the access networks operated by cable companies and telephone companies when they provision triple-play bundles of services (Internet access, television/video, and voice).[121] For those that are still in the process of converting to all-IP broadband access platforms, the services share the same physical network (and RF on the wires) but are

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PCMAG (Feb. 21, 2017), http://www.pcmag.com/article2/0,2817,2483780,00.asp (showing magazine's rated-best VoIP providers).

119. *Voice over IP—Per Call Bandwidth Consumption*, CISCO (Apr. 13, 2016), http://www.cisco.com/c/en/us/support/docs/voice/voice-quality/7934-bwidth-consume.html.

120. *Universal Service*, FCC, https://www.fcc.gov/general/universal-service (last visited Feb. 27, 2017).

121. ALCATEL-LUCENT, TRIPLE PLAY SERVICE DELIVERY ARCHITECTURE (2009), http://images.tmcnet.com/online-communities/ngc/pdfs/multimedia/whitepapers/Triple-Play-Delivery-Architecture.pdf.

delivered using a mix of IP- and non-IP-based network technologies.[122] When those networks are converted to all-IP, the traffic may continue to be delivered over separately managed IP networks that will continue to share the physical network, but with much more dynamic network control over how the available resources may be shared across the services.[123] There is a continuum of potential provisioning models. At one end, there could be an IP network for best-effort Internet traffic plus one or more specialized IP networks for video, VoIP, or some other (future) segregated traffic type. In that case, the capacity allocations across the different IP flows may be managed at variable time scales and levels of granularity. For example, the allocations may be set according to relatively static constraints that are managed based on aggregate per-IP flow characteristics. At the other extreme, one might envision a single IP network with per-packet or per-flow QoS management.

Today, we accommodate the variety of traffic flows in the best-effort Internet with a complex mix of workarounds that includes techniques, overlays, and value-added services such as VPNs, CDNs, and MPLS.[124] It is certainly possible that this adaptation by accretion may continue. However, it is unlikely that simply provisioning a single IP network offering only best-effort traffic management would be adequate to address the needs of traffic in the future.[125] If the future is separate IP networks that mix a best-effort Internet and specialized IP networks for other traffic while sharing the same physical network, then the issue to resolve will be how best to allocate resources. This is more than just a technical question since the technologies make it possible for us to address this question at a variety of time, geographic, and context-related scales. At one extreme, we could have static resource assignments (full capacity isolation), whereas with full-blown NFV/5G we could have dynamic resource assignment on a per-packet basis, and technically, the traffic would be fully converged (i.e., single IP network with QoS).[126] Or, we could have more limited integration, more closely approximating what we have today where video and VoIP are separate logical networks and integrated at gateways (at PSTN-SIP interconnection gateways for IP-TDM conversion, or set-top boxes where entertainment video and broadband traffic are split/integrated for distribution to appropriate devices in the home, etc.).[127]

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122. *See generally id.*

123. Karl Bode, *AT&T's "IP Transition" Will Make U.S. Broadband Even Less Competitive*, TECHDIRT (Mar. 3, 2014, 3:59 PM), https://www.techdirt.com/articles/20140303/04235226402/ats-ip-transition-will-make-us-broadband-even-less-competitive.shtml.

124. VPNs are virtual private networks, and MPLS stands for Multi-Protocol Label Switching. Both of these are techniques for adding QoS control and traffic management capabilities to the legacy Internet. For a discussion of overlays in the Internet, see Clark et al., *supra* note 95.

125. *See* Reed, *supra* note 62 (explaining how modern cable networks may provide the QoS support needed to handle the projected growth in video and other types of Internet traffic).

126. Even if all traffic shares a single IP network, we may still desire regulatory separation of the traffic. How to achieve that would present a challenge that would likely have implications for resource allocation decisions. For example, label all public-safety traffic with a special tag and then allow that to preempt any other type of traffic; or label all best-effort traffic with another tag and let that be buffered or dropped first whenever congestion occurs. The range of potential options enabled by technology is virtually unlimited.

127. *Communications Transformations 3: SIP Trunks for PSTN Access*, CISCO (Jul. 18, 2007),

If we considered what a separate IP network optimized for entertainment video traffic might require in the way of specifications and functionality, a range of (potentially) important features may be identified, including: (1) support for DRM management; (2) edge caching and CDN support (to optimize caching); (3) multicast support; (4) support for diverse video-encoding standards (which might be price-tiered based on bandwidth utilization, etc.); and (5) other requirements.

There are various reasons why it might make sense for broadband access service providers, particularly cable companies, to move their current linear video onto IP. Some of these are technology enablers and others are motivators. Advances in the design of their networks has allowed use of wideband channels, as opposed to the legacy 6 MHz channel, and these wider bands allow for much higher throughput.[128] Also, methods such as pruned multicast support more efficient and targeted usages of bandwidth.[129] Being in IP with the opportunity to dynamically adjust channel capacities could facilitate better signaling between edge devices (e.g., regarding screen size and desired resolution, DRM permissions, or other video features). It may also allow operators to dynamically choose between video encoding on the fly (e.g., to address different resolution preferences) or selecting pre-encoded content, depending on the nature of the content and its popularity.[130]

Being in an all-IP environment also offers benefits in terms of economies of scale, reduced complexity, and ease of implementation and ease of deployment of new features and service customizations. Today's video service providers often rely on hybrid technologies, distributing some content via broadcast RF to all subscribers (and not necessarily even in digital format) and distributing other programming via switched digital services (again, not necessarily IP), while offering "TV anywhere" access to selected programming over the Internet.[131] A cable company may choose to move its content into a single distribution network, served over one efficient network (CDN driving IP

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http://www.cisco.com/c/en/us/products/collateral/unified-communications/unified-border-element/prod_white_paper0900aecd806780df.html.

128. Hariharan Rahul et al., *Learning to Share: Narrowband-Friendly Wideband Networks* (ACM SIGCOMM Conf. on Data Commc'n, 2008), http://ccr.sigcomm.org/online/files/p147-rahulA.pdf (explaining benefits of wideband network usage).

129. *IP Multicast Technology Overview*, CISCO (Oct. 29, 2001), http://www.cisco.com/c/en/us/td/docs/ios/solutions_docs/ip_multicast/White_papers/mcst_ovr.html.

130. Video encoding incurs processing costs. For popular content that may be desired in multiple resolution formats, it makes sense to encode the content in advance and store multiple copies in different resolutions; while for content that may only occasionally be desired in multiple resolution formats, it may make sense to encode the content on the fly. Being in an all-IP environment enables these sorts of decisions to be made on a per-content or per-customer basis.

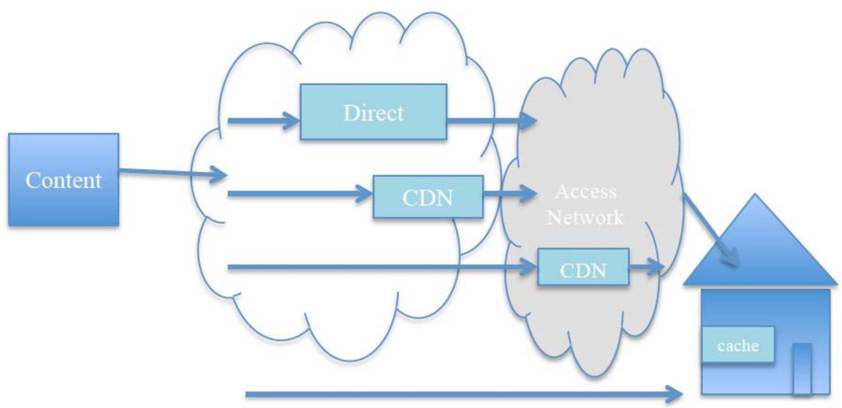
131. According to the FCC, 69% of MVPD households were served by all digital networks by the end of 2014, up from 57% in 2013. *See* Annual Assessment of the Status of Competition in the Market for the Delivery of Video Programming, Seventeenth Report, 31 FCC Rcd. 4472, 4474–75 (2016) [hereinafter Seventeenth Report], http://transition.fcc.gov/Daily_Releases/Daily_Business/2016/db0506/DA-16-510A1.pdf. At the end of 2013, 45% of the digital cable subscribers were served using switched digital video (SDV). *Id.* SDV allows providers to conserve bandwidth by using shared bandwidth to transmit video-on-demand for less popular programming. Traditional video service providers like Comcast and others are offering "TV Anywhere" services to allow their subscribers to access certain content over any Internet connection. This allows them to enhance the value of the service offered to their subscribers, and provides a competitive response to the threat posed by over-the-top programmers.

over the access network) and serving all its customers' points of consumption (in home, out of home, set-top box, smart TV, tablet, cell phone, etc.). The operational simplicity of this paradigm and the ability to switch to an agile/lean technology-deployment model on this platform offers a number of advantages.

1. Getting Video to the Customer

In this Subsection of the Article, we first consider how video content gets to the edge of the network. We then briefly consider how a Video-over-IP Access Service (VIAS) might work technically (addressing how this might work from a policy perspective in a subsequent Section).

Figure 1. Alternative Options for Delivering Video into Broadband Homes



As Figure 1 above depicts, at a high level of abstraction, one might think about a content provider seeking to deliver video to edge subscribers by direct streaming to the home without the use of a CDN (however, the content could still be cached at the home), placing content in a CDN close to the access network, or placing CDN within the BIAS provider's network. In each of these situations, the content provider could make use of transit, peering, or other network deployment strategies to reach the customer. Furthermore, the content provider could even be the same company that owns the access network. A fourth way would be to have content delivered without the use of the Internet (think Netflix DVD delivery).

Even with the significant architectural enhancements just described, the performance shortcomings of over-the-top video are well documented.[132] These include:

132. Xi Liu et al., *A Case for a Coordinated Internet Video Control Plane* (ACM SIGCOMM Conf. on Applications, Techs., Architectures & Protocols for Computer Commc'n, 2012), http://conferences.sigcomm.org/sigcomm/2012/paper/sigcomm/p359.pdf.

- Setup delays of five to ten seconds for a majority of sessions
- Downlink bandwidth variation, which leads to buffering and rate adaption
- Significant buffering and re-buffering (as a percentage of traffic and time)
- Variable-quality CDN performance

2. VIAS

Here, we briefly consider how a Video-over-IP Access Service might be offered to the customer.[133] This is simply to highlight how such a service could be isolated from Internet service and to further demonstrate the varying degrees of convergence on a network. The options, going from completely separate to completely converged, might include:

- Independent connections (e.g., BIAS for Internet, with video delivered over a completely separate physical network such as over-the-air broadcasting or satellite)
- Same connection, separated at the PHY layer
- Same connection, separated at the Data Link layer
- Same connection, separated at the Network layer
- Same connection, separated at the Transport layer
- Over-the-top (OTT) (e.g., Netflix)

When considering how video is delivered to a customer, we might start with the historic norm of it coming through a separate conduit. For example, it could come in via television broadcast or satellite transmission. This approach is still common, and it is even the basis of AT&T's motivation in acquiring the DirectTV satellite service.[134] Alternatively, video can enter the home on the same connection as the Internet access service by combining streams.[135] This combination of services can occur in a variety of ways at different layers of the network protocol stack as laid out above. For example, this could occur over MoCA,[136] DOCSIS, a VLAN,[137] VRF,[138] or some traffic-shaping method. The

133. Just as the FCC has chosen to define a new broadband Internet access service (BIAS) for the purposes of its Open Internet Order as a Title II telecommunications service, the FCC might define a VIAS service that might also be regulated under Title II or some other authority of the Communications Act. Discussing the precise regulatory classification and how it relates to network neutrality is beyond the scope of this discussion.

134. *AT&T Completes Acquisition of DIRECTV*, AT&T (July 24, 2015), http://about.att.com/story/att_completes_acquisition_of_directv.html.

135. *How MoCA Works Video*, MOCA, http://www.mocainyourhouse.com/how-moca-works-video (last visited Feb. 27, 2017).

136. MoCA stands for the Multimedia over Coax Alliance. *MoCA FAQs*, MOCA, http://www.mocalliance.org/index.htm (last visited Feb. 27, 2017). This industry alliance is focused on developing a suite of standard technologies for delivering a host of applications into homes over coaxial cables and within homes over coaxial, Wi-Fi, and other in-home networking infrastructures. *Id.*

137. VLAN stands for virtual local area network, which is a class of technologies that operates by modifying the headers of Ethernet packets to enable finer-grained traffic management capabilities. Edward Tetz, *How Virtual Local Area Networks (VLANs) Work*, DUMMIES, http://www.dummies.com/programming/networking/cisco/how-virtual-local-area-networks-vlans-work/ (last visited Feb. 27, 2017).

138. VRF stands for virtual routing and forwarding, which is a technique of provisioning for and

most familiar combined video and Internet access started with cable providers, who made use of DOCSIS technology to implement Internet access on top of the existing cable video distribution platform.[139] In this model, all downstream data arrived in 6 MHz channels (the traditional channel specification for broadcast video).[140] The video content is provided by Digital Video Broadcasting-Cable (DVB-C), which carries the video as MPEG-2 or MPEG-4 streams over QAM (the video is not carried over IP).[141]

The Internet access traffic is also carried in these 6 MHz channels, but makes use of a differing data link technology to separate it out.[142] Interestingly, cable operators are evolving toward a more IP-centric approach with plans to move linear channels and VOD over IP.[143] Even though all of this will be carried over IP, the video traffic will receive some differentiated treatment.[144] A similar all-IP approach is expected in the fiber and DSL space.[145] Continuing up the stack, it is possible to use Layer 3 or Layer 4 methods to separate and/or differentiate a video service from an Internet access service.[146] Lastly, there is the possibility of simply placing everything as just another app running on the broadband access service—i.e., over-the-top video.

Before leaving the subject of video delivery, it is worth mentioning some recent research. Caching content at the edge in CDNs is increasingly becoming the primary source for serving video traffic to consumers. A recent paper by Brzozowski and van Doorn argues that the cost of the cable access network is so high that it makes sense to cache selective content at the subscriber's residence.[147] This is not a new idea, but the paper does present a compelling argument that video is dominating the access network, particularly during peak usage, and that caching could reduce this load.[148] Earlier, Liu et al. argued in favor of implementing a separate Internet video control plane.[149] That case could be extended to make the case for a separate data plane for

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managing data traffic on a per-flow basis over cable modem networks that operate at Layer 2. *See, e.g.*, *Cisco CMTS Router Layer 2 and VPN Features Configuration Guide*, CISCO, http://www.cisco.com/c/en/us/td/docs/cable/cmts/config_guide/b_cisco_cmts_layer_2_vpn_features.html (last visited Feb. 27, 2017).

139. *DOCSIS® 3.1*, *supra* note 62.

140. *Id.*

141. *See DOCSIS® Specifications*, CABLELABS, https://www.cablelabs.com/specs/ (last visited Feb. 27, 2017) (describing the way in which the cable PHY layer is evolving to handle higher IP data rates).

142. Reed, *supra* note 62.

143. It is expected that VOD service will migrate first, followed by less popular linear channels, and eventually the top linear channels. This will allow multicast services to carry these linear streams and sports VOD to customers, which cannot be done for OTT content. This will further allow a switched video architecture that supports even higher IP data rates, including much higher Internet access data rates.

144. It is worth mentioning that even in early Data Over Cable Service Interface Specification (DOCSIS) versions, a method to offer high-quality voice was implemented as a QoS extension at the data link layer. *Cisco CMTS Router Quality of Service Features Configuration Guide*, CISCO, http://www.cisco.com/c/en/us/td/docs/cable/cmts/config_guide/b_cmts_Quality_Service_Features/b_cmts_Quality_Service_Features_chapter_01.html (last visited Feb. 27, 2017).

145. INTERNET TRAFFIC, *supra* note 62, at 13.

146. *Id.* at 9.

147. John Jason Brzozowski & Jan van Doorn, *Improving Customer Experience Through Cooperative In-Home Caching and Pre-Positioning (CIHCP)*, NCTA TECHNICAL PAPERS (2016), http://www.nctatechnicalpapers.com/Paper/2016/2016-improving-customer-experience-cihcp.

148. *Id.*

149. *See* Liu et al., *supra* note 132.

video. While HTTP and related protocols have been tweaked to better carry video, it is still not the most obvious and efficient method of transport.[150] Of course, the same argument was made against VoIP,[151] but, for a number of reasons, it worked well for transmitting voice.

F. Summary

Summing up our technical discussion of how video traffic has changed the Internet and what this may mean for the future architecture of the Internet, we offer the following observations.

First, video traffic is continuing to grow as a percentage of total traffic on broadband access links.[152] This growth is only expected to continue due to growing customer demand to access video via the Internet and the shift to higher-resolution (higher-bitrate) video content, more capable devices, and the opportunity to consume video in more locations (e.g., mobile, wireless). Traditional commercially produced entertainment video is a growing share of this traffic, but the volume of user-generated and non-traditionally produced content is also growing. The expectation is that if current trends continue, entertainment-dominated video traffic will comprise 80% or more of the traffic on last-mile broadband access networks (whether delivered via a single BIAS or multiple IP-based services).[153]

Second, while we can model the current state of traffic, projections of future traffic are fraught with uncertainty. Nonetheless, it is possible to consider broad traffic types and the implication of the growth of each. Our simple model suggests that if entertainment video is extracted from the general mix, the resulting "other 20%" will grow at a slower rate (in terms of aggregate traffic), be more symmetric, and include more delay-sensitive traffic than would be the case if all of the traffic were aggregated.

Third, the Internet (including backbone, interconnect, distribution, and access networks) has evolved to accommodate the shift to more video traffic. These changes include CDNs, dense interconnections, higher backbone data rates, higher access data rates, and more.[154] These enhancements, not completely attributable to the rise of video traffic, have delivered service quality improvements to all applications in terms of enabling higher data rates, reduced latency (delay), and reduced losses.[155] This implies that a model

150. Conor Cahir, Approaches to Adaptive Bitrate Video Streaming (Mar. 2014) (unpublished M.S. thesis, University of Glasgow), http://theses.gla.ac.uk/5093/1/2014cahirmsc.pdf ("Many over the top services use the Hypertext Transfer Protocol (HTTP) to deliver [video] content. . . . The downside of this approach is that the networks can be unpredictable and TCP, which is the underlying transport protocol for HTTP, was never designed with high performance real time applications in mind.").

151. *See, e.g.*, Jon L. Jacobi, *How to Optimize Your Router for VoIP and Video*, PCWORLD (Dec. 8, 2010, 6:30 PM), http://www.pcworld.com/article/212867/optimize_your_office_router_for_voip_video.html ("VoIP is the trickiest application for vendors to offer tweaks for because it's *bidirectional* . . . .").

152. CISCO, *supra* note 75, at 2.

153. *Cisco Visual Networking Index Predicts Near-Tripling of IP Traffic by 2020*, CISCO (June 7, 2016), https://newsroom.cisco.com/press-release-content?articleId=1771211.

154. CISCO, *supra* note 75, at 2.

155. BROADBAND INTERNET TECH. ADVISORY GRP., INTERCONNECTION AND TRAFFIC EXCHANGE ON THE INTERNET 8 (Nov. 2014) [hereinafter TRAFFIC EXCHANGE], https://www.bitag.org/documents/Interconnection-

where video continues to move into the Internet-access pipe might imply a "rising tide" of service quality for all services.

Fourth, we expect video to further converge onto the IP pipe, as linear content is moved over IP in light of the benefits of moving to all-IP for wired last-mile networks.[156] The real question is how broadband network resources may be managed over all-IP networks and how edge and core functionality may be allocated. The manner in which video is delivered on a converged access service matters. For example, shifting from a unicast over-the-top model to one that made coordinated use of VOD or switched video, and also made coordinated use of network and customer-premises caching, could actually free up bandwidth resources for non-video Internet access and improve the quality of experience for all services.[157] In contrast, simply moving current linear video traffic wholesale into the IP pipe without traffic management could congest last-mile networks, resulting in reduced performance for Internet access services.[158] The implication is that the architecture of this converged pipe will matter.[159]

Fifth, the entertainment industries continue to evolve both new services and business models for capturing consumer attention and dollars. As entertainment content continues to shift from a broadcast model (which was the television broadcast model of the twenty-first century) toward a model relying more on storable media and customized viewing experiences, the requirements for what is demanded from the electronic distribution networks is changing. The key question that emerges in a world that relies more on VOD is whether to store locally or in the cloud, which is a choice that often hinges on issues of costs, functionality, and market structure. Planning for a mix of edge-based and cloud storage and for localization of functionality, with consumers having the ability to substitute between the options, is likely to force cost equalization.[160] That is, the ability of consumers to switch between

and-Traffic-Exchange-on-the-Internet.pdf ("Interconnection methods are constantly evolving, and one of the most important developments in interconnection is the use of CDNs and caches . . . . Further evolution of interconnection has come about as a result of shifts in Internet traffic patterns . . . including the rise in streaming video services.").

156. A case can also be made for all-IP in wireless networks, but that is rendered more complex by the requirements of operating over a wireless physical layer at different frequencies. William H. Lehr & John M. Chapin, *On the Convergence of Wired and Wireless Access Network Architectures*, 22 INFO. ECON. & POL'Y 33 (2010).

157. *See, e.g.*, *OTT Content Caching*, CONCURRENT, https://www.concurrent.com/content-delivery/solutions/ott-content-caching/ (last visited Feb. 27, 2017) ("Delivering content from servers located closer to the subscriber enables a better quality of service for OTT [over-the-top] streams. With reduced traffic through the Internet peering point and over the IP backbone, the performance of Internet services is significantly improved for all customers.").

158. *Id.* ("Without a traffic management solution, bandwidth across service provider's IP network is unmanaged. . . . [An] OTT content caching solution reduces the impact of the usage spike . . . .").

159. Our simple model also shows that a more converged network could benefit from potential traffic differentiation. As video traffic consumed more of the access service, all traffic suffered in terms of delay and loss (note that this assumes that the bandwidth of the connection does not increase, or does not increase proportionally). This raises questions about how this would be implemented and who decides the allocation and issues of fairness that surrounds it. How does a separate network for specialized services impact value of differentiated services for Internet (versus best effort)?

160. *See* Puneet Jain, *Will There Be a Change in Supply with Decrease in Price of Substitute Goods?*, QUORA (Dec. 11, 2014), https://www.quora.com/will-there-be-a-change-in-supply-with-decrease-in-price-of-

cable television provider services, buying movies from iTunes, or subscribing to Netflix will impose reciprocal constraints on what features video service providers need to offer, and at what prices, if they are to remain competitive in the evolving markets for entertainment video.

IV. ECONOMICS

In the preceding Section, we discussed some of the ways in which the design of the Internet might be different if video and data traffic were provided via separate logical networks. In this Section, we consider how bundling services into the same broadband access service affects the business model for access ISPs, as well as for other providers of entertainment video services that might rely on the access ISPs in order to deliver their content to end users. These are the over-the-top providers that may choose to deliver their video either via Web-based streaming (enabled by a browser) or via an application (e.g., a Netflix application running on a tablet, smartphone, personal computer, or connected television) that presently uses a broadband access connection to deliver the video content from the content providers' server (or cache) to the individual subscriber households.[161]

In the following two Subsections, we first consider how the economics of bundled services impacts the business models of video providers, and then how entertainment economics might bias the evolution of the Internet.

A. Benefits of Bundling Services

Bundling is an important strategy for both the delivery of network services and entertainment media.[162] Bundling occurs in multiple ways. One way, for example, is where the content and conduit are bundled when the network provider also offers the services (e.g., Comcast provides cable television programming services over its broadband network platform).[163] Another way is where content choices are bundled when programmers offer a menu of selections (e.g., Netflix offers a library of movies and television networks offer suites of program choices).[164] Bundling may also occur at the retail level when a provider sells complementary retail services to consumers (e.g., Verizon sells telephone, broadband data, and video services as a triple-

substitute-goods (explaining substitute goods and effect of price changes).

161. In many cases, Wi-Fi may be used to connect the end-user device to the fixed broadband access service in the subscriber's home or in a café, hotel, or other outside-the-home location. It is also possible that the content may be delivered via a mobile broadband service when Wi-Fi is not an option. *See* NETFLIX, https://devices.netflix.com/en/ (last visited Feb. 27, 2017) (listing the ways you can watch and stating that an Internet connection is needed).

162. For a discussion of how some of the issues discussed here are cast within the context of the network neutrality debates, see Shane Greenstein et al., *Net Neutrality: A Fast Lane to Understanding the Trade-Offs* (Nat'l Bureau of Econ. Research, Working Paper No. 21950, 2016), http://www.nber.org/papers/w21950.

163. *See What Is Voice over Internet Protocol?*, XFINITY, https://www.xfinity.com/support/internet/voice-over-internet-protocol/ (last visited Feb. 27, 2017) (stating phone calls would happen over XFINITY's broadband network).

164. *See How Does Netflix Work?*, NETFLIX, https://help.netflix.com/en/node/412 (last visited Feb. 27, 2017) (explaining that Netflix offers a variety of "TV shows, movies, documentaries and more . . .").

play package).[165] Finally, bundling occurs at the technical level through the choice of IP as the fundamental network protocol, which offers advantages in terms of interoperability and network layering.[166]

Bundling facilitates resource sharing and the realization of scale and scope economies, which can lower overall costs and facilitate more dynamic and flexible capacity scaling.[167] Bundling of content choices in entertainment media and with particular distribution channels facilitates addressing heterogeneous consumer demand and "windowing" by content providers.[168] Bundling also provides strategic benefits for both network service providers and entertainment media companies, which can have an impact on competition.

For example, access ISPs prefer to sell a bundle of services to consumers, which includes voice, video, and data—or broadband Internet access—services for multiple reasons.[169] Once a provider has installed the last-mile facilities needed to provide any one of the services, the incremental costs of providing additional services over that network are relatively small.[170] The most significant components of access network costs are associated with deploying the wired facilities that increase with the number of households that are passed by the wired infrastructure.[171] Those costs are mostly fixed, and a large proportion of those costs do not vary with the number of actual subscribers, nor with the traffic utilization of those subscribers.[172] Selling multiple services

165. *See The Complete Package*, VERIZON, http://fios.verizon.com/fios-triple-plays.html (last visited Feb. 27, 2017) (listing the options in Verizon's Triple Play package).

166. *See Network Level Interoperability*, FCC, https://www.fcc.gov/general/network-level-interoperability (last visited Feb. 27, 2017) (stating that IP allows for interoperability).

167. When traffic with imperfectly correlated peak-capacity demands shares resources, total provisioning costs are reduced, and sharing capacity enables flexible provisioning in face of uncertainty. *See* Fung Po Tso et al., *Network and Server Resource Management Strategies for Data Centre Infrastructures: A Survey*, 106 COMPUTER NETWORKS 209 (2016) (discussing cloud-based services and cost).

168. Consumer tastes for programming vary (across consumers, time, context), and to address those heterogeneous tastes, entertainment companies sell bundles of content (e.g., amusement parks have many different types of rides, Netflix has a library of movies, and channels offer streams of programming). "Windowing" is the term used to describe the practice of media companies using distribution channels to segment markets to facilitate price discrimination. Traditionally, theatrical releases and hardback books were released in the first window at the highest price per viewer, with subsequent windows designed to capture the demand of lower-price consumers (e.g., paperbacks and broadcast television). Today, the timing and ordering of media distribution windows has been disrupted, but the term is still used to refer to how bundling with distribution channels is used to segment markets. Chris Meadows, *Media Publishers Continue Windowing, Though Windowing May Not Do What They Want*, TELEREAD (Feb. 29, 2012), http://teleread.com/media-publishers-continue-windowing-though-windowing-may-not-do-what-they-want/.

169. Access ISPs are expanding their bundled offerings with new services like home security and smart-home management services, additional web services (e.g., access to premium content or online storage), or in some cases, mobile services. *See, e.g.*, *Internet Service Providers (ISP)*, VERIZON, https://www22.verizon.com/wholesale/solutions/industry/ISP.html (last visited Feb. 27, 2017) (listing services that Verizon offers).

170. Padmanabhan Srinagesh, *Internet Cost Structures and Interconnection Agreements*, 1 J. ELEC. PUB. (1995), http://dx.doi.org/10.3998/3336451.0001.121.

171. NAT'L RESEARCH COUNCIL ET AL., BROADBAND: BRINGING HOME THE BITS 160 (2002), https://www.nap.edu/read/10235/chapter/7#160.

172. Note, we are not saying that access network providers do not also confront traffic-sensitive network costs that vary with the aggregate traffic loads that the operators must handle. The interconnection and middle-mile facilities of access providers vary with the aggregate traffic loads that providers must handle. The desire to manage these costs, while ensuring high-quality access to content induces operators to seek to locate cacheable content as close to end users as possible and deploy other strategies (e.g., compressing content files,

to subscribers strengthens the relationship with those subscribers[173] and provides a larger revenue base over which to spread the shared and fixed (and sunk) costs of operating a facilities-based access network.[174] Finally, providing multiple services over a common all-IP broadband platform (i.e., bundling at the technical level) offers both demand- and supply-side benefits by making it easier to offer new, more capable, and better integrated services.[175] IP serves as a spanning layer that can be supported across diverse physical layer infrastructures (wired and wireless; copper, coaxial cables, and fiber) and can allow multiple applications to be supported (video, voice, and data).[176] The use of IP also enables interoperability and interconnection across networks of different types.[177]

The ISP's consumers also benefit from the opportunity to purchase bundled services because it enables one-stop shopping that may simplify customer billing and interactions with customer support. This is of special importance when trying to diagnose service problems. Additionally, consumers who purchase bundled services typically receive a discount relative to the sum of the à la carte prices, which allows consumers to share in the cost savings afforded by bundling.[178]

Content providers also benefit from bundling content choices and from bundling those choices with distribution channels. First, it is worth noting that providers of entertainment programming have multiple delivery options for getting their content into the hands of consumers. This includes movie theaters, over-the-air broadcasting, digital broadcast satellites, and cable—as well as using broadband Internet service. Indeed, Netflix originally distributed its content by bundling it with a high-latency, high-bandwidth broadband network.[179] That is, Netflix used the U.S. Postal Service to deliver its content.[180] Each of these distribution channels offers different benefits, and

employing multicast or any-cast routing) to economize on network resources wherever possible. Content delivery networks like Akamai (and proprietary ones deployed by large content providers like Netflix and Google) overlay ISP networks, assisting in the management of capacity to efficiently deliver content while preserving a good experience for the content provider's customers. For further discussion, see Stocker et al., *supra* note 71.

173. Bundled subscribers churn less frequently (i.e., have longer subscriber lives with a provider). Reducing churn (the percentage of subscribers who leave each month) is a key strategic goal that contributes directly to profitability.

174. The opportunity to realize scale and scope economies is not limited to network costs, but also applies to a significant share of other business cost elements. For example, brand advertising, billing, back-office operations, and other components of non-network costs are fixed to a significant extent and do not vary with the number of subscribers or their traffic.

175. For example, although it was possible to augment basic telephony service with enhanced features such as voicemail and call forwarding even with legacy circuit-switched telephone networks, the ability to manage, define, and customize features in an all-IP, software-manageable network is much greater.

176. YVES HERTOGHS ET AL., CISCO, IP NETWORKS FOR BROADCASTER APPLICATIONS 7, http://www.cisco.com/c/dam/en/us/solutions/service-provider/media-satellite-broadcast/ip_networks_for_broadcaster_applications.pdf (last visited Feb. 27, 2017).

177. *Id.*

178. David S. Evans & Michael Salinger, *Why Do Firms Bundle and Tie? Evidence from Competitive Markets and Implications for Tying Law*, 22 YALE J. ON REG. 37 (2005).

179. WILLY SHIH ET AL., HARV. BUS. SCH., NETFLIX (Apr. 27, 2009), https://canvas.harvard.edu/courses/11278/files/1746172/download?verifier=QfVxrwNYWn4x8NWf9f4V8it3wX6GiUTfYUvMxKsj&wrap=1.

180. *Id.*

most content rights holders seek to maximize the revenue that can be captured by their content by using multiple channels through the process of "windowing," discussed earlier.

Although multiple distribution channels for media content exist, these vary in cost and quality and so are, at best, imperfect substitutes for IP-based delivery (although, depending on the circumstances, not necessarily inferior).[181] The benefits of digital distribution via wired broadband networks, and increasingly, over all-IP networks, means that in many cases this will offer the lowest cost and most flexible network option for distributing entertainment video. This helps explain why so many entertainment content providers are interested in expanding their Internet-based service offerings.

In addition to the benefits of IP as a distribution channel, the Internet has expanded opportunities for end users to access a greatly expanded selection of content from a much larger universe of content providers. The rise of user-generated content associated with services like YouTube, the globalization of the Internet, and the rise of search tools and social networking (with recommendation applications) have all contributed to making it feasible to present consumers with a larger library of usable entertainment video options than was ever possible before.[182] A number of researchers have identified the benefits from bundling digital media content (not just for access to video, but also other digital print and audio content), and the opportunity it provides for essentially unlimited shelf space for consumer choices.[183]

While there are many benefits from bundling video content in the multiple ways in which it may be bundled, there are also potential risks. Bundling may have anticompetitive effects to the extent that it may raise entry barriers and impose switching costs on consumers.[184] To the extent this is the case, consumer choice may be limited if the market is not sufficiently large to support adequate competition among providers offering bundled services. As will be discussed further below, concern over the economic viability of sufficient facilities-based competition in access networks has provided a long-term justification for regulation of last-mile networks, although historically this

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181. A general theme is that content providers of video entertainment are in the business of delivering a wide range of consumer experiences from the content they offer, and whether high resolution, mobile access, programming selection, advertising inclusion, viewing screen, time, interoperability with other applications, price, or some other attribute is most important in a particular viewing context will vary, and may be impacted by the delivery option chosen. Thus far there has not been, nor do we think there will be, a single way to deliver entertainment video that is optimal for all situations.

182. When the only way to see Hollywood movies was in theaters, the number of theaters limited the number of movies that could be viewed. With the rise of television, viewing options expanded but were still limited to linear programming available on a relatively small number of channels. With the rise of video-on-demand and now the Internet, the limits on consumer choices that may be presented, searched, and sorted has become effectively unlimited.

183. *See, e.g.*, Yannis Bakos & Erik Brynjolfsson, *Bundling Information Goods: Pricing, Profits, and Efficiency*, 45 MGMT. SCI. 1613 (1999) (discussing the benefits of bundling digital media content); *see also* Gregory S. Crawford & Ali Yurukoglu, *The Welfare Effects of Bundling in Multichannel Television Markets*, 102 AM. ECON. REV. 643 (2012) (same); Yannis Bakos & Erik Brynjolfsson, *Bundling and Competition on the Internet*, 19 MKTG. SCI. 63 (2000) (same).

184. For example, consumers who switch a single service may lose their bundled discount, while consumers who switch the entire bundle may confront service-specific switching costs (e.g., difficulty in migrating a customer's email address).

has tended to be service *and* network specific because, originally, each service was supported by its own network (i.e., cable supported video media, the telephone network supported voice calls, etc.). Concerns that bundling might lead to market power over distribution channels (conduit), choice (content), or both, have motivated a range of regulatory interventions, including common carrier regulation, media concentration, and program access rules.[185]

Bundling can also have ambiguous effects on service pricing from a consumer welfare perspective. For example, for continued investment in access network infrastructure to remain economically viable and incentive compatible, investors need to be able to recover their economic costs. From a pricing perspective, there is no single best way to allocate the shared and fixed costs of the local access network across the different services. The optimal allocation of costs depends on demand and competitive considerations. However, it is reasonable to expect that if an access ISP sold only broadband service, then the total costs of the access network would need to be recovered from that single service.[186] Whether that would mean that total household payments to the last-mile facilities providers would increase is uncertain and depends on market dynamics.[187]

Another important question is how other video providers that are not affiliated with the access ISP deliver their programming to end users. Indeed, over-the-top entertainment video providers like Google (YouTube) and Netflix were among the strongest advocates in favor of the FCC adopting its Open Internet Order[188] rules that are designed to protect consumers and edge providers (which include entertainment video as well as other content and application providers) from discriminatory treatment by access ISPs. They argued that in the absence of network neutrality protection, access ISPs with market power might abuse their power to extract excess rents from edge providers and consumers, and might discriminate in favor of affiliated content.[189] It is interesting to contemplate how the policy debate would have unfolded if the entertainment video content providers' traffic had not been part of the picture.

The Internet's ability to present consumers with unlimited choice has ambiguous implications for the production of diverse quality content. For creators of commercial content, the fragmentation of markets may reduce the potential revenue that could be captured by a program, which might reduce ex ante incentives to invest in its creation, possibly resulting in fewer and/or lower

185. Competitive Broadband Coalition, Comment Letter on Implementation of the Cable Television Consumer Protection and Competition Act of 1992, CS Docket No. 01-290, at 10–11 (Dec. 3, 2001), https://ecfsapi.fcc.gov/file/6512974090.pdf; *see also* OECD, OECD DIGITAL ECONOMY OUTLOOK 2015, at 180–82 (2015) (identifying anti-competitive effects of bundling and describing some countries' regulatory responses that address those concerns).

186. Note that revenue for cost recovery need not come solely from end users, but may also come from other value chain participants, including advertisers and content or application providers.

187. Too much or too little competition could result in higher total costs and/or prices and reductions in high-quality programming choices (although deciding what constitutes appropriate quality is likely to be highly contentious).

188. Open Internet Order, *supra* note 22.

189. *Id.* at 5629–30.

quality choices being available. Moreover, the marginal benefit of additional programming choices is likely to decline and may actually become negative (too much choice, especially if much of it is of very low quality, may actually result in diminished consumer surplus and may crowd out more socially desirable content).[190]

Today, access ISPs provide Internet, video, and voice services via separately managed networks.[191] This does not preclude them from providing bundled service offerings to consumers, and has not limited the ability of access ISPs to expand into online or other new media entertainment offerings when those seem attractive. From a cost perspective, being able to offer all these services over a common, integrated IP platform may offer important economies. It would simplify network provisioning and operations, and could allow the ISP to avail itself of global economies associated with commodity IP hardware and software solutions. However, as already noted, these cost economies could be realized by sharing the IP platform across multiple IP networks, each of which might be logically separated and dedicated to a different service.

Thus, while service bundling offers important advantages for many access network providers and consumers, and while it seems clear that the ability to share the cost-recovery burden associated with deploying broadband infrastructure with entertainment video services, it does not require that the services be delivered into the home over a single converged IP network called "the Internet" via the regulated BIAS. Although, if the video is not delivered via the BIAS service, we might have to create a new regulated service (e.g., VIAS) if we want to ensure competitive access to last-mile bottleneck facilities.

B. Entertainment Industry Economics and Broadband

In this Section, we focus on how the economics of entertainment media are distinct from the economics that motivate the "other 20%" of Internet traffic. Our goal here is to sketch a picture in stereotypes, which oversimplifies the actual situation but is useful in highlighting important lessons. We begin by characterizing the demand drivers that motivate the economic activity broadband is intended to address. Next, we contemplate what insights may be revealed regarding the societal value and willingness to pay for broadband services. We then consider the relative importance of different network capabilities. We conclude with speculations about how this impacts the behavior and structure of markets for broadband services.

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190. The debate over choice and consumer surplus is a long one. Traditionally, economists argued that more choices have to be Pareto improving because consumers could simply ignore options they were not interested in. However, because making decisions is costly, this is not obviously true. Barry Schwartz, a psychologist, explained how excess choice can actually result in consumers being less happy. BARRY SCHWARTZ, THE PARADOX OF CHOICE: WHY MORE IS LESS 22 (2004).

191. The video services are typically provided as a broadcast service using RF channels that are separate from the RF channels used for broadband, although with the transition to all-IP cable platforms (and FIOS/ADSL for other access ISPs), the technical flexibility to dynamically manage resources across services is greatly enhanced.

We will use "Smart-X" to represent the demand that results in the traffic that is included in the "other 20%."[192] By Smart-X, we mean all of the ways in which an optimistic vision of "pervasive computing" might allow us to realize the full promise of information and communications technologies (ICTs) for enhancing the performance of complex systems across the economy.[193] The "X" refers to the many different complex systems that ICTs are expected to enhance. The "X" may be replaced with healthcare, public safety, or energy grids (the three to keep in mind for our discussion here), but also e-commerce, e-government, and so on.[194] The "Smart" refers to enabling ICTs in the X. We assume this requires Internet access, but are interested in exploring whether the access that is needed to support Smart-X would be different (and how different) if the access were not also called upon to support entertainment video.

In thinking about how entertainment economics and Smart-X economics may differ, it is useful to note that consumer expenditures for entertainment come out of discretionary leisure expenses that are generally a relatively small share of income (around 5%).[195] Over time, the budget shares allocated (in time and dollars) to different categories of activities have remained far more stable than the shares of specific items within categories.[196] This suggests that households and individuals first allocate their income and time to various activity categories, and then within those categories substitute among activities. In recent decades, the average working person spends about forty hours per week working, and close to seventy hours per week on personal care (which includes sleeping), which leaves about fifty-eight hours per week for everything else.[197] Over the past hundred years, shifts have occurred with a significant decrease in work time and expansion in leisure time; and of course, the young, elderly, and unemployed have more time for leisure activities.[198]

192. This is not all of the "other 20%" of the traffic because that includes some entertainment video as well as everything else that is not Smart-X.

193. The vision of "pervasive computing" is one in which networked processors and software applications that can make use of the networked processors are ubiquitously available in the real world. This extreme vision is one in which everyone/everything is always/everywhere connectable, and big data analytics and AI/robot automation empower real-time, granular (local) decision making. This has the potential to deliver more dynamic, flexible, and customizable resource allocation decisions to improve the operation of complex systems. Of course, we recognize that the extreme version of this optimistic vision will confront numerous challenges and is unlikely to be realized.

194. We focus on these three because we believe the economics of healthcare, public safety, energy grids, and entertainment as "economic goods" are sufficiently distinct that readers will be able to follow our stereotypes without too much resistance. While we recognize that the first three may be as different in their needs as they are from entertainment, we want to focus on what it may mean to consider entertainment separately, and provide a potentially common infrastructure for everything else.

195. For example, the Bureau of Labor Statistics (BLS) reported that U.S. consumers spent about 5% of their budgets on entertainment in 2003, slightly up from what they spent in 1950, but significantly more than they spent in 1900. BUREAU OF LABOR STAT., 100 YEARS OF U.S. CONSUMER SPENDING: DATA FOR THE NATION, NEW YORK CITY, AND BOSTON (May 2006), http://www.bls.gov/opub/uscs/report991.pdf.

196. *Id.*

197. News Release, Bureau of Labor Stat., American Time Use Survey—2015 Results tbls.4 & 12 (June 24, 2016) [hereinafter BLS Time Use Survey], https://www.bls.gov/news.release/pdf/atus.pdf.

198. One source shows that since 1870, the hours worked per week in many countries has fallen by slightly less than half to reach the thirty-five- to forty-hour work week we have today. Brian Wu, *How Humans Spend Their Time Has Changed*, BUS. 2 CMTY. (Dec. 28, 2014), http://www.business2community.

The American Time Use Survey reports that the average citizen over fifteen years of age spent 5.21 hours per day on leisure and sports activities.[199] According to Nielsen data, the average household is streaming video entertainment 6 hours per day, with 5.1 of those hours being watched on television sets and the rest on other connected devices (tablets, personal computers, smartphones, etc.).[200] It is likely that for some of that time no one is actually paying attention.

While consumers allocated significant time to leisure activities, and the leisure share of consumer expenditures is significant, the budget shares are less than what consumers spend on healthcare, housing, or transportation.[201] Entertainment video is competing for a relatively small share of consumers' time and discretionary budget dollars. Not surprisingly, competition for consumer attention is intense, and the quality and choice of entertainment options are key features that drive consumer demand. Allowing consumers to watch what they want to watch, where and when they want to watch it, and improving the resolution quality have all proved important. Furthermore, consumers are directly involved in making the choices of when and how to consume entertainment video.

Another key feature of video entertainment (and many other information goods) is that there is a high and irreversible (i.e., sunk) first-copy cost to produce video content, with low incremental costs to make additional copies available for consumption.[202] This is what provides a key economic justification for copyright and other intellectual property rights law, and creates the need for digital rights management technologies.[203] Because the costs of producing content are incurred up front and sunk once the content is created—often before its value is really known[204]—policymakers have created a tradable property right to the content that allows creators to require payment for legal distribution of the content.[205]

This helps ensure that content creators will have an incentive to invest in creating good content since it protects their ability to appropriate some of the

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com/tech-gadgets/humans-spend-time-changed-01108897#sLiYcuFujDDTjvLh.97.

199. BLS Time Use Survey, *supra* note 197, tbl.12.

200. *Television Is Still Top Brass, but Viewing Differences Vary with Age*, NIELSEN (July 18, 2016), http://www.nielsen.com/us/en/insights/news/2016/television-is-still-top-brass-but-viewing-differences-vary-with-age.html.

201. In 2015, the average expenditures per consumer unit were $55,978 in the United States, with 8% going to healthcare, 33% to housing, and 17% to transportation. News Release, Bureau of Labor Stat., Consumer Expenditures—2015 (Aug. 30, 2016), http://www.bls.gov/news.release/cesan.htm.

202. Helen Youngelson-Neal, *Linkages Between Popular Culture and Economics*, *in* POPULAR CULTURE STUDIES ACROSS THE CURRICULUM 122, 126 (Ray B. Brown ed., 2004).

203. *See* WILLIAM M. LANDES & RICHARD A. POSNER, THE ECONOMIC STRUCTURE OF INTELLECTUAL PROPERTY LAW 20 ("Socially desirable investments . . . may be deterred if the creators of intellectual property cannot recoup their sunk costs. That is the dynamic benefit of property rights . . . ."); *see also* Christopher Buccafusco & Jonathan S. Masur, *Innovation and Incarceration*: *An Economic Analysis of Criminal Intellectual Property Law*, 87 S. CAL. L. REV. 275, 281–82 (2014) ("IP rights exist in order to solve [the] public goods problem . . . .").

204. It is hard to predict audience interest in entertainment content until audiences can experience the content, but by then, the production costs have already been incurred.

205. Buccafusco & Masur, *supra* note 203, at 282.

value for their content if, once produced, it actually finds a market.[206] The desire to maximize the revenue to be realized leads to the practice of windowing, or market segmentation, discussed earlier.[207] DRM helps facilitate the segmentation of markets.[208] In many cases, the DRM is embedded in the contracts and distribution agreements, but sometimes it is implemented using encryption or video-coding technologies.[209] Content rights holders seek to segment the market along all possible dimensions of the consumption experience (e.g., the resolution quality, bundled versus à la carte pricing, the platform delivered on, and the location where viewing takes place).[210] Additionally, because digital media, once created and once online, can be shared at low incremental cost, the potential for losses due to piracy (i.e., illegal free goods competing with legitimate sales) is significant. Also, when attempting to capture revenues in different markets, content rights holders need to protect against self-cannibalization, which occurs when low-revenue alternatives compete directly with higher-priced alternatives.[211]

The proliferation of distribution channels and, increasingly, of over-the-top video service providers complicates efforts to price discriminate and segment markets. For example, content providers typically received higher prices from cable television distributors (like Comcast) than from over-the-top distributors (like Netflix). This is in part because when Netflix initially negotiated its content deals, it was not expected to become as successful as it has, and also because much of the content is not premium content (e.g., first-run movies and sports).[212] Although the movie libraries differ, there is significant overlap in the movies available via Netflix and cable television. This overlap has led a growing number of subscribers to ask whether it makes sense to continue to pay for a cable television service (at close to $100 per household per month[213]) that includes many more programming options to select from, but which may include much that is not of interest to particular consumers. For a growing number of subscribers, a skinnier bundle of

206. Like with venture capital, many of the programs produced fail to recover the costs associated with their production. To make up for this, program producers often invest in portfolios of programs with the few hits making up for the many programs that fail to be successful. This is another form of bundling.

207. Buccafusco & Masur, *supra* note 203, at 282.

208. *Id.* at 283.

209. For example, encrypted content can be sold with different usage rights that are only enabled with the appropriate key. Or, video distributors may offer different quality resolution programming at different prices, with or without commercials, or any other variety of options.

210. Aarti Bahirat, *Digital Rights Management Market: Trends, Key Growth Factor, Demand, Opportunity by 2024*, LINKEDIN: PULSE (Oct. 10, 2016), https://www.linkedin.com/pulse/digital-rights-management-market-trends-key-growth-factor-bahirat.

211. Lisa Cameron & Coleman Bazelon, The Impact of Digitization on Business Models in Copyright-Driven Industries: A Review of the Economic Issues 32 (Feb. 26, 2013) (unpublished draft), http://sites.nationalacademies.org/cs/groups/pgasite/documents/webpage/pga_063398.pdf.

212. One report claims that subscribers pay only $0.20 per hour for Netflix content compared to $0.61 per hour for cable television content. BeauHD, *Subscribers Pay 61 Cents per Hour of Cable, but Only 20 Cents per Hour of Netflix*, SLASHDOT (July 27, 2016, 2:00 AM), https://news.slashdot.org/story/16/07/27/0046200/subscribers-pay-61-cents-per-hour-of-cable-but-only-20-cents-per-hour-of-netflix.

213. Leichtman Research Group reported that the average household that subscribed to pay television services in 2015 paid $99.10 per month. Press Release, Leichtman Research Grp., 83% of U.S. Households Subscribe to a Pay-TV Service (Sept. 3, 2015), http://www.leichtmanresearch.com/press/090315release.pdf.

programming that offers fewer options may be preferable. For example, a bundle comprised of Netflix (about $9 per month), free over-the-air broadcast television (available in digital format that is of equivalent or better quality than may be available from cable television), and one or two other pay-per-view channels of special interest may be regarded as a superior option. Of course, the cable programming company bundles the cost of the programming and the digital delivery of the video via its broadband platform, whereas Netflix requires its streaming customers to pay for the broadband Internet access service used to receive its programming. Not surprisingly, Netflix would like the cost of that broadband Internet access to be as low as possible.

Most economists may agree that entertainment consumers benefit from the expansion of video programming options and increased competition that lowers pricing, so long as the competition does not adversely impact the ability of content creators to continue to create good-quality content.[214] It is unclear, however, what contribution all of this competition makes to the overall economy if most of the effect is to shift revenue from one set of providers or rights holders to another. If the budget shares of entertainment expenditures are relatively constant and not increasing in aggregate as much as they are shifting from one type of media to another (e.g., from print to video media, from legacy channels to Internet), then the potential for this to generate jobs and economic growth is also limited.

In contrast, Smart-X Internet services are expected to enhance the efficiency of transportation systems and household HVAC systems, improve healthcare, and facilitate telecommuting.[215] The potential of such innovations yielding significant economic benefits seems very promising. The expenditures and time budgets for these activities come out of the rest of—and by far the larger share of—consumer time and budget expenditure shares. But whereas the consumer expenditures on entertainment services are direct, many of the expenditures associated with Smart-X may be indirect. For example, they may be mediated by a third party (e.g., a doctor for healthcare, the power company for energy efficiency in the home, or an employer for telecommuting) or may be contingent on other decisions (e.g., durable goods purchase of an electric car, home improvement investment in renewable power, or a change in employment or how work is organized).

The economics driving these other Smart-X-related activities are diverse, and in many cases, may not be viewed as discretionary in the same way as consumer decisions about what entertainment consumption to engage in. For example, a consumer's investment in smart-home technologies may be motivated by the desire to save money on heating and electricity and to improve the quality of the consumer's home, which may involve a long-lived

214. A number of musical artists have looked with dismay at the rise of streaming music sites like Spotify that pay per each song actually listened to at rates that make it difficult for artists to earn a living wage. Paul Resnikoff, *My Song Was Streamed 178 Million Times. I Was Paid $5,679 . . .* , DIGITAL MUSIC NEWS (Sept. 24, 2015), http://www.digitalmusicnews.com/2015/09/24/my-song-was-played-178-million-times-on-spotify-i-was-paid-5679/.

215. ERIC A. FISCHER, CONG. RESEARCH SERV., R44227, THE INTERNET OF THINGS: FREQUENTLY ASKED QUESTIONS (2015).

capital investment and imply a lifestyle change. Alternatively, the expenditure to act on a doctor's recommendation for using Smart-X technology for at-home monitoring for an elderly relative will be viewed as healthcare related, not as a leisure expense.

Moreover, for many of the goods and services associated with Smart-X, there may be only limited need for DRM or price discrimination capabilities associated with the underlying digital delivery service. That is, the bundling of the digital distribution and the service provides less value for Smart-X than for entertainment goods, where such bundling of the content and distribution channel is often intrinsic to how the rights holders hope to capture value. With Smart-X, the need is for a basic communications capability. Additionally, while there may be strong reasons to protect the security and privacy of information flows associated with Smart-X (e.g., to protect the integrity and reliability of the electric power grid or secure the privacy of healthcare data), the security and privacy concerns associated with entertainment media seem far less pressing. Indeed, with much entertainment media, the popularity of the media may depend on fads and shared social interest. Knowing what other people are watching can result in positive feedback loops and bandwagon equilibria that make the content even more popular; whereas the same is often not the case with Smart-X information flows.[216]

Also, it is worth noting that the intellectual property regime associated with copyright is not troubled by the creation of monopolies. A rights holder may set the prices for access to content at whatever the market will bear, and collectively, we rely on robust competition for entertainment content to discipline the pricing of entertainment media.[217] It is only with a few special types of entertainment media that significant concerns regarding pricing and market power typically arise, with sports programming being the most notable example.[218] Taken together, these features make price discrimination and "content" management key attributes of entertainment media products. A video bit is not just a bit—it depends on where and how it is viewed and by whom.[219] All of those attributes need to be managed to extract consumer surplus, and the network can help support that fine-grained management.

In contrast, the Smart-X services may have need for basic communications functionality, but with much richer support for expanded abstractions for what constitutes electronic communications (any-to-any, real-time and asynchronous, mixed media, planned and ad hoc) that the Internet provides.

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216. Entertainment content may be a "search" good—so hearing that lots of others like a show can signal that the show is higher quality and therefore increase the audience. Also, entertainment is a social experience and the shared experience can contribute to its value.

217. Dana Griffin, *The Effect of Competition on Pricing Strategy*, CHRON: SMALL BUS., http://smallbusiness.chron.com/effect-competition-pricing-strategy-1109.html (last visited Feb. 27, 2017).

218. *Competition in the Sports Programming Marketplace: Hearing Before the Subcomm. on Telecomms. & the Internet*, 110th Cong. 9–10 (2008) (statement of W. Kenneth Ferree, President, Progress & Freedom Found.).

219. Elise Lagarde, *What Is Video Bit Rate?*, DACAST BLOG, http://www.dacast.com/blog/what-is-video-bit-rate (last visited Feb. 27, 2017).

With Smart-X, it is unclear what the right model is for bundling services, but it may make more sense to have consumers pay for the broadband Internet access generically, as a general service, that may then be used by other businesses. For example, the smart light bulb company or refrigerator company may wish to make use of the Internet access to the home, but would be unlikely to bundle that service with its offering in the same way as the New York Times or Netflix may (or may not) choose to bundle the cost of delivery in its basic service (e.g., both companies bundle delivery costs into home delivery of newspapers and DVD discs, but have the consumer self-provision broadband access for online access).

Before 2000, when broadband home access began to be generally available, it was relatively rare for employees to have high-speed digital connections that allowed them to work from home. In the cases where employees did have such access, it was typically provided as a business-grade service that was paid for by the employer (e.g., a T1 line).[220] Similarly, many of the employees with personal computers or cellular phones were provided those devices by their employers. As broadband, computers, and cell phones have now become mass-market consumer appliances, it is less common for users to separate business and personal uses across their devices. With the high penetration of broadband into homes, a growing number of broadband subscribers are telecommuting, and it is harder to identify what share of the value of having home broadband should be attributable to personal home use and what share attributable to business use.[221] Moreover, video conferencing and other rich, interactive (two-way) multimedia work applications are making telecommuting more productive.[222] This blurring of the boundaries between what is work-related, versus personal- or entertainment-related, infrastructure makes it more challenging to separate what broadband Internet capabilities and consumer expenditures may be needed for Smart-X versus for entertainment media.

In summary, entertainment media and Smart-X economics are sufficiently different that it is reasonable to anticipate they might give rise to distinctly different sets of network requirements if each were the sole motivator for investing in Internet infrastructure. Separating out these motivations, however, may be increasingly impractical as personal and business uses blur and as the rationale for bundling services on a common, all-IP platform converge. Moreover, the distinct differences in the economics for the ultimate goods and services giving rise to the traffic are likely to cause tension for determining how to best design and price different Internet capabilities such as price discrimination/DRM, security, basic transport, mobile access, and reliability.

220. *See, e.g.*, *Innovative Connections: Where the Cloud Meets Fiber to Drive Business Growth and Opportunity*, FORBES INSIGHTS, Sept. 2014, at 4 (noting that, until 2013, Pfeifer's employees were still using "three legacy T1 lines").

221. In 2015, 24% of all workers did some or all of their work from home, up from 19% in 2003; and for managers, the share who worked partly from home was 38% in 2015. BLS Time Use Survey, *supra* note 197.

222. Ali James, *The Remote Workforce: Virtual Offices Boost Productivity, Attract Talent*, KNOXVILLE NEWS SENTINEL (May 1, 2016), http://archive.knoxnews.com/business/the-remote-workforce-virtual-offices-boost-productivity-attract-talent-318dbe3f-16b9-5bfc-e053-01000-377741291.html.

V. POLICY

Even if one concludes that technical and market forces are compelling us toward convergence and that that is desirable, we would still need to confront the difficult challenge of how to bring about the necessary policy reforms. Historically, in keeping with the "silo" nature of legacy networks and the markets they served, and the public policy issues of greatest concern that naturally arose in each of those silos, separate regulatory frameworks evolved for each: PSTN regulation for the telephone networks and other telecommunication services; broadcasting, cable television, and media regulations for television services; and a mix of PSTN and computer industry regulation for data services and the Internet.[223]

In the following, we briefly characterize some of the different concerns that arise in each of these domains that will pose problems for convergence at the policy level. We discuss one model for how regulatory policy might deal with separating most entertainment video traffic from other broadband Internet traffic, and speculate about what this might mean for several of the policy issues with which the FCC is currently grappling.

A. Separate Policy Domains and the Challenge of Convergence

In the following three Subsections, we briefly characterize the traditional regulatory constructs that emerged to govern telecommunications (PSTN), television (broadcasting/cable), and data (Internet), and today's "policy patch" for addressing convergence issues today.

1. PSTN Regulation

PSTN regulation evolved over the course of a century of building what originally was the analog, circuit-switched telephone network that became the AT&T Bell System, and which subsequently has been restructured several times.[224] This restructuring was to enable competition to proceed where feasible (first in equipment markets, then long distance services, then local services) and in response to changing technology, regulatory, and market dynamics.[225]

The telephone companies owned the network facilities that provided the bidirectional, real-time connectivity that eventually made universal access telephone service feasible—any telephone number could establish a call to any other telephone number.[226] These networks were multiplexed to facilitate sharing of backhaul transmission capabilities and support hierarchical switched

223. *See Technologies for Universal Access and Service*, ICT REG. TOOLKIT, http://ictregulationtoolkit.org/toolkit/4.8.3.1 (last visited Feb. 27, 2017) (discussing various types of regulation).

224. *See* Richard N. Clarke, *The Case for Reforming Regulation of PSTN Voice Services*, 2 J. INFO. POL'Y 287, 287–88 (2012) (giving a history of PSTN regulation).

225. *Id.*

226. *See Analog vs. Digital Phone*, CONNECTION, http://internet.frontier.com/resources/resources/home-phone-information/analog-vs-digital-phone/ (last visited Feb. 27, 2017) (explaining the capability of a bidirectional telephone system).

routing.[227] Over time, these legacy telephone networks evolved into the modern, nation-spanning, global-reach telecommunications networks of today.[228] This network of interconnected telephone networks became the PSTN, which was subject to strong regulations to ensure universal (affordable) accessibility to basic telephone services and end-to-end connectivity (interconnection).[229] The former concern gave rise to universal service mandates,[230] while the latter gave rise to a range of interconnection regulations impacting how telephone calls were interconnected across local, long distance, and international networks and services.[231]

In addition to providing end-to-end telephone (and other electronic communication services) for both mobile and fixed telephones, these networks provided the basic network infrastructure that supported bidirectional data services, which, prior to the rise of the Internet as a mass-market platform in the 1990s, was almost exclusively used by commercial, government, and other non-consumer entities (e.g., universities).[232] Private data lines and other business services were regulated as telecommunications services under the same general framework as the PSTN.[233]

The telecommunication service providers were principally regulated under a two-tiered model in which state-level public utility commissions (PUCs) and the FCC set rules for how these providers offered services to both residential and commercial customers.[234] The bifurcation into intrastate/local and interstate jurisdictions was due in part to (1) the local concerns associated with building out the last-mile infrastructure, (2) the fact that long distance services were open to competition whereas local services were still regulated as monopoly franchises, and (3) the differentiating between intrastate and interstate traffic facilitated by the hierarchical nature of telephone networking.[235] With the rise of one-rate plans, mobile telephony (and later VoIP), and industry restructuring, the rationale and feasibility of separate

227. *See* Lehr et al., *supra* note 14 (discussing broadband becoming the new PSTN in terms of providing universal access).

228. *See The Internet and the Public Switched Telephone Network*, INTERNET SOC'Y, https://www.internetsociety.org/sites/default/files/The%20Internet%20and%20the%20Public%20Switched%20Telephone%20Network.pdf (last visited Feb. 27, 2017) (discussing the evolution of the telephone network).

229. *See* Tian Davis, *The History of the PSTN*, TIANDAVIS.COM (Nov. 21, 2014), http://tiandavis.com/thoughts/posts/the-history-of-the-pstn/ (discussing the connected networks becoming the PSTN).

230. In the United States, universal service policies included federal and state subsidy programs, as well as "carrier of last resort" and "duty to serve" obligations imposed on local telephone service providers. There were also service quality, reporting, and pricing regulations that applied to different services.

231. *See, e.g.*, Telecommunications Act of 1996, Pub. L. No. 104-104, 110 Stat. 56 (1996) (codified as amended in scattered sections of 47 U.S.C.).

232. Charles J. Cooper & Brian Stuart Koukoutchos, *Federalism and the Telephone: The Case for Preemptive Federal Deregulation in the New World of Intermodal Competition*, 6 J. ON TELECOMM. & HIGH TECH. L. 293, 315–43 (2008).

233. *Id.* at 303–15.

234. Paul Teske, *Introduction and Overview*, *in* AMERICAN REGULATORY FEDERALISM & TELECOMMUNICATIONS INFRASTRUCTURE 3, 4–5 (Paul Teske ed., 1995).

235. Glenn A. Woroch, *Local Network Competition*, *in* 1 HANDBOOK OF TELECOMMUNICATIONS ECONOMICS 642, 680–83 (Martin E. Cave et al. eds., 2002). For further discussion of why the intrastate/interstate separation of jurisdictions is increasingly nonsensical, see Douglas C. Sicker, *The End of Federalism in Telecommunication Regulations?*, 3 NW. J. TECH. & INTELL. PROP. 130, 130–59 (2005); Cooper & Koukoutchos, *supra* note 232, at 293.

jurisdictions for interstate and intrastate has eroded, with the FCC assuming principal responsibility for PSTN regulations. Over time, the FCC has evolved separate wireline and wireless bureaus to manage the extensive fabric of rules and regulations governing the technologies, services, and pricing of the various services provided over the PSTN.[236]

Today, many of these legacy telephone networks are well on the way to morphing into all-IP broadband networks capable of supporting the full spectrum of wireless and wired electronic communication services.[237] Many have already substantially replaced legacy copper wire distribution plants and switching systems with fiber optic cables and software switches, which poses a challenge for regulatory authorities seeking to manage the retirement of the legacy PSTN infrastructure.[238] Increasingly, telephone services that were embedded in the fabric of the technology from whence the PSTN was constructed have become just another application that can ride on top of IP (i.e., VoIP) and that can be supported over diverse network infrastructures (wired or wireless, fixed or mobile, etc.). Some of the VoIP traffic today rides over the Internet, making use of broadband access services to provide connectivity to traditional telephones or softphone applications that may be running on multiple types of customer premise equipment.[239] However, most of the VoIP services operate over managed IP networks that share many of the same physical and other network resources that support the Internet, but are managed separately for business and technical reasons.[240] When cellular services are added to the mix, these divergent ways to deliver services that consumers regard as (imperfect) substitutes for each other are regulated with a patchwork of divergent regulatory permissions and obligations. For example, when cable-television-based providers (like Comcast or New Charter) offer voice services, they provide those services over managed IP networks that interconnect with the PSTN and support emergency calling (e911) and other services not supported by pure voice-over-the-Internet providers.[241]

Moving voice services into the IP domain makes it possible to redefine the communications abstraction that characterized legacy telephone services.

236. *Offices & Bureaus*, FCC, https://www.fcc.gov/offices-bureaus (last visited Feb. 27, 2017).

237. For further discussion of the challenges of morphing today's telecommunications regulatory framework for the broadband Internet future, see Lehr et al., *supra* note 14, at 411–41.

238. The Telecommunications Act of 1996 required local telephone companies to unbundle core elements of their network infrastructure. This included unbundling access to the copper loops that were used by competitive local exchange carriers (CLECs) to offer DSL-based broadband and telephone services in competition with the incumbents (ILECs). We are rapidly approaching the point—some would argue are past the point—where turning off the copper networks makes sense, but that raises the question of what happens to the CLECs and others who are still using the legacy equipment and the plethora of rules and regulations that were specifically crafted with the legacy PSTN and its embedded technologies in mind. *See Telecommunications Act of 1996*, FCC, https://www.fcc.gov/general/telecommunications-act-1996 (last visited Feb. 27, 2017).

239. Jayne Gest, *Laying to Rest the Biggest Concerns and Misconceptions About VoIP*, SMART BUSINESS (Nov. 1, 2015, 1:37 AM), http://www.sbnonline.com/article/laying-to-rest-the-biggest-concerns-and-misconceptions-about-voip/.

240. *Hosted and Managed VoIP Fundamentals*, TECHTARGET (Aug. 2007), http://searchunifiedcommunications.techtarget.com/tutorial/Hosted-and-managed-VoIP-fundamentals.

241. Michael Talbert, *Voice over IP Telephony Comes of Age*, NUSOUND (Apr. 3, 2009), https://www.nusound.com/pdf/news/indnews/voiceip.pdf.

What used to be a real-time analog-voice-to-analog-voice call, can now be any-time (with voicemail), any-format (audio, text, or video), any-to-any (persons-to-persons for conferencing, or persons-to-machines) communications by integrating with other IP-enabled services that take advantage of the computer processing and storage capabilities increasingly available both in the core and at the edge of modern telecommunication networks.

The core regulatory concern that arises in telecommunications is how to separate the regulation of the network services that provide the basic electronic transmission and connectivity functionality ("the conduit") from rules and regulations that may govern the information that is conveyed via the electronic communications ("the content"). The basic idea is that "communications" is about sharing information between end points that control what that information is, while "telecommunications" is about providing the supporting network infrastructures to make such communication feasible. In the United States, the principle regulatory framework for managing the provision of telecommunications services has been Title II of the Communications Act that treats the regulation of such services under a common carrier framework.[242]

Deciding how to separate content and conduit has proved to be an enduring challenge that has manifested in different ways as technologies, markets, and regulatory policies have evolved. One key challenge has been to determine which services should be regarded as Title II telecommunication services (subject to much more stringent regulatory controls), and which should be regarded as information services (more lightly regulated under the Communications Act). Another challenge is to draw the line between the computer processing and telecommunications industries. A series of consent decrees between the U.S. Department of Justice (DOJ) and industry leaders in the sector helped steer the early development of the computing and telecommunications industries along separate paths.[243]

In a world of all-IP broadband networks, the underlying technology does not limit the services that can be offered or how they might be classified from a regulatory perspective. This poses challenges for determining how to transition legacy regulations for telephony to the new world of any-to-any communications capabilities supported on modern all-IP broadband capable networks. How should today's separate regulatory frameworks—which apply to fixed versus mobile voice, legacy TDM versus VoIP, "voice over the Internet" versus "voice over other IP"—be harmonized and reconciled? What about when voice becomes video or text?

242. Communications Act of 1934, Pub. L. No. 73-416, 48 Stat. 1064 (1934) (codified as amended at 47 U.S.C. §§ 201–76 (2012)).

243. In 1956 and 1982, the DOJ reached consent decrees with IBM and AT&T, respectively, that in part, limited the ability of the former to enter the telecommunications industry and the latter to enter the computer processing industry. The lines between these two industries have continued to blur as processing has become more distributed and telecommunications has become more intelligent. *See* Peter Passell, *I.B.M. and the Limits of a Consent Decree*, N.Y. TIMES (June 9, 1994), http://www.nytimes.com/1994/06/09/business/ibm-and-the-limits-of-a-consent-decree.html.

Ensuring continued access to (universal service) and connectivity (interconnection, interoperability) for essential electronic communication services are core policy mandates that relate to "conduit" network services. Determining which of these require regulatory interventions, and potentially new rules, and which may be left to market forces to be sorted out is both contentious and unclear. Managing the transition from the legacy copper-wire-based PSTN to the new all-IP broadband-capable PSTN presents a daunting challenge across a host of policy issues both near and longer term.

Of special note is the need for such essential telecommunication services as public safety (e911 emergency services) and lawful wiretaps and investigations of electronic communications services (CALEA). The design of modern communications systems for public safety and law enforcement in today's post 9/11 world raises numerous technical and management issues that are far removed from the concerns that arise in the context of designing network services for the electronic delivery of entertainment media. Addressing issues where the principal users of the services are government employees (not for-profit businesses and their customers), where life and death situations are common, and which may engage national security concerns (including access to classified information) presents a fundamentally different decision-making context than is confronted in the case of entertainment media.

The people who need to be "in the room" for the discussions about designing new e911 or CALEA rules and systems are unlikely to be the same as those who need to be there to discuss new video codec protocols or program licensing regimes for entertainment media. These discussions will, for the most part, engage different commercial and public entities, representing different stakeholder interests and requiring different types of expertise and knowledge about the legacy context that is being reformed. Of course, some of the key participants will be common across the different decision domains (e.g., the broadband platform providers); but others will not (e.g., the producers and rights holders for video entertainment media).

2. *Broadcast, Cable, and Media Regulation*

First radio and then television began as over-the-air services delivered via broadcast networks, which provided channels of programming that could be received by customer-owned radios and televisions.[244] The original idea was for manufacturers of the radios and televisions to subsidize programming in order to stimulate demand for consumer appliances.[245] Relatively quickly, however, it became clear that the programming provided a vehicle for consumer advertising, and advertising support became the principal funding vehicle to subsidize the delivery of broadcast media services.[246] Consumer

244. FCC, THE PUBLIC AND BROADCASTING: HOW TO GET THE MOST SERVICE FROM YOUR LOCAL STATION 10 (July 2008), https://apps.fcc.gov/edocs_public/attachmatch/DA-08-940A2.pdf.

245. JOHN CAREY & MARTIN C. J. ELTON, WHEN MEDIA ARE NEW: UNDERSTANDING THE DYNAMICS OF NEW MEDIA ADOPTION AND USE 101–02 (2010), http://dx.doi.org/10.3998/nmw.8859947.0001.001.

246. *See* David S. Evans & Richard Schmalensee, *The Industrial Organization of Markets with Two-Sided Platforms*, 3 COMPETITION POL'Y INT'L 151, 155–56 (2007) (discussing the economics of two-sided

product companies paid for the programming in return for having access to consumer leisure attention to advertise their products.[247] Other forms of pay-per-view entertainment media such as live performances, movie theaters, and print media used non-electronic distribution networks to reach their audiences and capture leisure expenditures.[248]

In the world of over-the-air broadcasting, and with the technologies in use at the time, the FCC restricted and regulated commercial broadcaster access to scarce spectrum (below 1 GHz).[249] In return for compliance with a range of public interest commitments (e.g., providing news services), the FCC granted over-the-air broadcasters exclusive licenses to use the airwaves.[250] Consequently, the choice of networks or channels and the programming selections that could be provided in each local market were severely limited.[251]

Beyond spectrum regulation, the focus of media regulation was on ensuring that diverse programming choices were available.[252] Programs promoting public interest and children's programming, rules restricting pornography, access for persons with disabilities (e.g., closed captioning requirements), and support for emergency public notification services (e.g., to make public announcements broadly accessible in the event of a national emergency) needed to be balanced with First Amendment protections for free speech and media access.[253] In contrast to telecommunications regulations that focused on the "conduit," broadcasting and media regulations focused on the "content."

With the rise of cable television systems, over-the-air RF signals were increasingly moved to higher-capacity wired (coaxial cable) RF systems for local delivery.[254] Cable television networks were granted local monopoly franchises in return for providing public access services (e.g., network services for the municipal government) and meeting community coverage commitments.[255] The new cable networks enabled a large expansion in the

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platforms and their application to competition policy issues, especially as it relates to advertising-supported media).

247. Christina Austin, *The Billionaires' Club: Only 36 Companies Have $1,000 Million-Plus Ad Budgets*, BUS. INSIDER (Nov. 11, 2012, 11:39 AM), http://www.businessinsider.com/the-35-companies-that-spent-1-billion-on-ads-in-2011-2012-11.

248. *See* Seventeenth Report, *supra* note 131, at 4527–28.

249. *Id.* at 4510–11.

250. JIM KOHLENBERGER ET AL., BENTON FOUND., CITIZEN'S GUIDE TO THE PUBLIC INTEREST OBLIGATIONS OF DIGITAL TELEVISION BROADCASTERS 3–5 (2015), https://www.benton.org/sites/benton.org/files/citizensguide.pdf.

251. *Id.*

252. *See generally* Lori A. Brainard, *Television Policy: Economic v. Content Regulation and Deregulation*, FOCUS ON LAW STUDIES (Am. Bar Ass'n, Chicago, IL), Fall 2004, at 1, 8, http://www.americanbar.org/content/dam/aba/publishing/focus_on_law_studies/publiced_focus_fall04.authcheckdam.pdf (discussing one goal of ownership controls being diversity in programming).

253. *See generally* Adam Candeub, *Broadcast Media Ownership Rules: Can the FCC Get It Right?*, FOCUS ON LAW STUDIES (Am. Bar Ass'n, Chicago, IL), Fall 2004, at 2, 10, http://www.americanbar.org/content/dam/aba/publishing/focus_on_law_studies/publiced_focus_fall04.authcheckdam.pdf (discussing one example of comporting with First Amendment protections).

254. *See, e.g.*, *Coaxial Feeder/RF Coax Cable Tutorial*, RADIO-ELECTRONICS.COM, http://www.radio-electronics.com/info/antennas/coax/rf-coaxial-feeder-cable.php (last visited Feb. 27, 2017) (providing short history of coaxial cable).

255. *See, e.g.*, Theodore Bolema, *An Evaluation of Legislative Proposals for Higher Cable Fees to*

number of programming channels, including redistribution of higher-quality signals for the legacy over-the-air television stations.[256] Rather than separating the network services (the conduit) and the programming (the content), a new framework was crafted for regulating cable television service providers as a new category of providers. This became Title VI—Cable Communications, which was added to the Communications Act in 1984.[257]

Just as legacy telephone network providers were updating their networks, so too were cable television providers. They were motivated in part by the promise of being able to offer enhanced pay-per-view television services and to respond to competition from direct broadcast satellite (DBS) services. They were also motivated by the impending threat of telephone companies offering television services, as well as changing consumer habits for consuming entertainment media (including the use of VCRs to time-shift programs and bypass advertisements).[258] The cable providers added two-way capabilities to their legacy one-way broadcast networks in order to be in a better position to offer video-on-demand and interactive programming options, while also positioning themselves to better compete for services that had previously been provided solely by telephone operators.[259] This positioned them well to take an early lead in the market for broadband Internet access services that began to emerge after 1996.

Today, the largest cable programming providers are multiple system operators (MSOs) with all-IP broadband last-mile networks in markets across the United States.[260] Their video services are regulated as multichannel video program distributors (MVPDs).[261] The MVPD rules, which also apply to DBS and telecommunications-based providers of video programming, include a range of rules that seek to promote competition and protect access to programming.[262] These include program access rules, must-carry/retransmission rights, and special copyright rules.[263] The program access rules are designed to ensure that scarce programming rights are not monopolized by individual operators in ways that might threaten to foreclose other distributors from being able to offer potential subscribers attractive bundles of

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Finance Public, Education and Government Access Channels, POL'Y BRIEF (Mackinac Ctr. for Pub. Policy, Midland, Mich.), Nov. 10, 2008, at 3–4, 8, https://www.mackinac.org/archives/2008/2008-11REGfeesWEB.pdf (describing cable monopoly regulatory structure).

256. *See, e.g.*, *History of Cable*, CAL. CABLE & TELECOMM. ASS'N, https://www.calcable.org/learn/history-of-cable/ (last visited Feb. 27, 2017) (describing the transition from over-the-air television signals to higher-quality cable delivery).

257. Cable Communications Act of 1984, Pub. L. No. 98-549, 98 Stat. 2780 (1984) (codified as amended at 47 U.S.C. §§ 521–73 (2012)).

258. *History of Cable*, *supra* note 256.

259. Richard R. Green, *Cable Television Technology Deployment*, *in* THE UNPREDICTABLE CERTAINTY: WHITE PAPERS 256 (1997), https://www.nap.edu/read/6062/chapter/34.

260. Stuart Smith, *Introduction to the Cable MSO Industry*, MINTEK (July 21, 2010), http://www.mintek.com/blog/cpe-management/introduction-cable-mso-industry/.

261. *See* 47 U.S.C. § 522(13) (2012) (defining the term "multichannel video programming distributor").

262. *See* Matthew Syrkin, *U.S. Television on the Internet and the New "MVPDs" (Updated)*, DIGITAL HHR (Mar. 18, 2015), http://www.digitalhhr.com/2015/03/u-s-television-on-the-internet-and-the-new-mvpds/ (describing certain MVPD rules).

263. *Id.*

programming.[264] The must-carry/retransmission framework was adopted to ensure local over-the-air broadcasters would be able to continue to reach the homes of cable subscribers in their coverage areas.[265] Broadcasters have a right to require cable providers to retransmit local station broadcasts via the cable plant for stations that elect to invoke the "must-carry" right.[266] Alternatively, stations can elect to negotiate for retransmission rights, which may result in cable networks having to pay for the right to retransmit local stations (or, depending on the outcome of the negotiation, for over-the-air stations to have to pay for redistribution).[267] In recent years, payments of retransmission fees from cable companies to over-the-air broadcasters have been an important source of revenue for the broadcasters and a source of increasing program-related costs for the MVPDs.[268] Another key element of the MVPD framework is a special licensing arrangement for copyrighted material that allows MVPDs to distribute the copyrighted material under a single blanket licensing agreement, rather than being forced to negotiate separate usage rights arrangements with each copyright holder.[269]

Although many of the largest MVPDs are also providers of voice and broadband Internet access services (e.g., Comcast, New Charter, Verizon, or AT&T), the video entertainment business they are engaged in as MVPDs includes many content providers who do not own, operate, or sell broadband network services.[270] This includes media companies like Viacom, Disney, HBO, Netflix, and Paramount. Moreover, the "content" considerations that dominate their business decision making are quite distinct from the "conduit" considerations that dominate telecommunications industry decision making.

3. Data Communications and Internet Regulation

Prior to the emergence of the Internet as a mass-market platform for data communication services, these services were almost exclusively targeted at enterprise customers (businesses, governments, universities, etc.). The telecommunication services were provided using facilities largely owned and operated by the same telephone companies that supported the PSTN and were used to interconnect the computing and data networks of the enterprise

264. *See* Turner Broad. Sys., Inc. v. FCC, 512 U.S. 622, 662 (1994) ("[M]ust-carry provisions serve three interrelated interests: (1) preserving the benefits of free, over-the-air local broadcast television, (2) promoting the widespread dissemination of information from a multiplicity of sources, and (3) promoting fair competition in the market for television programming.").

265. *Id.*

266. Syrkin, *supra* note 262.

267. Tom Wheeler, *An Update on Our Review of the Good Faith Retransmission Consent Negotiation Rules*, FCC (July 14, 2016, 10:37 AM), https://www.fcc.gov/news-events/blog/2016/07/14/update-our-review-good-faith-retransmission-consent-negotiation-rules.

268. Diana Marszalek, *Nowhere to Go but Up for Retrans Fees*, TVNEWSCHECK (June 26, 2015, 5:54 AM), http://www.tvnewscheck.com/article/86466/nowhere-to-go-but-up-for-retrans-fees.

269. *See* Broadcast Music, Inc. v. Columbia Broadcasting System, Inc., 441 U.S. 1, 20 (1979) (holding that a blanket license is not a naked restraint on trade).

270. *In-Depth: FCC Opens Rulemaking on MVPD Definition*, BROADBAND CONNECTION IN-DEPTH (U.S. Telecom Assoc., Washington D.C.), Jan. 23, 2015, https://www.ustelecom.org/news/newsletters/broadband-connection-depth/depth-fcc-opens-rulemaking-mvpd-definition.

customers.[271] Private lines and a range of other data communication services were regulated as Title II services, subject to the same sort of strong regulatory oversight as other PSTN services.[272]

Meanwhile, the computer processing and services businesses were largely unregulated, or at least free from the sort of sector-specific regulatory oversight that characterized telecommunications and the media industries discussed previously.[273] Industry standardization (to define interoperability standards to enable components provided by different providers to interconnect), trade agreements (to manage international commerce in computing equipment and services), and general competition regulations were the principal mechanisms for ensuring that market forces could keep the computing industry on track.[274] When IBM was dominant (and later when Microsoft became dominant), antitrust suits brought by the DOJ helped regulate competitive dynamics in the computing sector.[275]

In contrast to the legacy of telecommunications regulation associated with the PSTN or the media regulations associated with broadcasting or cable network (MVPD) regulation, the Internet was largely unregulated. It first emerged as an application that was supported over dial-up telephone lines on the PSTN, and since 2000, has emerged as broadband Internet access services provided by today's broadband service providers that have evolved from the convergence of telephone and cable television networks.[276] From its legacy as an unregulated application that rode on top of the PSTN, the Internet is emerging as the platform for future communications and media services.

As broadband and the Internet have come to be seen by many as *the* global platforms for all electronic communication services, a natural question emerges as to how to morph or converge the legacies of PSTN and broadcast/cable/media regulations with the mostly unregulated Internet. Combining the delivery of all these services into the same "conduit" may make it more difficult to separate and manage needed policy transitions that address quite distinct and separate issues, requiring participation from different sets of stakeholders with very different realms of expertise. Much of the legacy regulation may be discarded as no longer necessary or relevant in an all-IP world, while other legacy regulations will require new frameworks to reconcile

271. Bradley Mitchell, *PSTN (Public Switched Telephone Network)*, LIFEWIRE (Sept. 26, 2016), https://www.lifewire.com/pstn-public-switched-telephone-network-818168.

272. Daniel Lyons, *Title II Does Not Prohibit Paid Prioritization*, TECHPOLICYDAILY.COM (July 25, 2014, 6:00 AM), http://www.techpolicydaily.com/communications/title-ii-prohibit-paid-prioritization/.

273. Clark et al., *supra* note 94, at 5 n.12.

274. Lehr et al., *supra* note 14; Stephanie Lynn Sharron & Nikita A. Tuckett, *The Internet of Things: Interoperability, Industry Standards & Related IP Licensing Approaches*, SOCIALLY AWARE (Feb. 2, 2016), http://www.sociallyawareblog.com/2016/02/02/the-internet-of-things-evaluating-the-interplay-of-inter operability-industry-standards-and-related-ip-licensing-approaches/.

275. In 1956, the DOJ reached a consent decree with IBM limiting its ability to abuse its market power over computing equipment, and also restricted its ability to compete in the telecommunications sector. *See* NIELSEN, *supra* note 200. In 1998, the DOJ brought an antitrust case against Microsoft alleging, in part, abuse of market power in the markets for web browsers. That case was ultimately settled in 2001. *See* Jamey Keaten & John Frederick Moore, *U.S. Targets Microsoft*, CNN MONEY (May 18, 1998, 8:01 PM), http://money.cnn.com/1998/05/18/technology/microsoft_suit/.

276. Lehr et al., *supra* note 14, at 413–14.

with the continuing public interest mandates (e.g., to ensure universal service, interoperability, and competition where feasible). Addressing issues like program access, e911, CALEA, or universal service raises special challenges in the context of the Internet.

Today, we have a patchwork of regulatory constructs that have sought to address the challenges of convergence piecemeal. For example, the FCC, after initially seeking to exempt broadband access services from Title II regulatory oversight (by classifying broadband as an information service), has opted to reverse itself and classify a new broadband Internet access service as a Title II service.[277] It was motivated in part by earlier challenges to the FCC's assertion of authority to impose regulatory obligations on broadband service providers under Title I and other provisions of the Communications Act.[278] Meanwhile, the FCC has chosen not to define VoIP as a Title II service,[279] and has sought to regulate voice services through a series of targeted proceedings focused on addressing specific issues, such as how VoIP providers support e911 services and their obligations to contribute to universal service subsidy programs.[280] A similar patchwork approach applies in the case of video distribution services. The MVPD framework and various provisions govern the distribution of video services over the same wires that are used to deliver broadband Internet access and voice services (whether VoIP or otherwise), but with different sets of rules applying to the different ways in which the traffic is delivered.[281]

As noted earlier, most of the entertainment video delivered into homes is delivered over non-IP RF transmission services or non-Internet IP networks, but a rapidly growing volume of entertainment video traffic is moving to the Internet and coming into homes via the BIAS service.[282] Once again, this is stressing the ability to separate content/conduit policy regulations, and blurring the boundaries between separate technical, business, and regulatory systems.

B. Relevance to Current Policy Issues

There are numerous current policy issues that underscore the challenges that arise as video traffic over BIAS grows. Obviously, the principal debate relates to network neutrality as already discussed in Section II.A. In the following Subsections, we discuss a number of additional examples of policy issues that may be addressed and/or complicated by whether entertainment video remains integrated with the BIAS traffic, or is carried in a separately managed IP network.

277. *Id.* at 418 n.14.

278. *Id.* at 420 n.21.

279. Judith A. Endejan, *Will the FCC Ever Make the Call on VoIP Service?*, 25 COMM. LAW. 1, 2–3 (2007), http://www.americanbar.org/content/dam/aba/publishing/communications_lawyer/endejan.authcheckdam.pdf (stating that the FCC has not, but could, define VoIP as a Title II service).

280. *See* 47 C.F.R. § 9.5 (2016) (providing that VoIP providers must support e911 services).

281. *See* 47 U.S.C. § 252(d) (2012) (providing the requirements for various types of service providers).

282. PETER F. ORAZEM, THE IMPACT OF HIGH-SPEED INTERNET ACCESS ON LOCAL ECONOMIC GROWTH 3 (Aug. 2005), https://business.ku.edu/sites/businessdev.drupal.ku.edu/files/images/general/Research/Internet%20and%20Growth.pdf.

1. Performance Measurement and Managing Consumer Expectations

Delivering high-resolution entertainment video via the BIAS will require high data rates downstream to the consumer's home; and if the goal is to deliver multiple such streams, still higher data rates will be required. Moreover, if the content to be viewed is not cached relatively close to the edge of the network and has to travel across ISP interconnections, then there is a risk that congestion of those interconnection links might degrade performance.

In an earlier paper, we discussed the challenges for performance measurement that arise as the speeds for the typical BIAS connection exceed 100 Mbps.[283] With such superfast broadband access services, it will not be reasonable to sustain those rates as average speeds to arbitrary Internet destinations, but consumers will expect to realize those rates for particular services (e.g., perhaps for Netflix) and to some set of destinations.

As discussed earlier, if the entertainment video were carried via a separate IP service (i.e., VIAS), then the data rates required for the BIAS might be lower, and the measurement challenges and expectations would certainly be different. At the same time, knowing that the VIAS service was supporting entertainment video might allow for better performance measurements that are closely tailored to the requirements of entertainment video.[284]

2. Universal Service

One of the key justifications for PSTN regulation was the recognition that telephone service is essential basic infrastructure for society and the economy, and thus, the government confronted a policy mandate to ensure universal and affordable access to telephone service for all citizens and businesses.[285] This has resulted in the creation of regulatory obligations like "duty to serve" and "carrier of last resort" obligations.[286] It has also justified rate regulations that embedded implicit price subsidies (e.g., from long distance to local, from urban to rural, and from business to residential services), as well as justified the creation of a $4 to $8 billion per year set of subsidy programs funded by telecommunication service revenues and directed at supporting universal access to affordable telephone service.[287]

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283. *See* Steven Bauer et al., *Gigabit Broadband, Interconnection Propositions, and the Challenge of Managing Expectations* (43rd Research Conf. on Commc'n, Info. & Internet Policy, 2015), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2586805.

284. Knowing what the traffic is and what quality of service is needed to ensure a good user experience simplifies the measurement challenge (design, interpretation, etc.). *See* Jason Fitzpatrick, *How to Use Quality of Service (QoS) to Get Faster Internet when You Really Need It*, HOW-TO GEEK (Mar. 22, 2016), http://www.howtogeek.com/75660/the-beginners-guide-to-qos-on-your-router/.

285. Technology Transitions, Order, Report and Order and Further Notice of Proposed Rulemaking, 29 FCC Rcd. 1433, 1450 (2014), https://apps.fcc.gov/edocs_public/attachmatch/FCC-14-5A1.pdf.

286. PETER BLUHM, CARRIERS OF LAST RESORT, ELIGIBLE TELECOMMUNICATIONS CARRIERS, AND STATE ADMINISTRATIVE ROLES 4 (Feb. 7, 2011), http://www.kcc.state.ks.us/telecom/roundtable032011/COLR_ETCs_and_State_Roles_White_Paper.pdf.

287. UNIVERSAL SERV. ADMIN. CO., MOVING FORWARD TOGETHER—2014 ANNUAL REPORT 2–13 (2014), http://usac.org/_res/documents/about/pdf/annual-reports/usac-annual-report-Interactive-Layout-2014.pdf.

It has long been recognized, and since the National Broadband Plan,[288] has been national policy to determine how to transition a program focused on supporting telephone service access to one focused on supporting broadband access. The motivation for this is the growing recognition that broadband is the essential infrastructure that is needed to support the full spectrum of electronic communication services, of which voice telephony is just one application.

As noted earlier, those who seek to justify broadband as essential infrastructure make frequent reference to the capabilities required to enable Smart-X solutions, but seldom or in more muted tones, argue in favor of broadband so everyone can have access to additional channels of high-definition entertainment video.

If the Internet were not the principle service for delivering video, this would have a number of interesting implications. First, the capacity needed would be reduced, so the overall investment required to ensure ubiquitous Internet access and subsidies desired to ensure affordable access might be less. Second, the standard for what might constitute adequate Internet access might be more easily met by cellular-based services, facilitating more symmetric regulation of mobile and fixed broadband Internet access service.

It is unclear how national support for Internet as an essential service, versus broadband as an essential service, might shift. Some might argue that an Internet largely stripped of entertainment traffic would be more easily justified as necessary for economically productive Smart-X activities, and so would be even more essential to preserve as an open, ubiquitously available platform for innovation. Some may view access to Internet-enabled electronic communications as essential human rights, while viewing the ability to access entertainment media as merely something that may be nice to have but is not worth expending public subsidies on. Others may disagree and argue that a sufficient share of the populace wants access to high-quality entertainment video such that providing ubiquitous access ought to be a national priority.

These divergent views might be addressed by separating universal service support for broadband and universal support for Internet access. However, separating universal support for Internet and broadband access will not be easy in practice. For example, it is unclear to what extent video revenues currently subsidize Internet infrastructure. As noted earlier, the broadband networks are shared across triple-play offers and the total revenues captured by the network operators need to be sufficient to recover network operators' economic costs for their businesses to remain viable—but there is no single best way to allocate the shared costs back to the individual services. To the extent public funds may be made available to subsidize Internet infrastructure (instead of broadband infrastructure that may also support the delivery of entertainment video), ISPs may have a perverse incentive to shift network costs to the Internet service. On the other hand, to the extent video service revenues are

288. *See generally National Broadband Plan*, *supra* note 46. "Congress directed the Federal Communications Commission (FCC) to develop a National Broadband Plan to ensure every American has 'access to broadband capability.'" *Id.* at xi.

contributing to covering network costs, the loss of those revenues (potentially due to competition from over-the-top video services) may force operators to shift the cost burden to the remaining services, including the Internet access service.

3. *Internet Interconnections*

Historically, Internet interconnection was not regulated. A tiered structure of peering and transit relationships emerged with so-called Tier 1 ISPs at the top, exchanging traffic via revenue-neutral peering agreements.[289] Other providers, lower in the hierarchy, purchased transit services to ensure delivery of traffic to all public Internet addresses.[290] The rise of video and other developments in the Internet ecosystem have resulted in significant changes in how traffic is managed in the Internet and the types of interconnection arrangements that govern the exchange of traffic among ISPs.[291] There has been a proliferation of new types of arrangements with peering occurring lower in the hierarchy, and involving payment flows and special traffic management requirements.[292] The Internet topology has flattened and we have seen the rise of hyper-giants that include the largest ISPs that provide broadband access services (e.g., Comcast) and the largest content providers and content provider networks (e.g., Netflix, Google).[293]

Much of the traffic that has driven the changes in the Internet interconnection ecosystem is entertainment video, as already noted. This traffic has been highly asymmetric (from content providers into access ISP networks), causing stresses for the legacy model of revenue-neutral peering and resulting in congestion that deteriorates the end users' quality of experience when using broadband Internet access services.[294] Figuring out who should pay and how payment should be made for expanding these interconnection links has led to well-publicized disputes between providers, and to calls for increased regulation of interconnection.[295]

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289. MARK WINTHER, TIER 1 ISPS: WHAT THEY ARE AND WHY THEY ARE IMPORTANT 5 (May 2006), https://www.us.ntt.net/downloads/papers/IDC_Tier1_ISPs.pdf.

290. *Id.*

291. INTERNET TRAFFIC, *supra* note 62, at 14–16.

292. Clark et al., *supra* note 94, at 21.

293. Danny McPherson, *ATLAS Internet Observatory*, ARBOR NETWORKS (Nov. 12, 2009), https://wiki.tools.isoc.org/@api/deki/files/2426/=isoc-researchers-lunch.pdf.

294. *See Why Quality of Experience Is the Most Critical Metric for Internet Video Profitability*, CONVIVA (Aug. 7, 2013), http://www.conviva.com/why-quality-of-experience-is-the-most-critical-metric-for-internet-video-profitability ("[N]etwork connections are a shared resource, and more users simply add more congestion. This leads to slower page loads, delayed video starts, stream interruptions and video degradation, creating a poor quality of experience (QoE) for the end-user.").

295. *See, e.g.*, Steven Bauer et al., *A Data Driven Exploration of Broadband Traffic Issues: Growth, Management, and Policy* (TRPC, 2012), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2029058 (advocating for increased regulatory oversight of broadband pricing).

4. *MVPD Regulatory Reform*

With the rise of online video distributors (OVDs) like Hulu, Netflix, and YouTube, the legacy framework for managing video services is increasingly under stress. The OVDs do not confront the must-carry/retransmission, special access, or rate regulations that apply to MVPDs, but also do not benefit from the program access and copyright licensing provisions that benefit many MVPDs.

Extending the MVPD obligations to OVDs risks imposing media regulations on the Internet, while retaining the two-tiered regulatory structure risks distorting competition and investment incentives in the (mostly) highly competitive video entertainment industry. The differences in regulatory treatment are understandable in light of the history of how these businesses have evolved, but become increasingly untenable as the services become closer substitutes that are competing directly for the same pool of consumer dollars. At the end of 2014, the FCC launched a proceeding to address whether certain OVDs should be classified as MVPDs.[296] Industry stakeholders differed widely in their support for the proposal, with Verizon and programmers favoring it, and cable operators (via the NCTA[297]) and Amazon opposing it.[298]

To the extent the principal concerns relate to the entertainment video programming industries, it might be easier if the traffic were not carried in the BIAS but via a separate service that might be more easily integrated into a common framework that applied to video distribution services in the last mile (i.e., a VIAS).

5. *Set-Top Boxes*

Set-top boxes are another hot point of contention being addressed by the FCC. In February 2016, the FCC proposed new rules that would require MVPDs to unbundle the set-top boxes that are used to control access to the programming MVPDs deliver.[299] Today, most subscribers rent their set-top boxes from their MVPD providers. The FCC proposal is to establish rules that would require MVPDs to provide three streams of information that could be accessed by third parties and would allow consumers to use their own set-top boxes.[300] The three streams of information would include: (1) service discovery information, which would include information about the channel

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296. Promoting Innovation and Competition in the Provision of Multichannel Video Programming Distribution Services, Notice of Proposed Rulemaking, 29 FCC Rcd. 15995 (2014), https://apps.fcc.gov/edocs_public/attachmatch/FCC-14-210A1.pdf.

297. The National Cable & Telecommunications Association (NCTA), now named the Internet & Television Association, is the cable industry's principal trade association. John Eggerton, *National Cable & Telecommunications Association Rebrands*, BROAD. & CABLE (Sept. 18, 2016, 11:45 PM), http://www.broadcastingcable.com/news/washington/national-cable-telecommunications-association-rebrands/159708.

298. Mari Silbey, *To Be or Not to Be an MVPD*, LIGHT READING (Apr. 6, 2015), http://www.lightreading.com/video/ott/to-be-or-not-to-be-an-mvpd/d/d-id/714880.

299. *See* Expanding Consumers' Video Navigation Choices, Notice of Proposed Rulemaking and Memorandum Opinion and Order, 31 FCC Rcd. 1544 (2016), https://apps.fcc.gov/edocs_public/attachmatch/FCC-16-18A1.pdf.

300. *Id.* at 1545.

lineup and the available selection of programming; (2) rights information about what permissions were associated with the programming restricting its use by consumers; and (3) the video programming stream.[301] Proponents of the rules argue that they would increase competition in video services, including allowing OVDs to better integrate programming with other new Internet services.[302] Opponents argue that the rules impose additional regulatory costs and obligations on an industry that are unnecessary or worse.[303] They point to the vibrancy of competition and the potential risks that such rules may pose for Internet technology, consumer privacy, and the video distribution marketplace.[304] Industry opponents have proposed abandoning the set-top boxes as gateway devices that control access to video programming distributed via last-mile networks in favor of an approach that would rely on open-standards-based software applications that could run on televisions and other devices to control access.[305]

While it is unclear what will happen, the debate over the set-top boxes highlights the potential risks to Internet openness when multiple industry stakeholders with substantial marketplace presences are tussling over the future of the way digital entertainment media gets delivered to households over last-mile networks. These issues would not go away, but they might be rendered more tractable from a policy perspective if the BIAS traffic and the entertainment video traffic were delivered via separate channels.

6. *Summing Up the Policy Challenges*

In the preceding five Subsections, we briefly reviewed current policy issues that are impacted by the fact that entertainment video is integrated with Internet traffic in a hybrid model of patchwork policies. This is helping drive discussions across the range of communications policy issues—from measurement to interconnection, from universal service to media regulation. Although we have only skimmed the surface of how entertainment video concerns may complicate crafting good policy for either the Internet or markets for entertainment media, we believe engaging in the thought experiment of asking "what if the entertainment video traffic and its proponents were not in the room?" is useful. As we have suggested, there are ample arguments on both sides of the debate to suggest that we are not ready ourselves to conclude whether things would be better or worse if the video traffic were carried in a

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301. *Id.*

302. *See, e.g.*, Computer & Communications Industry Association, Comment Letter on Proposed Rulemaking on Expanding Consumers' Video Navigation Choices (May 23, 2016), http://www.ccianet.org/wp-content/uploads/2016/08/16-42-CCIA-Reply-Comments-Final.pdf.

303. *See, e.g.*, Peter M. Lenkov, *The FCC Hoists the Jolly Roger on Your Cable Box*, WALL ST. J. (June 7, 2016, 6:35 PM), https://www.wsj.com/articles/the-fcc-hoists-the-jolly-roger-on-your-cable-box-1465338921.

304. For example, opponents argue that the new proposal would allow third parties to have access to consumer viewing data, posing additional threats to consumer privacy and allowing those parties to gain free access to programming they did not pay for. *Id.*

305. *See* John Eggerton, *NCTA Pitches "Ditch the Box" Set-Top Proposal*, MULTICHANNEL NEWS (June 16, 2016, 1:30 PM), http://www.multichannel.com/ncta-pitches-ditch-box-set-top-proposal/405730.

separately managed network. However, we believe that it may still be possible and there may be benefits in keeping the regulatory challenges distinct, at least in the near to medium term.

C. A Framework for Separating Broadband and Video

In this Section, we take up the question of how a separate video service (from the Internet) might be regulated and what some of the challenges would be. The most obvious model would be to mirror the approach that the FCC used in crafting a regulatory framework for BIAS.

Today, cable operators' use of RF for video is governed by MVPD regulations; the use of broadband service to make content like Xfinity available is covered by the FCC's Open Internet Order.[306] The regulatory posture is that a Comcast subscriber should have no better experience when accessing affiliated Xfinity content than when accessing content from other providers (e.g., HBO, Netflix) by virtue of how packets are managed in the BIAS flow. Of course, if Netflix under-provisions its servers or the interconnection links, then the QoE might be different (worse) for Netflix relative to Xfinity for that subscriber. At the same time, the BIAS-delivered content is being delivered (in many cases) over the same wires but over different technologies (often not IP) or over separately managed IP services (e.g., IPTV) that are not part of the BIAS flows. This gives rise to additional QoE differences and business relationships that are difficult to regulate without distorting market competition and investment incentives across the entertainment media value chain.

In principle, the FCC could consider defining a new Video-over-IP Access Service that would be a new BIAS service. As with BIAS, the FCC could preempt state regulation, asserting plausibly that the basic service was inseparably interstate, and thereby limit the risk that excessive use of legacy Title II authority might be applied.

Postponing for a minute the sizable challenges confronting such an approach, it is worthwhile considering what this might enable. First, if VIAS were a viable regulatory model, then it would provide an obvious trajectory for what to do with OVD reclassification and the MVPD regulatory framework. This might help isolate the Internet (i.e., BIAS) from the effect of spillover of entertainment industry regulatory issues. Likewise, the FCC may be able to define a special requirement for VIAS interconnection to isolate pressure to regulate Internet interconnection arising from the incredible growth of asymmetric video traffic over BIAS services. Third, a separate VIAS service might be better positioned to add on features and capabilities for service and content management that are video specific. This could include such things as better in-network support for digital rights management and video-specific encoding support (variable-bitrate encoding to address different video standards). This might spur the development of better and more capable IPTV network support that would be optimized for the needs of entertainment

306. Open Internet Order, *supra* note 22.

businesses.

Of course, the above regulatory model would confront numerous challenges, so it might not even be politically or legally feasible, even if a case could be made for the economic merits of such an approach. First, unlike with the BIAS service, where the regulatory framework was imposed on an existing marketplace with well-developed broadband services already being provided by ISPs, the marketplace for VIAS services is not yet developed. It is uncertain that either the ISPs or content providers, who would be expected to make use of the service, would prefer it to the alternative of either unregulated IPTV delivery or strong protections for video delivered over BIAS. The FCC would lack an existing service model to point to in order to specify the new VIAS framework. Moreover, ISPs would likely resist any attempt to extend FCC regulatory authority over additional services, and their opposition would find significant political support in the U.S. Congress from politicians strongly opposed to almost any sort of government regulation. If, in addition, the content providers thought they could ensure a better regulatory deal for themselves by pushing for stronger BIAS protections, the prospects for advancing such an idea would be even more daunting.

Second, even if a VIAS framework were created, it would not eliminate the need to balance the sharing of cost-recovery burdens and resource allocations of the broadband platform infrastructure between BIAS, VIAS, and potentially other IP-based services delivered over the broadband wired infrastructure. Earlier, we discussed the technical options for allocating capacity between services. These arise in any case, so they would not be a *result* of creating VIAS, but might be more easily addressed under the VIAS framework.

Third, it is unreasonable to expect that all video content, or more narrowly, entertainment video content, would migrate to VIAS, which some might use as a basis for arguing that the framework would not provide a complete solution. Indeed, the VIAS approach is really just a different framing of the current patchwork situation, in which the largest share of entertainment video traffic is regulated under a different framework than Internet traffic. Our goal in suggesting that regulatory options exist for sustaining a world in which traffic is not fully converged into a single BIAS service is that it may offer advantages either in the long term, or at a minimum, in establishing a good glide path for regulatory reform if the longer-term-horizon goal is for full convergence.

VI. SUMMARY CONCLUSIONS

In this Article, we took up the question of whether the convergence of entertainment media traffic and the Internet is desirable or inevitable. To investigate this question, we explored the different ways in which this convergence may occur at the technical, business/market, or policy level. This leads us to conclude that the jury is still out.

Although most of the traffic on the Internet is already entertainment media, and that traffic is growing rapidly, most of the entertainment media delivered into homes is not being delivered via the Internet. We still have a long way to go before all entertainment video is delivered via IP ("everything over IP"), or even stronger, over the Internet ("everything over a single IP network"). It is far from clear whether getting to either of those points is a good thing for either the Internet or for video entertainment services, and it is certainly not inevitable. While we feel comfortable in those assertions, figuring out how much convergence is appropriate and at what level is a much more difficult question, and one we do not have an answer to.

Instead, we propose that it will be helpful to continue to examine the counterexamples to convergence. Exactly when folks say "everything over IP" or "everything over the Internet" is the right answer, pause and ask yourself how that may be wrong. While convergence brings many benefits, it also poses unavoidable challenges. Some of those may be fundamental in the bringing together of stakeholders with divergent interests, capabilities, and constraints; and some of those may be the pains of transitioning from yesterday's world to whatever comes next. By continually investigating the alternatives to convergence, we may be better positioned to address the challenges that will continue to arise.