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ARTICLES

DEBATABLE PREMISES IN TELECOM POLICY

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INTRODUCTION

Around the world, telecommunications policy is one of the most important areas of public policy. The modern economy is driven by telecom technologies, and many telecom-related firms – Google, Apple, Facebook, and myriad fixed and mobile Internet service providers – are among the largest companies in the world. The Internet is opening up new platforms for business, education, government, and civic engagement. It has literally been a driving force in toppling governments. Telecommunications policy is important to every government in the world, and debates over what policies should be implemented are heated in almost every country in the world.

Unfortunately, many of the arguments used in these debates – especially those supporting regulatory intervention – rest on faulty premises. These premises often follow from ideas that make intuitive sense – and that have great political valence – but that don't stand up well to critical analysis. This paper collects and responds to a number of these

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premises that, collectively, underlie much popular, political, and academic support for increased telecommunications regulation in the United States and Europe – as well as much of the rest of the world.

The primary purpose of presenting these arguments in this form is to focus attention on the nature of telecommunications policy debates and the role of telecommunications research in these debates. The critiques offered in this paper are, at some level, meant to challenge the validity of these premises. Their primary goal however, is more modest: to demonstrate that these premises are debatable. Too often they are assumed to be true or are simply presented as fact. One of this paper's own premises is that a core function of telecommunications research should be to add nuance and sophistication to policy discussions – not to further entrench already ossified positions.

On the other hand, it does not require great introspection to recognize that this is a field in which the line between scholarship and research on the one hand and advocacy, policy, and the press on the other is blurry and at times permeable. This is driven largely by the social and political role that communications infrastructure plays in modern democratic societies, both as a tool for communications and as a symbol of freedom, equality, and related values – these are the concerns that drive most popular and policy interest in these topics, as well as much scholarship. At the same time, these issues can be looked at from more technocratic perspectives, focusing on the underlying economics, technologies, demographic and usage patterns, and similar factors. It is frequently the case that these different approaches to the same questions lead to divergent policy proposals. Even when they could lead to convergent policy outcomes, the different approaches to issues may lead to divergent viewpoints in the discussions.

The broadest goal of this paper, in some ways modest, in others ambitious, is to shed light on how those involved in telecom policy discuss these issues and to encourage us to think about the role of scholarship and research in policy and popular telecommunications debates.

More narrowly, the goal is to demonstrate that important ideas in these debates require greater nuance than they are ordinarily afforded. In some cases, this lack of nuance yields a false dichotomy, such that consumers (it may be asserted) either need or do not need a given service; in some cases it results from incorrect technical understandings or overly-simplified models; and in other cases it results because the ideas that we debate are really implicit proxies for other political or policy views. In any of these cases, however, the result is that participants in telecom policy debates often talk past each other and adopt entrenched, self-reinforcing, positions.

The five premises that this paper considers are:

1. Everyone needs low-cost access to high speed broadband service
2. High-speed broadband is necessary for education, health, government, and other social services
3. Wireless can't compete with cable
4. An open Internet is necessary for innovation and necessarily benefits consumers
5. Telecommunications are better somewhere else.

Debates over telecom policy are necessary to the wellbeing and prosperity of citizens around the world. Sound telecom policy can benefit consumers in every nation; bad ideas can be terribly costly to them. At its best, telecom policy can help lift the poorest and least fortunate among us to prosperity, afford unparalleled access to education, health, and other essential services, and create platforms for expression and enterprise unknown at any prior point in human history. Few, if any, other technologies or industries have the potential to create so much good for so many.

As a result, these arguments tap into deep currents in the popular psyche. The questions at issue in telecommunications policy reflect values at the core of democratic societies, social commitments to equality and universal access, and concern over censorship and centralized control of information. The intuitive appeal of these arguments ensures that they find substantial support among well-intentioned legislators, regulators, and much of the public. However, intuitive appeal often leads analysis astray. This paper relies primarily on economic and technical analysis and research to demonstrate that the intuitive approach to these issues often leads to conclusions deleterious to consumers.

That the consumer must come first is a central theme that runs throughout this analysis, and should be a guiding principle through all telecom policy debates. It is too often the case that even well-intentioned and seemingly consumer-friendly policies do not fully appreciate the complexity of the market and therefore fail to place the interest of all consumers ahead of the interests of specific, often narrow, interest groups.

Hopefully, identifying faults in these premises will help us to address the issues that they represent with greater care; and hopefully this paper's presentation will foster discussion about the role of economically- and technically-informed research in policy debates. This is an exciting time in telecom policy. It is also a challenging time, given the fundamental shifts in technology and the industry that have occurred in recent decades.

This paper proceeds in six parts. Each of the first five parts corresponds to one of the premises listed above. Part six discusses themes that run through several of these premises and considers the role of substantive telecommunications research in telecommunications policy debates.

I. PREMISE ONE: EVERYONE NEEDS LOW-COST ACCESS TO HIGH-SPEED BROADBAND

The first premise we consider is that everyone needs low-cost access to high-speed broadband. This idea is central to contemporary debates in the telecom space and guides much of current policy. This premise gives rise to several related policy prescriptions: ensuring the availability of service everywhere (universal service); ensuring that service is either low-cost or subsidized for those who may not be able to afford access; ensuring that at least one carrier offering such service is available to every consumer (a "carrier of last resort"); and imposing various service-level guarantees and quality of service requirements on every carrier.

As an initial matter, universal telephone service has historically been leveraged to support various important social commitments. Ensuring that everyone has access to some basic communications platform, so that they are able to get access to emergency services and avail themselves of other important government and social programs is an important value that we should strive to maintain. As will be repeated several times in this paper, the consumer must come first – it is unquestionably the case that there is a set of basic services that we should ensure are available to all consumers.[1]

The challenging questions are at what level and by what means do we maintain these commitments. Many in the telecom policy space – often those with the loudest voices – have long advocated that every American needs access to high-performance telecommunications services (today, that is high-speed Internet service) at low cost.[2] Indeed, a majority of what the FCC does today is done with this goal, directly or indirectly, in mind.[3] But while there is a strong argument that we should endeavor to provide every American with access to some level of connectivity, it is unclear what that level of connectivity should be. Indeed, as we have transitioned from narrowband voice communications to broadband Internet connectivity, the advocates and policy makers

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1. *See, e.g.,* Tom Wheeler, Chairman, Fed. Comm. Comm'n, Remarks at Ohio State University (Dec. 2, 2013), *available at* http://www.fcc.gov/document/remarks-fcc-chairman-tom-wheeler-ohio-state-university (discussing the "Network Compact").

2. *See, e.g.,* SUSAN CRAWFORD, CAPTIVE AUDIENCE: THE TELECOM INDUSTRY AND MONOPOLY POWER IN THE NEW GILDED AGE (Yale University Press, 2012).

3. Wheeler, *supra* note 1.

have consistently increased their target for sufficient levels of connectivity. This is most recently seen in the FCC's re-definition of "broadband" Internet as service of at least 25 mbps – a level of service sufficient to simultaneously stream four High Definition video streams.[4] Importantly, these changes have tracked changes in median (or even high-end) usage patterns, as opposed to tracking what is sufficient to provision socially necessary services: the resources required to watch multiple High Definition video streams are orders of magnitude greater than what is required to use the Internet to access the range of services needed to support basic social and political services.

Historically, the difficulty of determining what services belong in this set has been masked by the nature of telephone technology. The basic unit of connection – the twisted pair of copper wires – that was necessary for any service was also sufficient for most services of interest to most consumers. As a result, by requiring universal provision of the most basic services, we also facilitated the provision of more advanced services.

This no longer holds in today's digital economy. One can get connected to the communications network through various means: fiber, coaxial cable, wireless voice, fixed and mobile wireless data, satellite, and even still, the good old twisted pairs of copper wire. Each of these means of connecting to the network offers better or worse support for various services and applications. Fiber is very fast but expensive; cable and (especially) DSL are somewhat slower, but are also somewhat cheaper; wireless is generally a bit slower still (at least as of today), a bit less reliable and often somewhat more expensive than cable – but it's mobile, which is pretty great! Some of these technologies are better for voice service, for video service, for downloading large amounts of data, or for playing video games. Some of these services are also better or worse regarding our social commitments: mobile wireless, for instance, is great in that you can bring your connection to emergency services wherever you go; but it is problematic that it can be difficult for those emergency services to know your location should you need them to find you.[5]

Developments in the many technologies suggest that we need to take a more nuanced view of how to provision communications net-

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4. *See* 2015 Broadband Progress Report and Notice of Inquiry, In the Matter of Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment, No. 14-126, FED. COMM. COMM'N (Jan 29, 2015), *available at* https://apps.fcc.gov/edocs_public/attachmatch/FCC-15-10A1.pdf.

5. *See, e.g.*, Fourth Report and Order, In the Matter of Wireless E911 Location Accuracy Requirements, No. 07-114, FED. COMM. COMM'N (Jan. 29, 2015), *available at* http://transition.fcc.gov/Daily_Releases/Daily_Business/2015/db0310/FCC-15-9A1.pdf.

works to support important social commitments. The historical precedent, that we would provision a connection capable of supporting nearly the full range of possible services, was a happy historical accident. It was possible in part because the basic unit of service was capable of supporting the full range of consumer-oriented communications services. And it was possible in part because the relative elasticity of demand for communications services offered a relatively efficient mechanism for funding universal service buildout.[6]

The most difficult aspect of this more nuanced view is that we need to think seriously about what services are included in the bundle of basic social commitments.[7] Many advocates argue that every American should have access to low-cost Internet service capable of supporting streaming video services. That is quite an upgrade from the basic services historically provided through universal service – basic local voice communications service (long distance was available, but at substantial cost). Many advocates justify promoting this class of Internet service as "basic" on the grounds that such high-speed service is needed to ensure access to, for example, educational, health care, and governmental services. However, the reality is that most (and possibly all) of the services that clearly belong in the bundle of basic commitments – affordable access to a reliable communications platform that provides access to emergency services, essential government services and information, employment applications, and even basic e-commerce – do not require a class of service sufficient to support high quality streaming video. Those who think that other, more resource-intensive services do belong in the bundle should face a stiff burden in advancing their argument.

Rather than drafting a new regulatory requirement, the FCC could encourage that the services people consume (particularly video, which

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6. This is because universal service has traditionally been supported by a cross-subsidy from relatively inelastic-demand services (such as business-oriented calling plans) to relatively elastic-demand services, like local calling. This is an example of Ramsey pricing. *See* F.P. Ramsey, *A Contribution to the Theory of Taxation*, 37 Econ. J. 47, 58-59 (1927).

7. This theme, developed further in this Part, comes up frequently in discussions about universal service. Historically, the range of communications services was relatively limited and almost entirely voice-oriented; as such nearly *all* communications services could be provided over a connection sufficient to provide *any* communications service. In other words, if the telephone company could run a pair of copper wires to a customer's premises, that pair of wires would be sufficient to provide the full range of services that the telephone company offers. This meant that we had the luxury of not differentiating between the social value – and therefore the necessity of ensuring access to – different services, because any consumer who could get access to any services could get access to all services, this is not the case in the Internet era. The characteristics of a given Internet connection affect the services that can function over that connection. As such, today we need to think about the qualitative aspects of an Internet connection – what services that connection can support – not just whether there is a connection.

takes up over half of America's network peak capacity)[8] make more efficient use of bandwidth. Improved content encoding and video compression can save 30-50% of bandwidth, not to mention drive cost reductions for content and video providers.[9] As explained in a report commissioned by Ofcom, the bit rate required to achieve the same audio and video quality is halved every five years – a Moore's Law for bandwidth efficiency.[10] This means that today's networks will continue to deliver more data as innovation enables ever-increasing levels of throughput.

Indeed, the idea that high-speed broadband is necessary in order to meet these social commitments, and also to provide various educational, healthcare, government and other services, implicitly excludes various disadvantaged communities from these services.[11] The only reason that high-speed broadband is necessary for many of these services is because they have been developed to offer rich multi-media experiences. That is, they use audio and video. This means that service often are not accessible to the deaf or blind. In our race to leverage the latest and greatest technologies for various (legitimately important) services, we too often forget that not everyone can avail themselves of those technologies.

Perhaps the most tragic aspect of this premise is that it is largely needless: there is little reason for many of the services being deployed online to require rich multi-media. The push for a resource-intensive user experience is in many cases driven by the existence of the technology, not by the needs of the users. This, in turn, drives up consumer need to high-speed broadband.[12]

A better, more modest, regulatory initiative may be to require essential services – the sort of applications that would justify ensuring access to broadband – to be developed so as to not require high-speed broadband. Rather than fueling a race to use more bandwidth-intensive design practices, the government could instead lead the way in the adoption of more efficient, resource-conscious, design practices. This

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8. *See* SANDVINE, GLOBAL INTERNET PHENOMENA REPORT 2H 2014, at 5 (Fall 2014), *available at* https://www.sandvine.com/downloads/general/global-internet-phenomena/2014/2h-2014-global-internet-phenomena-report.pdf.

9. Roslyn Layton, *FCC and Verizon: There is a technical solution*, FORBES (Aug. 6, 2014), http://www.forbes.com/sites/roslynlayton/2014/08/06/fcc-and-verizon-there-is-a-technical-solution/.

10. KEN MCCANN & ADRIANNA MATTEI, TECHNICAL EVOLUTION OF THE DTT PLATFORM, ZETACAST 18-19 (Jan. 28, 2012), *available at* http://www.zetacast.com/wp-content/uploads/2013/10/Evolution-of-DTT.pdf.

11. *See infra*, Part II.

12. One may think of this as a form of Baumol's Cost Disease, in which bandwidth consumption (instead of salaries) increases across the board in response to increased bandwidth consumption by a small number of in-demand applications. *See generally* WILLIAM J. BAUMOL & WILLIAM G. BOWEN, PERFORMING ARTS, THE ECONOMIC DILEMMA: A STUDY OF PROBLEMS COMMON TO THEATER, OPERA, MUSIC, AND DANCE (1966).

would serve the parallel goals of improving accessibility and decreasing reliance on high-speed broadband.

There is a more fundamental point underlying this idea: engineers optimize – that is they design products around – the simplest and least costly constraints. This means, for example, that if bandwidth is cheap and plentiful, programmers will design applications that make use of that bandwidth. If, on the other hand, bandwidth it costly, programmers will design applications that make less use of data – and consumers will demand such applications. Indeed, we see examples of this in the mobile space, in which engineers design applications to minimize bandwidth requirements because mobile bandwidth is relatively expensive. For example as more users access Facebook with mobile devices, Facebook re-engineered its mobile platform, decreasing average monthly data use from 14MB/mo to 2MB/mo.[13] Not only does this lower long term operating costs for Facebook, the lowered data requirement of the platform encourages users to access it more. Or consider recent research that computer users on metered Internet connections are more concerned about viruses and other harmful programs – thus they expend more resources to keep their computers free of such software to keep their monthly Internet bills lower.

And consider that in environments where bandwidth is scare, for example India, Pakistan, and parts of Africa, engineers and entrepreneurs conceive applications from the beginning as needing to function within strict bandwidth constraints. Due to the limited bandwidth available in these regions, video conferencing and streaming video applications need to be delivered on less than 1 mbps connections, so they design technologies that make more efficient use of bandwidth than do engineers in economies where bandwidth is cheaper and greater.[14]

Recent telecommunications policy discussions have increasingly embraced ideas of dynamic competition and innovation. In the context of network neutrality, for instance, the FCC has made use of the idea that there is a "virtuous cycle," where openness today drives innovation in application development, which in turn will drive increased consumer demand for broadband.[15] But this cycle need not be "virtuous." If we

13. *See* Isaac Munyampama, Mark Zuckerberg at Mobile World Congress 2014 (Full Video), YOUTUBE (Feb. 24, 2014), https://www.youtube.com/watch?v=VHwkHZpXqWc (at minute 28:20).

14. *See* N. Narendra et al., *MobiCoStream: Real-Time Collaborative Video Upstream for Mobile Augmented Reality Applications*, IEEE INT'L CONF. ON ADVANCED NETWORKS & TELECOMM. SYS. 6 (Dec. 14, 2014); D. Chattopadhyay et al., *Adaptive Rate Control for H.264 Based Video Conferencing over a Low Bandwidth Wired and Wireless Channel*, IEEE INT'L SYMP. ON BROADBAND MUTLIMEDIA SYS. & BROADCASTING 6 (May 13, 2009).

15. *See* Report and Order on Remand, Declaratory Ruling, and Order, In the Matter of Protecting and Preserving the Open Internet, No. 14-28, FED. COMM. COMM'N 2 (Feb.

peg required bandwidth floors to a level sufficient to accommodate the most bandwidth intensive applications, this will tend to increase the bandwidth consumed by all applications by virtue of removing bandwidth as a constraint – this, in turn, will increase the amount of bandwidth that needs to be offered. The resulting incentive structure unravels, creating a constant upward pressure. A policy that implements such an incentive structure has the perverse effect of supporting – even incentivizing – lazy innovation and poor design practices.

A critical question – the most important one – about these services is often overlooked: where is the consumer in all of this? Those advocating high-speed broadband as a universal service often have more to gain from such programs than the median consumer. Firms such as Google, that provide services and applications that run over communications infrastructure, are clear beneficiaries; as are networking equipment manufacturers. Politicians, too, often have much to gain from this strategy, as the costs of provisioning these networks are not transparent to voters and indirectly bourn. Also, the academy is more likely to reward academics who promote regulatory programs that appear to advance social needs than those who argue against programs that appear to benefit the public interest.

However, just as communications technologies and the services that they facilitate are diverse, so too are consumer preferences. It is absolutely the case that there are basic services to which we should do our best to ensure that everyone has reasonable access. Though today we need to think more carefully about what these services are than we have historically needed. Most importantly still, we should resist the urge to treat every consumer as though he or she has the same needs and wants as Washington, DC, Silicon Valley, and academic policy makers.

Along these lines, the meaning of "universal service" is long past a need for review. Returning to the earlier discussion of how the basic unit of transmission has changed – from a unit capable of supporting the full range of telecommunications services to a range of units capable of supporting a range of services – the central question that "universal service" faces is what services need to be universal. There is a strong argument, for instance, that the basic service universally available should be sufficient to support access to basic news and information, health, educational, and governmental services. There may be some argument that such a connection should be capable of supporting basic online video services. But there is only a weak argument that high-definition, or even 4K, online video needs to be universally available.

26, 2015), http://transition.fcc.gov/Daily_Releases/Daily_Business/2015/db0312/FCC-15-24A1.pdf.

It may make sense, for instance, to reframe universal service goals to focus on enabling certain classes of applications. Rather than define universal service as generic high-speed Internet (itself defined as, e.g., "25 mbps down/3 mbps up" service[16]), universal service could be defined as service sufficient to support a minimum bundle of services. That bundle may include, for instance, healthcare, education, employment, and government services; common news and information services; basic online video services; and VoIP and other common over-the-top services.

There are two basic challenges to such an approach. The obvious challenge is defining what services should be included in this basic bundle – though this is the sort of task routinely overseen by regulators. A more subtle and potentially difficult challenge is that it may create an incentive for application designers to make excessive use of bandwidth. This incentive may exist because access providers would be required to provide a bundle of services sufficient to support those applications, no matter how inefficiently designed they may be. This approach to defining universal service, therefore, would need to be careful to take this into consideration. It may, for instance, be possible to competitively benchmark the bandwidth (and other) requirements of like-services in determining whether an access provider is sufficiently provisioning its network.

More generally, the Commission may want to encourage similar experimentation with how Internet services are marketed and sold. Few consumers have an appreciable understanding of the difference between 6 mbps and 25 mbps service, or of the difference between the resources required to deliver an e-mail as compared to a 60-minute streaming video. The norm of marketing Internet access in terms of peak download and upload capacity is confusing to consumers, ignores the possibility of service commitments and competition along other metrics (e.g., latency or jitter), and is generally irrelevant to what consumers care about.

It would almost certainly be more relevant and less confusing to consumers if Internet access was marketed in terms of the services it supports. Perhaps even more important, such marketing would likely provide consumers with more meaningful remedies should access providers fail to live up to these promises. An express commitment that a given service package is capable of supporting HD streaming video, for

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16. *See* 2015 Broadband Progress Report and Notice of Inquiry, In the Matter of Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment, No. 14-126, FED. COMM. COMM'N (Jan 29, 2015), *available at* https://apps.fcc.gov/edocs_public/attachmatch/FCC-15-10A1.pdf ("we find that, having "advanced telecommunications capability" requires access to actual download speeds of at least 25 Mbps and actual upload speeds of at least 3 Mbps (25 Mbps/3 Mbps).").

instance, would more likely create an enforceable contractual commitment than the current approach to marketing; it would make enforcement actions by the FCC or FTC easier to bring and more likely to be successful; and it would require Internet access providers to upgrade their infrastructure to match changing requirements of various services. Anathema to the views of many policy advocates – those, for instance, who would view this idea as turning Internet access into a "cable-like" system – it could be among the most consumer-friendly of possible changes to how Internet services are marketed and provided.[17]

A final possible innovation to universal service would be to allow localities to "buy out" of the system. While universal service, as defined by the FCC, may be an important federal goal, local municipalities may face other priorities, or have other ideas about how to best achieve the universal service goals. Just as we should recognize consumer welfare and preferences should be the loadstone of telecommunications policy, we should recognize that municipal governments may have a better sense of the wants and needs of a local population than the federal government. It may therefore be reasonable to allow local governments to "buy out" of federally-administered universal service programs by accepting a one-time payment of some amount less than that which would be invested in the locality through the federal program.

II. PREMISE TWO: HIGH-SPEED BROADBAND IS NECESSARY FOR EDUCATION, HEALTH, GOVERNMENT, AND OTHER SOCIAL SERVICES

The idea that high-speed broadband is necessary for education, healthcare, and other social and government services, is related to the first premise. This premise is problematic both because it is factually dubious, and also because its power is based in an implicit appeal to inherently emotional issues. It creates a sense that the only way to support high-quality education, provide access to healthcare and employment opportunities, and address concerns about the digital divide is to support a specific broadband policy – namely one of extensive government subsidies for high-speed broadband. As recognized in the previous section, broadband Internet service and other communications technologies support many important services that should be viewed as basic social commitments – but the focus in telecom policy debates should be on ensuring Internet access that is sufficient to realize these basic social commitments, not on subsidizing higher-speed luxury services or services that the market would otherwise provide at competitive prices.

The first, most important response to this premise is that high-

17. *See, e.g.*, *The Team Behind John Wooley*, INTERNET MUST GO, *available at* http://www.theinternetmustgo.com/about/ (last visited June 1, 2015).

speed broadband connectivity isn't typically needed for education, healthcare, or other social services. It is especially true that the bandwidth sufficient for high-quality video streaming services – a critical benchmark for broadband advocates and the FCC[18] – isn't necessary for these services. For example, today's system requirements for video conferencing applications, including programs routinely used for distance education and MOOCs ("Massive Online Open Courses"), is in the 1-2 mbps range.

The developers of these applications recognize that their products need to work even in low bandwidth environments, so they design their applications to function even without high-speed broadband. Adobe Connect, for instance, only requires 512 kbps connection for classroom participants. Coursera, a popular MOOC platform developed by Stanford, Princeton, the University of Michigan, and the University of Pennsylvania and today comprises a consortium of over 100 universities, has a mobile-optimized app that allows students to view recorded class sessions on their mobile devices. Similarly, Adobe Connect has a mobile application that allows for real-time video participation.

More bandwidth is of course preferable, but typically is not required for basic operation. In technical terms, it is important to recognize that most of the video delivered in the MOOC setting is highly compressible. Unlike television or movie content, most of the frame is generally static, with relatively simple background settings. Such video is readily and substantially compressible. Moreover, because MOOC software needs to support the typical student's computer hardware (e.g., a moderate resolution monitor displaying both in-class video and other class-related materials on a single screen), the typical resolution of video in the online teaching environment will be far below that of HD streaming video services.[19] Additionally, and perhaps counterintuitively, MOOCs with their large enrollments generally require less bandwidth than smaller online teaching settings. The large class sizes mean that most video will be delivered one way, from the instructor to the students – due to the large number of students, interactivity will be achieved through non-video means (such as quizzes or written questions moderated by an in-class assistant). In such a setting, the user experi-

18. *See, e.g.,* 2015 Broadband Progress Report, No. 14-126, FED. COMM. COMM'N (listing video as the first "common application" requiring redefinition of broadband Internet service to require 25 mbps speeds).

19. *See also* Arnold Kling, *Many-to-One vs. One-to-Many: An Opinionated Guide to Educational Technology*, AM. ENTER. INST. (Sept. 12. 2012), http://www.aei.org/publication/many-to-one-vs-one-to-many-an-opinionated-guide-to-educational-technology/ (arguing that the more fundamental change to education enabled to technology is many-to-one teaching through adaptive textbooks, rather than the massive one-to-many model of teaching facilitate by MOOCs).

ence will be less sensitive both to bandwidth and latency variations.

This reveals another often overlooked aspect of broadband policy debates: bandwidth isn't the only and often isn't the most important, metric. Latency (the time it takes a packet of data to traverse the network), jitter (the chance in latency between packets), and packet loss (the percentage of packets of data that never make it across the network) are incredibly important metrics, especially for applications in education and health care – applications where the user may need to interact in real time with a teacher, classmates, or healthcare professional. Substantial or irregular latency and packet loss can lead to jumpy, broken, or lost audio and video – it is preferable to have a lower resolution with consistent-quality audio and video than high-quality with unreliable audio and video.

The idea that latency and packet loss can be as important as bandwidth is not new, but it is one that plays little role in contemporary policy debates. The failure to appreciate the importance of these metrics is a serious flaw in these policy discussions. It is akin to having a transportation policy that focuses on miles of highway constructed but pays no attention to whether those highways actually decrease commute times or accidents.[20]

Indeed, where education, healthcare, or other services require high-performance Internet service, one important alternative to provisioning high-speed Internet service in high-cost areas is to rely instead on quality of service (QoS) and prioritization techniques to ensure sufficient performance over lower-speed links. This would not allow a service requiring an average 2 mbps throughput to operate over a 1 mbps link – but, where such a service may not function well on even a 3-4 mbps connection, prioritization could allow it to operate satisfactorily over a lower-speed (e.g., 2 mbps) link. To make sure this paragraph's suggestion is clear: lower-speed links that do not adhere to "network neutral" routing may often be able to support the same services that would require a higher-speed (and higher-cost) connection on a neutral network.

Another important, and often overlooked, metric is adoption. In recent years survey evidence, such as the Pew Research Center's study on Internet and American Life,[21] has made clear that availability and price

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20. *See, e.g.,* Steinberg & Zangwill, *The Prevalence of Braess's Paradox*, 17 TRANSP. SCIENCE 301 (1983) (discussing Braess's Paradox, which demonstrates that adding roads to a transportation network can actually increase traffic congestion).

21. *Broadband Technology Fact Sheet*, PEW RESEARCH CTR., http://www.pewinternet.org/fact-sheets/broadband-technology-fact-sheet/ (last visited May 29, 2015); Aaron Smith, *Older Adults and Technology Use*, PEW RESEARCH CTR. (Apr. 3, 2014), http://www.pewinternet.org/2014/04/03/older-adults-and-technology-use/; Aaron Smith, *Statement of Aaron Smith – Broadband Adoption: The Next Mile*, PEW RESEARCH CTR. (Oct. 29, 2014), http://www.pewinternet.org/2013/10/29/statement-of-aaron-smith-

are not the primary reasons that people in the United States do not have Internet access. Rather, low adoption is driven by concerns about usability, relevance, and worries about online harms.[22] These concerns are particularly salient among older demographics – those who would be most likely to benefit from (or even need) Internet-based healthcare, government, and other services.

Other issues with the idea that high-speed broadband is necessary for these services become clear when looking at each service individually. In the case of health care, for instance, it is unlikely that residential users would have any need for the sort of telemedicine devices that require high-speed connections.[23] Rather, consumer-grade healthcare applications are more likely to be used for monitoring and reporting – applications that either send occasional large bursts of data or send consistent, possibly latency-sensitive, small packets of data, and that in either case do not require particularly high-speed connections. The greater challenge for these applications is likely to come from the multiplicity of such devices – the so-called Internet of Things, where dozens of devices in one home or millions of devices on larger networks. There is concern that millions or billions of devices, each sending small bursts of data, will overwhelm networks. In such cases, even if the network provides sufficient bandwidth, it may not be able to handle the multiplicity of connections. To use the comparison with highways, the more cars you put onto a single road, the more accidents and delays there will be, independent of the speed limit or number of lanes. A network transmitting 100 million small packets per second will be far more congested than one transmitting 10 million large packets per second, even if they are both transmitting the same total amount of data.[24]

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broadband-adoption-the-next-mile/.

22. *Broadband Fact Sheet*, *supra* note 21; *Older Adults and Technology Use*, *supra* note 21; *Statement of Aaron Smith – Broadband Adoption: The Next Mile*, *supra* note 21.

23. Consumer- and patient-oriented devices are unlikely to require substantial bandwidth. Rather, they are more likely to require a reliable connection of almost any speed. See, for example, the Pipaluck telemedicine device, a comprehensive medical examination workstation used in Greenland since 2008, which only requires a 1 mbps connection. Roslyn Layton, *Broadband in Greenland: How Non-neutral Traffic Management Betters Society*, TECH POLICY DAILY (May 22, 2015, 6:00AM), http://www.techpolicydaily.com/internet/broadband-in-greenland/ (discussing the Pipaluck). Devices that require high bandwidth, such as MRIs and other advanced imaging devices, are generally housed in institutional settings (e.g., hospitals). *Id.*

24. Importantly, most network switches are provisioned in terms of the number of packets they can switch per second, as the switching logic is more computationally intensive than copying data from an input port to an output port. For instance, the standard line-rate gigabit Ethernet port can switch 1,488,100 packets per second. If the typical packet size is 100 bytes, which may be typical for machine-to-machine communications, the network will only be able to run at less than 20% of its provisioned capacity. *See, e.g.*, *Bandwidth, Packets Per Second, and Other Network Performance Metrics*, CISCO,

And, while each student remotely connecting to a video-based classroom may only need a modest amount of bandwidth, on the institutional side, connecting several students to the classroom will require a much greater amount of bandwidth for the institution as a whole. There is legitimate concern that students need access to some sufficient level of bandwidth at home for educational purposes, but to date there have not been serious efforts to determine how much bandwidth is "sufficient" for educational purposes – rather, advocates' estimates have tracked median consumer bandwidth preferences, which in turn track the bandwidth requirements for high-definition streaming video content.

Similarly, the amount of bandwidth needed by a hospital for real-time telemedicine applications, even for things as simple as transferring a patient's MRI data to a doctor in another hospital for a "virtual" consultation, can be substantial. So, it is certainly the case that that these institutions need for high-speed Internet access. But the market for these sort of institutional connections is much different from – and much more competitive than – the market for consumer-oriented Internet access. Still, as is usually the case for commercial-quality products compared to their consumer-oriented counterparts, Internet connections suitable to meet these institutions' needs are often quite expensive, especially for public and non-profit institutions such as schools and hospitals. While current programs to assist in getting these institutions online[25] have their problems, there is a much stronger argument to be made for government support of these institutional Internet-access needs than for government support of consumer-oriented high-speed Internet access.

It is undoubtedly the case that broadband Internet can be an important tool for various educational, healthcare, and other social and government services. To be sure, it is important to distinguish between consumer-oriented Internet service and Internet service used by institutions such as schools and hospitals. These are two different markets with different requirements.

Speed – especially "high-speed" – isn't the only or most important metric to consider when provisioning these services. It is unfortunate that advocates of government-sponsored consumer high-speed broadband Internet use the indisputable importance of services such as healthcare and education to buttress their argument for government intervention in the high-speed broadband market. At best, this represents

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http://www.cisco.com/web/about/security/intelligence/network_performance_metrics.html (last visited May 29, 2015).

25. *See, e.g.*, *E-Rate – Schools & Libraries USF Program*, FED. COMM. COMM'N, https://www.fcc.gov/encyclopedia/e-rate-schools-libraries-usf-program (last visited May 19, 2015).

a misunderstanding of these services' actual requirements. It may also represent a willingness on the part of broadband advocates to assert their idealized view of how the Internet should be used over the needs of those who actually will rely on these services. At worst, it is a deliberate tactic, being used as an emotional appeal to advocate for a preferred policy that is not otherwise supportable by technical requirements.

III. PREMISE THREE: WIRELESS CAN'T COMPETE WITH CABLE

The next premise is that wireless is not a viable competitor to wireline broadband services – and in particular that it is not a viable substitute for cable.

The basis for this premise is seemingly reasonable: both wireline services (such as cable) and wireless services transmit data over electromagnetic spectrum. They both use the same techniques to encode machine-intelligible bits of data into electromagnetic energy, and the laws of physics subject both to the same constraints. Wireless carriers in any geographic area share several hundred megahertz of spectrum, and their signals are subject to interference from both other carriers and natural and artificial sources.[26] Coaxial cable, on the other hand, gives a cable company (at least) roughly 800-MHz of dedicated spectrum – several times the spectrum available to most current wireless carrier – and transmits signals along a shielded corridor that protects them from most sources of interference.[27] Because coaxial cable offers cable companies more spectrum than is available to wireless carriers, and because that spectrum is better shielded from interference, one may rea-

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26. Prior to the recently-concluded AWS-3 Auction, *see Public Notice: Auction of Advanced Wireless Services (AWS-3) Licenses Closes*, FED. COMM. COMM'N (Jan. 30 2015), *available at* http://apps.fcc.gov/edocs_public/attachmatch/DA-15-131A1.pdf, there were approximately 580 MHz of spectrum available in US markets, spread across several bands. *See* In the Matter of Policies Regarding Mobile Spectrum Holdings, No. 12-269, FED. COMM. COMM'N, (May 15, 2014), *available at* https://apps.fcc.gov/edocs_public/attachmatch/FCC-14-63A1.pdf (listing CMRS-licensed spectrum bands including the 700 MHz band (70 MHz between 698 – 806 MHz), Cellular band (50 MHz between 824-849 and 869-894 MHz), SMR band (14 MHz between 817-824 and 862-869 MHz), PCS band (120 MHZ between 1950-1910 and 1930-1990 MHz), AWS-1 (90 MHz between 1710-1755 and 2110-2155 MHz), WCS (20 MHz between 2305-23020 and 2345-2360), BRS (156.5 MHz between 2496-2690 MHz), and approximately 65 MHz in various bands between 1670-2000 MHz. The AWS-3 and upcoming incentive auctions are likely to yield up to 120 MHz).

27. Traditional modern cable systems (e.g., those capable of carrying 120 television channels) typically had an 800 MHz capacity. More recent systems are installed with even greater capacity. 1.2 and 1.8 GHz are typical. *See* DATA-OVER-CABLE SERVICE INTERFACE SPECIFICATIONS, CABLE LABS, INC. § 7.2 (2013), *available at* http://www.cablelabs.com/wp-content/uploads/specdocs/CM-SP-PHYv3.1-I01-131029.pdf.

sonably expect that cable companies will always have a competitive advantage compared to wireless.

While this intuitive understanding seems reasonable, it grossly oversimplifies the underlying technology, unsurprisingly leading to incorrect conclusions. As an initial matter, the differences between wireline and wireless explained above refer to the peak capacity of individual transmission units – i.e., a coaxial cable or cell tower – not the capacity available to individual users. An individual coaxial cable is typically shared by a couple hundred users; an individual cell sector may be shared by a few to a few hundred active users. Therefore, the correct thing to look at is each system's capacity per user, not the peak capacity of the individual transmission unit, and the costs (in terms of both money and time) of provisioning new resources to add capacity or to address congestion.[28] Whether provisioning additional capacity to meet demand is more economic for either cable or wireless will depend on the particular characteristics of a given network, it's surrounding physical and regulatory environments, and the underlying cost structure.

More important, wireless has clear advantages over coaxial cable in the long run. This is because anything coax can do wireless can do, too – and there are things that wireless can do to improve performance that coaxial cannot. As mentioned above, both technologies transmit a signal over spectrum, and both use the same encoding techniques. Any new encoding technique that works for a signal sent via cable will also work for a signal sent via wireless, but cable has a fundamental limitation compared to wireless: a cable transmits its signal, in one dimension, along a straight line. A wireless signal is transmitted through space, in three dimensions. This means that wireless can avail itself of transmission and reception techniques using multiple antennas – so-called spatial diversity or antenna arrays. Such systems are often referred to as MIMO ("multiple-input, multiple-output," referring to the number of receiving and transmitting antenna).

MIMO technologies have been taking the wireless world by storm over the past decade – early MIMO technologies have been incorporated into current standards for WiFi and LTE. And there is active discussion

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28. Assuming a greenfield build, the economic case for wireline over wireless generally turns positive with three or more active Internet users per household. *See* Michael Horney & Roslyn Layton, *Innovation, Investment and Competition in Broadband and the Impact on America's Digital Economy*, MERCATUS CTR. (August 15, 2014), *available at* http://mercatus.org/sites/default/files/Layton-Competitionin-Broadband.pdf. This assumes that the users do not also have mobile Internet access, or derive incremental value from mobility. Where that is the case, the economic case for wirelines likely turns positive at an even larger household size.

of developing "Massive MIMO" technologies for 5G wireless networks.[29] There are three primary applications for MIMO: interference mitigation, signal multiplexing, and beam-forming. By comparing the signals received at each of multiple antennas, complex algorithms are able to detect, and cancel-out, interference. This means that MIMO-based wireless transmissions can have interference characteristics comparable to those of coaxial cable. Using this interference-cancellation technology, MIMO also allows multiple signals to be sent over the same spectrum simultaneously. In other words, a carrier with 40-MHz of spectrum could use a 4x4 antenna to transmit 160-MHz worth of signal (4 x 40-MHz carriers) in that spectrum. There is some loss as signals are added – but MIMO systems are already able to increase capacity by 200% to 300% using 4 streams. In other words, 300-MHz of wireless spectrum can carry as much as 800-MHz of coaxial spectrum. Massive MIMO technologies are being developed today that could increase performance by another factor of 30 in 5G wireless networks.

(The third basic MIMO technique, beam-forming, is a bit too complicated to explain here. Basically, using multiple antennas, a wireless signal can be focused in a single direction (into a "beam") – or into multiple beams, each going a specific direction. The beams don't interfere with each other, such that each can use the full spectrum capacity of the sector, allowing more users to be served by a single cell or access point without reducing speeds available to each other user.)

Some advocates dismiss MIMO's capabilities by arguing that MIMO does not work well in a mobile setting. This is not a technically accurate statement. The correct statement is that mobile MIMO cannot work better than fixed MIMO. MIMO technologies can work in a mobile setting – and, indeed, they are already being implemented in LTE devices. The number of antennas that can be fit in a cellphone is limited (typically to two) due to the size of the device; and fast-moving devices (e.g., a cellphone in a car) receive reduced benefits from, for instance, interference mitigation and beam-forming. But the basic technologies do work in a mobile setting, are being deployed today, and are improving at a rapid pace.

There is a more fundamental problem with the critique that MIMO doesn't work well in a mobile setting: high-speed broadband is generally needed in fixed, not mobile, settings. That is, you are far more likely to need high-speed broadband to watch high quality streaming video on your large television than on your small phone. The proper comparison between cable and wireless capacity is between cable and fixed wireless.

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29. *See, e.g.*, Erik G. Larsson et al., *Massive MIMO for Next Generation Wireless Systems*, IEEE COMM., Feb 2014 (an example of an article in IEEE Communications, which regularly includes articles discussing developments in MIMO in the 5G setting).

Here, given the availability of, and continued development of, MIMO technologies, the long-run advantage is with wireless. It is difficult to argue that wireless cannot compete with cable in a world where a single base station using 20-MHz of spectrum is capable of concurrently delivering 20 mbps service to 950 homes over a multi-mile radius.[30]

This is particularly true given that the capacity of cable is limited to perhaps a couple of GHz of spectrum. Cable operators cannot change this without massive upgrades of their infrastructure – which would likely require replacing the last mile with fiber instead of coaxial cable. Wireless is not subject to this limitation. As wireless applications are reaching into the millimeter-band ranges (technically in the 30- to 300-GHz range, but often also including spectrum in the 15-GHz range), engineers are developing fixed wireless systems delivering 10- to 100-gbps class performance over multiple-kilometer distances, and mobile wireless delivering 10- to 100-mbps class performance in dense cell environments.[31] Such technologies have real potential to dethrone coaxial cable as the dominant residential fixed broadband technology.

One of the most common critiques of this possibility is that millimeter-wave spectrum is subject to substantial atmospheric attenuation, primarily in the form of "rain fade." Because the wavelength of millimeter-wave spectrum is similar in magnitude to the diameter of rain drops and other atmospheric moisture, such moisture can cause substantial degradation in signal quality. But the most recent research suggests that rain fade is a surmountable obstacle, particularly in cellular networks but also over longer distances.[32] The other common critique is

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30. *See, e.g., Id*.

31. *Id*.; *see generally* EVOLUTIONARY & DISRUPTIVE VISIONS TOWARDS ULTRA HIGH CAPACITY NETWORKS, INT'L WIRELESS IND. CONSORTIUM (April 2, 2014), *available at* https://www.keysight.com/main/editorial.jspx?cc=US&lc=eng&ckey=2280123 &id=2280123&cmpid=46278; *see also* Eric Torkildson, et al, *Millimeter-wave MIMO: Wireless Links at Optical Speeds*, ALLERTON CONF. ON COMM., CONTROL, & COMP. PROC. 44 (2006), *available at* http://www.ece.ucsb.edu/wcsl/Publications/mm_MIMO_Allerton06.pdf; *see also* Mark Jackson, *Ericsson Trial 10Gbps 5G Mobile Broadband Network in Japan*, ISPREVIEW (May 12, 2014, 8:36AM), http://www.ispreview.co.uk/index.php/2014/05/ericsson-trial-possible-10gbps-5g-mobile-broadband-network-japan.html (discussing testing of 10gbps+ cellular technologies in the 15 GHz band).

32. Torkildson, *supra* note 31, at 4 ("a 5 Gbps link over a 1 km range, even in heavy 25 mm/hr rain, can be maintained with only 160 mW transmit power at each subarray."); F. Versluis, *Millimetre wave radio technology,* MICROWAVE ENG'G EUR. 33 (Nov 2008) ("The physical properties of high-frequency radio transmission in the presence of various weather conditions are well understood. With proven models of worldwide weather characteristics available, link distances [in the 71 - 86 GHz range] of several miles can confidently be realized over most of the globe. ... New millimetre wave radio systems can provide 'fibre like' connectivity at distances of up to 2 miles in cities such as New York, and can deliver significantly longer lines in cities with drier climates."); Theodore Rappaport,

that the power required to transmit at millimeter-wave frequencies is substantially greater that that required to transmit in the traditional CMRS bands – and, to a lesser extent, that the signal processing required by MIMO technologies also requires more power than traditional signal processing. Both of these are valid concerns in the mobile setting. In the fixed wireless setting, where radio equipment does not rely on battery power, these issues are not a serious concern.

And while the characteristics of mobile devices – that they are small and mobile – means that they will not be able to reap these benefits to the same extent as fixed wireless networks, they too stand to see marked improvements in performance with these technologies. Indeed, the short wavelength of millimeter-wave spectrum means that mobile devices operating on that spectrum are better able to take advantage of MIMO technologies. In particular, the shorter wavelength means that more antenna can be placed in a single device, substantially increasing the device's resistance to interference and signal fade and increasing the potential bandwidth available to the device.[33] This next generation of devices therefore has the potential to offer better performance than current lower-frequency spectrum technologies. It is entirely possible that the next generation of mobile wireless devices will offer performance comparable to what is available from cable Internet providers today; in the future they may even be on parity with then-available ca-

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et al, *Millimeter Wave Mobile Communications for 5GCellular: It Will Work!*, 1 IEEE ACCESS 335, 338 (May 2013), *available at* http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6515173 ("A common myth in the wireless engineering community is that rain and atmosphere make mm-wave spectrum useless for mobile communications. However, when one considers the fact that today's cell sizes in urban environments are on the order of 200 m, it becomes clear that mm-wave cellular can overcome these issues. Fig. 1 and Fig. 2 show the rain attenuation and atmospheric absorption characteristics of mm-wave propagation. It can be seen that for cell sizes on the order of 200 m, atmospheric absorption does not create significant additional path loss for mm-waves, particularly at 28 GHz and 38 GHz. Only 7 dB/km of attenuation is expected due to heavy rainfall rates of 1 inch/hr for cellular propagation at 28 GHz, which translates to only 1.4 dB of attenuation over 200 m distance. Work by many researchers has [demonstrated] that for small distances (less than 1 km), rain attenuation will present a minimal effect on the propagation of mm-waves at 28 GHz to 38 GHz for small cells."); Zhao, et al, *28 GHz Millimeter Wave Cellular Communication Measurements for Reflection and Penetration Loss in and around Buildings in New York City*, 2013 IEEE INT'L CONF. ON COMMS. 1 (June 2013) ("In addition, despite myths to the contrary, rain attenuation and oxygen loss does not significantly increase at 28 GHz, and, in fact, may offer better propagation conditions as compared to today's cellular networks when one considers the availability of high gain adaptive antennas and cell sizes on the order of 200 meters.").

33. T. S. RAPPAPORT ET AL., MILLIMETER WAVE WIRELESS COMMUNICATION (Prentice Hall, 2014); *See also* Tianyang Bai & Robert W. Heath, Jr., *Coverage and Rate Analysis for Millimeter Wave Cellular Networks*, 14 IEEE TRANS. WIRELESS COMM'S.1100, 1100 (2015) (citing same).

ble offerings.

And lest we forget, portability is a desirable characteristic that itself creates a great deal of value for many consumers. Here, consumers have been voting with their wallets in ways that demonstrate the value of mobility. This is a fundamental point that those who assert wireless cannot compete with wireline broadband have yet to confront: evidence shows that for many consumers wireless does compete.[34] Wireless broadband subscription growth is outpacing wireline broadband growth by double-digit percentages in the US and other countries around the world. Mobile broadband has proven to be attractive relative to wireline for several discrete populations. This is particularly true for some minority groups, younger or single demographics, and those who move or travel frequently.[35]

Contrary to common assertions by many who would like to see the market for high-speed Internet service more broadly regulated – and especially by those who see government-sponsored deployment of high-speed broadband infrastructure as the necessary response to a perceived lack of competition in the communications industry – wireless is a strong potential competitor to cable Internet. Today, wireless may play a limited role as a competitor to wireline Internet services, but its future as a competitor is bright. Indeed, the technological opportunities for growth in wireless capacity likely exceed those available to coax-based broadband providers and should provide comfort to those who are worried about the relative lack of competition in today's communications marketplace.

IV. PREMISE FOUR: AN OPEN INTERNET IS NECESSARY FOR INNOVATION AND NECESSARILY BENEFITS CONSUMERS

While it is true that openness can facilitate some types of innovation, it both precludes other forms of innovation and imposes costs of its own.[36] In the telecommunications context, openness is mostly about network neutrality – the idea that broadband providers should not be able to charge users or content providers for preferential access to specific services, let alone block specific content or services entirely (absent

34. In Denmark 7 percent of the population has chosen to rely solely on 3G or 4G mobile connectivity. Mobile-only broadband subscribers outnumber FTTH subscribers by 100,000, even though 100 mbps connections are available to 70 percent of the population. *See* Roslyn Layton, *The European Union's Broadband Challenge*, AM. ENTER. INST. (Feb. 19, 2014), http://www.aei.org/publication/the-european-unions-broadband-challenge/.

35 Mary Madden et al., *Teens, Social Media, and Privacy*, PEW RESEARCH CTR. (May 21, 2013), http://www.pewinternet.org/2013/05/21/teens-social-media-and-privacy/.

36. For one of the seminal treatments of this subject, *see* Timothy Bresnahan & Manuel Trajtenberg, *General Purpose Technologies "Engines of Growth?",* 65 J. ECONOMETRICS 83, 94–96 (1995).

some compelling legal or technical justification).

The key takeaway from the relevant technical and economic literatures is that "openness," in whatever forms it may take, is rarely unambiguously good or bad. It is unquestionably the case that open access can facilitate certain types of innovation. It reduces R&D and other transaction costs (especially search and negotiation costs to get permission or access to use existing infrastructure) and reduces opportunities for rent extraction by those who otherwise control an infrastructure. On the other hand, it makes some forms of innovation more expensive or difficult to implement.

There is substantial literature showing the benefits of vertical integration[37] and the importance of defining proper modular boundaries.[38] Nowadays, however, this point can be made more simply by analogy: Apple's hardware and software designs are part of a tightly-controlled, vertically integrated, closed product ecosystem. Apple would not exist if we had the equivalent of network neutrality for computer hardware or software. This does not mean that either an open or a closed model is necessarily better in any given case; it does mean that we want a more nuanced approach than one that mandates either approach in every situation.

It should be noted that engineers employed by the Department of Defense to develop the then top secret project of the ARPANET, the forerunner of today's internet, did not work in an "open" environment. Openness or neutrality was not a goal for the design of that system. This is not to say that they would have frowned on such concepts, but as ARPANET engineer and co-author of the original "end to end paper" David Clark explains:

> Back then we didn't use the word 'open'. It's not really part of our language. We understood generality…if you go back to the end to end paper I wrote with Jerry Saltzer and David Reed – which has been used as a religious tract far beyond what it will sustain if you are a strict constructionist (A person who construes a legal text or document in a specified way) – I believe I verified that the paper does not contain word 'open'. That paper was about correctness, which is a narrow objective. It's not even about performance.[39]

The assertion that the internet was "always open and neutral" isn't necessarily the characterizations of its founding engineers.

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37. *See also* Brent Skorup & Adam Theirer, *Uncreative Destruction: The Misguided War on Vertical Integration in the Information Economy*, 65 FED. COMMS. L.J., no. 2, Apr. 2013, *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2162623.

38. *Id*.

39. Julius Genachowski, *Open Internet Advisory Committee Meeting*, FED. COMM. COMM'N (July 20, 2012, 10:00AM), http://www.fcc.gov/events/open-internet-advisory-committee-meeting (at minute 65).

There is no doubt that platforms can have market power, but there is also evidence that consumers benefit from the bundling effects of platforms. The point is openness and neutrality can have both welfare enhancing and welfare reducing effects, but a blanket standard applied to just one part of the Internet or all parts of the Internet will likely have negative consequences for consumers. It may be better to adjudicate these matters on an *ex post*, case-by-case, basis to ensure that consumers are not deprived by the preclusion of any technology or business model

The scale is tipped even further against mandated openness and neutrality in the case of the Internet when looking at the literature of two-sided markets, which numbers more than 360,000 articles and is less than a decade old. The Internet is a two-sided market – a market in which two or more distinct groups of consumers are brought together via some intermediary platform. That is, users and Internet content providers (e.g., firms such as Google, Facebook, and Netflix) reach each other via the Internet. This has both technical and economic implications.

On the technical side most historical perspectives on the Internet architecture make clear that, while it has long had an "open" character, this character is at least in part accidental, does not equate with "neutrality," and in any event may be undesirable.[40]

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40. For a sampling of technical literature explaining that mandated network neutrality is not desirable, *see* Richard T.B. Ma et al., *On Cooperative Settlement Between Content, Transit and Eyeball Internet Service Providers*, 19 IEEE/ACM TRANSACTIONS ON NETWORKING 802, 812-813 (June 2011) *available at* http://dna-pubs.cs.columbia.edu/citation/paperfile/194/ToN_InternetEco2.pdf ("Paid-peering is identical to zero-dollar peering in terms of traffic forwarding, except that one party needs to pay another. By applying the Shapley revenue distribution to the Content-Transit-Eyeball model, we find the justification of the existence of paid-peering between transit ISPs. ... "Our previous work ... showed that ... selfish ISPs have incentives to perform globally optimal routing and interconnecting decisions to reach an equilibrium that maximizes both individual profit and global social welfare. ... In this paper we extend our model ... Our result [finds instances where paid-peering can benefit welfare]."); David Clark, *Network Neutrality: Words of Power and 800-Pound Gorillas*, 1 INT'L J. COMM. 701, 705-706 (2007), *available at* http://groups.csail.mit.edu/ana/Publications/PubPDFs/Network-Neutrality-Words%20of%20Power%20and%20800-Pound%20Gorillas.pdf ("As a technical mechanism, QoS seems to be beneficial. It directly addresses the real performance requirements of different sorts of Internet traffic … This reality begs the question of whether we can find a set of rules that might distinguish between "good" or "acceptable" forms of discrimination, and "bad" discrimination. Unless we can find a bright line, using regulation of discrimination to define acceptable behavior may cause more trouble than it cures."); Thomas Hazlett & Joshua Wright, *The Law and Economics of Network Neutrality*, 45 IND. L. REV. 767, 785 (2011), *available at* http://mckinneylaw.iu.edu/ILR/pdf/vol45p767.pdf (quoting 2009 Comm Daily discussion with David Clark: "'The network is not neutral and never has been,'" Clark said, dismissing as 'happy little bunny rabbit dreams' the assumptions of net neutrality supporters that there was once a 'Garden of Eden' for the Internet.

Similarly, on the economic side, the crux of the two-sided markets analysis is that the platform that brings the different sides together – that is, broadband Internet access providers – ordinarily charge either or both sides of the market for access to the other. How much to charge each side, including whether to charge either side nothing or even to subsidize one side's access to the platform, involves a complex set of tradeoffs – and, most important, how much each side is charged can have substantial effects on the social value of the network. Critically, and we will say this in italics because it is so important, *the literature studying two-sided markets consistently shows that there is no reason to believe that a network neutrality rule necessarily benefits consumers,*

NSFnet, an early part of the Internet backbone, gave priority to interactive traffic, he said: 'You've got to discriminate between good blocking and bad blocking.'"); Jon Crowcroft, *Net Neutrality: The Technical Side of the Debate*, 1 INT'L J. COMM. 567, 567 (2007), *available at* http://ijoc.org/index.php/ijoc/article/viewFile/159/84 ("This paper describes the basic realities of the net, which has never been a level playing field for many accidental and some deliberate reasons"; "In conclusion then: We never had network neutrality in the past, and I do not believe we should engineer for it in the future either."); Douglas A. Hass, *The Never-Was-Neutral Net and Why Informed End Users Can End the Net Neutrality Debates*, 22 BERKELEY TECH. L.J. 1565 (2007), *available at* http://scholarship.law.berkeley.edu/cgi/viewcontent.cgi?article=1717&context=btlj; S. Blake et al., *An Architecture for Differentiated Services*, REQUEST FOR COMMENTS 2475, at 2 (Dec. 1998), *available at* https://tools.ietf.org/html/rfc2475 ("Service differentiation is desired to accommodate heterogeneous application requirements and user expectations, and to permit differentiated pricing of Internet service."); K. Nichols et al., *A Two-Bit Differentiated Services Architecture for the Internet*, REQUEST FOR COMMENTS 2638, at 3 (July 1999), *available at* https://tools.ietf.org/html/rfc2638 (discussing paid prioritization, saying: "It is expected that premium traffic would be allocated a small percentage of the total network capacity, but that it would be priced much higher."); R. Braden et al., *Integrated Services in the Internet Architecture: An Overview*, REQUEST FOR COMMENTS 1633, at 1 (July 1994), *available at* https://tools.ietf.org/html/rfc1633 ("real-time applications often do not work well across the Internet because of variable queueing delays and congestion losses. The Internet, as originally conceived, offers only a very simple quality of service (QoS), point-to-point best-effort data delivery. Before real-time applications such as remote video, multimedia conferencing, visualization, and virtual reality can be broadly used, the Internet infrastructure must be modified to support real-time QoS, which provides some control over end-to-end packet delays." ... "The first assumption is that resources (e.g., bandwidth) must be explicitly managed in order to meet application requirements. … An alternative approach, which we reject, is to attempt to support real-time traffic without any explicit changes to the Internet service model. The essence of real-time service is the requirement for some service guarantees, and we argue that guarantees cannot be achieved without reservations. … We conclude that there is an inescapable requirement for routers to be able to reserve resources, in order to provide special QoS for specific user packet streams, or 'flows'."); *see also* Justin (Gus) Hurwitz, *An unfounded principle: Ammori's non-neutral network history*, TECH POLICY DAILY (Nov. 13, 2013, 6:00AM), http://www.techpolicydaily.com/internet/unfounded-principle-ammoris-non-neutral-network-history/ (explaining that network neutrality is not "a foundational principle" of the Internet).

and consistently shows that such a rule can harm consumers.[41]

In practice, a network neutrality rule is little more than a subsidy from the consumer side of the market to the content provider side of the market.[42] Some, but not all, content providers benefit from this rule. Other content providers may be harmed by such a rule – especially those who offer, or would like to develop, services that would benefit from enhanced quality of service features or other features that may require some integration with Internet service providers.

Even more problematic, a network neutrality rule can harm consumers. It prevents ISPs and content providers from working together to offer innovative new products that consumers want. More tragic, it prevents these providers from developing lower-cost service packages –

41. The literature here is voluminous, often demonstrates benefits from non-neutrality, and consistently notes ambiguous results. For some examples (most of which cite to the broader literature). *See* Nicholas Economides & Joacim Tåg, *Network neutrality on the Internet: A two-sided market analysis*, 24 INFO. ECON. & POLICY 91, 100 (2012) ("We have showed that one can find such parameter ranges both in the monopoly model and in the duopoly model suggesting that network neutrality regulation could be warranted even when some competition is present in the platform market. *However, the overall effect of implementing network neutrality regulations can still be both positive and negative depending on parameter values*.") (emphasis added); Paul Njoroge et al, *Investment in Two-Sided Markets and the Net Neutrality Debate*, 12 REV. NETWORK ECON. 355, 356 (Feb 2014), *available at* http://www.columbia.edu/~gyw2105/GYW/GabrielWeintraub_files/RNE_paper_NN.pdf ("This paper adds to the growing body of formal economic analysis that will help inform policy makers on the net neutrality debate and sheds light on the validity, or lack thereof, of the arguments proposed by the different advocacy groups involved. In particular, this article develops a game theoretic model based on a two-sided market framework … to investigate the effects of a net neutrality mandate on investment incentives of ISPs, and its concomitant effects on social welfare, consumer and CP surplus, and CP market participation. ... More specifically, the results regarding the comparison between the neutral and non-neutral regimes for our theoretical and numerical-simulation models are as follows. *In both models, the non-neutral regime leads to a higher overall social welfare*. This result is driven by the higher investment levels caused by the non-neutral regime, which in turn increase consumer surplus and CP gross surplus.") (emphasis added); Jay Pil Choi & Byung-Cheol Kim, *Net Neutrality and Investment Incentives*, 41 RAND J. ECON. 446, 466 (2010) ("Considering all three channels through which net neutrality can have an influence upon short-run total welfare, we can conclude that static welfare implications of net neutrality regulations depend on the trade-off between transportation cost saving and inefficient production. If the margin difference is significantly large relative to the degree of product differentiation, the discriminatory network would be preferred from the viewpoint of social welfare." "We find that the relationship between the net neutrality regulation and investment incentives is subtle. Even though we cannot draw general unambiguous conclusions, we identified key effects that are expected to play important roles in the assessment of net neutrality regulations.").

42. *See, e.g.*, Justin (Gus) Hurwitz, *Let Them Eat Cake and Watch Netflix*, 8 FREE STATE FOUND. PERSPECTIVES, no. 22, 2013, *available at* http://www.freestatefoundation.org/images/Let_Them_Eat_Cake_and_Watch_Netflix_090413.pdf.

packages that could expand opportunities for access to currently underserved and disadvantaged communities. These rules likely increase cost of access and limit the development of potentially cheaper offerings that are more responsive to consumer demands – this is exactly the opposite of good telecom policy.

This point relates back to a concern in the first premise considered above: the paramount importance of respecting consumer preferences, and not substituting the Washington-Silicon Valley-academic views of what consumers should want for what they actually do want (and, more importantly, need). By requiring that every consumer's Internet connection offers full-fare, first-class service, complete with movies, television, and free drink service, we price consumers who would be happy with discounted-fare economy Internet service out of the market.

We don't mean to give away the barn. The key takeaways from the literature in this field are all nuanced – different price structures "can" or "may" benefit *or* harm consumers. In some cases, "non-neutral" price structures may benefit consumers, in some it may harm them, and *vice versa*. But this does not mean that we should prescribe *ex ante* prophylactic pricing rules – rather, it means that we should monitor conduct and pricing in the Internet ecosystem and be ready to bring *ex post* actions against pricing decisions that are demonstrably harmful to consumers.

V. PREMISE FIVE: TELECOMMUNICATIONS ARE BETTER IN EUROPE, ASIA, OR SOMEWHERE ELSE

The final premise is that things are better in Europe, Asia, or other regions of the world – or, from their perspectives, in America. A corollary premise is that such a comparison matters at all. This premise, frequently expressed as "America falling behind in ____ (fill in the blank)," is a common refrain for the policy *crise du jour*. Essentially it says that America, and other nations, are simply the sum of a single measure. It begs the question as to better for what and for whom and to what end. Similar concern can be seen in other countries. As Neelie Kroes, EU Commissioner for the Digital Agenda, has frequently declared, "High speed networks are the backbone of the digital market but compared to international competitors, Europe lags behind in providing those networks – fixed and wireless."[43]

Comparative rankings of global Internet speeds and prices are a staple of telecom debates. They feature prominently in the work of ad-

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43. Jake Sturmer, *Slow Internet 'Not Sustainable,' Tech Chief at Browdband World Forum in Amsterdam Says*, ABC NEWS AUSTRALIA (Oct. 23, 2013, 5:16PM) *available at* http://www.abc.net.au/news/2013-10-24/slow-broadband-nbn-amsterdam-neelie-kroes/5042068.

vocates across the political spectrum and the past year has seen at least three major efforts to study the relative costs and speeds of Internet access around the world: the ITIF,[44] ITU,[45] OTI[46], Christopher Yoo,[47] and AEI/Richard Bennett[48]. Smaller scale, but no less important, work has been undertaken by scholars such as Susan Crawford[49] and Roslyn Layton.[50]

With regard to broadband in the popular press, the "America is falling behind" assertion is "evidenced" by reference to citing a specific statistics on speed or price without proper context. Cherry picking any one measure or data point can make a country look good or bad, but that doesn't translate into bankable insight for economic growth, let alone informed policymaking. Being the "best" in any broadband measure matters little if it does not does not improve social welfare or make an economy and its workforce more productive. Indeed, such cherry-picking has even been used by the FCC, selectively using data from its own reports to support its preferred conclusions.[51] For instance, on January 29, 2015, the FCC released two related reports, international broadband performance and the definition of broadband.[52]

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44. RICHARD BENNET ET AL., THE WHOLE PICTURE: WHERE AMERICA'S BROADBAND NETWORKS REALLY STAND, INFO. TECH. & INNOVATION FOUND. (Feb. 2013), *available at* http://www2.itif.org/2013-whole-picture-america-broadband-networks.pdf.

45. COSMAS ZAVAZAVA ET AL., MEASURING THE INFORMATION SOCIETY 2013, INT'L TELECOMM. UNION (2013), *available at* https://www.itu.int/en/ITU-D/Statistics/Documents/publications/mis2013/MIS2013_without_Annex_4.pdf

46. Nick Russo et al., THE COST OF CONNECTIVITY 2014, NEW AM. FOUND. (2014) *available at* https://static.newamerica.org/attachments/229-the-cost-of-connectivity-2014/OTI_The_Cost_of_Connectivity_2014.pdf.

47. Christopher Yoo, *U.S. vs. European Broadband: What Do the Data Say?*, INST. FOR L. & ECON. RESEARCH, Paper No. 14-35 (2014), https://www.law.upenn.edu/live/files/3352-us-vs-european-broadband-deployment.

48. RICHARD BENNETT, G7 BROADBAND DYNAMICS: HOW POLICY AFFECTS BROADBAND IN POWERHOUSE NATIONS, AM. ENT. INST. (2014), *available at* http://www.aei.org/wp-content/uploads/2014/11/G7-Broadband-Dynamics-Final.pdf.

49. SUSAN CRAWFORD, CAPTIVE AUDIENCE: THE TELECOM INDUSTRY AND MONOPOLY POWER IN THE NEW GILDED AGE (Yale Univ. Press, 2012).

50. Layton, *supra* note 34; Horney & Layton, *supra* note 28.

51. *See* Justin (Gus) Hurwitz, *Regulating the Most Powerful Network Ever*, 10 FREE STATE FOUND. PERSPECTIVES, no. 9, 2015, *available at* http://www.freestatefoundation.org/images/Regulating_the_Most_Powerful_Network_Ever_021815.pdf.

52. 2015 Broadband Progress Report and Notice of Inquiry, In the Matter of Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment, No. 14-126, FED. COMM. COMM'N (Jan 29, 2015), *available at* https://apps.fcc.gov/edocs_public/attachmatch/FCC-15-10A1.pdf; Fourth Report, In the Matter of International Comparison Requirements Pursuant to the Broadband Data Improvement Act, No. 14-126, FED. COMM. COMM'N (Jan. 29, 2015), *available at*

The International broadband report found, among other things, that the US has the among the lowest cost Internet service when measured in terms of cost-per-gigabyte; it also finds that the US has significantly better rural high-speed Internet coverage than Europe (roughly 45% vs. roughly 13%).[53] Yet the broadband definition report simply ignores these data, focusing instead only on data that show the US to be behind other countries – while noting that the FCC is statutorily required to consider factors such as it ignores.[54]

The faulty premise of the assertion implies that broadband itself, measured by a discrete variable such as speed, is the end goal. However it is arguably more important not to view broadband as an end in itself, but as an enabler of social and economic value. Viewed in this way, we need to take a more comprehensive, holistic view of broadband that encompasses not just networks and their characteristics, but adoption, applications, digital readiness, market development, and so on. Indeed the OECD Council's principles[55] for Internet policy embrace a range of broad outcomes, but no one metric of speed or network type.

There is an assertion that we need better, faster broadband for the sake of "innovation", but there is no reliable measure of broadband as an input to innovation. The OECD reports that broadband penetration has only a mild correlation to GDP in its member countries.[56] Innovation is highly complex and results from the interplay of many factors in a larger innovation ecosystem comprising entrepreneurs, firms, human and financial capital, knowledge and technologies, market structure, and so on.

From an economic perspective, America's historic broadband policy, which focuses on dynamic competition between networks and a limited role for government has been successful to stimulate investment in broadband networks in a nearly unprecedented scale, some $1.2 trillion since 1996 and ongoing high rate of investment per capita for some time. This contrasts with European investment, which has largely fallen across the continent on a per capita basis. As one of us has explained elsewhere:

> A decade ago, the EU accounted for one-third of the world's communications capital expenditure. Today, the EU's share has plummeted to less than one-fifth. Americans, on the other hand, are just 4% of the world's population, have enjoyed one-fourth of the world's broadband

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https://apps.fcc.gov/edocs_public/attachmatch/DA-15-132A1.pdf.

53. *See* Hurwitz, *Regulating the Most Powerful Network Ever*, *supra* note 41.

54. *Id.*

55. OECD COUNCIL RECOMMENDATION ON PRINCIPLES FOR INTERNET POLICY MAKING, ORG. FOR ECON. CO-OPERATION & DEV. (2011), *available at* http://www.oecd.org/internet/ieconomy/49258588.pdf

56. *See* Layton, *supra* note 34.

> capex for a decade. In fact, per capita investment in the US is twice that of Europe, and the gap is growing.[57]

At this point, it has been amply demonstrated that the idea that the US is "falling behind" is debatable at best.[58] We might not have the fastest Internet in the world – but the countries who do often lament the low adoption rates seen after billions of dollars of state-sponsored investment. We might not have the cheapest very-high-speed Internet access in the world – but we have some of lowest prices for access to entry-level high-speed Internet–which is most important for consumers, especially when the essential set of services does not require high speeds and, as much as we lament how much better everything is in other countries, those other countries lament how much better things are in the United States.

The results of this market-driven investment are clear: US consumers enjoy significantly higher rates of access to cable, LTE, FTTH, and 100+mbps broadband than their European peers. Despite this higher per-capita investment, these numbers also show that when you include fees collected by the government (e.g., taxes and media licensing), US consumers pay less for broadband than their European counterparts.

When taking these points into consideration, it is difficult to deduce that America is falling behind in broadband. America's broadband networks have allowed the country to develop new digital industries and transform old ones. Users are on track to consume more data than any country in world. A more correct premise may be to pursue the level of broadband development appropriate to America's economic and social needs, rather than aspiring to be the "best", which is certainly subjective and not necessarily welfare-enhancing for consumers.

There is a perhaps even more important question than whether the US has the fastest Internet in the world: does it even matter? We talk about these comparisons because we don't have a better way to assess our spending on broadband infrastructure. However, we could unquestionably have the world's fastest broadband service if we wanted – all it takes is money. Would such an investment at a scale to ensure we would top the Internet speed rankings from now and into eternity make sense? Probably not. We could also have the world's fastest roads, high-

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57. *Id.*

58. *See, e.g., Id.*; Yoo, *supra* note 37; *see also* Richard Bennett, *Not Falling Behind*, TECH. POLICY DAILY (Dec. 30, 2013, 5:12PM), http://www.techpolicydaily.com/ communications/falling-behind/; Richard Bennet, *Qu'ils Mangent de la Brioche?*, TECH. POLICY DAILY (Oct. 28, 2013, 8:50PM), http://www.techpolicydaily.com/internet/quils-mangent-de-la-brioche/; Sarah Leggin, *Less Is Not Necessarily More*, 8 FREE STATE FOUND. PERSPECTIVES, no. 35, 2013, *available at* http://freestatefoundation.org/images/Less_is_Not_Necessarily_More_122313.pdf.

est literacy and graduation rates, safest schools, largest airports, and cleanest energy – if we were willing to pay for any of these things. Figuring out how much to spend on any of these priorities requires a complex set of tradeoffs that is ignored by advocates concerned with whether average broadband speeds in the United States are a few percent slower than our friends in Europe. And it bears emphasizing that even the studies most critical of US broadband speeds show only minor differences in absolute speed between ordinal rankings. (And recall, as discussed in the second premise, speed and cost are only two of many metrics important to understanding the value of broadband Internet access – others, especially latency and jitter, can be as or even more important than speed.)

If we are to have a coherent discussion about how fast our Internet architecture should be, we need to have a more sophisticated goal than "faster than anyone else." In particular, we need a more sophisticated metric than just speed. More speed will always be better than less speed; and more speed can always be acquired by expending more resources. The race to have the fastest Internet in the world, therefore, is little more than a race to spend resources. Maximization always needs to be done subject to some constraint. Rather than comparing speeds, we should instead think about why we value high-speed (and, then, higher-speed) Internet service, and how marginal increases in Internet speeds affect that goal.

VI. PART SIX: THE ROLE OF TELECOM RESEARCH IN TELECOM POLICY

Having looked at several important, but problematic, premises in current telecommunications policy debates, we now turn to consider several themes that run through these premises and also the role of telecommunications research in telecommunications policy debates.

A first theme seen in several of these premises is constrained vs. unconstrained optimization, and the selection of relevant metrics and policy levers – or, stated differently, consideration of benefits of a given policy change without respect to costs or costs without respect to benefits. Thus, it will always be the case that more bandwidth is better than less, and that if we are willing to spend more money we can have better or faster networks. It is meaningless to discuss how robust networks should be without consideration of the value of applications that more robust networks may support as compared to the cost of building out those more robust networks.

Related to this, there has been surprisingly little attention paid to the requirements of applications running over broadband networks. What we expect of networks has been driven by the requirements of median uses of networks. This, in turn, has largely tracked the bandwidth (and other) requirements for streaming video. But streaming video's technical requirements are different from many other applications – it generally requires orders of magnitude more bandwidth than any other applications, and is less sensitive to latency and jitter than many other important applications.

The focus on supporting the requirements for video has been driven in large part by the high private value placed on streaming video. It is almost certainly the case that video is the Internet's "killer app" – the one thing for which consumers are likely to pay the most. But the social value of online video is likely small relative to other applications – and these other applications likely have very different technical requirements. Thus, the goal of provisioning ubiquitous high-speed Internet access is at odds with provisioning ubiquitous access to important online educational, health care, employment, and government service resources. In a world of unconstrained resources we would of course have unlimited bandwidth connectivity that supported universal access to these socially-valuable resources. But in a world of constrained resources, we face a tradeoff between the rate of provisioning networks that support the most resource-intensive and highest private-value services and the rate of provisioning more modest networks that support the most socially-valuable services but that may not support the highest private-value services.

This idea of constrained vs. unconstrained optimization doesn't only apply on the policy side: it also applies on the application side. A common definition of engineering is solving problems subject to constraints. Good engineers find ways to work within technical constraints – but in the telecom arena, engineers have the option of petitioning the government to obviate those constraints. This is one understanding of the modern network neutrality debate, combined with arguments for universal availability of low-cost high-speed broadband access: proponents are trying to leverage regulation to overcome technical constraints; opponents are advocating engineering the network to work within these constraints. Neither of these approaches is necessarily "better" or "worse" than the other, let alone "right" or "wrong." Indeed, the best approach is probably the combination of both that minimizes the cost of building new infrastructure subject to the constraint of engineers' ability to design applications that can run on the available network resources.

Another aspect of the premises considered above is that they are often framed in terms that have substantial emotional valence. This can again be framed in terms of constrained vs. unconstrained optimization. Arguments with strong emotional valence are framed to overcome or deny practical constraints – at a policy level, to say that something is necessary is to say that it must be provided no matter the cost. Thus, we need to have universally available, open, high-speed networks in order to support various applications (both socially and commercially necessary). However an appeal to emotional valence – really, any argument that denies marginal constraint – is rarely analytically rigorous. Indeed, from an economic perspective "necessary" services will have very inelastic demand, and therefore are often the most likely services to be provisioned by the market.

A single thread has run throughout this discussion: good telecommunications policy is rarely simple. The premises considered above are faulty because they are binary and unbounded. They yield policy prescriptions that are invariant with respect to any state of the world: we must always invest more in building consistently faster wireline networks; those networks must always be neutral and support both privately-and socially-valuable applications.

Sound policy demands constraint – and sound policy should reject premises that do not submit to constraint. One of the most important roles of research is to identify those constraints and to operationalize them into meaningful policy levers. Much of the literature that this paper relies upon is in one sense very unsatisfactory. The technical and economic literature relating to general purpose technologies and network neutrality, for instance, is unambiguously ambiguous. At the same time, this is perhaps some of the most important literature for modern telecommunications policy, precisely because it identifies a range of outcomes and relevant factors to consider in understanding why the market may obtain various results within that range. In a world where the lines between research, policy, and advocacy are often blurry the most important research may not be that which provides answers but rather that raises questions.

CONCLUSION

In examining the faulty premises of telecom policy, we acknowledge our own premise, that telecom policy should be informed by critical analysis and evidence not just normative statements, however compelling they may sound. We consider addressing consumer needs as the ultimate goal, but demonstrate that seemingly consumer-friendly policies, when they don't take into account the complexities of economics and engineering, can have the opposite or negative effects of what they intended. The faulty premises are examined to improve policy proposals, transcend the narrow interests of specific groups, and create better outcomes for consumers.

The first premise is that everyone needs low-cost access to high speed broadband. Users have a diverse set of needs, which might not reflect the preferences of Washington or Silicon Valley. We explore the historical notion of basic telephone service and find that is has limited application to inform what kind of services should be part of the basic bundle of social commitments today. Emergency, employment, health, government, and e-commerce applications don't require high speeds. Thus a question remains whether high speed video should be part of the basic set of essential services. Indeed rich media is not driven necessarily by consumer demand, but rather the bandwidth and technology that make it available. Furthermore rich multi-media is not accessible to the deaf and blind, so a key group is already marginalized by insisting that video is an essential service.

An alternative approach to mandating high speeds at low cost is to require that essential services be developed so that they do not require high speed broadband. Another pro-consumer policy would be to move away from defining broadband in terms of speed (mbps) but instead offer categories of service depending on application, e.g. a basic services package for health, education, government, and employment applications versus a streaming video package. This will make it easier to enforce remedies that ensure providers fulfill their obligations with a particular package, rather than to attempt to deliver everything on a given speed.

We examine the specific bandwidth requirements for key applications in health and education and show that the bandwidth needs for these services are modest and thus we expose the fallacy that high speeds are needed so that these essential services can be realized. Moreover we demonstrate that speed is not the only important aspect of broadband. For certain health and education applications, which require real time communications, the elimination of latency, jitter and packet loss are more important.

We challenge the notion that wireless can't compete with cable. While wireless may have certain limitations currently, in the short term, its portability makes it the preferred broadband connection for an increasing number of people. In the mid- to long-term, as wireless moves into millimeter-wave bands accessing many GHz of capacity, wireless may well supplant cable in terms of throughput. In any case, it's important to recognize that different users may value the technologies differently, and it is by no means a *fait accompli* that basic set of services can only be realized on one kind of technology.

In current telecom debates the premise that openness and neutrality are perquisites for innovation border on religious dogma, but we find that this premise too is not necessarily true. Indeed openness and neutrality are not unambiguously good or bad. Openness may facilitate some innovation, but inhibit others. We see a variety of open and closed business models in which consumers benefit. Furthermore openness and neutrality are under-theorized concepts in the academic literature of innovation, and there is little evidence for the benefits they are purported to provide.

In fact, not only do the most cited articles of the net neutrality literature conflict about the welfare effects of the policy, a review of the literature of innovation suggests that openness and neutrality are not key drivers for innovation. However, the literature notes other salient factors for innovation such as the joining of complementary assets,[59] partnerships, and the need to look "outside the box" for new ideas.[60] We find that, ironically, proposed net neutrality policies may prohibit the very things that the literature suggests promote innovation, namely partnerships. In any case, it may be premature to build a regulatory regime on the notion of net neutrality, which lacks intellectual consensus on the issue of market failure, let alone the build a regulatory regime of an a priori concept that mandates openness while prohibiting other models. Until more evidence is available, an *ex post* case by case approach to determine whether consumers are being harmed by any particular model is prudent.

We investigate the claims that telecommunications are better in Europe, Asia, or somewhere else. We find the statement "America is falling behind" is a common refrain across a number of policy issues where emotion and fear overrule analysis and rigor. No country is the sum of a single measure. As such, the myopic focus on broadband as an end in itself, by simply the sum of discrete measures such as speed or price, miss important nuances about how broadband is create economic and social value. Simply put, broadband is not an end in itself but an enabler.

There is no value in being the "best" in any broadband metric if it does not increase economic or social welfare. Assertions that America is falling behind in broadband are frequently based on cherry-picked data taken out of context to gratuitously support a particular policy position. Informed policymaking on broadband necessarily requires the analysis of many measures and a holistic perspective.

The sixth section reviews the themes that run through the policy debates, namely constrained vs. unconstrained optimization. There is a lack of attention to bandwidth requirements of applications, which is arguably more important than bandwidth itself. Indeed consumers don't buy bandwidth for its own sake but to access content and applications.

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59. David Teece, Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy, 15 Research Policy 285 (1986).

60. WILLIAM HENRY CHESBROUGH, OPEN INNOVATION: THE NEW IMPERATIVE FOR CREATING AND PROFITING FROM TECHNOLOGY (Harvard Bus. School Press, 2005).

Certain users place a high value on streaming video, but the social value of streaming video compared to other applications, whether emergency communications, government, education, health, or ecommerce, may be much smaller. Thus we must address the tradeoff between resource-intensive networks serving high private value services versus modest networks that support socially-valuable services, that may not be first be the main interest of highest private value users.

Finally we analyze critically emotional arguments in favor of certain telecom policies, that certain things need to be done regardless of the cost, a technique which is often used to end debate and discussion about important issues. However if any service is inelastic as advocates purport, then it is more likely to be provisioned by the market anyway.

Good telecommunication policy is rarely simple. As such we should resist temptation to make binary interpretations of the world where more nuanced views can ultimately deliver better social outcomes.