Innovation and National Broadband Policies:

Facts, Fiction and Unanswered Questions

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EXECUTIVE SUMMARY

"Innovation" has emerged as a pivotal element in the debate over whether the Federal Communications Commission (FCC) should impose new constraints on managers and providers of broadband network infrastructures. This study brings to bear facts and analysis emerging from a review of much of the literature on innovation and especially that bearing on claims by advocates of "net neutrality," "open networks" and related notions.

We find that innovation is thriving at both the core and the edge of the network in the current policy environment, which has fundamentally allowed the Internet to evolve with little government involvement. Further, we find no evidence that greater FCC involvement in markets for broadband services would protect or promote innovation in the Internet Ecosystem. Indeed, we believe that such intervention is more likely to discourage innovation than to stimulate it.

In addressing these issues, the study finds and presents support for the following conclusions:

- Responding to incentives and opportunities availed within the prevailing scheme of regulatory forbearance, network infrastructure providers have compiled an impressive record of innovation reflected in a cascade of new transmission and switching technologies; new local distribution and devices; an impressive array of new services; dramatically increased functionality; and adoption of creative business practices tailored to the changing topology of networks;

- By any reasonable assessment, core cable, wireline and wireless networks reflect enormous historical and ongoing innovation as marked by the adoption of new technologies, incorporation of advanced equipment and software, expansion and improvement of services offerings, and the introduction/diffusion of new business models;

- Presence of pervasive complementarities among services dictates that core innovations in network platforms have enabled, encouraged and increased the value of important edge innovations that would otherwise have been impossible;

- While good and unambiguous measures of innovation are often lacking, there is an undeniable link between diffusion of network innovation and the enormous network investments now being made by broadband infrastructure providers;

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- Many of the innovations now apparent at the edge reflect investment and business model applications of services first introduced by Internet Service Providers at very early stages of the development of the Internet;

- Imposing common carrier type regulation on network providers would diminish network providers incentives and opportunities to continue historic trends in innovation and investment;

- There is no analysis or data in the literatures on innovation and regulation to prove claims that the proposed net neutrality rules would on balance promote innovation in the Internet Ecosystem;

- Net neutrality proponents incorrectly characterize the incidence of innovation activities and accomplishments, particularly with respect to core v. edge innovation; and

- The proposed net neutrality rules might be expected to reduce innovation in broadband networks and those that would be enabled at the edge. They would do so to the extent that new constraints on broadband network providers would increase uncertainty and risk, reduce prospects for growth, and undermine network managers' incentives and opportunities to adapt to rapidly changing technical and economic conditions in the Internet Ecosystem.

This study finds no support in theories of innovation, innovation practice, or reviews of numerous empirical studies, of drivers of and constraints on innovation, for the main contentions of net neutrality supporters. Available data and analysis do not establish: a) the absence of network innovation in general; b) the primacy of innovation at the edge over the core; or most importantly; c) that greater *ex ante* regulation of markets for broadband infrastructure is needed, or can reasonably be expected to increase the rate of innovation and consumer welfare creation by network providers and elsewhere in the Internet Ecosystem.

Our review finds no significant market failure attributable to insufficient innovation by network providers or superior innovation outside network infrastructures. As to the need for new regulations, the public interest would be well served were the Commission to heed the wisdom of Hippocrates: "First, do no harm!"

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I. INTRODUCTION

"Innovation!" "Innovation!" Innovation!"

Fostering, enabling, promoting, removing barriers to "innovation" (not otherwise specified) has become the pivot about which several important Federal Communications Commission decisions will revolve in the next few months and years. The relationships between innovation and regulatory outcomes are central to recent Commission Notices addressing elements of a National Broadband Policy, the future of wireless regulation, proposed net neutrality rule changes, as well as in several longer standing dockets addressing intercarrier compensation, special access rates and universal service regulations. Indeed, it is fair to say that the impact of Commission rule changes on innovation is, or certainly should be, a significant consideration in most FCC proceedings related to the underlying networks -- the foundations -- on which the entire "Internet Ecosystem" relies.[1]

The Commission has consistently called attention over the years to the importance of innovation and investment in sectors falling within its influence, and to the impact of its regulations on either or both.[2] Rightly so, since it is almost universally recognized

[1] Firms in the Internet Ecosystem include all those that contribute jointly to end users' Internet experiences. Those include network operators, equipment and component providers (from chips to routers to cabling, etc.), software providers, as well as content and applications providers. For more detail and structure of these relationships, see the excellent, seminal 2006 report by Morgan Stanley. http://www.morganstanley.com/institutional/techresearch/pdfs/Internet_ecosystem0306.pdf.

[2] Most recently the Commission declared: "Policies that foster continued innovation have helped to encourage capital investment in wireless and to deliver new and empowering technologies and applications to American consumers." Notice of Inquiry, In the Matter of Fostering Innovation and Investment in the Wireless Communications Market GN Docket No. 09-157 A National Broadband Plan For Our Future GN Docket No. 09-51, released August 27, 2009, p. 2. The Commission recognized the potential barriers to technological change, innovation and economic progress of its own well meaning *ex ante* regulations. "At times, we have seen innovators subjected to lengthy regulatory processes - such as debates over what constitutes harmful interference or how to fit new spectrum use within our framework of rules - that can be an obstacle to progress in the wireless arena." Ibid.

that economic growth, productivity and job creation derives from the economy's dynamism and not its static efficiency, while the IT sector, the foundation of which -- network infrastructure providers -- is a principal source of that dynamism and is directly regulated by the Commission.

Advocates of new, more binding regulatory constraints on infrastructure providers -- many of familiar forms previously applied to services provided by broadband network owners -- insist that the recommended regulations will maximize or optimize the rate of innovation in the Internet Ecosystem by favoring providers of applications, content, and other non-network components of the Ecosystem. Indeed, claims about innovation impacts are the heart of the case for new and stronger regulatory net neutrality provisions that restrict market conduct of broadband network providers.

A central question in the net neutrality debate is: If, how and to what extent would the regulations proposed in the Notice of Proposed Rulemaking (NPRM) lead to greater consumer welfare resulting from their impact on innovation among firms in the Internet Ecosystem?

The content of the analysis and data that follow is structured by an effort to identify the key questions and data points that the Commission ought, at a minimum, to consider in reaching findings and making decisions about the impact of its rules on innovation in the Ecosystem. As such it addresses questions, facts, assertions, and conclusions that are material thereto. We believe the following questions ought to be addressed and answered by the Commission:

1. What is innovation and how can it be identified and measured?
2. How does innovation relate to investment?
3. Where has it been occurring (edge v. core; different networks v. applications)?
4. What are the relationships among different kinds of innovation and how do they interact to create economic welfare?

5. How will public policy incent or hinder innovation among various entities in the Internet Ecosystem?

Accordingly, this paper focuses on available data and analysis addressing these questions. It reflects a comprehensive, if selective and not exhaustive, review of the innovation claims of numerous parties in their submissions, as well as a similar review of the voluminous, multidisciplinary (economics, management science, technological, organizational, knowledge management, entrepreneurial) literature on innovation that has developed since the seminal work of Professor Schumpeter who famously called attention to the importance, causes and sources of innovation.

II. FINDINGS

1. Literature and FCC Record Lack an Operational Definition of Innovation. Despite the bread and depth and diversity of coverage that innovation has been given by scholars, policymakers, business managers, consultants, and other experts, there is no settled definition of "innovation." The term is used to describe broad ranges of activities and outcomes, but seldom in ways that permit robust identification, measurement or analysis. Most writers reflect a broad sense of what innovation means, but not one that permits third-party evaluation of various contentions about its sources, importance, frequency, incidence, effects or ways government can successfully intervene to promote it. A recently suggested definition drawing from more than 60 variations in assorted literatures suggests the range of considerations that come to bear in any attempt to assess it: "Innovation is the multi-stage process whereby organizations transform ideas into new/improved products, services or processes, in order to advance, compete and differentiate themselves successfully in their marketplace."[3]

2. Unsupported Claims about the Incidence and Value of Innovation. Claims about innovation by net neutrality advocates are offered almost entirely without supporting data or analysis. They are generally conjectural, vague, and next to impossible to subject to rigorous testing. This is especially true with respect to claims about the importance – frequency, economic value, relation to other policy goals – of innovation at the edge v. innovation in the core. On closer examination, neither core nor edge is defined, nor in all too many instances can they reasonably be regarded as separate or separable. Important innovations cannot be attributed solely to one or the other.

3. Substantial Innovation in Broadband Networks. Broadband networks are not dumb and bereft of prior and ongoing innovation. A survey of the history of the development of wireline, wireless, and cable networks reveals an impressive amounts of innovative activities reflected in the introduction and diffusion of new technologies, new

[3] Anahita Baregheh, Jennifer Rowley, and Sally Sambrook, "Towards a Multidisciplinary Definition of Innovation," Management Decision, vol. 47, no. 8, p. 133.

production processes, new services, and new business models (all of which reasonably qualify as innovations). Much analytical attention has been focused on wireless networks, and rightfully so. Perceptions that wireline and cable networks have been technologically stagnant cannot be verified. To the contrary, historical developments in transmission, switching, local distribution, applications and business models by cable and telco infrastructure providers make clear both the dynamism of these sectors and, most importantly, their roles as enablers and facilitators of innovations in content provision and applications.

4. Enormous Complementarities of Innovations in the Ecosystem. Without regard to whether they are core or edge innovations, they all take place in an ecosystem marked by interdependencies, complementarities, and externalities wherein the value of innovations by individual firms is critically dependent on, and in some cases largely determined by, past, concurrent, or future innovations by others within the Ecosystem. These interdependencies and complementarities are especially important with respect to the external benefits conveyed by innovation in broadband network infrastructures without which most of the highly touted innovations at the edge would not be possible or would have minimal value.

5. Investment and Innovation Are Largely Inseparable. While it is difficult to measure innovation and many suggested measures (patents, research and development expenditures, etc.) are not useful here, recent work suggests that large shares of investment supporting new services and processes may be regarded as useful proxies.

6. Current Services by Edge Providers Are Built on Network Innovations. Many innovations trace themselves to early initiatives by fledgling Internet Service Providers (ISPs) in the late 1990s during the early days of the Internet. Successful edge businesses of today derive from development and diffusion of those early initiatives. Much is different, but many are not new. They often reflect application of new business models.

7. No Correlation between Market Structure and Innovation. Despite claims about the deadening effect of market structure in the broadband network access provider sector, there is no evidence – none – that current market structure has hindered the introduction of new technology, the development of new production processes, the introduction of new services, the use of new business models or of any other reasonable indicator of innovation.

8. No Empirical Evidence of Beneficial Regulatory Impacts on Innovation. There is little conclusive, or even reliable, empirical or theoretical evidence about linkages between regulation and innovation. This is largely due to the conceptual and factual breadth of each. Regulation has as many aspects as innovation (as described above). However, the limited empirical support available on the matter offers no basis for believing that rate and service regulation of network providers will lead to more innovation by them or by others in the Ecosystem. Given the complementarities and externalities involved, individual firms generally have little or no incentive to restrain other firms in ways that can successfully be offset by affirmative regulations. To the contrary, early, if limited, research indicates that interconnection regulations had a negative impact on new service introduction and investment by network operators.

9. Regulation May Destroy Innovation Opportunities. Regulations should be evaluated for their impact on opportunities and incentives to innovate for major players in the Internet Ecosystem. We are unpersuaded that there are ways for the Commission to create opportunities and/or incentives for some firms in the Ecosystem without destroying them for others. The clear implication is that the Commission is obliged to balance at the margin the costs and benefits across all sectors and firms in the Ecosystem of any remedial or prescriptive regulation. Any rule changes must minimize the prospect of unintended or unanticipated costs to some sectors resulting from efforts to prevent, *ex ante*, potential harms of market forces in other sectors.

III. DEFINING INNOVATION

In keeping with its calls for data and analysis, the Commission should insist that any representations about the frequency, location, or value of innovation be accompanied by an operational definition that will permit claims to be represented or challenged in a meaningful way. Notwithstanding claims offered by net neutrality advocates about the source and value of innovations originating at the edge in the Internet Ecosystem, a search for a definition usable to test those claims is unavailing. Lack of definition is not limited to FCC proceedings. Indeed, a search of the "innovation" literature reveals both widespread use of the term and absence of effort to define it in many studies. There is no consensus among others who do attempt definition.

A recent review of the literature concluded: " . . .the term 'innovation' is notoriously ambiguous and lacks either a . . .definition or measure."[4] Another survey found that definitions of innovation, even when offered, were substantially different and varied in several dimensions. Typically, any randomly selected set of definitions will reflect different "idea" stages (creation, formulation, development, implementation); different locations in the value chain (individuals, suppliers, sellers, customers, managers, etc.); different means (technical, intellectual, market-related, etc.); different purposes; different kinds of processes (inputs, outputs, mixes, services, products, etc.); and different characteristics of change (new, diversified, modified, improved, combined, etc.).[5] The complexity of any inclusive definition is borne out by attempts to bring together these various dimensions.

From the many ways to categorize and sort innovations, the economics literature frequently divides it into two kinds: those on the production side (new production

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[4] R. Adams, J. Bessant and R. Phelps, "Innovation Management Measurement: A Review," International Journal of Management Review, vol. 8, no. 1, p. 22. Some writers beg the question of definition entirely and assert that there is no such thing as genuine innovation, inasmuch as all change is a manifestation, modification or application of something that already exists. They implicitly agree with the biblical admonition that: "What has been will be again, what has been done will be done again; there is nothing new under the sun." Ecclesiastes 1:9 (New International Version).

[5] Anahita Baregheh, Jennifer Rowley, and Sally Sambrook, "Towards a Multidisciplinary Definition of Innovation," Management Decision, vol. 47, no. 8, p. 133.

processes or inputs) and those on the output side (measured by new products and services). That division is neither exhaustive nor mutually exclusive and ignores a third class that is widely considered in the business management literature and recently recognized by the FCC.[6]

The Commission has diverged from tradition in the economics literature, and correctly so, by soliciting comment on new business models without regard to technology or side of the market. Thus, in the Wireless Notice of Inquiry (NOI), the Commission mirrored recent developments in the literature on actual business practices and sources of innovative progress by seeking comment on ". . . what innovative business models and practices are being adopted in the wireless sector, in this country as well as in foreign markets, and on the Commission's role in fostering such innovations." The Commission specifically noted: ". . . one potential business model, the multi-sided platform (MSP), brings together two or more inter-dependent groups of customers in order to produce economic value for all of them, typically by reducing their search costs and shared transaction costs. . ."[7]

The Commission frequently uses the term in different contexts, without definition, but recently suggested a very broad rendering by defining innovation as: ". . . the pragmatic application of new ideas to productive ends."[8] On that definition, the

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[6] The Commission is consistent with recent perspectives from the business sector. Thus, IBM in a 2006 survey and study of innovation identified three types of innovation: Business Model Innovations; Operational Innovations; and, Innovations involving Product changes in products, services, or addressable markets. The IBM study concluded: ". . . Innovating with respect to business models and operations will not only create opportunities for cost savings, but will also lead to additional revenue generation opportunities." Online at: http://www-935.ibm.com/services/us/gbs/bus/pdf/g510-6630-01-paths2success.pdf. Furthermore, business model innovation matters. The IBM 2006 Global CEO Study found that business model innovation had a much stronger correlation with operating margin growth than other types of innovation, including those embodying new technologies. This implies that business model innovation is a key to providing funds for future investment and suggests, among other things, that patents and R&D not a very good measure of innovation output or effort.

[7] In the Matter of Fostering Innovation and Investment in the Wireless Communications Market, GN Docket No. 09-157, par. 62.

[8] Ibid, p.2.

Commission concluded that innovation in the IT sector“. . . has been at the heart of the extraordinary economic growth of the 20th Century.”[9]

Our interest in the meaning of the term innovation is more than academic. The range and variety of definitions, and the lack of consensus, is not surprising. Nor does it necessarily estop reasonable efforts to recognize it, measure it, analyze it and understand how to know it when we see it and fashion policies to encourage it. It does not prevent such efforts, but it does command humility in discussions and recognition of the subjectivity in judgments about, among others, where it prevails, where it does not, its magnitude/economic value, and the merits of different policy approaches for encouraging it. Insistence on clear and consistent meaning is especially critical in light of a) claims made by advocates about the importance of innovation at the edge and the inconsequential nature of that at the core, and b) the Commission’s expressed intention to place investment and innovation at the top of the list of considerations that will shape its development of an Open Internet Policy.

[9] Chairman Genachowski recently elaborated by pointing out more specifically the importance of innovation in broadband networks. “We’ve seen powerful innovation and staggering investment from American companies managing broadband networks, as well as U.S. companies at the edge. DOCSIS 3.0 and fiber, from cable operators and telcos, are extraordinary wired broadband technologies with the promise of offering faster speeds to consumers and businesses with access to them. And mobile carriers are readying the next generation of mobile broadband, also with massive potential.” Prepared Remarks of Chairman Julius Genachowski, “Broadband: Our Enduring Engine for Prosperity and Opportunity” NARUC Conference Washington, D.C., February 16, 2010. http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-296262A1.pdf. We provide support for these observations in our review of network innovations in Sections VI, VII and VII below.

IV. INNOVATION AND INVESTMENT

Few innovations of significant economic consequence take place without substantial investment. To be sure, the discovery of ideas and formulation of notions about how to implement them may be done with modest cost, but the procedural chain involving implementation and diffusion will in most cases require substantial capital outlay for research, development, production, and diffusion. Given the capital intensity of much of the Information Technology sector, capital formation as a part of the innovative process is particularly important. A recent study of innovation in the wireless sector put it succinctly and correctly:

> "Innovation and Investment are two sides of the same coin; new ideas, new technologies and new business methods cannot happen without investment, and neither investment nor innovation will happen without incentives for innovators and investors to perform their roles."[10]

The link between investment by incumbent cable and (wireline and wireless) telecom companies and their initiation and diffusion of broadband innovation is not a one-to-one, dollar for dollar conversion. Breaking down publicly available investment data into capital expenditures for old, narrowband or legacy applications versus that in support of new and innovative, broadband services can be done clearly for some categories of capital expenditures, but is subject to some ambiguity for others. Broadband providers offer different services over the same network. Some plant and equipment and other capitalized outlays are dedicated wholly or in substantial part to new, improved, broadband services, while others are fairly allocated to legacy applications such as plain old voice or narrowband data applications. Different accounting techniques, not surprisingly, lead to different estimates of the shares of capital budgets going to what may be regarded as innovative services or to legacy services.

[10] Gerald R. Faulhaber and David J. Farber, "Innovation in the Wireless Ecosystem: A Customer Centric Framework," Submission in response to the Federal Communications Commission's Notice of Inquiry in GN 09-157, Fostering Innovation and Investment in the Wireless Communications Market.

Data on point were recently compiled and submitted by analysts at the Columbia Institute for Tele-Information (CITI). For 2009, CITI estimates total capital expenditures by all network providers (telco, cable, wireless, satellite and wireless ISP platforms) at a shade over $60 billion of which they estimate $30 billion or half to be for broadband.[11] This suggests that investment may be regarded in part as a reasonable proxy for a key aspect of innovation – the incorporation of new technology in legacy businesses and their extension to new areas or services.

Total Capital Expenditure and Broadband Innovation by Network Sector[12]

BROADBAND CAPEX (in millions)	2008	2009E	2010E	2011E	2012E	2013E	2014E	2015E
Major Telco Wireline Capex	26,283	21,060	19,353	17,458	16,755	16,420	16,203	16,095
Total Telco Capex	32,289	25,872	23,775	21,447	20,583	20,172	19,905	19,773
% Broadband[251]	*48%*	*52%*	*54%*	*58%*	*62%*	*62%*	*62%*	*62%*
Telco Wireline Broadband	**15,499**	**13,454**	**12,839**	**12,439**	**12,762**	**12,506**	**12,341**	**12,259**
Major Cable Capex	13,148	11,817	12,109	12,237	12,476	12,818	12,969	12,986
Total Cable Capex	15,956	14,342	14,695	14,851	15,140	15,556	15,739	15,760
% Broadband[252 253]	*30.0%*	*30.0%*	*30.0%*	*25.0%[253]*	*25.0%*	*20.0%[253]*	*20.0%*	*20.0%*
Cable Broadband	**4,787**	**4,302**	**4,408**	**3,713**	**3,785**	**3,111**	**3,148**	**3,152**
Major Wireless Capex	19,520	18,597	17,990	17,449	17,251	17,140	17,070	17,036
Total Wireless Capex	20,700	19,721	19,077	18,504	18,294	18,176	18,102	18,066
%Broadband[254]	*50.0%*	*60.0%*	*64.0%*	*68.0%*	*73.0%*	*78.0%*	*81.0%*	*85.0%*
Wireless Broadband	**10,350**	**11,833**	**12,210**	**12,583**	**13,354**	**14,177**	**14,663**	**15,356**
Satellite Broadband	**200**	**200**	**200**	**300**	**400**	**400**	**200**	**300**
WISP Broadband[255]	**199**	**219**	**241**	**265**	**292**	**321**	**353**	**388**
TOTAL CAPEX	**69,344**	**60,354**	**57,989**	**55,367**	**54,709**	**54,624**	**54,300**	**54,287**
TOTAL BROADBAND CAPEX	**31,035**	**30,008**	**29,898**	**29,300**	**30,593**	**30,516**	**30,705**	**31,455**

Source: Average of analyst data provided to CITI, with adjustments as described in the accompanying text. *Telco*: AT&T (excluding wireless), Verizon (excluding wireless), Qwest; *Cable*: Comcast, Time Warner, Cox, Cablevision, Charter, Mediacom, and Insight; *Wireless*: AT&T, Verizon, Sprint, T-Mobile.

[11] According to CITI data the trend in broadband innovation share of investment will grow and exceed 60% within five years. Robert C. Atkinson and Ivy E. Schultz, "Broadband in America: Where It Is and Where It Is Going," Preliminary Report Prepared for the Staff of the FCC's Omnibus Broadband Initiative, November 11, 2009, Table 15. CITI efforts to distinguish "broadband" and "legacy" capital expenditures (p. 30 and pp. 64-67, Tables 5, 14, and 15, and Figures 20 and 21). It is worth noting that AT&T estimated that about 2/3 of its 2009 investment can reasonably be attributed to be in support of broadband networks by providing more users more functionality as reflect varying combinations of more coverage, speed, and/or capacity. CITI, p. 30.

[12] CITI Broadband Study, Table 15, p. 66. The investment figures in the CITI study may underestimate industry broadband investment. Substantial plant upgrades were necessary to enable broadband technologies. For example, investment into quality 2-way transmission for cable TV networks was a precursor to a broadband service.

As with all accounting allocations, questions about the definitions, treatment of common costs, and other matters by CITI muddy the water a bit. It is not clear how CITI defines the two categories or what is included in each. Much new capital expenditure is for categories that may fairly be categorized as for joint use by both legacy and innovative applications. Nobody will dispute that. At issue is the reasonable allocation to legacy and innovative services of expenditures on investment in long haul backbone, metro transport and other network components that support growth in data traffic; wireless data backhaul growth; enterprise data services; or assorted classes of facilities supporting both broadband and traditional services (central office upgrades, trucks, billing and business support systems, and others). The allocation is not so simple and involves judgment not science.[13] While there may be some dispute at the margin about where to allocate specific items in broadband provider capital budgets, the larger picture is clear. A substantial share of network operators' investment – half or more -- is fairly credited to diffusion of broadband technology innovations. It is worth noting in this context that recent data on uses of cash by different firms in the Internet Ecosystem indicate that investment in the core, as a percent of cash flow, is occurring at a much higher rate than investment at the edge.[14] This suggests an even larger relative role for investment driven innovation in networks.

[13] For an elaboration of these and other accounting ambiguities that may lead to understatement of the share of CapEx reasonably attributable to provision of broadband or other innovative services, See, Comments of The United States Telecom Association, In the Matter of Comments – NBP Public Notice # 23 GN Docket Nos. 09-47, 09-51, 09-137.

[14] Larry F. Darby, Joseph P. Fuhr, Jr. and Stephen B. Pociask, "The Internet Ecosystem: Employment Impacts of National Broadband Policy," The American Consumer Institute, January 29, 2010. This study provides data from audited financial reports showing that, on average, network companies produce twice the investment and twice the jobs that edge companies produce on a dollar-for-dollar cash flow or revenue basis.

V. NETWORK INTELLIGENCE AND INNOVATION IN WIRELINE TELEPHONY

Despite suggestions to the contrary from Net Neutrality advocates, the rate, depth, and breadth of innovation in broadband networks has been remarkable.[15] Deployment of intelligence throughout networks, introduction of advanced digital switching/routing schemes, upgrades to next generation transmission equipment, as well as thousands of miles of fiber extending to, and nearer to, end user locations is merely suggestive of the broad innovations that have been incorporated variously into different competitive broadband platforms, including cable, wireless and wireline communications networks. Economic benefits of these innovations can be observed in metrics of increased network output, customer subscriptions, greater functionality, more and more diverse service features, better overall quality of service, higher speeds, as well as declining costs and rates. This section provides an overview of the major innovations that have cut across all of these network platforms, with emphasis on wireline telephony. Sections VI and VII provides supplemental illustrations and examples for wireless and cable platforms, respectively.

Traditional communications networks contained most of the complex processing intelligence in the core of the network with simpler, dumb devices (voice transceivers, video/audio receivers, fax machines, recorders, etc.) connected at the customers' premises.[16] These intelligent networks took decades to build and were subsequently transformed in ways that enabled and encouraged incorporation of intelligent devices by users.[17] In a nutshell, the technology foundation migrated from analog to digital signal

[15] The sections on network changes, topology and innovation reflect our extensive discussions with Dr. Charles Jackson who is not, of course, implicated by any of our mistakes.
[16] There have been relatively few major innovations at the interface between the telephone network and user equipment. Perhaps the biggest innovation between 1900 and the present was the development of digital interfaces known as ISDN. Innovation in wireline networks has often been hidden from users due to the need to preserve the external interfaces on the network. Thus, a candlestick telephone with a carbon microphone and a rotary dial could still work with the network 50 years after it was installed. But, on the other end of the wire there was a continuing flurry of innovation. Over the decades a wide variety of innovations reduced costs and improved performance while maintaining compatible interfaces. Local distribution plant was improved. Cables became less costly and more reliable. Remote electronics in the loop plant lowered costs.
[17] Even the terms intelligence and intelligent network in this context are somewhat ambiguous. http://en.wikipedia.org/wiki/Intelligent_network.

propagation; telephone networks migrated from circuit switching to packet switching, while cable networks reflected similar transformations; throughput capacity escalated from narrow band (voice and slow speed data) communications to broad(er) band (high speed, audio, video); and, finally, both telco and cable networks diversified legacy voice or media service offerings to embrace voice, video, audio, and data, that is, “Everything over Internet Protocol.” These transformations required incorporation within legacy networks, more and diversified intelligence embedded in software controlled switches, proliferation of routers, as well as completely modernized central offices and cable TV head-ends.

Transmission. Generations of improvements in transmission systems lowered the cost of long-distance communications by many orders of magnitude, while at the same time they improved the quality of the connection provided to customers. Coaxial cable and microwave replaced open wire. Satellites supplemented microwave and cable. Optical fiber created another cost revolution. Early fiber systems operated at 45 Mbps; today’s networks can carry multiple signals (lambdas) each delivering tens of gigabits per second with total capacities on a single fiber in the terabits per second range. Given that much of the cost of a fiber network comes from the civil engineering enterprise of stringing or burying the fiber, these higher speeds translate almost proportionately into lower transmission costs. Long distance calling went from about $1.00 per minute in 1950 (in 1950 dollars or about $9 in 2010 dollars) to “too cheap to meter” in many calling plans today.

Switching. There have been multiple “revolutions” in switching networks. Automatic systems replaced manual systems. Solid state replaced relays and stored program control replaced hard-wired relay logic. Hardwired addresses were replaced by the use of symbolic names with meanings defined by translation tables. New network services, such as 911 and E911 were defined, perfected, and deployed. Smart routing of 800 calls permitted the destination of 800 calls to be a function of the calling party’s location and the time-of-day as well as simply the dialed number.

Digitalization permitted computer communications, first among firms, then among households, and then among a variety of intelligent, fixed and mobile, devices. Few will deny that the digital communications platform has become a critical enabling technology in which interconnection, interoperability, and maximization of available functionality to end users have become essential ingredients to continued flow of opportunity and incentive for dynamic innovation at the edge.[18] It is worth noting that effectively all the revolutionary changes in computers (compaction and speed) are mirrored in telephone switching equipment. Huge central offices, like the original mainframes, were sized for steppers and crossbars, and were eventually replaced by ESS and other switches that were about the size of a big screen home entertainment center. Telephone central offices are mostly empty today. More recently, computers eventually became the switches – ATM switches, soft-switches and servers.[19]

Fiber in Local Distribution Networks. The introduction of fiber in local distribution telephone and cable networks is a signal development and one that reflects substantial investment directly enabling dramatic increases in speed and functionality. At the same time, fiber has enabled new applications both by cable and telco network providers themselves and by other Ecosystem firms that rely on networks to power and support their services.[20] Home bandwidth availability has increased dramatically over the past decade – from 33K bits per second (bps) in the late 1990s; to 1 million bps at the

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[18] Multi-Protocol Label Switching (MPLS) is now widely used as the underlying technology in IP networks. MPLS provides a host of capabilities that are not as easily provided using pure IP networking. It can provide quality of service; it enables secure routing of traffic from corporate networks using overlapping IP address spaces (e.g. 192.168.x.x); and it can carry other traffic, such as Ethernet frames or ATM cells, as well as IP datagrams.

[19] For an informative if fairly simple and general history of switching, see, http://www.phworld.org/switch/softswitch.htm.

[20] An insightful early study of innovation in the fiber optical communications sector anticipated some of the issues now being considered in the broader context of the Internet Ecosystem. See Yanming Liu, "A Strategic Study of Technological Innovations in the Fiber Optical Communications Industry," submitted to the Alfred P. Sloan School of Management, May 2001. http://mitsloan.mit.edu/research/clockspeed/MBAthesis-Liu.doc, pp. 14-23. Liu links changes in technology at the firm and industry level to changes in business strategies; pp. 41-50; he explores the fiber optical "value chain" and its linkages to other elements of communications networks; and, he explores how firms attempt to recover the costs and appropriate value from complementary assets. Finally, at pp. 81-88, Liu explores the linkages between the evolution of technology, innovation, and imperatives for firms to adapt overall corporate strategies with respect to financing, marketing, outsourcing, acquisitions and strategic alliances with firms producing complementary outputs.

turn of the century; to 8 million circa 2005; to projections and expectations of 100 million bps available in some markets in the next couple of years.[21] The number of homes passed by fiber increased in five years (March 2004 to March 2009) from 189,000 to 15,170,900.[22] Numerous new applications – beyond the highly publicized Triple Play of voice, high speed data, and increasingly bandwidth demanding video -- are enabled by fiber in local telco and cable networks. These are materializing rapidly and include: community based security systems, social networking applications, arts and educational applications, home automation services, backhaul for local Wi-Fi connections, higher capacity online storage, home security, a whole host of new applications linking computers and television receivers (so-called "convergence applications"), and property management applications (security, energy management, "smart grid" services for electric utilities), to name a few.[23] These applications also contribute to energy efficiency and environmental preservation by making more attractive and economical both teleconferencing and telecommuting.[24]

Intelligent Core Networks. The amount and location of intelligence built into telco broadband networks is a matter of discretion for their owners.[25] In a recent White Paper, the Yankee Group summarized this choice as follows.

> As service providers migrate toward converged, multiservice IP core networks, network planners are confronted with an important choice. One option is to choose the path of least resistance, which is to design the core network for inexpensive, scalable, simple IP transport. The alternative is to infuse intelligence in the IP core.

In a recent and comprehensive study of the evolution of intelligent networks, Yankee Group concluded that most top tier and competitive broadband service providers are opting to build intelligence into the network. Taking as given the prospect of

[21] Fiber to the Home, FTTH Council, 3rd edition, Spring 2009, p. 11. http://www.ftthcouncil.org/sites/default/files/FTTH%20Fiber%20Primer%20low%20res.pdf
[22] Ibid, p. 18.
[23] Ibid, pp. 12-15.
[24] Ibid, p. 16.
[25] For examples of how features may be incorporated either at the edge or the core and the advantages of each, see: "A Step Ahead: The Cisco ASR 1000 Series Router -- A Quantum Shift at the Network Edge." http://www.cisco.com/en/US/solutions/collateral/ns341/ns524/ns562/ns592/brochure_Cisco_ASR1000.pdf.

continuing exponential growth in IP traffic, diversification of user needs, and uncertainty about evolving demands, Yankee Group cites the following drivers for increasing incorporation of intelligence in core networks.[26]

> • Acceleration in the demand for premium, personalized broadband IP services, such as IPTV, internet video, Voice-over-IP (VoIP) and gaming, which require all of the essential components of IP core intelligence to guarantee user experiences.
>
> • Strong demand for high-value, profitable "managed" services and premium business applications, such as telepresence, which require an intelligent protocol to assure quality of service (QoS), security and other service requirements:
>
> • Momentum toward converged, multiservice IP networks that require more IP core intelligence for controlling and maximizing network adaptability and revenue potential in the context of an unpredictable range of user demand for services diversity and new applications.

An impressive array of innovations reflecting these forces in network design and investment programs has been occurring and will continue to do so. The migration process will continue to require significant transformation of and innovation within legacy networks.[27] These innovations are required by and reflect efforts to accommodate

[26] Mark Bierberich, "IP Core Network Intelligence: Essential Components and Drivers," A Cisco Systems Sponsored White Paper, October 2007. http://www.cisco.com/en/US/solutions/collateral/ns341/ns524/ns562/ns573/net_implementation_white_paper0900aecd806fc3f0.pdf.

[27] For a discussion of the requirements, and implicitly, the innovations involved in continuing the migration of broadband telco networks from analog to IP to Next Generation Networks, see: "Building the Carrier-Class IP Next-Generation Network," Cisco Systems White Paper, 2006. http://www.cisco.com/en/US/prod/collateral/routers/ps5763/prod_white_paper0900aecd802e2a52.pdf The paper illustrates how this transformation might occur for a typical traditional service by sketching out a scenario of necessary innovations to support migration from traditional circuit switching to Next Generation IP. Innovation in data networks has been more visible outside the network than was the case in voice. The earliest modern data networks used modems that transmitted data signals over voice-grade connections within private-line networks or over the switched voice network. Shortly thereafter, the industry provided various forms of high-speed services with probably the most widespread being use of the 1.5 Mbps T1/DS1 transmission path that was originally developed for voice service. As higher speed transmission paths were developed to support voice services, these capabilities were also made available for point-to-point data services. These point-to-point network services were supplemented with a changing and growing array of switched data services. The first of the modern switched data services was X.25, an early packet service. Other switched data services have included frame relay, ATM, IP, carrier Ethernet, and MPLS as well as several other services that did not attain major market shares. The greater visibility of data networking innovations arose for two related reasons. First, there was not a huge base of operating equipment using a single, well-defined interface that almost defined the relevant market. Second, user

"convergence" in three domains: networks, services and applications.[28] They also are reflected in the need for implementation by substantial investment.[29]

Indicators of Early Network Innovative Activity. Prior research on services derived from core networks and offered to consumers in the early days of the Internet gives one indication of the early proliferation and diversification of innovative applications provided by commercial suppliers of Internet access in the United States. The study summarized below provides data describing the diverse array of services offered by 2,089 ISPs in the summer of 1998.[30]

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needs were growing and changing rapidly. Users were upgrading systems and installing new systems. This process of change made it relatively easy to introduce new data services—certainly far easier to introduce new data service interfaces (e.g., ATM) than to introduce new voice service interfaces.

Rapid improvements in fiber capacity and increases in data networking within enterprises have spurred the adoption of some of these technologies. For example, carrier Ethernet services complement the widespread use of Ethernet local area networks (LANs) in offices. They allow firms to interconnect multiple offices or campuses using virtual LANs that support legacy protocols as well as IP networking.

MPLS provides another illustration of carrier network evolution. The MPLS protocol was developed to combine the advantages of ATM with the advantages of IP. MPLS is widely used in IP networks; indeed, people often speak of IP/MPLS networks. http://www.cisco.com/en/US/solutions/collateral/ns341/ns524/ns562/ns577/brochure_c02-496508.html).

[28] Cisco Systems, a major provider of innovation embedded in new networks, elaborated as follows:

Application Convergence - Using Internet Protocol (IP) technologies, service providers can integrate new data, voice, and video applications over a single broadband infrastructure reducing cost and increasing functionality. Application convergence opens the doors to "all-media services" such as telepresence and multimedia collaboration.

Service Convergence - Virtualization technology is changing the nature of computing by effectively decoupling "the service" from "the box." Service providers can use virtualization to deliver computing, storage, network, and security services with dynamic scalability that senses workload demands and responds with additional capacity. This kind of "service agility" creates a stronger relationship between the service provider and end user.

Network Convergence - In the past, network convergence referred to retrofitting traditional voice networks of the big telecommunications companies so they could support new business systems. Today, this convergence refers to a new breed of network…This network is seamlessly integrated with data centers and computing, storage, and network platforms to deliver IT infrastructure as a service.

"The Power of Intersection - A Tale of Two Infrastructures, Cisco Systems White Paper." http://www.cisco.com/en/US/prod/collateral/routers/ps6342/prod_case_study0900aecd805f62d4_ns573_Networking_Solutions_Case_Study.html, p. 2.

[29] As discussed earlier, innovation (inputs, outputs, processes, activities, etc.) may be defined and measured in several ways. A very important one, and one that is generally neglected in the net neutrality debate, is the acquisition and incorporation into extant networks of plant, equipment, and other forms of capital expenditures that are linked to, or occasioned by, new forms of production and/or new forms of product and service outputs. While not all of these capital expenditures are linked or dedicated to "innovation," increasingly large shares of them are. Some "old" plant and equipment is being replaced in kind or maintained by current capital spending, but the lion's share is devoted to putting in place these innovations.

[30] Shane Greenstein, "Building and Delivering the Virtual World: Commercializing Services For Internet Access," The Journal of Industrial Economics, vol. XLVIII no. 4, December, 2000, p. 391.

The study involved grouping new, emerging commercialized Internet services into five broad categories: basic access, frontier access, networking, hosting, and web page design. The categories suggest the range, diversity and innovativeness of the economic activity of ISPs.[31] The work emphasizes which activities push out frontier access and which provide services complementary to access. Since little, and very coarse, information was available about the characteristics of demand, these categories generally reflect the perspectives of individual service providers as to how activities should be grouped. Thus, they mirror the fact that the diverse array of Internet services offered brought together different skills, backgrounds and commercial intentions.

Inspection of **Appendix A** illustrates vividly range of new services, activities, and innovations that emerged more than a decade ago, well before the emergence of large non-network firms that now populate the Internet Ecosystem and claim many of these innovations as their own. Many of the innovations observed today as applications at the edge reflect implementation, investment, variations and applications of new business models based on services initiated more than a decade ago.

Early Indications of Regulatory Impact on New Services Introduction. There have been few studies of the direct impact of regulation on network innovation. Even fewer are devoted to a particular sector and even fewer address the impact of rate and service regulation on firms in the Internet Ecosystem. There are lots of claims about how regulation will promote innovation, but little in the way of facts or analysis. That is not surprising given the nature of the breadth of the terms innovation and regulation combined with the scarcity of data to quantify either. These limit the ability of analysts to devise operational, testable definitions. Both regulation and innovation are complex phenomena and difficult to model in testable ways.

One notable attempt took advantage of the opportunity to compare a specific subset of innovation – the introduction of new telecommunications services—in the context of a discretely measurable, changing regulatory environment that made possible a

[31] A complete description of these is included for reference in **Appendix A**.

"before/after" or "with/without" regulation experiment.[32] The experiment was made possible by the changing regulatory requirements imposed on local Bell operating companies following the breakup of AT&T. Changes in the regulatory environment involved requirements of the regulated firms to file "comparably efficient interconnection" (CEI) and "open network architecture" (ONA) plans and obtain approval from the Federal Communications Commission prior to their introduction in the marketplace.[33] While these were in effect, local Bell Operating Companies were required to file detailed plans for offering new "enhanced" (that is other than "basic" switched voice) services. These filings were to describe and assure interconnection arrangements to competitors in the retail market network that were "comparably efficient" to those they provided to themselves. For a period during 1992-1995, owing to Court orders, these detailed plans and time-consuming approvals were not required and, accordingly, the FCC permitted Bell companies to introduce new enhanced services without the uncertainty and delay occasioned by the obligation of *ex ante* review by competitors and the Commission.

Carriers likely found it more financially appealing to introduce new services during the interim of reduced regulation. As Prieger explained:

> The CEI requirements reduced the expected profit of introducing a new service, for at least three reasons. First, there are substantial direct costs of preparing a CEI plan, which require great amounts of technical and legal staff time. One BOC claims that the CEI plan requirement is "the

[32] James E. Prieger, "Regulation, Innovation, and the Introduction of New Telecommunications Services," The Review of Economics and Statistics, vol. 84, no. 4, Nov., 2002, pp. 704-715. "In regulated industries such as telecommunications, however, firms attempting to introduce new services often must contend with restrictions designed more to protect the *status quo* than to promote innovation. Despite the prevalence of such restrictions, little effort has been devoted to measuring the effects of regulation on product innovation." On that point, see Paul L. Joskow and Nancy L. Rose, "The Effects of Economic Regulation," in R. Schmalensee and R. D. Willig (Eds.), Handbook of Industrial Organization, vol. 2, Amsterdam: North-Holland, 1989, pp. 1449-1506. They noted that such studies were virtually nonexistent. So far as we can determine the dearth of empirical work on regulation and product innovation has largely remained.

[33] Changes in the regulatory environment were the joint result of FCC rule changes related to Computer Inquiry II and Computer Inquiry III decisions, as well as an Appeals Court holdings about the applicability of the comparably efficient interconnection and open network architecture standards in FCC Computer Inquiry III. Taken together, these created a window of "less regulation," characterized by less obtrusive FCC review standards, in a timeframe characterized on either side of the window of what may be characterized as "more regulation." See Prieger, pp. 705-706, for discussion and a time chart showing the interactions of FCC rules and reviewing Court holdings as they defined the regulatory environment.

> most significant" regulatory burden imposed on BOCs' enhanced service operations. Second, the plan reveals information to potential competitors before the service is introduced, allowing competitors to preempt the BOCs. Third, there are long delays associated with plan approval-over 200 days on average, a long time in the rapidly evolving telecommunications industry. Once proposed, the plans typically went through several rounds of public comment and rebuttals, and in six cases the FCC requested changes to the plans. The delay reduces the present value of a proposed new service and allows competitors to beat the regulated firm to market.[34]

Using the period of lighter regulation as an experiment and the opportunity to test the regulatory regime's impact, Prieger designed an econometric model comprising an arrival process for service innovation followed by a duration process for regulatory delay. He concluded:

> The number of services the firms created during the interim is 60%-99% higher than the model predicts they would have created if the stricter regulation had still been in place. Overall, firms would have introduced 62% more services to consumers during the study period if the regulation had not been in place.[35]

The Prieger study is one of the few to test the regulation/innovation linkage for communications network providers. While limited in its conception and application, its major conclusion about the negative effect of regulation on innovation reflected in new service introduction is persuasive and unrebutted.[36]

[34] Ibid, p. 705.
[35] Ibid, pp. 704 and 712.
[36] Claims that regulation would lead to increased investment in the industry are simply wrong. See Larry F. Darby, "The Informed Policy Maker's Guide to Regulatory Impacts on Broadband Network Investment," The American Consumer Institute, December 2009.

VI. CORE AND EDGE INNOVATION IN WIRELESS NETWORKS

Claims about the incidence and importance of innovation at the core and edge typically fail to define these terms or specify a clear, operational dividing line between the two. Interdependencies and complementarities between network components and non-network or terminating devices make it arbitrary at best, and in some cases, impossible to distinguish core v. edge boundaries. The difficulties of distinguishing core from edge innovations are most pronounced and observable in the case of wireless networks, but exist as well in the case of wireline networks.

It is well established not explicitly contested by net neutrality advocates that handsets are both technically and economically integral parts of wireless networks. The reasons are straightforward. While it is generally recognized that handset capabilities are complementary to network functions, it is also the case that handset functionality and network functions are substitutable. Network design engineers have the option of placing intelligence in either or both the core or edge of network locations. They do so in the context of maximizing overall efficiency and value to end users by trading off cost and value of alternative distributions of functionality. Investment in handsets can reduce the need for investment in networks and vice versa. In the same sense, the location of innovation depends on tradeoffs among value and cost inside or outside networks as traditionally construed. The most authoritative study to date of the boundary between core and edge in wireless networks concluded that performance linkages are inseparable and that no such boundary exists in real world networks.

> In practice in today's wireless networks, the handset and the network are not two separate products-as are automobiles and gasoline or shoes and shoe polish-but are aspects of a single product. Most important, purchase of improved equipment by one subscriber can improve service for other subscribers. Handsets are part of the wireless network, and the performance of handsets has substantial static and dynamic efficiency implications for the operation of the network as a whole. Investments in handsets can reduce the investment needed in the rest of the network.[37]

[37] Charles L. Jackson, "Wireless Handsets Are Part of the Network," April 27, 2007, p. 1.

A recent study of wireless innovation – perhaps the most complete and insightful collection of data on the matter to date – makes clear the interdependencies among wireless networks, wireless equipment, and wireless applications.[38] The analysis sharply differentiates innovation in wireless networks from that in the personal computer/wireline network ecosystem and thereby gives the lie to claims that the most important innovations takes place outside the domain of network providers.

Taken together innovations in devices, networks and applications have contributed to the fact that US wireless carriers lead those in all other OECD countries – Japan, Korea and European countries included -- in spectral efficiency as measured by the number of subscribers per megahertz and by average subscriber usage per megahertz.[39] Given that spectrum is ultimately the most binding input constraint in wireless networks, this techno-economic measure reflects the extent to which innovation in networks, handsets and applications has permitted enormous growth in subscription and usage from the finite spectrum resources made available. In less than two decades successive generations of networks have advanced spectral efficiency from the 2G rate (GSM standard) in 1993 with an efficiency of 0.17 [(Bits/Sec.)/Hz] to the 4G rate of about 1.7 (Bits/Sec)/Hz (LTE standard) 16.32 [(Bits/Sec.)/Hz].[40] Nowhere is the mismatch more pronounced between net neutrality claims and market reality than in the evolution of wireless technology and services.

Core Wireless Network Innovations. Technological and economic innovation in the wireless sector can be identified and measured in several ways.[41] Faulhaber and Farber use a commonsense taxonomy to classify wireless innovations into three classes – those in networks, those in equipment, and those in applications. Much of the quantum

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[38] Gerald R. Faulhaber and David J. Farber, "Innovation in the Wireless Ecosystem: A Customer-Centric Framework", September 2009.

[39] G. Campbell, "Global Wireless Matrix 2Q09; Voice and Data Divergence," Bank of America / Merrill Lynch Research, June 25, 2009.

[40] The highest nominal rate of the LTE standard is 16.32 (Bits/Sec.)/Hz. Faulhaber and Farber, p. 9. However, that rate would rarely be achieved in real-world use and the average rate seen in practical use would be much lower.

[41] As discussed above in Section III, there are no well defined consensus metrics for documenting innovation.

leap in spectral efficiency is attributable to innovation in the core networks. Those innovations are largely invisible to end users, but are indispensable to innovations in equipment and in applications. In recent years announcements of several important innovations involving network protocols enabling faster and more diverse information transfers have come in a torrent of alphabetical acronyms like 3G, CDMA, 4G, EV-DO, HSPDA, UMTS, WIMAX, LTE and others.[42] Each enables more efficient use of available spectrum and thereby substitutes for more spectrum, while also enabling and accompanying new and innovative equipment and applications. It is worth emphasizing again that innovations at the edge are critically dependent on the prior innovation, investment and implementation of network improvements. Innovation opportunities at the edge are created by those at the core and as networks evolve in capacity and functionality, even more opportunities to be explored at the edge are created.

The value of these network innovations to consumers and to commerce is enormous, if essentially inestimable. The spectrum efficiencies involved have allowed dramatic expansions in throughput, functionality, cost savings, more subscribers and usage per subscriber -- all while enabling new applications. Most importantly, the innovations have deferred the date at which new spectrum must be diverted from other uses at substantial opportunity costs from losses in other services.

Customer Equipment Innovations. Network upgrades have supported a proliferating array of customer equipment options provided by device manufacturers worldwide. US customers of Verizon or AT&T, for example, can choose from dozens new phone models and a wide assortment of used devices and numerous smartphone, Blackberry or other wireless devices embodying substantial and diverse processing power distributed across numerous applications.[43] A recent tally by CTIA submitted to the FCC reported that US wireless customers could choose from among more than 630 handsets

[42] Faulhaber and Farber, pp. 10-11. The interested reader will find there several links to online sites featuring announcements over the past two years of some of these wireless network innovations by different operators.
[43] http://www.wireless.att.com/cell-phone-service/welcome/index.jsp?WT.srch=1; http://www.verizonwireless.com/b2c/index.html; T-Mobile and Sprint also offer a wide array of phone and other wireless devices.

provided by at least 33 different manufacturers. Competition among wireless service providers is prompting the introduction of new devices, at both the high end (as rivals to the iPhone) and at lower levels of functionality used by most consumers.[44]

Applications Innovations. There is rapid proliferation in the number and variety and functionality added by new applications enabled by new equipment and innovations in wireless networks. While it is futile to try to count the actual number, it is clear that the order of magnitude of new applications is in the tens of thousands with new ones appearing virtually daily.[45] Applications originate with each of the players in the wireless ecosystem – wireless carriers, equipment suppliers, software providers, and independent innovators, including end users themselves. They reflect variations that address an astounding array of human information needs and wants. The extent and diversity beg easy summary and can only be appreciated by reference to some of the websites where they are described and made available.[46] These innovations are being driven by consumer needs reflected in open markets and are the joint and sometimes separate results of wireless ecosystem stakeholders – network providers, equipment providers, software and applications providers, as well as end users themselves.

There are no data, analyses or other indicators that innovation of any kind is being stymied by the lack of rate and service regulation of network providers of the sort being considered under the proposed Net Neutrality regime.

[44] Faulhaber and Farber, p. 8 and references there.
[45] It is likely that several new applications have appeared since the time this report was written.
[46] Faulhaber and Farber, pp. 4-5.

VII. INNOVATION IN BROADBAND CABLE NETWORKS

A broad, but informative view of innovation in broadband cable networks emerges from a mental comparison of technologies, production processes, business practices, services/products offered to consumers, and geographic reach characterizing the sector today with where it was 30, 20, 10, or even 5 years ago. The industry was started by small companies offering retransmission and distribution of programmed signals initially broadcast over the air that were for reasons of distance or terrain could not be received in acceptable quality in some communities or locales.

Early cable networks were basically simple television relay systems using low capacity, analog, coaxial cable and serving only users outside the contour of the local, over-the-air broadcast stations. The transformation from that to what is now available can best be appreciated by reference to the web sites of leading broadband cable network services providers.[47] It will become quickly apparent that the popular term "cable television industry" is no longer apt or even remotely descriptive of the industry's technology, production methods, or services provided to consumers. Details are beyond our scope here, but what follows is a sketch that will make indicate the scope of innovation in the sector and of consumer welfare attributable thereto.[48]

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[47] Time Warner Cable: http://www.buytimewarnercable.com/?cpao=201&kw=Time%20Warner%20Cable&cpca=twc_restrictedterms&cpag=twc_restrictedterms_timewarnercable&kmmt=e ; and Comcast http://www.comcastoffers.com/?cid=63216&exp=vid&affid=415707498::e::Comcast::comcast

[48] The following is taken from Time Warner's description of its business in its 10-K filing with the SEC. Underlining has been added to highlight the "network innovation enabled" diversity of output from its broadband services network.

> "As of December 31, 2008, TWC served approximately 13.1 million basic video subscribers. Of those, approximately 8.6 million (or 66%) received some portion of their video services at their dwelling or commercial establishment via digital transmissions ("digital video subscribers"). Also, as of December 31, 2008, TWC served approximately 8.4 million residential high-speed data subscribers (or 32% of estimated high-speed data service-ready homes passed) and approximately 3.7 million residential Digital Phone subscribers (or 14% of estimated voice service-ready homes passed). TWC markets its services separately and in "bundled" packages of multiple services and features. As of December 31, 2008, 54% of TWC's customers subscribed to two or more of its primary services, including 21% of its customers who subscribed to all three primary services. As part of an increased emphasis on its commercial business, TWC began selling its commercial Digital Phone service, Business Class Phone, to small- and medium-sized businesses in the majority of its operating areas during 2007, and substantially completed the roll-out in the remainder of its operating areas

The industry has incorporated new technology (from analog to successive generations digital transmission); added new services (telephony and broadband Internet access); dramatically diversified its video offerings to consumers (numerous new, and frequently changing, combinations of video program packages with different price points); diversified and bundled programming according to different "genres" (family, news, sports, educational, assorted and targeted entertainment, and others); added quality upgrades to its core offerings (from standard definition television to digital television to high definition television); differentiated service "levels" (basic analog or digital, high definition TV networks) while adding premium programming – sports, entertainment and others, pay-per-view, and video-on-demand (VOD). Broadband cable network providers offer a variety of service "types" including audio, video of different levels, Internet and related broadband services, "planned" services and regional, as well as national offerings. Again, the scope and depth of innovation emerges from a simple comparison with the early offering of retransmitted over-the-air broadcast signals.

Details of the contribution of cable to the evolution of digital broadband networks are spelled out in **Appendix B** which chronicles selected developments by Cable Labs. Calling attention here to a few of them highlights some key developments of the technological dynamics at play.[49]

The cable network industry played a significant role in the development of Digital and HDTV. The system selected by the FCC Advisory Committee for HDTV was an all digital system developed for the cable television industry by Motorola. A new video compression system (based on cosine transforms) was the pivotal element in that development and was introduced by General Instruments as a supplier to cable networks. Time Warner pioneered switched digital video which dramatically increased the

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during 2008. . . As of December 31, 2008, TWC served 283,000 commercial high-speed data subscribers and 30,000 commercial Digital Phone subscribers. In addition, TWC sells advertising to a variety of national, regional and local customers." Time Warner Corporation, 10 K. http://ir.timewarnercable.com/secfiling.cfm?filingID=950144-07-1551.

[49] For many of the details in this description we are indebted to discussions and exchanges of views with Mr. Dick Green, former chairman of Cable Labs.

performance and efficiency of cable broadband networks. Fiber has been widely deployed in cable broadband networks. Currently 95 percent of the homes passed in the US are served by fiber trunks bringing cable services into neighborhoods. Cable transmission has migrated from lower efficiency 16 and 64 QAM to 256 QAM, while higher orders are under evaluation and likely to be timely introduced. All these changes increased network efficiencies, lowered costs and opened new avenues for applications innovations and consumer services.

Cable broadband network operators pioneered an open standard interface that permits television sets to be directly connected to cable systems and enables portability of set-top boxes throughout the US. The core of the Open Cable (Tru2way) specification has been standardized in the ITU. The world wide (Java) interface is compatible with BluRay devices as well as European interactive specifications (MHP). The PacketCable standard allows interoperability of the PSTN with the voice-over-IP services widely deployed by broadband cable networks. Advanced features have been introduced with this technology and include transmission innovations which will support emerging business applications (including telepresence). These applications require advanced protocols to assure quality of service (QoS), security and other improved support from the network. Several innovations in by US cable broadband network providerss have been adopted globally by the ITU (DOCSIS, cable modems, packet cable, and others) thereby enabling scale economies that can be reflected in lower costs to consumers.

Simple performance improvement measures include: investment by the industry totals more than $160 billion since passage of the Telecom Act of 1996 and has averaged over $14 billion per year in the 2006-2009 timeframe;[50] the real inflation adjusted cost to subscribers per hour of digital video viewing has declined since passage of the Telecom Act, according to industry data, from slightly below 35 cents to slightly above 25 cents in 2007;[51] and, broadband cable providers, like some other firms in the Internet Ecosystem, have made good use of innovative, two-sided market pricing practices whereby costs of production are recovered in substantial part not from end users but from advertising

[50] NCTA citing SNL Kagan, at http://www.ncta.com/StatsGroup/Investments.aspx.
[51] NTCA estimates, at http://www.ncta.com/Stats/ViewingHourPrice.aspx.

revenue from other businesses. Ad revenues have more than doubled in a decade to reach over $26 billion by year-end 2008 – an amount that otherwise would have to be recovered from consumers in the form of higher subscription costs.[52] Whether measured by innovation on the input side or by new services and offerings on the output side, there is no denying the existence of substantial technological and commercial dynamism among cable broadband network providers in the absence of net neutrality style regulations.

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[52] NTCA estimates at http://www.ncta.com/Stats/AdvertisingRevenue.aspx.

VIII. CONJECTURES ABOUT INNOVATION AT THE EDGE

The terms "edge" and "core" appear frequently to signify division between firms and services in the Internet ecosystem. There is no common definition of the term, but from the context it is reasonable to infer that the core generally refers to components (hardware or software), systems, and applications provided by broadband network infrastructure firms, while the edge refers to applications, content and other complementary goods or services provided by non-network firms. More simply and practically, claims about edge and core seem mainly to be based on differentiation made on the basis of companies and not on the basis of technical, functional or economic differences.[53] As a practical matter this division reflects end user perceptions derived from expenditures on Internet access, devices, services and ancillary inputs to their Internet experience. While this division may not be perfect, it is no less imperfect than a division based on technical definitions of what is or is not a part of the core of common user networks.

It is difficult precisely to characterize views on innovation by net neutrality advocates because so many of the key terms involved – openness, neutrality, end-to-end, innovation, and even edge and core -- are not operationally defined, if at all, in their published work. However, the following seems to be a fair characterization of the central elements of the claims of net neutrality advocates:

- *Most of the important innovations within the Internet Ecosystem take place outside networks or by firms (applications and content providers in particular) other than network providers;*[54]

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[53] Most of the claims made by net neutrality advocates about core v edge innovation can be interpreted as comparing the contributions of broadband network providers and those of applications providers – Google and others. The use of edge v core seems a matter of convenience, but should not be permitted to shroud the intercorporate aspects of the comparisons.

[54] Professor Lessig if frequently quoted by net neutrality advocates. He concluded: "All the innovation is being done by kids and non-Americans . . .," and "Innovation is at the edge of the network." Lessig Makes Plea For Read/Write Internet," February 16, 2006. Professor Lessig advised the Senate Committee on Commerce, Science and Transportation: "New innovation always comes from outsiders." More explicitly in defense of net neutrality Professor Lessig advised that a neutral network: ". . . assures that in the negotiation between buyer and seller, or innovator and consumer, the network itself plays little or no substantive role. All the power within this negotiation is shifted to the edge, to those economic actors directly responsible for innovation and growth in network applications and content — namely, consumers and innovators."

- *While generally unstated by net neutrality advocates, it follows that the absence of innovation in networks by network operators, or incorporated in their capital expenditures, implies that little or no innovation is taking place– or has taken place -- in firms who provide network equipment systems, software, applications, or other components routinely incorporated over time into broadband networks;*

- *Growth attributed to the IT sector generally is accounted for in large measure, or predominantly, by innovations "at the edge";*[55]

- *The major risk with respect to policy change is that failure to impose regulations will harm "innovation at the edge" (a term that remains to be defined). A corollary is that risks to core innovation are minimal (also undefined).*[56]

We note these assertions in passing, since there is in the record little or no supporting data or analysis of the sort being sought by the Commission. We have not

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http://www.internetnews.com/bus-news/article.php/3585731.

[55] A well known specialist in network economics recently supported this view as follows: "The Internet's amazing and immediate benefits have been based on its openness, ubiquity, and non-discrimination. This non-discrimination – dubbed "network neutrality" – means that content from anyone and of any type is treated equally by broadband providers. Its open and public standards and the fact that no one has had to ask permission from network operators to innovate have resulted in rapid innovation that contributed to one of the greatest periods of economic growth in history, unprecedented access to information, and fostered amazing creative interactions." Nicholas Economides, "Why Imposing New Tolls on Third-Party Content and Applications Threatens Innovation and Will Not Improve Broadband Providers' Investment" p. 1. Notably, for a scholar specializing in network economics, Professor Economides' entire discussion of benefits, incentives, sources and other beneficial aspects of innovation is directed to the edge – mainly content and applications providers -- without a single reference to the impact of the proposed rules on innovation by network providers or their capital asset suppliers. Appendix A to Comments of Google Inc. in GN Dkt. 09-191; WC Dkt. 07-52, January, 2010.

[56] Professor Lessig urges net neutrality regulation while conceding that the impact of such market constraints and new rules cannot be known ahead of time. "How much innovation is protected by these regulations is a hard question. How much less innovation there would be if these principles of the original Net were ignored is also a hard question. We have no good way to measure the effect of these regulations protecting innovation. We have no good way to tell whether in fact they were necessary . . . .But neither do we know enough to say the opposite." Lessig Testimony, pp. 1-2. Professor Lessig has made the claim for some time. Lawrence Lessig, "Competition Policy and Innovation," http://assets.wharton.upenn.edu/~faulhabe/732/Lessig%20innovation%20regulation%20Internet.html. Without any supporting data or economic analysis or recognition of the facts of historical network evolution, Professor Van Schewick opines as follows:

- ". . . application-level innovation is the main determinant of economic growth."
- ". . .increasing the amount of application-level innovation is relatively more important than increasing innovation at the network level.
- ". . . in trading off application-level innovation against infrastructure deployment, it seems reasonable to opt for fostering application level innovation in order to realize the enormous growth potential inherent in Internet technology, and to contemplate other ways of ensuring a sufficient deployment of network infrastructure, if necessary."

Barbara Van Schewick, "Towards an Economic Framework for Network Neutrality Regulation," Journal on Telecommunications & High Technology Law, vol. 5, pp. 329-391.

been able to verify, or otherwise test, claims about the magnitude, variety, location, source and consumer value of innovations specifically allocable to edge service providers. It is fair to say that the current record is inadequate on that score and that much research and documentation needs to be done before the Commission can reasonably come to a conclusion about the incidence, type and value of "edge" innovation by applications and content providers – standing alone and in relation to that done in the underlying broadband networks.

IX. EFFECTS OF INNOVATION AND CHANGES IN NETWORK TOPOLOGY.

The architecture of the Internet has changed dramatically since papers on "end-to-end" principles and other early descriptions of the Internet were written. Those changes have rendered questionable, and often misleading, characterizations of the Internet as being made up of discrete and largely independent layers. Topological innovations, such as private peering, multi-homing, secondary peering, server farms, content delivery networks, and others are transforming the Internet's traditionally hierarchical architecture into one that is far more heterogeneous.[57] Professor Yoo explained this phenomenon:

> The network no longer adheres to the rigid and uniform hierarchy the characterized the early Internet and its predecessor, the NSFNET. Packets can now travel along radically different paths based on the topology of the portion of the network through which they travel. This is the inevitable result of reducing costs and experimenting with new structures.[58]

New two-sided Business Models Respond to Changing Network Topology. The changing architecture of the Internet has substantially modified relationships among interconnecting network providers.[59] Some of the changes are in response to the emergence of peer-to-peer technologies and services; others like paid peering and partial transit reflect the growth and efficiencies of advertising based pricing models structured along the lines of "two-sided" market principles.[60] Professor Yoo summarized the impact of topological changes borne of network innovations:

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[57] Christopher S. Yoo, "Innovations in the Internet's Architecture that Challenge the Status Quo," University of Pennsylvania Law School, 2009, p. 1. Yoo elaborates with references at pp. 10-16 while discussing the role and impact of private peering, multihoming. See also the discussion of secondary peering and the development of server farms and new content delivery networks, p. 28.

[58] Ibid.

[59] For a detailed discussion of how business models and pricing structures have changed to reflect the changing topology,–paid peering, partial transit to two-sided business practices similar to that in print media and elsewhere (subscribers and advertisers pay , see Yoo at pp. 22-28.)

[60] According to Yoo, "At times interpreted as network providers' attempts to promote their self interest at the expense of the public, these changes often reflect network providers' attempts to reduce cost, manage congestion, and maintain quality of service. As such, they have the potential to yield substantial benefits both to individual consumers and to society as a whole." The consumer welfare impacts have been estimated variously. See: Larry F. Darby and Joseph P. Fuhr, Jr., "Consumer Welfare, Capital Formation and Net Neutrality: Paying for Next Generation Broadband Networks," Media Law and Policy, Summer 2007, pp. 122-64; J. Gregory Sidak, "A Consumer Welfare Approach to Network Neutrality Regulation of the Internet, "Journal of Competition Law and Economics, vol. 2, no .3, 2006, pp. 349-474; Stephen Pociask, "Net Neutrality and the Effects on Consumers," The American Consumer Institute, May 9, 2007.

> Gone are days when networks interconnected through peering and transit and imposed all-you-can eat pricing on all end users. That . . . has been replaced by a much more complex set of business relationships that reflect creative solutions to an increasingly complex set of economic problems. . .[T]he service that any particular packet receives and the amount that it pays will vary with the business relationships between the networks through which it travels. . . [These changes] represent nothing more than the natural evolution of a network trying to respond to an ever-growing diversity of customer demands.[61]

The implications for pricing and for acceptable business models of innovation driven changes in network topology are indeed far reaching and should be considered by the Commission in its evaluation of the proposed net neutrality rule changes that would restrict the ability of network providers either a) to manage networks and reprice services to reflect capacity costs and/or b) to adopt two sided pricing models reflecting charges to applications providers in addition to those imposed on subscribers.

Consumers Buy Services, not Innovation. Consumers are not aware of these specific network innovations and investments in their technical detail, nor do they care. They perceive innovations in the services and products they use, in terms of changes in service quality, functionality, diversity, bandwidth, availability and prices. Changes in the output of services, both in terms of diversity and in terms of quantity, enabled by the foregoing investments are another way to appreciate how users perceive, and are harvesting the value of, innovation in broadband networks.

Given the existence of high fixed costs and relatively low variable and incremental connection costs, there are substantial competitive pressures on suppliers of broadband access to lower rates to achieve fill and to contribute to coverage of fixed costs. At the same time, network productivity and innovations lead to per unit cost

[61] Yoo, p. 28.

reductions for network providers.[62] These operational efficiencies, coupled with competitive pressures, yield lower consumer prices for broadband services.

There is readily available, if frequently ignored, empirical evidence that broadband prices are falling. One ISP dropped its broadband prices for 1.5 MB DSL from $80 per month to $15 per month over the May 2001 to May 2006.[63] According to a June 2008 report by USTA, as broadband speeds have increased, in the face of extraordinary increases in demand, prices have significantly declined.[64] And, there are other examples of declining broadband prices.[65] In addition, recent government statistics suggest that these online ISP prices continue to decline. The Bureau of Labor Statistic's Consumer Price Index for Internet Services and Electronic Information Providers shows that from November 2005 to November 2009 consumer prices declined by 5% per year in

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[62] The telecommunications industry is well known for its ability to achieve productivity gains that exceed gains in other industries, which explains why the sector was subject to a productivity offset during the transitioning from rate-of-return regulation to market competition. This productivity change has come from operational efficiency and technical change, both stemming from network innovation.

[63] See, J. Gregory Sidak, "A Consumer Welfare Approach to Network Neutrality Regulations of the Internet," Journal of Competition Law & Economics, vol. 2, no. 3, 2006, p. 400.

[64] For example, DSL services running between 768 kbps to 1.5 mbps downstream in 2001 could be purchased at half the price just six years later. Similarly, DSL services running between 768 kbps and 1.5 mbps were priced nearly equivalent to DSL services running 15 mbps in 2007. Evidence of falling prices is documented by the United States Telecom Association. http://www.ustelecom.org/uploadedFiles/Learn/Broadband.Pricing.Document.pdf.

[65] One well documented source is work by Professor Ellig. Ellig summarized recent developments in a report to the Federal Trade Commission:

> Substantial price reductions have occurred in recent years. Between 2004 and 2005, BellSouth cut the monthly price of 1.5 mb DSL from $39.95 to $32.95, a 17 percent drop. Qwest dropped its promotional price from $26.99 to $19.99 and extended the term from three months to a year. SBC cut its promotional price, good for a year, from $26.95 to $14.95. Verizon Wireless reduced the monthly fee for wireless broadband service using a PC card by 25 percent, from $79.99 to $59.99. Another indicator of dynamic performance competition in broadband is the rate at which maximum speeds have increased. In its first report on the extent of broadband deployment, the FCC noted that the maximum speeds were 3 mbps for cable modem service, 1.5 mbps for DSL, and under 500 kbps for satellite. Speeds have obviously improved greatly. Between 2004 and 2005, a number of major broadband providers increased the speed of their service. SBC increased the upload speed of its DSL service threefold, from 128k to 384k. Cablevision increased its download speed from 5 mb to as much as 10 mb. Comcast increased its download speed from 3 mb to 4 mb and its upload speed from 256k to 384k. Time Warner increased download speed from 3 mb to as much as 8 mb. These changes represent performance improvements of between 25 percent and 200 percent—in one year. In 2006, company web pages indicated further improvement in maximum speeds, where Comcast offered a maximum download speed of 6 mb, Cox offered 15 mb and Cablevision offered 30 mb.

nominal terms and 8% per year when adjusted for inflation.[66] ISPs are dropping network prices while increasing speeds, which reflects the combined effects of network innovations, increased operational efficiency, and intermodal rivalry.

Lower consumer prices impel increased consumer demand for more and faster broadband services. According to the FCC's latest report, from December 2005 to December 2008, high-speed connections roughly doubled. However, in 2008, there were six times as many high-speed subscribers that used speeds of 10 mbps to 25 mbps, and five times as many high-speed subscribers that used speeds over 25 mbps than there were in 2005.[67] With these speeds and lower prices come increased reliability, functionality and convenience.

Increases in network speeds and decreases in price stimulate consumer use, while both enabling and encouraging innovation by applications and content providers at the edge. Without faster speeds, peer-2-peer technologies and video sites would not have the utility that they have today. Because broadband consumers visit (on average) twice as many web pages as dialup consumers, these broadband consumers are more valuable than dialup consumers to advertisers and search engine providers.[68] E-commerce transactions, once slowed by a high rate of "abandoned shopping carts" are now being completed due to faster network speeds.[69] Web applications online today substantially owe their success to the increased reliability, bandwidth and functionality of innovations embedded in broadband networks. Future applications are enabled and encouraged.

[66] BLS CPI-U indexes available at: www.bls.gov. The Internet service index includes all online consumer services, such as dialup and broadband services.
[67] These figures come from the FCC's broadband report "High-Speed Services for Internet Access" Status as of December 31, 2008, FCC, February 2010. They exclude wireless subscribers with broadband capability on their devices that are not on a monthly data plan.
[68] For example, see "Three Quarters of Web Users on Broadband," Associated Press, Dec. 12, 2006.
[69] The major reason that shoppers abandon their online shopping carts is inconvenience, predominantly caused by delays and service reasons. Forrester Research has estimated that 66% of online shopping carts were abandoned a decade ago, when dialup services were still common. For a discussion of this problem, Rajasree K. Rajamma, Audhesh K. Paswan and Muhammad M. Hossain, "Why Do Shoppers Abandon Shopping Carts? Perceived Waiting Time, Risk, and Transaction Inconvenience," Journal of Product & Brand Management, vol. 18, no. 3, 2009, pp. 188-197.

X. INNOVATION AND SELLER CONCENTRATION IN THE INTERNET ECOSYSTEM

A recurring theme in the net neutrality debate is a contention by advocates of common carrier type regulation that the market structure for broadband network access, seller concentration in particular, leads to lack of innovation and other signs of poor economic performance.[70] The contention relies on an assumed linkage between seller concentration and the incentive and opportunity to innovate, which, taken together, lead to technological stagnation. The discussion in Sections V, VI and VII refutes the "network stagnation" theory, but it is instructive nonetheless to report the results of numerous studies and surveys attempting to link market structure to innovation.

Despite an enormous amount of literature and academic attention devoted to the matter, no theoretical or empirical connection between market structure and innovation has been established in general, nor, by inference or direct measure, in markets for broadband Internet access. A recent survey of the links between market structure and innovation concluded:

> The theory leaves significant gaps in our understanding of the effects of market structure on innovation, and hence it is all the more important to turn to empirical studies. Unfortunately, although many studies test the hypothesis that market structure influences research and development, most have serious deficiencies that greatly undermine their value.[71]

Efforts to measure empirically such a relationship have not proven to be productive either. Thus, according to Gilbert:

> The literature does not find a strong link between the structure or amount of R&D and the supply of new goods and services.[72]

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[70] Generally, the charge is embedded in complaints about "cozy duopolies" that refer to cable and telco network providers.

[71] Richard J. Gilbert, "Competition and Innovation" Journal of Industrial Organization Education, vol. 1 no.1, 2006, p. 17.

[72] Ibid, p. 7.

Scholarship on the matter does not resolve the longstanding debate over the roles of market rivalry versus market power on the one hand and technological progress reflected in high rates of innovation on the other. More particularly:

> The large body of economic theory and empirical studies on the relationship between competition and innovation fails to provide general support for the Schumpeterian hypothesis that monopoly promotes either investment in R&D or the output of innovation. The . . . evidence also does not support a strong conclusion that competition is uniformly a stimulus to innovation.[73]

A major infirmity in efforts to link innovation and concentration is the lack of a good measure of innovation owing in large part to the lack of definition described in section III. Exploring the effects of seller concentration on R&D, patents activity, or other easily measurable proxies for innovation fail to capture the complexities of information technology network adaptations over time. Gilbert's assessment of the competition policy implications of his findings is instructive as well: "Determining the effects of a merger on innovation will require a detailed analysis of the specific facts in each case."[74]

The conclusions in Gilbert are generally consistent with those of earlier reviews of the literature.[75] The inescapable conclusion is that the voluminous literature on

[73] Ibid, p. 24. http://works.bepress.com/cgi/viewcontent.cgi?article=1014&context=richard_gilbert
[74] Ibid. While Gilbert was focused on identifying the likely impact of mergers, his conclusion is applicable to an assessment of market structure more generally.
[75] See, Morton I. Kamien and Nancy L. Schwartz, Market Structure and Innovation, Cambridge University Press, 1982: "Studies relating concentration to productivity [process innovation] increases have found high concentration alternatively harmful, neutral, and helpful" at p. 90. "The inconclusiveness of [theoretical] studies of concentration and innovational effort is reinforced by. . . [empirical] studies." Philip Nelson, et al, "The Economics of Innovation: A Survey", American Bar Association, Section of Antitrust Law, July 2002 at pp. 92-3. Finally, ". . . [W]e find that the empirical results bearing on the Schumpeterian hypotheses are inconclusive, in large part because investigators have failed to take systematic account of more fundamental sources of variation in the innovative behavior and performance of firms and industries." Wesley M. Cohen and Richard C. Levin, "Empirical Studies of Innovation and Market Structure", in Richard Schmalansee and Robert Willig, eds., Handbook of Industrial Organization, North Holland, 1989, at p. 1081. Nor does market structure seem to have any identifiable impact on the timing of innovation. See, Jennifer F. Reinganum, The Timing of Innovation: Research, Development and Diffusion, in Richard Schmalansee and Robert Willig, eds., Handbook of Industrial Organization, North Holland, 1989.

innovation will not support a decision to impose regulatory restrictions based alone, or even significantly, on claims of a link between market structure and innovation.

It is notable in this context that the entire Internet Ecosystem is marked by substantial seller concentration. The structure of all submarkets in the Internet Ecosystem falls short of textbook models of competition. While the share of broadband access markets of cable and telco network providers is substantial, so too is there significant seller concentration in microprocessors (where Intel dominates); in operating systems (where Microsoft dominates); in browsers (where MS Explorer dominates); and, very importantly, given the source of contention about market failure attributable to seller concentration, in applications, content and related services (where Google enjoys nearly over 70% of the search market and nearly 60% of the online advertising market). Markets for online social networking, email, and other applications are concentrated as well.[76]

Notwithstanding this widespread seller concentration throughout the Internet Ecosystem, net neutrality advocates make no similar claims about its impact on innovation anywhere except in markets for broadband network access.

[76] See **Appendix C** for the sources for the data underlying conclusions about widespread concentration in the Internet Ecosystem.

XI. COMMON VALUE CREATION IN THE INTERNET ECOSYSTEM.

Too much of the discussion about Internet innovation, and particularly that embedded in claims about the predominance and greater value of edge over core innovation, misses the very fundamental, and quite obvious fact that the Internet itself, and the overall economic value to society, are derived from the combination of products and services supplied by different firms in the Internet Ecosystem. This has long been recognized:

> Internet technology is not a single invention, diffusing across time and space without changing form. Instead, it is a suite of communication technologies, protocols and standards for networking between computers. This suite is not valuable by itself. It obtains economic value in combination with complementary invention, investment and equipment.[77]

These interdependencies have recently been specifically noted by the FCC in the context of wireless markets, but clearly apply to wired platforms as well.[78]

The economics of common costs are widely discussed and understood. Common costs are those incurred by an individual firm or group of firms on behalf of all classes or units of output and/or customers. The resources that create these costs are necessary inputs valued by all customers and benefitting all outputs. They are not directly or individually "caused by" a single customer or output unit. Their assignment to and recovery from individual customers or output units may be done in numerous ways, each of which is arbitrary and without economic foundation.

A companion and closely related notion, common value produced by complementary individual firms often without contractual arrangements, is less

[77] Shane Greenstein, "Building and Delivering The Virtual World: Commercializing Services For Internet Access," The Journal of Industrial Economics, vol. XLVIII, no.4 December 2000, p. 391.

[78] "Toward this goal, we seek to further our understanding of where and how key innovations are happening across the full "value chain" of the wireless market, including spectrum utilization, technologies, business models, and services." FCC Wireless NOI, p. 2. In the Matter of Fostering Innovation and Investment in the Wireless Communications Market and A National Broadband Plan For Our Future GN Docket No. 09-157 GN Docket No. 09-51.

recognized and understood in its implications in broadband policy contexts. Common value may be thought of as the utility, satisfaction, or economic welfare enjoyed by individuals from the use of a good or service that is produced by a horizontal array of firms that are generally linked in the market place by formal contracts, exchange agreements or less formally. The absence of contractual agreements differentiates these associations from better known vertical relationships or resource acquisition methods.

The value of Internet usage by consumers and others depends on activities taking place in the value chains of numerous firms.[79] Value chains are defined in various ways in different contexts, but they typically link together direct and supporting business functions and processes related to designing, producing, marketing, and delivering a good or service.[80] Firms have differing value chain linkages both internally (intrafirm) and with other firms (interfirm). Our focus is on the interfirm linkages among suppliers (that is between the value chains of individual firms) in the information technology space and in particular among providers of networks, content and applications. These interfirm linkages take place in what is called the "Internet Ecosystem."[81] The term suggests the importance of interdependencies and calls attention to the notion that the value created for different uses and users of the Internet is the outcome of combined and complementary efforts of several firms, no one of which can offer the basis for claiming a lion's share of the joint value.

The value of the contribution of each firm is in part dependent on the contributions of other firms. The degree of this value interdependency varies and is not precisely reciprocal. In the present context, that is to say networks are necessary for all the applications, but while applications may add value to networks, they are not

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[79] The Commission has not only recognized, but solicited comment on, the implications of value chain links. "Toward this goal, we seek to further our understanding of where and how key innovations are happening across the full "value chain" of the wireless market, including spectrum utilization, technologies, business models, and services. The Commission observed in this context that "Value chain" means the chain of individual, value-creating activities. This chain includes not only activities performed by wireless communications service providers themselves, but also those performed by all other entities, including providers of inputs and complements to wireless communications services." Wireless NOI at p. 2.

[80] The notion of a firm's value chain was popularized by Professor Michael Porter. See Michael E. Porter, Competitive Advantage: Creating and Sustaining Superior Performance, Free Press, 1985.

[81] http://www.morganstanley.com/institutional/techresearch/pdfs/Internet_ecosystem0306.pdf, Morgan Stanley, 2006.

individually indispensable. The costs of the cooperative activities must be recovered in the aggregate from consumers and others that derive value from the Internet, but there is no one-to-one relationship between costs incurred and costs recovered. Much like common costs to a firm, the value to Internet users commonly created by several firms and enjoyed by all can be, and is, attributed to individual firms and inputs in different ways. Just as common production costs cannot be allocated on a cost causation basis, neither can commonly created value be attributed specifically and quantitatively to different firms in the Ecosystem.

In the case of both cost allocation (to different cooperating inputs) within a firm and value allocation (among cooperating firms) in the Ecosystem, the final outcomes are: a) circumstantial and cannot be determined *a priori*; b) changing over time; and c) the result of both market forces and government rules. Through private incentives and constraints on firm conduct, markets shape the distribution of joint value among firms producing complementary outputs. These market forces are reflected through private negotiations and private contracting. Both are subject to rules imposed by government. However, changes in government rules alter strategies and permissible business conduct of firms, as well as the distribution of joint value among firms.[82]

These interdependencies, the facts of joint value creation, and complementarities among innovations by different firms, particularly in the information technology space, were long ago recognized in the economics literature.

> When innovations occur in one area, there are benefits. But, when complementary innovations occur together, the effects can be greatly increased. The combination of rapid advances in computing power, software and communications capabilities form a set of complementary innovations. Large amounts of data can be processed in a way that nontechnical personnel can use. Then the information can be

[82] Firms within the Internet Ecosystem are converging in the sense that each is considering the business models and market focus of others and then looking to diversify in ways that best complement and add value to current activities. Thus, content providers look to alternative distribution and transmission options; applications providers look to get into the customer equipment and network distribution business; and network operators look to expand into content and applications and consider successful business models already at work and proven in those sectors. This suggests that over time the rules governing market conduct for all the diversified firms must also converge.

> transmitted to remote locations within the same firm or other firms [or customers of either]. [83]

The importance of these value interdependencies and complementarities has also been recognized and discussed in the technology management literature. Thus, drawing from his book and previous articles, MIT Professor Cusumano,[84] concludes that there are essential differences in looking at a firm's output as a product or service versus looking at it as a platform that creates value directly for end users, but also indirectly as a result of value created for other firms who also provide service to end users. Network platforms, in contrast to network services or products, provide ". . . a common foundation or core technology that a firm can reuse in. . . different variations that provides this [platform] function as part of a technology "system" whose components are likely to come from different companies [or] maybe different departments of the same firm, which we call *complementors*." [85]

The platform both derives value from other complementary products and services, but, concurrently, it is a value driver or creator of value for these complementary firms, products and/or services. In a world of reciprocal network effects ". . . the more external adopters in the ecosystem that create or use complementary innovations, the more valuable the platform and the complements become . . ."[86] (emphasis added)

A related characteristic of network platforms, driven by the existence of accompanying externalities (network effects) is their association with evolving business models – two sided market pricing practices in particular. According to Cusumano, ". . .

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[83] Martin Neil Baily and Robert Z. Lawrence, "Do We Have a New E-conomy?" American Economic Review, vol. 91, no. 2, AEA Papers and Proceedings, May 2001, p. 310. (Parenthetical added.) See also their discussion of supply chain management and linkages among supply chains.

[84] Michael Cusumano, Platform Leadership: How Intel, Microsoft, and Cisco Drive Industry Innovation, Harvard Business School Press, 2002. See also, A. Gawer and M.A. Cusumano, "How Companies Become Platform Leaders," MIT Sloan Management Review, vol. 49, no. 2, 2008, pp. 29–30.

[85] Cusumano, p. 34. For elaboration and support for these core points about platforms and complementarities and two-sided market models, see also, R. Schmalensee, D. Evans, and A. Hagiu, Invisible Engines: How Software Platforms Drive Innovation and Transform Industries, MIT Press, 2006; D.B. Yoffie and M. Kwak, "With Friends Like These: The Art of Managing Complementors," Harvard Business Review, vol. 84, no. 9, 2006, pp. 89–98; R. Adner, "Match Your Innovation Strategy to Your Innovation Ecosystem," Harvard Business Review, vol. 84, no. 4, 2006, pp. 98–107.

[86] Cusumano, p. 33.

platform industries tend to have more than one market "side" to them." And businesses "In newer 'multi-sided' platform markets such as. . . Internet media. . . Google, Microsoft. . . and other companies compete not simply for end users and applications developers, but also for advertisers."[87] The conclusion is inescapable. Absent regulatory constraints on the pricing practices of firms, two sided business models will be diffused widely among firms in the Ecosystem in ways that will create significant efficiencies and consumer welfare.

Research on platforms, platform complementarities, and business practices has not been fully developed and there are several important unanswered questions. According to Cusumano: "We are in the early stages of understanding how common and important industry platforms really are. . . Who wins and who loses these competitions is not simply a matter of who has the best technology or the best product. It is often who has the best platform strategy and the best ecosystem to back it up."[88]

In this context it is also clear that losers and winners can be substantially determined by regulatory constraints that tilt the playing field toward one platform or another and favor some providers by restricting others. Current FCC proposals to limit network operator discretion to manage networks, explore new business models and experiment with commercial approaches restrict opportunities and incentives for network operators to innovate, while protecting and promoting such opportunities and incentives for applications providers and others in the Internet Ecosystem.

[87] Cusumano, p. 34. See also, J. C. Rochet and J. Tirole, "Platform Competition in Two-sided Markets," Journal of the European Economic Association, vol. 1, no .4, 2003, pp. 990–1029; J.C. Rochet and J. Tirole, "Two-sided Markets: A Progress Report," RAND Journal of Economics, vol. 37, no. 3, 2006, pp. 645–667.
[88] Cusumano, p. 34.

XII. CONCLUSIONS

There is no disagreement about the role that Internet Ecosystem firms play in creating consumer welfare and economic value in the larger economy, or about the stakes involved in current FCC deliberations respecting how that Ecosystem, and firms within it, will in the future be impelled by private incentives versus public restraints. There is, however, fundamental disagreement about which firms are, or are not, in fact creating that value and how expansion of the reach of economic regulation to network operators would impact that value.

We share the views of the Commission about the importance of providing data and analysis of the impact of alternative courses of regulatory action. Research underlying this report was undertaken in an effort to meet that challenge on a set of key issues related to innovation in the Ecosystem.

A recent statement by FCC Chairman Genachowski reflects, but preceded, our research and general findings.

> We've seen powerful innovation and staggering investment from American companies managing broadband networks, as well as U.S. companies at the edge. DOCSIS 3.0 and fiber, from cable operators and telcos, are extraordinary wired broadband technologies with the promise of offering faster speeds to consumers and businesses with access to them. And mobile carriers are readying the next generation of mobile broadband, also with massive potential.[89]

We agree. The facts and analysis above provide reasons why. In response to incentives and opportunities availed within the prevailing scheme of regulatory forbearance, network infrastructure providers have compiled an impressive record of innovation reflected in a cascade of new transmission and switching technologies; new local distribution and devices; an impressive array of new services; dramatically increased functionality; and adoption of new business practices tailored to the changing

[89] Prepared Remarks of Chairman Julius Genachowski, "Broadband: Our Enduring Engine for Prosperity and Opportunity" NARUC Conference Washington, D.C., February 16, 2010, available at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-296262A1.pdf.

topology of networks. Imposing common carrier type regulation on network providers would diminish network provider's incentives and opportunities to continue, or perhaps, as the economy improves, accelerate historic trends in broadband network innovation and investment, as well as the applications and content innovations they support.

Our disagreement goes to the role of applications companies and, more specifically, to conjectures by net neutrality advocates with respect to a) where the main innovations are taking place, b) how those innovations create Ecosystem-wide and economy-wide values, and most importantly, c) the optimal mix of government restraints and private market incentives for protecting and promoting the current and historic dynamism of the Ecosystem that has delivered so plentifully to date. The following conclusions emerging from our research detail the basis for our disagreement:

- There is no analysis or data in the literatures on innovation and regulation, to prove claims that the proposed net neutrality rules will on balance promote innovation in the Internet Ecosystem;
- Net neutrality proponents' case contains no definitions of innovation, nor verifiable or testable propositions respecting their claims about it;
- Net neutrality proponents incorrectly characterize the incidence of innovation activities and accomplishments, particularly with respect to core v. edge innovation;
- On reasonable definitions of core and edge, there is no clear dividing line, particularly with respect to wireless networks;
- By any reasonable assessment, core cable, wireline and wireless networks reflect enormous historical and ongoing innovation as marked by the adoption of new technologies, incorporation of advanced equipment and software, expansion and improvement of services offerings, and introduction/diffusion of new business models;
- Presence of pervasive complementarities among services dictates that core innovations in network platforms have enabled, encouraged and increased the value of numerous, important edge innovations that would otherwise have been impossible;
- While good and unambiguous measures of innovation are often lacking, there is an undeniable link between diffusion of network innovation and the enormous network investments now being made by broadband infrastructure providers;
- Many of the innovations now apparent at the "edge" reflect investment and business model applications of services first introduced by Internet Service Providers at very early stages of the development of the Internet;

- No policy relevant linkages have been established between market structure and innovation despite numerous studies attempting to do so; and
- The proposed net neutrality rules would likely reduce innovation in broadband networks and those that would be enabled at the edge. They would do so to the extent that new constraints on broadband network providers would increase uncertainty and risk, reduce prospects for growth, and undermine network managers' incentives and opportunities to adapt to rapidly changing technical and economic conditions in the Internet Ecosystem.

This study finds no support in theories of innovation, innovation practice, or reviews of numerous empirical studies of drivers of, and constraints on, innovation for the main contentions of net neutrality supporters. Available data and analysis do not establish: a) the absence of network innovation in general; b) the primacy of innovation at the edge over the core; or c) most importantly, that greater *ex ante* regulation of markets for broadband infrastructure are needed, and can reasonably be expected to increase the rate of innovation and consumer welfare creation by network providers and elsewhere in the Internet Ecosystem.

Our review finds no significant market failure attributable to insufficient innovation in networks or superior innovation outside network infrastructures. Concerning the need for new regulations, the public interest will be well served if the Commission heeds the wisdom of Hippocrates: "First, do no harm!"

By any reasonable assessment of the record of innovation in networks, the current regulatory regime is working.

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Appendix A:
Early Indications of Innovative Activity by ISPs
Services Available in Calendar Year 2000

(100) Access set up, service, and maintenance

(110) Providing and servicing access through different channels

(111) Analog access
(112) ISDN access
(113) Nationwide and worldwide dial-up (800 numbers)
(114) WebTV access
(115) Wireless access
(116) Generic dedicated Internet access (e.g., Ti)
(117) Access through cable modems
(118) `Frontier' dedicated Internet access (e.g., T3, DSL)

(120) Providing basic functionality associated with access

(121) E-mail and e-mail functionality
(122) Necessary complementary technology (e.g., Shell accounts, PPP/SLIP/ CSLIP)
(123) Domain name registration
(124) Internet search engine registration
(125) Links to portals and directories (includes Newsgroup access)
(126) RealAudio and Video
(127) Old access technology (e.g., FTP, Telnet, Gopher, Archie)

(130) Advanced functionality associated with access

(131) Online games
(132) Chat room
(133) Video conferencing
(134) Screening services

(200) Network, set-up, service and maintenance

(210) Providing and installing network equipment on customer premises

(211) WAN installation
(212) Network colocation services
(213) Network consulting associated with installation
(214) LAN installation

(220) Maintenance of network facilities on customer premises

(221) Network maintenance
(222) Dedicated line maintenance
(223) Backup/restoration of data

(230) Networking and server software

(231) Lotus Notes
(232) SQL
(233) Novell
(234) Windows NT (installation and service)

(300) Web site hosting

(310) Providing basic and generic hosting services

(311) Business or Web page hosting
(312) FTP Server hosting
(313) Personal/undifferentiated hosting
(314) Ancillary hosting services

(320) Providing tailored hosting services (i.e., hosting a customized to specific application)

(321) Advertising hosting
(322) Hosting a virtual mall/virtual stores
(323) Hosting a bulletin board Hosting a special interest information page

(400) Web page development and servicing

(410) Providing generic and basic WWW functionality

(411) Activepages (e.g., Shockwave, ActiveX, NetShow, VR, QTVR, etc.)
(412) Basic design and programming
(413) Advanced programming, excluding Activepages (e.g., CGI scripting, Java, Perl)
(414) Editing tools for customers (e.g., Microsoft FrontPage)
(415) Security and firewall development

(420) WWW development and service tailored for business and administrative processes

(421) Internet commerce: retailing/procurement
(422) Business software design

(500) Telecom services
(510) Providing traditional communication services
(520) Providing traditional communications services using TCP/IP technology
(521) Internet telephony
(522) Convergent technologies
(523) Cable telephony
(600) Computer hardware and software sales, maintenance and service
(610) Providing computer equipment
(620) Servicing computer equipment
(630) Software design and service
(631) Software design and services, n.e.c. (includes custom software, programming)
(632) Packaged software installation and service
(700) Training
(800) Services not elsewhere classified
(810) Television services
(811) Cable television
(812) Satellite television
(820) Copy services
(821) Photocopying
(822) Faxing
(830) Multimedia services
(822) Document scanning
(823) Converting movies to films
(824) Convert catalog to CD-ROM format
(840) Cafes and meeting places
(841) Food and beverages
(842) Books
(850) Newspapers

APPENDIX B
Timeline of Innovation Benchmarks For Cable [90]

Data Services

August 1993: CableLabs initiates an effort to initiate cable's move to the Internet with an internal working group. The annual summer conference that month was themed after the Electronic Superhighway and included demonstration of Internet data transport.
April 1995: A 90-page RFP, targeted at high-speed data systems, is issued, seeking proposals for a standalone data delivery system. Specific areas of interest include headend, network operations and control, encryption, tiering of best-effort and guaranteed speed services, billing, and cable modems. Vendor responses were reviewed at the 1995 Summer Conference, in Keystone, Colorado
September 1996: Five vendors **-** Com 21, General Instrument, Hewlett-Packard, LANcity and Motorola **-** are chosen as "vendor authors" for the high-speed data specifications that became DOCSIS (Data over Cable Service Interface Specification).
March 1997: The cable industry announces that the DOCSIS specification has been completed and CableLabs issues an RFP for fabrication and delivery of some modems for the purpose of evaluating interoperability and compliance with the specifications.
July 1998: CableLabs implements first royalty-free intellectual property pool around DOCSIS technologies and creates a royalty-free IPR (intellectual property rights) pool for PacketCable.
April 1999: Specifications issued for DOCSIS 1.1 cable modems.
2000: In a series of certification waves, more than 86 new modems receive CableLabs certification, up from 14 modems certified at the end of 1999. Nearly a dozen in 2000 included Universal Serial Bus (USB) connections. Proprietary modems, with a price tag of $500 in 1995, ceded to standards-based modems, selling in the mid-$100s.
2001: Introduction of enhanced mode DOCSIS **--** v. 1.1. The foundation technology for PacketCable and CableHome, DOCSIS 1.1 augmented DOCSIS 1.0 in three ways: (1) Quality of Service (QoS): Enabled cable providers dynamically offer tiers of data service, not unlike how video services are sold as "basic" and "premium." (2) Data Fragmentation: Assisted with isochronous services, such as voice-over-IP, or any service where data timeliness matters as much as raw speed. (3) Enhanced Security: Augmented the existing link layer security available in DOCSIS 1.0 with military-grade encryption
December 2002: CableLabs awards first DOCSIS 2.0 certification to modems from Motorola, Scientific-Atlanta, Terayon, Texas Instruments and Xrosstech.
November 2004: CableLabs issues a request for information (RFI) for Integrated DOCSIS® Access Device (IDAD) equipment. The IDAD will enable cable operators to offer voice and data services for small business and commercial customers.
April 2005: CableLabs issues RFP for high-speed data products.
August 2006: CableLabs issues DOCSIS 3.0 specifications, which enable cable operators to offer significantly higher data rates to their broadband customers. The new specifications describe downstream data rates of 160 Mbps or higher and upstream data rates of 120 Mbps or higher.
December 2006: CableLabs and EuroCableLabs issue ROI on DOCSIS 3.0 devices.
December 2007: First DOCSIS 3.0 gear is certified. Specifically, Casa Systems received a silver qualification, while Arris and Cisco received bronze qualifications, for their CMTS gear.

Voice Services

1992: CableLabs commissions consulting firm Arthur D. Little to research personal communications services (PCS). The Federal Communications Commission authorizes CableLabs to build a PCS (Personal

[90] Source: As reported by Cable®Labs, online at http://www.cablelabs.com/anniversary.

Communication Services) wireless telephony test bed, in downtown Boulder. At the time, participants thought PCS might become cable's first digital offering.
July 1994: CableLabs issues $2 billion RFP on cable telephony signaling the cable industry's interest in achieving interoperable interactive cable networks.
September 1997: PacketCable™ initiative is formed. Its purpose: To identify suppliers and participants in Internet Protocol technologies, initially focusing on voice and video telephony applications.
June 1999: The first PacketCable interoperability tests are held, with voice products from 11 suppliers. Equipment tested for interoperability included multimedia terminal adaptors (Mats), call agents, and test equipment. Three interoperability rounds are completed in 1999.
December 1999: PacketCable 1.0 publicly released as a finished suite of specifications.
2000: Interoperability testing of PacketCable-based digital voice equipment is initiated. Tests included basic voice calls, multi-codec calls, and feature assessment and billing.
December 2002: First residential VoIP devices certified. Specifically, E-MTAs (Embedded Multimedia Terminal Adaptor) from Arris and Toshiba were certified, on the conclusion of certification wave #24.
July 2004: RFP issued for voice-over-IP equipment, built for commercial applications.
January 2005: CableLabs releases PacketCable 1.5 specifications.
November 2005: RFI issued for Voice-over-IP peering technologies, used to help cable operators interconnect their IP backbones and exchange voice traffic
April 2006: The specifications for PacketCable 2.0, enabling cross-platform applications and services, are issued. The first application for the PacketCable 2.0 platform, Residential SIP Telephony (RST), is also released.
April 2007: CableLabs® launches the PacketCable™ 2.0 Applications Lab, with the successful installation of an Ericsson IMS (Internet Protocol Multimedia Subsystem) core network, Cedar Point Voice Application Server, and SIP voice user endpoints.
July 2007: Signaling progress in its advanced Internet Protocol initiative, CableLabs® has issued a Request for Information (RFI) to solicit responses from vendors regarding their PacketCable™ 2.0 product roadmaps. The RFI also seeks information regarding any IMS-based applications these suppliers are developing for the cable industry.
June 2008: Arris and Motorola receive PacketCable certification **-** the industry-first certification for devices that integrate DOCSIS 3.0 with the ability to deliver cable digital voice.

Video Services

March 1991: CableLabs, General Instrument (now Motorola) and Scientific-Atlanta form Cable Digital Transmission Consortium to gather information and proactively develop digital video compression systems. In addition, a Video Compression Subcommittee (of the larger Technical Advisory Committee) forms and issues an RFI on consumer focused digital video compression.
August 1991: CableLabs participates in the laboratory phase of advanced television testing.
August 1991: Tele-Communications Inc., Viacom Cable, and CableLabs jointly issue a request for proposals (RFP) for a studio-to-headend video compression delivery system. Plans call for launches in late '92. Public Broadcasting Service subsequently joins the two MSOs in its intention to buy gear. From this, the era of Quadrature Amplitude Modulation began.
1995: Installation of cable test laboratory at the Louisville, Colo. headquarters. The lab built upon the HDTV impairment test facility in Alexandria, Va., to assure that test existed for equipment conformance with transmission standards, such as 64-QAM (quadrature amplitude modulation, the underpinning of cable-delivered digital transmissions).
August 1997: OpenCable Task Force formed…First task: An RFI seeking vendor input on how to best configure its next-gen digital video platform. The RFI signaled the industry's intent to only buy set-tops that complied with the interface specifications of OpenCable. More than 20 responses came in, from 32 computer, consumer electronics, and cable industry suppliers.
August 1999: CableLabs issued a final set of hardware specifications that form the foundation of the cable industry's OpenCable™ advanced digital services project. All portions of the OpenCable hardware specifications now have been released to the manufacturing community.
September 1999: RFP issued for OpenCable middleware, which would subsequently be called "OCAP," for "OpenCable Application Platform," later to be known as "tru2way®" in its consumer-facing orientation.

First applications identified: Electronic program guides. Sixteen companies reply, among them Microsoft, Sun Microsystems, NDS, Liberate, Hewlett-Packard Co., General Instrument, Excite@Home, and the Advanced Television Systems Committee.

October 1999: The first OpenCable specifications are publicly released as part of the suite of OpenCable 1.0 specifications.

September 2000: CableLabs selects lead authors to begin development of OCAP specifications. Sun Microsystems became the lead contributor and Sun's contributions were based upon significant work already completed in applying Java™ technology for television applications. Corresponding Java technologies, including Java TV, have been licensed by Sun to CableLabs for use in the specification.

September 2000: OpenCable's second 2000 milestone was its September resolution on advanced set-top software, known as "OCAP" (OpenCable Application Platform). OCAP separated the set-top software environment into two pieces, and specified vendor authors for each to develop written specifications. The advantages of OCAP and its two layers were envisioned as beneficial to software developers, cable MSOs and cable subscribers. For programmers, it means a content authoring environment that is "write once, run anywhere." For cable MSOs, the specification assured parity among interactive TV suppliers, so that no one operating system or middleware gained control over the interactive authoring environment. For cable subscribers, OCAP, while transparent to their usage, assured a wider range of interactive applications.

March 2001: The first cable middleware (OCAP) specifications are released for industry review and comment.

February 2002: First CableLabs Developers' Conference for OCAP attracts 90 companies and 165 attendees. Presentations span developer toolkits, content authoring tools, applications management, Java trends, and support programs. Demonstrations focus on "application portability," or, the ability to write and sell at retail an application that runs on multiple cable systems.

August 2002: Cable operators issue RFP to solicit industry implementations of the OCAP middleware and to hasten the ability of cable operators to launch new OCAP-based services. CableLabs facilitates the RFP. Fourteen companies respond, among them: ADB, Alticast, Canal+, Liberate, Microsoft, OpenTV, Panasonic, Phillips, and Pioneer.

June 2003: Microsoft signs OpenCable CHILA agreement paving the way to the development of a technical solution to deliver digital cable content directly to the Vista Media Center PC using CableCARD technology.

June 2003: Scientific Atlanta successfully passes certification testing of the first security module (CableCARD) fully compliant with the December 2002 CE agreement and the updated FCC rules for separable security.

July 2003: Motorola successfully passes certification testing of their first security module (CableCARD) fully compliant with the December 2002 CE agreement and the updated FCC rules for separable security.

August 2003: NDS becomes the third manufacturer to pass certification testing of their updated CableCARD removable security module.

August 2005: In a major milestone for cable's interactive digital evolution, Samsung Electronics achieved Certification status for an OCAP™-enabled interactive digital television set. "Samsung is the first consumer electronics manufacturer to build a 2-way integrated digital television. This is quite a feat considering the complexity of these new devices," said CableLabs President and CEO Dr. Richard R. Green.

November 2005: Microsoft agrees to enable HD, digital cable programming on Windows-based PCs in announcement with the cable industry in a joint announcement about what came to be known as OpenCable Unidirectional Receivers (OCUR). CableLabs approves the Windows Media DRM for use in these devices for content security.

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March 2006: Under the FCC Plug & Play Rules, CableLabs announced today that it has approved a recording technology developed by EnCentrus Systems, Inc. that enables consumers to enjoy home recordings of certain high-value cable programming for use in DCR products which are compatible with

the cable industry's CableCARD removable security modules. The CPDO technology is the first secure hard drive recording solution approved by CableLabs for use inside and outside such products.
January 2007: More than a dozen manufacturers displayed two-way "plug-and-play" TVs, set-top boxes and other cable-ready devices at the 2007 Consumer Electronics Show. This marked a significant milestone in the cable industry's efforts to bring interactive digital TV services to consumers that will not require the use of a leased set-top box.
June 2007: Intel Corporation and CableLabs announced the two companies signed an OpenCable Platform Agreement that will include support for the OpenCable Platform in future Intel consumer electronic (CE) system-on-a-chip (SoC) products. Incorporating support for OpenCable allows digital televisions, set-top boxes, digital media recorders and other networked consumer electronics devices to run standard applications and services delivered by cable operators, consumer electronics companies, program networks, and other software developers.
June 2008: Arris and Motorola receive PacketCable certification **-** the industry-first certification for devices that integrate DOCSIS 3.0 with the ability to deliver cable digital voice.

APPENDIX C

Source Data for Estimation of Internet Ecosystem Subsector Market Shares[91]

Segment	Leader	Share	Second	Share	Remaining	Share	Measure	Source
Social Networking	Facebook	42%	MySpace	21%	YouTube, Tagged, Twitter, Yahoo! Answers, My Yearbook, et al	37%	Visits for the week ending 09/26/2009.	http://www.hitwise.com/us/datacenter/main/dashboard-10133.html
Email	Yahoo! (Yahoo Mail and Yahoo Address Book)	57%	Microsoft (Windows Live)	23%	Gmail and others	20%	US Internet visits, week ending 9/26/09	http://www.hitwise.com/us/datacenter/main/dashboard-10133.html - analysis of top 4 email sites among top 20 sites overall. See also. Hitwise/Tancer at http://weblogs.hitwise.com/bill-tancer/2008/02/microsoft_and_yahoo_putting_th.html
Search	Google	71%	Yahoo! + Microsoft (Bing)	25%	Ask, MSN.com, Live.com	4%	Volume of searches for 4 weeks ending 9/26/09	http://www.hitwise.com/us/datacenter/main/dashboard-10133.html
Online Advertising	Google-Doubleclick	57%	Yahoo! + Microsoft	15%	Revenue Science, AOL, ValueClick, AdBrite, Other	29%	Ad Server Market Share of monthly unique users December 2008	http://www.attributor.com/blog/category/ad-networks/
Broadband Estimate - Companies	AT&T	20%	Comcast	20%	Other	59%	% of all high-speed subscribers	Leichtman Research Group 2Q09, FCC 2Q08, USTelecom analysis, conservatively assuming minimal wireless substitution (~1% share)
Broadband Estimate - Industry	Cable	53%	Telecom	43%	Wireless, Satellite, Overbuilder, BPL, etc.	4%	% of all high-speed subscribers	Leichtman Research Group 2Q09, FCC 2Q08, USTelecom analysis, conservatively assuming minimal wireless substitution (~1% share)
Browser (Global)	Microsoft	67%	Firefox	23%	Safari, Chrome, Netscape, Opera, other	10%	Browser share of users, 3Q 2009	http://marketshare.hitslink.com/browser-market-share.aspx?qprid=0
Operating System (Global)	Microsoft	93%	Mac	5%	Linux, iPhone, iPod Touch	2%	OS share of users., 3Q 2009	http://marketshare.hitslink.com/operating-system-market-share.aspx?qprid=8&qpmr=100&qpdt=1&qpct=3&qptimeframe=Q
Semiconductors (Global microprocessors)	Intel	81%	AMD	12%	Other	8%	Shipments, 2Q09	http://www.isuppli.com/News/Pages/Intel-Microprocessor-Domination-Reaches-Four-Year-High-in-Second-Quarter.aspx

Some figures may not add to 100% due to rounding

[91] US Telecom Comments in The Matter of Preserving the Open Internet, GN Docket No. 09-191; Broadband Industry Practices, WC Docket No. 07-52, January 14, 2010, Appendix 1, p. 57.