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THE EFFICIENCY RISK OF NETWORK NEUTRALITY RULES

Abstract: In this POLICY BULLETIN, we evaluate Network Neutrality proposals from the standpoint of consumer welfare and economic efficiency by presenting a cost/benefit analysis framework for examining the effect on consumers of Network Neutrality proposals that would limit operators from injecting intelligence into broadband Internet access networks. For a Network Neutrality proposal to be justified, the purported benefits of that proposal must exceed the costs, including the inefficiency in network design as well as the risk of increased industry concentration and market power. Publicly available cost studies show that if IP video services increase in popularity, the cost of providing a residential subscriber a "stupid" network that is video-capable could reach $300 to $400 per month more than an "intelligent" network, which would certainly put broadband out of the reach of many Americans. We also present a simple model which shows that voluntary investments in network efficiency always improve consumer and social welfare—even if, as some Network Neutrality proponents contend, stupid networks are otherwise preferred by consumers.

I. Background

Some proponents of Network Neutrality argue that only a "stupid," or commodity-priced, broadband Internet will preserve the current free-wheeling nature of competition for Internet applications and services. But building and operating a communications network, like all forms of engineering, involves trade-offs. While the current Internet infrastructure may appear to be an "open" and somehow passive conduit of bitstreams, the Internet is, in fact, anything but passive. Routers, perhaps the core infrastructure of the Internet, are highly intelligent devices that pick and choose which route, among many, is least congested and thus capable of delivering the bits the fastest. IP multicasting capabilities, which operate pursuant to complex protocols, make efficient video transmission over IP networks possible.[1] Of course, there are a host of other types of network "intelligence" that have been (and can be) integrated into the network in order to improve network efficiency and quality.

From a consumer and social perspective, whether or not increasing intelligence along with increasing bandwidth (the "smart" network) or just expanding bandwidth (the "stupid" network) is preferred depends on the relative costs of these alternatives at some specified level of quality. Bandwidth is by no means free, and the per-household cost of bandwidth sufficient to support future Internet services (e.g., multiple streams of video services) has not been a significant part of the Network Neutrality debate. Moreover, in the case of wireless broadband providers, spectrum is closely controlled by the government and, therefore, capacity cannot be increased without bound. As such, Network Neutrality proposals that would limit or effectively restrict the injection of intelligence into broadband Internet access networks could present a significant risk to Internet users and the economy.

In this POLICY BULLETIN, we provide a cost/benefit analysis framework for evaluating various Network Neutrality proposals from a consumer and social welfare perspective. The general and specific applications of this framework build off the analysis that we presented in PUBLIC POLICY PAPER NO. 24, in which we showed that Network Neutrality proposals that seek to commoditize the market for broadband Internet access services would harm consumers by increasing industry concentration.[2]

Our discussion in Section II shows that not only do Network Neutrality proposals present potential harms from increased industry concentration, but that these proposals also risk consumer and social welfare harm due to the loss in efficiency by preventing network owners from making investments to improve the management of their networks. The general cost/benefit framework set forth in Section II.A shows that for a Network Neutrality proposal to be justified, the purported benefits that the proposal would create must exceed the costs of producing those benefits, including differences in the incremental network costs and market power. The cost and benefits of investing in network intelligence are evaluated using a more specific economic model in Section II.B. This model shows that all voluntary investments in network efficiency improve consumer and social welfare even if, as some Network Neutrality proponents contend, stupid networks are (for some reason) preferred by consumers. In fact, we

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1 F. Fluckinger, UNDERSTANDING NETWORKED MULTIMEDIA (1995) at ch. 9.

2 George S. Ford, Thomas M. Koutsky and Lawrence J. Spiwak, *Network Neutrality and Industry Structure*, PHOENIX CENTER POLICY PAPER NO. 24 (April 2006) (available at: http://www.phoenix-center.org/pcpp/PCPP24Final.pdf).

show that, at least from a consumer and social welfare perspective, firms actually have too little and not too much incentive to invest in network intelligence that increases network efficiency.

Our cost/benefit analysis framework in Section II is simply that—a framework that lays out the important factors to consider but does not provide specific calculations for any particular Network Neutrality proposal. In Section III, we review some of the publicly available evidence in order to provide the reader with some guidance as to how large these consumer and social welfare losses may be if network owners were prevented from injecting "intelligence" into the Internet. Significantly, some studies show that a mandated "stupid" network could increase the per-subscriber cost of providing service by $300 to $400 per month if IP video or other high bandwidth applications continue to grow in popularity. Because American consumers are sensitive to price for broadband services, actions that increase the cost of these networks could have a significant effect on broadband penetration.

The purpose of the BULLETIN is to raise the level of debate by exposing some of the trade-offs inherent to Network Neutrality requirements. Importantly, we neither discount nor dismiss possible vertical leveraging about which Network Neutrality proponents claim concern and its potential to harm consumers. Our cost/benefit framework can encompass such concerns. Our specific model does not address these concerns, not because we seek to minimize them but to show that regardless of possible consumer harm from vertical leveraging, investments in network intelligence will still improve consumer and social welfare in the market for broadband Internet access. Any harm from potential increases in market power from these investments would need to be balanced against these unquestionable consumer and social benefits.

II. Economic Analysis of Investments and Welfare

In this section, we first present a simple cost/benefit framework for analyzing Network Neutrality proposals. The framework starts with the basic premise that governmental intervention to ensure Network Neutrality, like any other market intervention, is justified only if the benefits of such rules exceed the consumer and social costs of those rules.[3]

Although our framework is a highly stylized, we believe that it provides a palette from which to analyze the costs and benefits of any particular proposed approach, so that the policymaker may better understand the relevant tradeoffs between "intelligent" and "stupid" networks. Our initial analysis focuses only upon consumers, in that we consider only the value and price that consumers will place upon "intelligent" versus "stupid" networks. As a result,

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[3] Office of Management and Budget, Circular A-4 (Sept. 17, 2003) (available at: www.whitehouse.gov/omb/circulars/a004/a-4.pdf).

we ignore whether or not the economic conditions are such that a network of either type is more or less likely to be constructed. If a "stupid" network, for example, costs $1,000 per subscriber month to operate, then the welfare consequences of its mandate are somewhat obvious since such a network will not be constructed.

In Section II.B, we provide a more specific model of investment in network intelligence. In this model, we consider under what conditions a firm will invest in network intelligence if such investment also has the potential to reduce the marginal value of the service sold by the firm. This setup is a good match for the current debate. Proponents of government-mandated "stupid" networks contend that they are more valuable to consumers, and our model allows that to be the case. Opponents contend that the "stupid" network is more expensive to build, and we allow that to be the case. What we find is interesting: Under these conditions, the monopolist's incentive to invest in intelligence to reduce costs is aligned with both consumer and social welfare in that any voluntary investment in network efficiency increases not only profits but increases consumer welfare. Thus, viewing investments in intelligence as "anti-consumer" is misguided. In fact, our model shows that, if anything, firms invest too little in intelligence from a social welfare perspective because society benefits more from the investment than does the operator alone.

A. *A Cost-Benefit Test for "Smart" v. "Stupid" Networks*

We contemplate two competing network architectures: (1) "intelligent;" or (2) "stupid"—*i.e.,* a passive Internet in which the network passes information without regard to the nature of or importance of the content of that information. In the "stupid" network, the only solution to network congestion that a network owner may undertake is to expand the capacity of the network until bandwidth is sufficiently voluminous so that congestion does not occur. However, bandwidth is not free, so this approach will lead to higher network costs per end user (even with density economies in the network).[4] With a "smart" network, the network owner can avoid congestion not only by increasing bandwidth, but also by increasing the intelligence of the network so congestion can be avoided by "managing" the traffic flows (or, using an entirely different architecture to deliver some content), thereby reducing unit costs of throughput. A network owner following an "intelligent" network approach will of course need to make additional investment in parts of the network, such as deploying smarter routers or caching technologies, but the network owner will, of course, consider and balance those costs against the cost of simply increasing bandwidth.

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4 Assume a network is serving 100 customers. A circuit with capacity 100 costs $100, but a circuit with capacity 200 costs $150, so that there are economies of density. While the capacity costs decline in size ($1 per unit versus $1.33 per unit), the average cost per end user rises from $1 to $1.50. Thus, the presence of scale or density economies does not solve the problem we analyze here.

If increasing bandwidth is in fact the cheapest method of addressing network congestion, then the owner/operator of both a "stupid" and an "intelligent" network will make the same choice—if possible, it will add bandwidth. The two approaches to network architecture differ *only* in cases in which deploying intelligence into the network is *cheaper* than deploying more bandwidth. By definition, if a legal rule makes expanding bandwidth the only solution to congestion when intelligence may be more efficient, that legal rule has forced an inefficient network architecture on society.

Whether that inherent inefficiency in a "stupid" network harms society is, however, dependent upon several other factors. Proponents of government-mandated "stupid" networks would argue that the flexibility that a "stupid" network offers consumers makes it more valuable to consumers. At the same time, if the cost inefficiency foisted on the network is so large that prices for Internet access needed to sustain the "stupid" network are significantly higher than the "intelligent" network, these demand-side benefits might not be worth the expense. As we also discussed in POLICY PAPER NO. 24, another cost of a "stupid" network is the harm that would result from a concentrated market structure, or even monopoly.[5] Policymakers must understand these trade-offs and attempt to quantify the relative benefits and costs of alternatives in order to make sound policy. This task is not an easy one, no doubt, since each proposal has its own set of trade-offs and consequences, some intentional and obvious while others are inadvertent and veiled.

We describe this cost/benefit framework using simple equations. Say that a customer is values Internet service at R. In economic parlance, R is the reservation price (the maximum price the customer is willing to pay). This reservation price can be quite high—many Internet users derive tremendous value from Internet access and would pay prices several times higher than prevailing rates for that access. Other users consume Internet services on the margin, so an increase in price could result in them "dropping off the Net."[6] The ultimate value that a customer places on Internet access with price P is $R - P$, where P is the price for the broadband connection. For the marginal consumer, $R = P$. Since we are considering two potential network architectures, a "stupid" network (S) and an "intelligent" network (I), we can represent the net values to a representative consumer (V) of each as:

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5 *Supra* n. 2.

6 Studies have shown that the demand for broadband access is elastic, and sometimes highly elastic, so even moderate price increases should be expected to have a sizeable effect on subscription. *See, e.g.*, A. Goolsbee, *The Value of Broadband and the Deadweight Loss of Taxing New Technology,* (University of Chicago, 2000); H. Varian *The Demand for Bandwidth: Evidence from the INDEX Project,* (University of California, Berkeley 2002); P. Rappoport, D. Kridel, L. Taylor, K. Duffy-Deno, & J. Alleman *Residential Demand for Access to the Internet*, in Madden, G., ed., THE INTERNATIONAL HANDBOOK OF TELECOMMUNICATIONS ECONOMICS: VOLUME II (2002); *see also* Mohan, Suruchi, 1994, *Oracle, Bell South Pilot Service*, COMPUTERWORLD (July 4, 2006) at 4.

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$$V_S = R_S - P_S; \tag{1}$$

$$V_I = R_I - P_I. \tag{2}$$

The representative consumer prefers the network architecture that provides the largest ultimate benefits. The "stupid" network is preferred instead of the "intelligent" network if:

$$R_S - R_I > P_S - P_I, \tag{3}$$

implying that the additional benefit from the "stupid" network exceeds the increase in price for that network (if there is any). For example, if a consumer values stupidity by \$10 more than a "smart" network, but a "stupid" network costs \$20 more, then the "intelligent" network generates greater net benefit and is thus the preferred outcome. Consumers make decisions like this every day—they will opt to pay a little more for a product if they receive greater net utility for that product over a rival product. Of course, if the "stupid" network is cheaper than the "smart" one ($P_S < P_I$), and the "stupid" network is preferred ($R_S > R_I$), then the "stupid" network is more desirable.

In Section III of this paper, we review publicly available evidence on the cost (rather than price) of a "stupid" network. That analysis can be made more informative by assuming that P, the price for access to these networks, will be a function of costs and the competitiveness of the market:

$$P_S = M_S \cdot C_S \tag{4}$$

$$P_I = M_I \cdot C_I \tag{5}$$

where C is incremental cost and M is a markup factor (both unique to each network architecture). From Policy Paper No. 24 (and economic theory), we can assume that the value of M depends on the value of N, where N is the number of firms in the market, and that $M \geq 1$ (the service is profitable). The fewer the firms, the higher the markup ($\mathrm{d}M/\mathrm{d}N < 0$).

We can then re-write the consumer's cost/benefit analysis by substituting Equations (4) and (5) into (3):

$$R_S - R_I > (M_S \cdot C_S) - (M_I \cdot C_I). \tag{6}$$

Interpretation of Equation (6) is only a little different from that of Equation (3). Here, the "stupid" network is preferred only when the increase in the willingness to pay for a "stupid" network exceeds the margin-adjusted difference in cost. In Equation (6), we allow both the margin and cost to differ by network type. We can see from Equation (6) the relevant factors for evaluating the consumer's preference for a given network architecture:

(a) Is one architecture more desirable to consumers than another, and by how much?

(b) Does architecture affect industry structure and thus margins, and by how much?

(c) Is one network more costly than another, and by how much?

Some simple comparative statics along these lines are as follows. If consumers place only a small value premium on the "stupid" network, then consumers are less likely to prefer a "stupid" network, *other things constant*. If Network Neutrality increases industry concentration, as we posited in POLICY PAPER NO. 24, then margins will rise ($M_S > M_I$) and this will reduce the consumer's preference for a "stupid" network, other things constant. If the cost of the "stupid" network is lower (higher) than the cost of the "intelligent" network, then consumers are more (less) likely to value the "stupid" network, other things constant. Of course, we can devise many different comparisons like these and allow multiple factors to change simultaneously. Thus, Equation 6 only indicates some of the important factors to consider as tradeoffs; this analysis provides a framework only, not dispositive answers.

Unfortunately, there are very few constraints we can place on the relationship in Equation (6) to improve the predictive power of the analysis. Based on our analysis in POLICY PAPER NO. 24, we feel it is appropriate to assume that $M_S \geq M_I$ (industry structure is, if anything, more concentrated when the network is "stupid", so markups are, if anything, larger). Network Neutrality advocates would argue that $R_S \geq R_I$, but this need not be the case if quality is not constant across the networks. For example, streaming video may be of exceedingly low quality over the "stupid" network with inadequate capacity, so that $R_I > R_S$. Likewise, in the presence of network congestion, prioritizing voice traffic may render a higher value for the intelligent network than the "stupid" network, other things constant. Assuming that the quality of two networks is identical, we might expect $R_S = R_I$, so that the better network is determined solely by relative prices.[7] Proponents of government-mandated "stupid" networks may argue that $R_S \geq R_I$ even if network quality is equal in a static sense, because a "stupid" network is of higher quality in a dynamic sense. We are unaware of any compelling evidence to support this ranking, but as we show in the next section, it may not matter under certain conditions.

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[7] If consumers view them as having the same quality, there is no reason to believe reservation prices would differ (by definition in a static sense).

B. *Application of the General Cost/Benefit Framework: Voluntary Investments in Intelligence are Welfare Improving*

The cost/benefit analysis described above and summarized in Equation (6) sketches out the factors that should be considered when comparing "stupid" and "intelligent" network architectures. In essence, the social and consumer preference for network architecture depends on consumer valuations of the architecture, the costs of the architecture, and the profit margins of firms (which may be affected by industry structure). In this simple layout, unambiguous guidance is precluded; the analysis merely provides guidance on what to think about. However, it is possible to construct a more specific economic model that provides some insight on investments in network intelligence, even if a more "stupid" network is preferred by consumers. Specifically, we consider what happens to social and consumer welfare when a firm voluntarily makes an investment in network intelligence that reduces unit bandwidth cost and somehow also reduces the value of the service to consumers. This setup goes to the heart of the Network Neutrality issue: we allow the "stupid" network to be preferred by consumers, but we also allow it to be more costly to operate.[8]

We begin with a simple linear demand curve:

$$Q = A - P \tag{7}$$

where Q is quantity sold, P is the price, and A is the intercept of the demand curve. The slope of the demand curve is assumed to be -1 without loss of generality. Let unit bandwidth cost be C. Now, assume some investment K in network intelligence lowers incremental cost by reducing the capacity demands of the network (the change in cost is ΔC, which is negative). Also assume, consistent with arguments advanced by "stupid" network proponents, that the investment K also reduces A (writing the change as ΔA, which is negative). In other words, all consumers place a higher value on the "stupid" network. Assuming monopoly, equilibrium values of interest include:

$$Q^* = (A - C)/2\,; \tag{8}$$

$$P^* = (A + C)/2\,; \tag{9}$$

$$\pi^* = (A - C/2)^2\,; \tag{10}$$

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[8] Of course, any conclusions we draw are based on these assumptions. We address the relative cost issue in more detail in Section III.

$$CS^* = \pi^* / 2 : \tag{11}$$

$$W^* = 3\pi^* / 2 \tag{12}$$

where π is profit, CS is consumer surplus, W is social welfare ($\pi + CS$), and the * symbol indicates equilibrium values. Worth mentioning is that both consumer surplus and total welfare are proportionate to profits, so increases in profits increase welfare (the firm is a monopoly, so there is no market power consequence of investment).

We now turn to the question of when a firm voluntarily makes some investment K that reduces incremental cost and demand. The firm makes the investment K if and only if:

$$(\Delta A - \Delta C) > \frac{2K}{(A - C)}, \tag{13}$$

since profits do not rise if this condition is not met. The interpretation of Equation (13) is intuitive. Since the left-hand side of (13) must be positive, it must be the case that ΔC is more negative (a larger reduction) than ΔA for the investment to be profitable. Thus, the decline in cost must exceed the decline in consumer marginal value for the investment to be profitable.

Policymakers are often more interested in social or consumer welfare than firm profits. Social welfare rises with K if and only if:

$$(\Delta A - \Delta C) > \frac{4K}{3(A - C)}. \tag{14}$$

Observe that while the left-hand sides of Equations (13) and (14) are identical, the right-hand side of (13) is larger than (14) (that is, $2 > 4/3$). Thus, satisfying Equation (14) is easier than satisfying Equation (13). So, if a voluntary investment in reducing costs is made by the firm, then the investment must also improve social welfare, even if it reduces the value of the service. Since consumer surplus is proportional to profits by Equation (11), consumer surplus also rises with the voluntary investment.

A comparison of Equations (13) and (14) reveals that the hurdle for beneficial investment to the firm is higher than the hurdle for beneficial investment for consumers and society. Thus, the model indicates that, if anything, the firm's incentive to invest in cost-reducing intelligence is *too low* from a consumer and social perspective. As such, policymakers should be more concerned with the prospect for too little and not too much investment in cost-reducing network intelligence.

This proof that voluntary investments in network intelligence are welfare improving even if such investments reduce demand for Internet services is based on a specific formulation of demand, costs, and market structure. It is not obvious to us that reasonable alternative formulations would not find a similar result, but there may be some differences.[9] Despite the possibility of conflicting results, this simple proof remains important. We have provided theoretical evidence that voluntary investments in network intelligence to reduce costs will not be made if they reduce consumer and social welfare, even if, as some Network Neutrality proponents contend, they reduce the marginal value of the service. Thus, absent anticompetitive consequences, consumers are better off if firms can make voluntary investments in network intelligence.

III. Analysis of Publicly Available Industry Broadband Cost Models

As we described above, when comparing the social desirability of "stupid" and "intelligent" networks, the factors to consider are not limited to arguments about relative gross values. Rather, a complete analysis requires consideration of the prices consumers must pay for Internet access (where prices are margin-adjusted costs). As also noted above, several studies have shown that American consumers are very sensitive to price for broadband services.[10] As a result, actions that would increase the cost of these networks could have a significant effect on broadband penetration. In this section, we review some publicly available engineering and financial models, and these models show that a government policy to mandate "stupid" networks could increase the cost of providing broadband services to households by hundreds of dollars per month.

Perhaps the most important fact to consider in evaluating the current and future architecture of the Internet is the rapidly changing demands for services provided over it. Evidence indicates that the average consumer demand on the Internet will rise substantially over the next few years. In the "stupid" (unmanaged) network, higher bandwidth demands by consumers could be met only with increases in the capacity of the network.[11] An important question, therefore, is how much more expensive a "stupid" network would be for Internet consumers not only today but in the future, and how significantly this expense can be reduced through network management.

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9 It is always possible to posit some particularly odd and unrealistic formulation of demand or cost to prove just about anything.

10 S*upra* n. 6.

11 Advances in compression technologies, reductions in transmission costs, caching, and other technological advancements could reduce the need for and cost of bandwidth expansion.

In recent months, there have been a few attempts by the industry and Wall Street to estimate the cost of operating a "stupid" network. These publicly available studies contemplate a world where end-users are streaming multiple video entertainment signals at once, either in standard or high-definition formats. These cost calculations assume that a "stupid" network will adopt a "neutral" unicast-only technology, where the video content of each subscriber must transit the Internet backbone separately and independently of video content viewed by other subscribers. With simultaneous usage, the capacity demands on the Internet for video content in this architecture would be substantially larger than the email/browsing content that dominates the Internet today.

A. *Kafka Analysis*

In a recent presentation entitled *Drivers for Next Generation Networks*, BellSouth Chief Architect Hank Kafka discusses, in part, the bandwidth demands of the future Internet that is expected to deliver video services.[12] Kafka states that today the "key factor" for Internet networks is "access speed," or Megabits/second. In the future, however, the key factor will be the quantity of content delivered (measured, say, in Gigabytes per month). In this future Internet, network providers must pay careful attention to scheduling (i.e., busy hour) and the distance between content and consumer.

Today, Kafka suggests that the average busy-hour usage rate of a consumer is less than 50 Kbps, where access line speeds are generally on the order of 1.5 to 6 Mbps. On average, a consumer will download approximately two Gigabytes per month. Kafka estimates that this typical usage level amounts to about $1.00 in monthly bandwidth usage costs.

Table 1. Cost Estimates of the "Stupid" Network, Kafka Analysis

BH Capacity Utilization	*Access Speed*	*Avg Busy Hr Usage*	*Quantity (Gbytes/month)*	*Cost of Quantity*
Today's Internet	1.5 to 6 Mbps	< 50 Kbps	2	$1.00
SDTV, 5 movies/month	1.5 to 6 Mbps	190 Kbps	9	$4.50
SDTV, All Viewing	12 Mbps	1.3 Mbps	224	$112
HDTV, All Viewing	24 Mbps	6.7 Mbps	1120	$560

Source: H. Kafka, *Drivers for Next Generation Networks* (2006). All Viewing implies 8 hours, 11 minutes per day of viewing.

In a future with HDTV channels delivered over the Internet, however, the access speed would need to be 24 Mbps, with average busy-hour usage of 6.7 Mbps and monthly downloads of 1,112 Gigabytes (1.1 Terabytes). Obviously, in this scenario, the demands on the Internet

[12] H. Kafka, BellSouth Chief Architect, *Drivers for Next Generation Networks* (March 7, 2006) (available at: http://www.ofcnfoec.org/materials/2006KafkaPlenary.pdf).

network are significantly different than they are now, and Mr. Kafka concludes that video services "can overwhelm current Internet core technology." Kafka "guesstimates" that if video service is provided using technology that delivers one copy of the stream to each customer, without any intelligent replication or caching in the network, the average cost of Internet transit bandwidth for a typical customer would be $560 month.

Of course, we would not expect much demand for Internet service at a price reflecting a cost of $560 per month, and at that price the United States' world ranking in broadband subscription would certainly not increase. In fact, such a network would not be constructed and Internet consumers would not use it to access IP video (or quality video, at least). Kafka offers several potential solutions to keep Internet access affordable, including "new content distribution technologies/models," "network management/traffic control," "new business models for Internet services," "massive amounts of cheaper bandwidth," and "then some." Some of these proposals (like network management and traffic control) clearly reflect the necessity for a more intelligent Internet to reduce the end-user price of accessing the Internet of the future. Certainly, Kafka's presentation reveals that network owners and operators will need to devote considerable attention to the bandwidth demands that video will place upon the Internet and that "intelligent" investments will be needed to reduce costs substantially.

B. *Clarke Analysis*

A more detailed analysis of the potential cost of an unmanaged or "stupid" network is provided in a recent study entitled *Cost of Neutral/Unmanaged IP Networks*.[13] The study's author is Richard N. Clarke, AT&T Director of Economic Analysis. The study considers primarily the cost of delivering high bandwidth video-like services (say, a television show in HDTV) in real time using unicasting technology.

The study considers the cost of serving four types of customers, where the customers are differentiated temporally (current, future) and in their bandwidth demands (low, high). For a "Modest Future Video Usage," the study assumes receipt of two simultaneously streamed standard definition television channels ("SDTV"), whereas "Typical Future Video Usage" is the simultaneous streaming of one HDTV and three SDTV channels or two HDTV channels. The cost results are summarized in Table 2 below. Bandwidth demands in the busy hour are provided.

Costs are divided into four categories. "Outside Plant Costs" include the "last mile" link to the final user including drop, distribution and feeder plant, home optical terminals and so forth.

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13 Richard N. Clarke, *Costs of Neutral/Unmanaged IP Networks* (May 2006) (available on the Social Sciences Research Network at: http://ssrn.com/abstract=903433).

In this model, the last mile is fiber using PON ("passive optical network") architecture (e.g., Verizon's FiOS network is a PON). "WC+Cluster Costs" include optical line termination equipment located at a wire center and the facilities used to connect local wirecenters (including routers, interoffice fiber, etc). "Backbone" costs are special access links from a hub wire center to the Internet backbone point-of-presence plus IP transit costs. Operating costs are assumed to be constant across demand levels.

Table 2. Cost Estimates of a Neutral/Unmanaged IP Network

BH Capacity Utilization	*Busy-Hour Download*	*Outside Plant Costs*	*WC+Cluster Cost*	*Operating Cost*	*Backbone Cost*	*Total Cost*
Current Typical Usage	45 Kbps	$30.64	$2.77	$12.00	$1.30	$46.71
Current Power Usage	450 Kbps	$30.64	$3.07	$12.00	$8.84	$54.55
Modest Future Video Usage	5.5 Mbps	$30.64	$11.32	$12.00	$86.14	$140.09
Typical Future Video Usage	21.5 Mbps	$31.62	$86.49	$12.00	$336.15	$466.26

Source: Clarke, *Cost of Neutral/Unmanaged IP Networks* (2006).

From Table 2, we see the key drivers of the cost of the "stupid" network are wire center and backbone costs, and most of these usage-driven cost increases reflect the need to expand the capacity of transmission facilities and associated equipment.

This study echoes Kafka's analysis and suggests that in the future, when video streaming or other high bandwidth real time services become a more significant component of consumer demand, the cost of a "stupid" network will be very high. For "Typical" video usage as defined in the study, the monthly cost of serving a household is $466.[14] This estimate appears consistent with that in the Kafka analysis ($560). These estimates are static and do not take into account possible future developments, such as lower bandwidth costs or improvements in compression technology, which would reduce the bandwidth needed to transmit high-quality video. But the cost figures are striking and show that relying on such technological improvements may be a risky gamble, because if they fail to transpire, the price for broadband services could skyrocket to several hundred dollars a month, or, more likely, consumers get stuck with the capabilities of today's network.

C. *The "Managed Network"*

While the estimates of these studies are important to the Network Neutrality debate, neither of these analyses provides estimates of cost of a managed network that would provide the same level of video service contemplated in the analysis. Since prices typically exceed costs, we can

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14 A rough approximation of monthly costs can be computed for any given Kbps using the formula: $42.06 + 0.01962 \cdot \text{Kbps}$. The equation is based on the least-squares coefficients using the figures reported in Table 1.

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make some comparisons to the expected prices for services capable of delivering the services considered by these cost analyses. For example, the usage pattern of a "typical" customer in the Clarke study appears equivalent to AT&T IPTV service per-customer capacity (one HDTV and three SDTV channels).[15] While the price for AT&T's IPTV service is not yet formally determined, public statements indicate a price, including some content, of about $100 per month.[16] Similarly, Verizon's FiOS video service is priced under $100 including video content.[17] And, the traditional cable television network, the ultimate managed network (in a tie with the circuit-switched network), can deliver excellent broadband speeds and HDTV without difficulty and at a price substantially less than $500. Many large cable operators are now offering a triple play bundle of services for about $100.[18] So, it appears possible for network management to keep the cost of video-heavy Internet connections at affordable levels.

D. *Bernsten Research*

A recent report by financial analysis firm Bernstein Research, entitled *The "Dumb Pipe" Paradox (Part I)* is authored by Craig Moffett and Amelia Wong, purports to analyze the cost of building and operating a "dumb pipe" network.[19] The Bernstein Research report is the only study of which we are aware that suggests that operator of a "dumb pipe" would be more profitable than one also offering related, vertical services such as video.

Bernstein Research focuses on the cable network and concludes that if a cable firm was to sell its network as a "dumb pipe" and allow another entity to sell the programming, the cable firm would be more profitable. In essence, the argument is that if the cable firm becomes a "dumb pipe" that "revenues would fall significantly" but that "[o]perating expenses would fall even more significantly." This argument is (at best) a puzzling one.

In Bernstein Research's view, the cable industry sells two products: programming and transmission, and Bernstein Research posits that the total profits for transmission service would

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15 J. T. Stankey, *Lightspeed/Cost Initiatives*, presentation at AT&T Analyst Meeting (Jan. 31, 2006) (available at: http://library.corporate-ir.net/library/11/113/113088/items/181347/analyst06_color.pdf).

16 J. Roper, *CEO Out to Transform SBC Into a Diversified Global Giant*, HOUSTON CHRONICLE (April 20, 2006) (according to AT&T CEO Ed Whitacre, "we would offer voice service, we'd offer long-distance service, we'd offer broadband, we'd offer wireless service, and we'd offer video so the customer would get everything they needed in one package in a bundle for $100 to $110 a month.")

17 M. Morrison, *Battling For The Eyes Of Texas*, BUSINESSWEEK (March 20, 2006) ("Verizon is charging about $100 a month for a package of TV, Internet, and phone services in Keller, competitive with cable and satellite offerings in town.")

18 A. Breznick, *Comcast Joins Cable's Triple-Play Parade*, CABLE DIGITAL NEWS (March 1, 2006).

19 C. Moffett and A. Wong, *The "Dumb Pipe" Paradox (Part I)*, BERNSTEIN RESEARCH (Feb. 27, 2006).

be higher if no programming were sold. In other words, the report assumes that the sale of video programming takes away profits from the "dumb pipe" component of the cable industry. Of course, if programming and the "dumb pipe" were divested from one another, the entity now responsible for selling programming would be a money-losing venture. Exactly who would sell cable programming under these circumstances? Clearly, if it were profitable for another firm to sell cable programming profitably, the cable industry could increase its profits by contracting with this more efficient seller of programming, much in the way that certain areas of department stores, like jewelry counters, are run by separate firms. Yet, we are unaware of any occurrences of this arrangement in the cable industry. In our opinion, the Bernstein report lacks credibility from an economic or financial perspective.

E. *Other Commentary*

While we are unaware of any other documented analyses of the cost of managed versus unmanaged networks, there have been unsupported commentary on the issue by notable persons. For example, consider the testimony of Gary R. Bachula, Vice President of Internet2, a consortium of colleges and universities:

> [A]ll of our research and practical experience supported the conclusion that it was far more cost effective to simply provide more bandwidth. With enough bandwidth in the network, there is no congestion and video bits do not need preferential treatment. All of the bits arrive fast enough, even if intermingled. . . . We would argue that rather than introduce additional complexity into the network fabric, and additional costs to implement these prioritizing techniques, the telecom providers should focus on providing Americans with an abundance of bandwidth—that the quality problems will take care of themselves.[20]

Bachula did not provide this research to the Senate Committee, so we are not in a position to review it.[21] But the implication that expanding bandwidth is always cheaper than designing intelligence into the network seems plainly overstated, as Internet protocols are evolving to include quality of service provisions and Internet backbones and the electronics that run them

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[20] Testimony of Gary R. Bachula, Vice President, Internet2, Before the United States Senate, Committee on Commerce, Science and Transportation (Feb. 7, 2006) (available at: http://commerce.senate.gov/pdf/bachula-020706.pdf) at 2-3.

[21] We are, however, concerned that Mr. Bachula may be conflating backbone management needs with institutional network management needs. Internet2 is a backbone network that is likely engineered to handle (and not question) the loads offered to it and paid-for by its member institutions. This backbone network may have far less need for management than the last mile networks that institutions use to distribute connectivity to their end users. It is in these networks where capacity is typically greatly oversubscribed.

are highly intelligent. If presented with a proposal that asserts that an involuntary investment in more "dumb" bandwidth investment is the universal answer to every engineering challenge that the Internet presents, then a policymaker should at least demand to see the materials that support that assertion.

IV. Conclusion

The debate over Network Neutrality proposals needs to focus on balancing the competing concerns over the potential for anticompetitive vertical leveraging against the very real consumer and social harm that "stupid network" proposals would engender. In this POLICY BULLETIN, we present a general cost/benefit analysis framework for examining Network Neutrality proposals that would limit firms from injecting intelligence into Internet local access and backbone networks. We show that such Network Neutrality proposals risk significant consumer and social welfare harm because of the loss in efficiency by preventing network owners from making investments that would reduce network cost by improving the management of their broadband Internet access networks. Our review of publicly available evidence shows that if IP video services increase in popularity, the cost of providing a residential subscriber a "stupid" network capable of addressing those bandwidth demands could reach $300 to $400 per month more than an "intelligent" network. Increasing the cost of broadband to this degree would destroy the business case to build a network that would offer affordable, residential broadband services to American consumers.

Our theoretical analysis also suggests that the need for regulatory control of network design may be unwarranted. We show that under a simple theoretical framework, a firm will invest in network intelligence to reduce costs only when the investment improves both consumer and social welfare, even if the investment reduces the marginal value of the service sold. In fact, policymakers should be more concerned whether too little, and not too much, investment is being made in network efficiency, since the incentive for the firm to invest in network intelligence is below that of society in general. While this theoretical analysis ignores investments made strictly for anticompetitive purposes, it reveals that any general distrust of network investments in intelligence is misguided.

It is important to note that this POLICY BULLETIN simply provides a cost-benefit framework to analyze "stupid" networks from a consumer welfare and economic efficiency standpoint. We do not formally model anticompetitive behavior. This paper highlights the trade-off that would be inherent in any government mandate to build "stupid" networks and illustrates that the consumer welfare benefits that would result from stamping out vertical leveraging would need to be enormous to offset the sizeable efficiency losses we observe in our review of the evidence. Ignoring these efficiency losses would not simply be "stupid"—it would be crazy.