Unfortunately, there are really very few problems which can be solved exactly by analysis.

Richard Feynman

7. Structure and Operation of the Crandall-Jackson DSL Model

We developed two models to help predict the effects of regulation on LEC incentives to invest in DSL services. The first model, a demand model, predicts the level of residential subscribership to high-speed access services as a function of the price of such high-speed access services, the price of computers and ISP services, and time.

The second model, a cost and market share model, calculates the net present value to a LEC from entering the DSL business in a region as a function of several variables including the evolution of pricing over time, the presence and strength of competitors, and the pricing of complementary products.

Appendix C provides a detailed description of these models. Below, in Section 8, we first examine some of the impediments to rapid adoption of DSL service by LECs. Second, we draw together our demand and cost models to examine the likely profitability of DSL offerings by ILECs. In so doing, we isolate the variables that are critical to prospective profitability and demonstrate the likely effect of alternative regulatory scenarios on the success of DSL offerings.

Regulators should make sure that they have the powers available to them to deal effectively with anti-competitive behavior and then get out of detailed market management.

Don Cruickshank, Director General, Oftel

8. Regulation and the Rapid Adoption of xDSL Services

We have identified the following factors that we believe will slow the adoption of DSL technology by LECs:

- Standards uncertainty,
- Regulation of DSL retail rates,
- The unbundling requirements imposed on LECs,
- The inability of many consumers' loops to support DSL, and
- The rapid but uncertain evolution of competing technologies.

Below, we briefly consider each of these in turn and then we move to a more detailed examination of the effects of regulation on a carrier's incentives.

a. Standards Uncertainty

There are multiple, competing standards for DSL – offering different levels of performance, ease of installation, and cost. It is unclear which of these standards will prevail in the market.[23] An early investment in a technology that ultimately was not widely adopted in the marketplace would have to be written off much earlier than an investment in a technology that is widely adopted. LECs have an incentive to delay investment until the winning technology is more clearly identified.

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[23] The recent announcement by Microsoft, Intel, and Compaq together with several of the larger LECs of support for a specific version of DSL may have reduced concern about standards uncertainty. However, there still appears to be substantial uncertainty about such standards. See *U S West Scrambles DSL Picture*, Fred Dawson, MultiChannel News, Vol. 19, No. 6, February 9, 1998.

b. Regulation of DSL Prices

The specter of price regulation of DSL services is another factor that weakens LEC incentives to move quickly to adopt DSL technologies. LECs run the risk that regulators will limit the upside if DSL is highly successful.

c. Unbundling Requirements Imposed on LECs

Under FCC rules adopted after passage of the 1996 Telecommunications Act, LECs are required to unbundle their networks where technically feasible. This unbundling requirement appears to affect DSL services in three ways. First, LECs are required to permit other local carriers to use their loops – so-called *loop unbundling*. Such loop unbundling means that LECs will face DSL competition, at least in denser areas, from competitors who will use the LEC's own loops to gain access to consumers. Loop unbundling will provide a market constraint on the prices LECs can charge for DSL services. Note also that such competition will prevent using ILEC urban DSL revenues to cross-subsidize rural DSL services.

Second, if LECs supply DSL services as part of their regulated carrier offerings, then the obligation to unbundle may run to elements of the network supporting the DSL service. Some parts of this network may be relatively amenable to unbundling, but other parts of this network may pose substantial cost and management burdens if an unbundling requirement is applied. Given the newness of the technology it may be impossible to determine in advance which aspects of the DSL network can be affordably unbundled.

Rolling out a new and relatively poorly understood technology (DSL-to-ISP connectivity) runs the risk of creating features that competitors will ask to have unbundled even though such unbundling is technically infeasible. At best, such requests impose regulatory costs and permit the LEC to be painted as recalcitrant and opposed to unbundling. At worst, the LEC can be assigned an impossible task.[24]

The third unbundling concern associated with DSL service comes from the significant use of subscriber-loop carrier in local telephony. In modern subscriber-loop carrier systems, fiber is run to the neighborhood and the voice signal is transmitted digitally over the fiber. In the neighborhood, the digital signal is converted to an analog speech signal and carried the rest of the way to the subscriber over copper pairs. Some parties have asked LECs to unbundle the their networks at the point of connection between the fiber and copper in digital-loop carrier systems. LECs have resisted such requests, and current FCC rules limit the requirement for loop unbundling requests to the bona fide request process.[25] If LECs begin installing DSL capabilities at the interface used for the subscriber-loop carrier, they can anticipate that there will be additional pressures for unbundling at this point.

d. Inability of Many Loops to Support DSL

Although many loops will not support DSL services, the exact fraction of loops that will not support DSL is uncertain and varies with the technology. However, it is clear that longer loops (beyond 12,000 to 18,000 feet from the central office) are less capable of supporting DSL services. Similarly, loops served by digital-loop carrier technologies cannot support central-office-based DSL services. Different sources give different estimates of the fraction of loops that

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[24] While the FCC's rules do not require unbundling where unbundling is not technically feasible, humans and human institutions are imperfect. It is quite possible that the adversarial process at the FCC or before state regulators could result in a mandate to perform a technically infeasible unbundling. The combination of a new technology, DSL, with a technology not normally the province of regulators, IP transport, provides circumstances where mistakes are more likely than usual.

[25] LECs observe that the equipment cabinets used for such interconnection are typically sized to support the communications demand in the neighborhood they serve and do not permit the collocation of equipment from other service vendors. LECs also point out issues involving the use of maintenance and testing equipment on such unbundled subloops. Finally, privacy issues appear to be more of a concern in this context than with central office collocation.

will support DSL services. We believe that the fraction of loops supporting DSL service will vary substantially among LECs and central offices. An urban central office with no loop carrier and short loops may be able to support DSL on 80 or 90% of its loops. In contrast, a rural central office with many long loops and significant use of loop carrier may be able to support DSL on only 15 to 20% of its loops.

Such uncertainty poses a marketing and political dilemma for LECs that choose to offer DSL service. An inability to serve many customers translates to a restriction in the use of mass media to promote the service. Running an advertisement that encourages a customer to call the business office – only to have the business office tell the customer, "Sorry, that service is not available to you" not only wastes advertising and administrative costs but diminishes the LEC's brand name. Similarly, for a regulated company to provide a service that it can make available in some neighborhoods but not others invites charges of redlining and cream skimming. One must consider practical politics here. What happens if a highly regulated company cannot provide DSL service to the mother of the chairman of the state senate committee on commerce because her home is located six miles from the nearest central office? Is a LEC willing to get into a situation in which it will sell DSL services to some plumbing supply stores but not others?

e. Integration of Demand and Cost Models

In this section, we draw together our demand and cost models to examine the likely profitability of xDSL offerings by ILECs. In so doing, we isolate the variables that are critical to prospective profitability and demonstrate the likely effect of alternative regulatory scenarios on the success of xDSL offerings. We begin by combining the revenue and cost models into a net revenue model for an ILEC with a mixture of wire centers ranging from large centers in heavily urbanized areas to small wire centers in rural locations. The availability of xDSL service to households in any of these wire centers depends on the distribution of loop lengths and the condition of those loops.

Our model divides each region into three areas: urban, suburban, and rural. Because loop lengths are shorter in the more concentrated urban areas, we assumed that a new xDSL service can reach a maximum of 80% of urban subscribers, 70% of suburban subscribers, and 50% of rural subscribers.[26] Moreover, we assumed that xDSL is rolled out more slowly in rural and suburban areas than in urban areas. In urban areas, all wire centers are equipped with xDSL in the first year, whereas only 10% are so equipped in rural and suburban areas. We assumed that the share of xDSL-equipped wire centers increases linearly up to the tenth year so that 100% of suburban offices and 50% of rural offices are finally equipped with xDSL.

The demand for xDSL services depends on the real price of the service. We assumed that subscribers are initially required to pay a $200 installation charge that they amortize at $50 per year. Therefore, we added this $50 per year to the annual subscriber charges to estimate demand. In addition, the consumer must purchase a modem, whose cost enters his demand calculus. We assumed that modems cost $400 initially, but their price declines at a rate of 20% per year. This cost is also amortized at 25% per year. Finally, the customer is assumed to have to invest $100 in inside wiring to accommodate the full xDSL service. This cost declines at a 10% per year rate and is amortized at 25% per year.

We assumed that all ILEC charges decline at a nominal rate of 10% per year, and we assumed a 2.5% inflation rate over the next ten years. We began with the assumption that rates vary directly with costs and therefore that rates are higher in rural areas than in more populous areas. Specifically, we began with the assumption that our hypothetical LEC serving a 5 million subscriber region offers this service at $360 per year in urban areas, $360 in suburban areas, and $480 in rural areas. With the demand model derived in Section 3, above, and an assumed rate of nominal price decline of 10% per year, the number of subscribers at the end of the first and tenth years is shown in **Table 8-1.**

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[26] The model allows the user to vary these assumptions to reflect different telephone-plant configurations.

Table 8-1
Subscriber Demand for xDSL Service
(Share of Households Offered Service)

Year	Rural (P=$480/yr.)	Suburban (P=$360/yr.)	Urban (P=$360/yr.)
1	2.1%	3.5%	3.5%
10	21.8%	21.8%	21.8%

f. Profitability

To estimate the profitability of a new service whose penetration increases over time and that requires relatively long-lived, sunk investments, we need to calculate the present value of all investment, revenue, and current costs over the economic life of the assets. We assumed that ILECs will view any xDSL facilities as relatively risky investments with a useful life of no more than five to seven years. After that time, new technologies, perhaps implemented in different media, will render the original xDSL technologies economically obsolete. Indeed, it is possible that this obsolescence occurs even more rapidly.

We assumed that the real cost of capital for risky xDSL investments is approximately 10%. (This corresponds to a nominal after-tax return of 12.5%.) If the investment is amortized over five years, this return requires an annual after-tax capital charge of 25%. If the investment is amortized over seven years, the capital charge falls to 20%. These charges imply that an ILEC would have to achieve after-tax cash flows of 20 to 25% of the investment in xDSL assets. In other words, if xDSL requires an investment of $400 per subscriber, the service would have to generate $80 to $100 per year after taxes, but before depreciation, to be profitable. For the model runs described below, we used a hurdle rate of 20% before taxes to calculate present values given that corporate tax rates are about 36% of before-tax profits. Present values were calculated as the discounted cash flows over ten years plus a terminal value that is equal to the present value of the tenth year's discounted cash flow carried forward in perpetuity.

With the cost assumptions described above and the demand assumptions in **Table 8-1**, it is clear that initial annual service prices of $480, $360, and $360 that decline at a 10% rate are not sufficient to generate a positive present value (**Table 8-2**). The firm realized -$0.9 million in present value, but this included $5.1 million of terminal value at the end of year ten. Its cash flows over years three through ten were insufficient to offset $30 million in negative cash flows in the first two years. The net present value of the investment only turned positive when the ILEC decided not to serve rural areas at all.

If the ILEC and its rivals charged slightly higher initial prices in urban and suburban areas, $420 per year, the results would be far better. The ILEC realized a net present value of $18.7 million, but $8.4 million of this total reflects the terminal value after year ten. The cash flows in years two through five just offset the negative cash flow in year one, but the cumulative *discounted* cash flows did not turn positive until year eight. Offering the service only to urban and suburban areas at an initial rate of $420 per year raised the discounted present value of the project to $20.3 million and elevated the point at which the project had a positive discounted cash flow to year seven. This would seem to be the absolute minimum required to justify an investment of this magnitude in an arena in which technology is changing so rapidly.

Table 8-2
Present Value of Cash Flows from Unregulated xDSL Services
Under Alternative Assumptions in a Five-Million Subscriber Region
(Millions of 1998 Dollars)

Annual Subscriber Rates [Rural,Suburban,Urban]	Annual Decline Rate for Prices	Service Offered to All Areas	Service Offered to Urban and Suburban Areas
[$480, $360, $360] ILEC and Rivals	10%	-$0.9	$0.6
[$480, $420, $420] ILEC and Rivals	10%	$18.7	$20.3
[$480, $480, $480] ILEC and Rivals	10%	$36.6	$38.2
[$480, $480, $480] — ILEC [$480, $420, $420] — Rivals	10%	$9.1	$10.6
[$480, $420, $420] ILEC and Rivals No Inside Wiring; Modem Cost=$200	10%	$21.0	$22.5

If the ILEC offered the service at initial prices of $480 per year in all areas, the present value of profits would rise to $37 million and the ILEC would get its investment back on a discounted cash flow basis by year six. But even this rosy scenario evaporates if the rivals charge only $420 in the initial year in urban and suburban areas. As **Table 8-2** shows, in this case the ILEC would be forced to match its competitors' lower urban and rural prices.

Finally, even if the consumer faces no inside-wiring costs and only $200 in initial modem expense — the scenario reflected in the last row of **Table 8-2** — the present value of the new services would rise by only about 10%. This is because the consumer is assumed to amortize these outlays at 25% per year. Obviously, if we were to assume a 50% annual amortization, the effect would be about twice as large.

To demonstrate the effects of more optimistic and more pessimistic demand assumptions, we ran the model using the same logistic growth pattern, but with tenth-year (2007) penetration rates of 15% and 34%, respectively. In the former case, only 8 to 9% of households subscribe by the end of 2003, while in the latter 21 to 22% subscribe by 2003.

In the more pessimistic scenario, the present discounted value of cash flows through year ten are negative, but the terminal value of $5.4 million results in an overall discounted present value of $3.9 million. Under these assumptions, an investment in DSL appears to be only marginally attractive.

On the other hand, if demand is so robust that more than 21% of households subscribe by 2003, the present discounted value of the investment in the 5-million subscriber region is a robust $48.4 million. Under these assumption, DSL clearly appears to be a very attractive proposition.

In summary, our results show that even if the LEC obtained 50% of potential subscribers, it would take several years for it to recover its investment at initial prices in the $30 to $40 per month range. In our sample region, the LEC invested more than $75 million in the first five years and served about 160,000 subscribers by the fifth year, assuming a 10% annual decline in prices. For these five years, cash flows were persistently negative. The earliest year during which cumulative discounted cash flows turned positive is year six — and this required initial rates of $40 per month in all density zones. Obviously, if rates are assumed to decline more slowly, the prospective profitability of xDSL is greater, but we do not believe that rates can decline at much less than 10% per year, given the likely growth in competing technologies.

g. Regulation

Because ILECs are regulated both at the federal and state level and because they will use some facilities of their regulated local exchange plant, the regulation of xDSL services becomes a major issue and, therefore, an important determinant of profitability. The regulatory issues may be divided into three categories:

- Retail pricing
- Wholesale unbundling and pricing
- Universal service

i. Retail Pricing

Because xDSL is a retail customer service, some states may attempt to regulate the rates at which it is offered to residences or small businesses. Even if the state has initiated price caps, the initial regulated rate may be set on the basis of anticipated costs and customary regulatory approaches. Thus, states may use the ILEC's estimated cost of capital for utility services and standard depreciation rates, thereby requiring the ILEC to amortize its investment over a period much longer than five or seven years and allowing an annual capital charge that may be little more than half of our estimated 20 to 25% per year.

We assumed that the states would largely forbear in the first few years because xDSL services are novel services with only a few subscribers. But as the service spreads to more consumers, regulators may be under pressure to limit the retail prices charged by the ILECs or even to require geographic averaging of rates. Given the much higher cost of xDSL service in rural areas and the greater technical problems in delivering it, the latter regulatory strategy would be particularly unfortunate.

To model the impact of retail rate regulation on the profitability of xDSL services, we assumed rather conservatively that regulators would begin to examine the costs of the service in the second or fifth year and impose regulation based upon average costs, using regulatory accounting, in year six and require rates to decline at a rate of 10% per year thereafter. [27] Even though regulation came this late, it reduced the present value of cash flows from the LEC's xDSL service substantially.

We began by assuming that the service would be rolled out at initial-year prices of $480 in rural areas and $420 in urban and suburban areas. The regulator was assumed to examine expected average subscriber costs in each density zone in year three, using a 12% cost of capital and regulatory depreciation, and to set rates at this level for year three. Thereafter, they declined at 10% per year. This is a conservative assumption because, in fact, average costs using regulatory accounting fall more rapidly than 10% per year. Moreover, under this assumption, rural rates are left untouched because they are still below average cost in year three, even with regulatory accounting. But even with this "modest" regulation, the discounted present value of cash flows turned negative. (See **Table 8-3**) Rather than realizing a present value of $18 million, the ILEC's investment had a present value of -$3 million. After ten years, the cumulative discounted value of cash flows was -$10 million.

Ironically, if the regulator waited until year six to set rates at average cost based on regulatory accounting, the impact would be much more severe. By this time, average costs would be very low under regulatory accounting, and rates would be pressed down to between $11 and $15 per month in year six. The ILEC would realize a negative $36 million in present value, in no small part because the value of the enterprise at the end of year 10 was negative. This scenario merely adds emphasis to the fact that the ILEC does not recover its investment in the first five years.

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[27] Notice that this assumption is far weaker than current FCC regulatory practice. The FCC currently advocates setting prices based upon forward looking incremental costs – that is costs based upon 1998 technology, not upon a mix of 1983-1998 technologies weighted by investment dollars. One can imagine a world in 2002 or 2003 in which the FCC or the states are urged to set the price of DSL services using forward-looking costs generated by the McCoy model – a model developed by a consulting firm located in Slippery Rock, North Carolina.

Table 8-3
The Impact of Regulation on the Present Value of Cash Flows from xDSL Services (Millions of 1998$)

Type of Regulation	Annual Rate of Price Decline	Rivals Do Not Match Regulated Rate	Rivals Match Regulated Rate
Retail Price Regulation after Year 2	10%	-$3.4	N.A.
Retail Price Regulation after Year 5	10%	-$36.4	N.A.
"Universal" Service — $360 Initial Rate in All Areas	10%	$8.3	-$1.7
"Universal" Service — $360 Initial Rate in All Areas; Retail Regulation after Year 2 at Average Urban Cost	10%	-$13.3	-$11.7

ii. Wholesale Unbundling and Pricing

Under the 1996 Telecommunications Act, certified carriers must unbundle their network facilities and offer them piecemeal to competitors at cost-based prices. If these requirements apply to new services, such as xDSL, or to the new facilities that support that service, they could make investments in new technologies very unattractive. The effects will depend on the way in which the unbundling requirement is interpreted and the manner in which "cost-based" wholesale rates are calculated.

First, the degree of unbundling required is unclear. If an ILEC places its xDSL in a separate subsidiary, leasing loops from its regulated communications company, there may be no new unbundling requirements. In addition, regardless of the ILEC's corporate organization, a large share of the investment in xDSL involves equipment that is installed in the subscriber's premises and therefore presumably is not subject to unbundling. However, the easy entry afforded rivals who can now lease unbundled loops surely reduces the horizon over which a LEC may assume that it could recover its investment in this risky new service. If the technology proves more successful than anticipated, surely entrants — ISPs, CLECs, IXCs, or others — will queue up to lease loops and collocate in the ILEC's wire centers.[28]

Alternatively, these competitors may demand access to the ILEC's service for resale. Given the start-up and marketing costs of the xDSL service, entrants may attempt to argue that avoidable costs are substantial and thereby obtain the service at low rates.

Given the large negative cash flows in the early years, it is unnecessary to provide an explicit model of the unbundled-loop or resale competitive scenarios. Our results suggest that large positive cash flows must accrue to the ILEC in years six through ten to justify investment in this risky new technology. Wholesale unbundling and resale are likely to reduce rather severely the possibility of earning such cash flows.

Second, if some of the new facilities required for xDSL, such as the CO equipment, are indeed subject to unbundling, an important issue arises in setting the wholesale rates for such elements. The capital charges embedded in the wholesale rates should reflect the risk premium required for investing in such facilities, and the projected economic life should also reflect the likelihood of rapid obsolescence. Otherwise, the ILEC could be punished severely for undertaking these risky investments.

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[28] Indeed, such CLEC requests for ILEC copper loops facilities for use to provide DSL services have already been posed in several jurisdictions. While we have not attempted a survey of this topic, conversations with people in the industry and examination of the trade press indicates to us that CLECs are providing DSL services over LEC loops in Boston, the Washington, DC area, and California. It appears clear that regulators will require the ILECs to provide unbundled loops for use by CLECs for DSL and other services. Telecommunications equipment providers will provide the equipment needed for DSL service.

iii. Universal Service

New xDSL services are likely to be most attractive in densely populated areas with relatively affluent populations. In areas of low density, a substantial share of access lines may not be short enough to allow the delivery of xDSL services. Moreover, wire centers in these areas of low population density are likely to be small, thereby generating too few potential subscribers to spread the fixed cost of equipping the central office to provide the service. Obviously, the problems are even more serious in areas of low household income because such areas will clearly generate lower demand for xDSL anyway.

Given these considerations, any state — such as Wisconsin — that requires an ILEC to roll out xDSL services to all wire centers over a short time horizon will discourage *any* investment in xDSL. In **Table 8-2,** we demonstrated that avoiding rural areas, even at a premium of $10 per month over the urban rate, increases the present value of cash flows. What would happen if the ILEC were required to price uniformly across all areas, say at $360 per year, declining at 10% per year? If the rivals remained at our base rates of $420 in urban and suburban areas and $480 in rural areas, the ILEC would eke out a small positive present value ($8 million) because it would gain subscribers in the lower-cost areas. If, however, the rivals match the $360 rate, the ILEC would suffer a negative present value.

It is unlikely, however, that universal service obligations (at equal prices) would be imposed without further regulation. What if the universal service obligation is combined with retail rate regulation beginning in year three? If rates are set at the estimated level of urban cost per subscriber in year three and required to decline at 10% per year, the ILEC would never recover its investment. The discounted present value of the service would be between -$11 and -$13 million, depending on whether rivals were foolish enough to match these rates and thereby share the pain. (See the last line of **Table 8-3**.)

h. Conclusion

Our initial results from the model suggest that an ILEC could realize positive returns over its cost of capital if it were able to charge between $35 and $40 per month for the new DSL service and reduce these rates at a 10% annual rate. However, even these prices do not permit a recovery of the initial investment until year eight. Applying retail or universal service regulation to DSL service makes it is virtually certain that such investments would become unattractive. Moreover, if wholesale unbundling or resale were allowed in the first six or seven years, the ILEC would find it much more difficult to recover its investment. Indeed, the availability of unbundled copper loops may, by itself, require the ILEC to recover its DSL investment much more rapidly than our model allows.

Table 8-4 below summarizes our analysis of the impacts of various regulations.

Let us close with a quotation from FCC Chairman William Kennard:

> Like its appetite for ever-increasing computing power, I believe our nation will have an ever more voracious appetite for data transmission capacity, sometimes called "bandwidth." The key to satisfying this appetite will be to create real opportunities for companies to compete to deliver high bandwidth services over the "last mile" to consumers. Competition in our backbone networks today is driving backbone providers to keep increasing the capacity and speed of the backbones. We need to bring that competitive drive to expand capacity and improve service to the final links to consumers.[29]

We agree. One key step in bringing that competitive drive to local telecommunications is to ensure that LECs have the proper incentives to invest in the new data transmission technologies.

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[29] Chairman Kennard's homepage, http://www.fcc.gov/commissioners/kennard/, July 22, 1998.

Table 8-4 Effects of Regulation on DSL Service

Price Regulation Strict rate-of-return	Incentives to invest would be greatly weakened.	Slower development of service, less competition, higher prices.
Price caps set in 2003 on forward-looking costs at that time	Incentives to invest would be greatly weakened because it is harder to justify investments with lower returns.	Slower development of service, less competition, higher prices.
Regulatory depreciation	Rapid technological change and the assurance of competition would increase the risks of using regulatory depreciation. In addition, regulating depreciation would require regulation of prices generally. Again, incentives to invest would be significantly weakened.	Weakens LEC incentives to invest. May also deter competitors from investing in early years.
Universal service requirements Requirement to provide DSL service to all households served by a DSL-capable central office	Such regulation would give the LECs the incentive to deploy DSL technologies only in central offices where the vast majority of loops could support DSL service.	Restriction of LEC supply of DSL services to urban areas and to those suburban areas with little use of digital loop carrier.
Requirement to provide DSL service at all central offices	Some smaller central offices, especially those with few loops capable of supporting DSL service, would be uneconomic. Consequently, the LECs' incentives to invest would be reduced.	May deter some LECs from initiating DSL service.
Requirement to provide DSL service to all LEC subscribers, if requested	Cost of providing DSL service would increase significantly. Under all reasonable scenarios, a LEC's ability to make a viable business is severely handicapped by ubiquitous deployment requirements.	Less competition, slower service rollout.
Unbundling requirements Loop unbundling	Three different impacts: 1. The ability of others to provide DSL over LEC loops would ensure competition based primarily on CLEC facilities (e.g., DSLAMs, routers). 2. Regulators would not be able use LEC urban DSL profits to support other services. 3. The ability of others to provide DSL over LEC facilities would create difficult problems in managing interference in the outside plant.	Would ensure that DSL will be a competitive service. Would ensure that LECs face DSL competitors with deaveraged costs. Managing interference would create some difficult, but not unsolvable, regulatory problems.
Unbundling applied to unique DSL facilities	Would raises costs for LEC networks.	Would raise costs to consumers and discourage deployment of DSL facilities.
Assurances that DSL costs and revenues will be treated as competitive • Requirement to offer conditioned unbundled loops without electronics • Available on non-discriminatory basis • Not subject to price caps • Nondominant treatment of service	The LECs would be able to consider the DSL market as would other firms. The LECs' incentives to pursue market quickly to gain partial first-mover advantage would be increased.	Would speed availability of DSL service.

Appendix A Technologists' Forecast of the Demand for Digital Access

SRI International Report • February 1998

Demand for High Bandwidth Access

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SRI Project 3319

INTRODUCTION

This report addresses the recent phenomenal growth of the Internet[1], problems in accommodating that growth (e.g., slow performance, increased congestion and general user frustration), and the role that higher speed access links in the "last mile to the user" can play in helping to alleviate these "growing pains" and increase market acceptance. It also defines and quantifies current and prospective market segments (including the 4 out of 5 adults in the U.S. who do not yet use the net), develops models of nationwide demand curves for high bandwidth internet access as a function of price and bit rate, and forecasts residential demand for data network access at various speeds in 3-year increments to 2004.

The Internet is still relatively new and is evolving rapidly. As a consequence, the quantitative estimates of high bandwidth internet access demand offered in this report should be considered as somewhat speculative. To help quantify the more uncertain aspects of Internet evolution, we have developed scenarios of several emerging applications and their possible market acceptance. Our intent is to provide a useful framework for incorporating and interpreting better data as it becomes available.

INTERNET GROWTH

Measures of Internet Growth

It can be shown, by virtually every conceivable yardstick, that the Internet is growing at a dizzying pace. Figure 1 plots this worldwide growth over the past 18 years for three established network metrics: Hosts, Domains, and Websites[2]. Since these are logarithmic plots, the linear segments shown indicate exponential growth. Note that, since the inception of the Web in 1993, the number of websites has been growing much faster than the other two measures and has already overtaken the number of domains. By mid-1997, there were slightly more than 1 million websites and domains; and 19.5 million hosts, worldwide.

Given the complexity of the Internet and its uncontrolled development, it comes as no surprise that there are difficulties in characterizing it in quantitative terms. There are problems in defining precisely what the Internet is and in choosing which of its many measures to use—e.g., hosts, domains, websites, users, traffic in minutes (connect-time), traffic in Bytes or packets. Moreover, none of these measures is very precise. The data shown in Figure 1 have been widely quoted, but must be carefully interpreted.

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[1] These and other technical terms are defined in Appendix 1–Glossary

[2] http://www.nw.com/zone/WWW/top.html, see also URL group 3

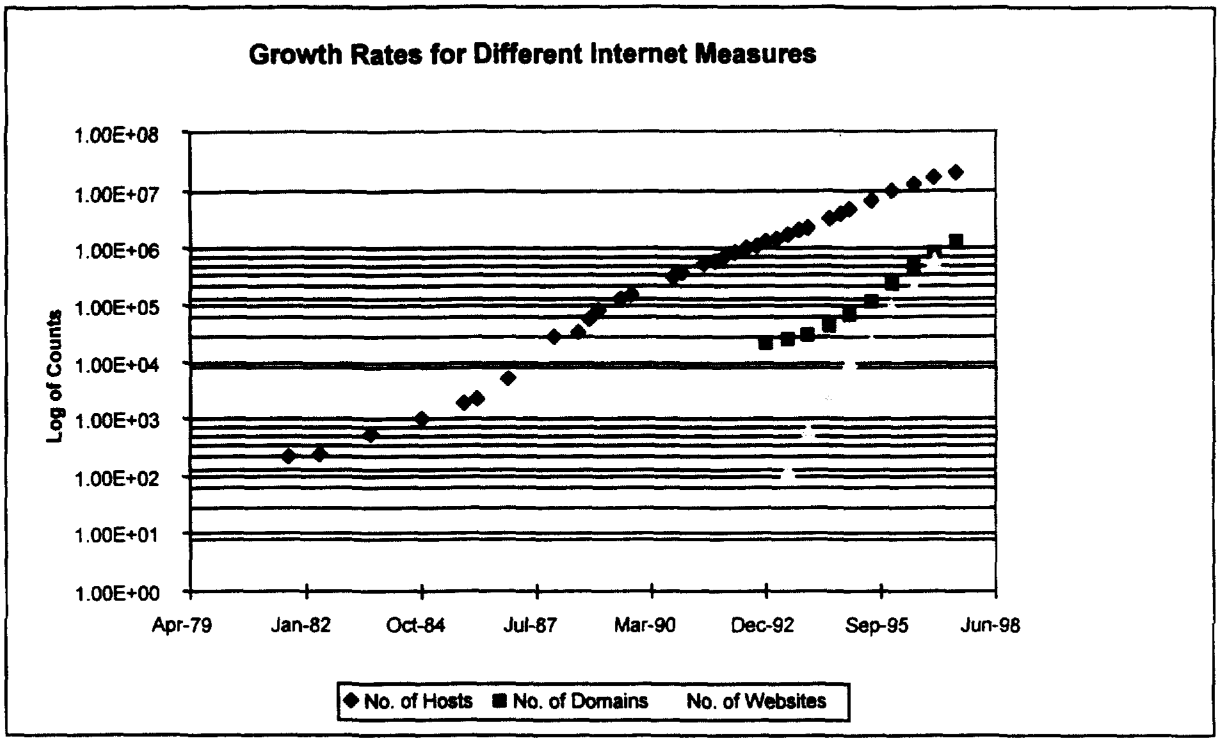

FIGURE 1: Three Measures of Internet Growth

In particular, the following caveats apply to the underlying data depicted in Figure 1.

- No information about users: These three yardsticks pertain to sites, addresses or machines, not users. Thus, they are not a direct measure of users or demand.
- No information about location: The data are worldwide counts of sites or identifiers whose location cannot be deduced. Thus, the information cannot be desegregated by country, urban/rural, etc.
- Problems with data collection: Some entities exist that are not counted (e.g., hosts not registered in a domain server); other entities are counted but don't actually exist (e.g., bogus server or host records)
- Non-Internet sites: Not all hosts counted in the database are reachable from the net (e.g., many companies have firewalls or mail gateways between the Internet and their local nets, thus disallowing direct access). And some of the domains counted are merely mail-forwarding (MX) entries for off-Internet sites.

For example, the number of hosts shown in Figure 1 is derived from a bi-annual census conducted by Network Wizards, a company that uses a computerized robot called ZONE to conduct the count. Note that: "on the Internet" can mean that:

- there is a listing for a hostname and IP address on a name server. The machine does not actually have to exist, but by virtue of its mention on a name server, it is counted.

- the machine is both listed on a name server and is responding to a short query or "ping"—an Internet utility that determines if a machine is actually on and connected to the network. The count must be inferred by using other information for machines that are behind restrictive firewalls (used to increase network security) or machines that are not on at the time of the pinging.

The Network Wizards survey provides numbers for both of these definitions. The host count plotted in Figure 1 is based on the first definition—about 5 times the number of hosts that actually respond to pings.

For purposes of interpreting the data shown in figure 1, the three types of entities counted can be defined, somewhat simplistically, as[3]:

- Host: A networked computer or (often) its namesake—i.e., its net interface, IP address or hostname
- Domain: A part of the internet naming hierarchy.
- Web Site: A host that is part of the Web

In summary, it is difficult to get accurate estimates of demand in the local access loop. Most all reliable[4] estimates of demand for internet services only count users, or at best households. A more useful measure would be number of phone lines and the amount of time these lines are used for internet access. With these measures, it would be possible to define a relationship between the projections of the demand and the infrastructure needed to support that demand. In this report we have gathered estimates of number of users, but only count active users (log on at least once a week). The average time is estimates to be between 6 and 8 hours, but there is little reliable data to further quantify this number.

Web Site Growth

The Web has grown very fast—substantially faster than the Internet at large, as measured by number of hosts. This growth, worldwide, is highlighted in Figure 2 which plots the number of web sites and the number of hosts per web site[5]. As is evident, more and more hosts are becoming websites—about one in 25 or 4% of all hosts as of January 1997, where hosts are defined as above.

The Web's growth has been and continues to be exponential, but the rate is slowing somewhat. During the second half of 1993, the Web had a doubling period of under 3 months; today the doubling period is still under 6 months, and the total number of sites has exceeded 1 million.

As with most information regarding the size and growth of the Internet, these data are only a crude measure of the actual number of web sites/servers, since the count is largely based on URLs. It is important to note that several URLs can be (and increasingly are) on a single web server—e.g., www.Independence_Day.com and www.Amistad.com may be on the

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[3] See Appendix 1–Glossary for more detailed definitions of these terms.
[4] By reliable, we mean data that was collected using a random sample telephone survey.
[5] http://www.mit.edu/people/mkgray/net/, see also URL group 3