

A COST MODEL OF INTERNET SERVICE PROVIDERS:
IMPLICATIONS FOR INTERNET TELEPHONY AND YIELD MANAGEMENT

by

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ABSTRACT

A cost model of Internet service providers is developed in this thesis. The model is used to gain insight into an ISP's present costs and to quantify the impact on these costs of Internet telephony. In addition, the model is used to understand how management techniques can be applied to the provision of Internet access services, and more generally to the telecommunications industry. Policy implications of Internet telephony and yield management are also presented.

The model considers five cost categories of an ISP: capital equipment, transport, customer service, operations and other expenses (sales, marketing, general and administrative). Results show that the costs of providing Internet service exceed slightly the revenues and that no particular cost category dominates an ISP's costs. Variation in the cost distribution among the five types of subscribers studied in the model is considerable. Residential dial-in, business dial-in, 128 kb dial-in ISDN, 56 kb leased-line, and T1 leased-line subscribers were modeled. Hence, the ISP's overall cost distribution will vary substantially if the mix of subscribers is varied.

The Internet telephony scenario considers the impact of computer-to-computer use of Internet telephony. The results show an increase in total ISP costs that is more than double the increase in revenue. The costs are still relatively evenly distributed among the five cost categories, but transport costs become the highest costs. Each subscriber type's cost increases differently, but transport and customer service costs have the largest impact.

Policy issues studied include U.S. and European decisions on regulating ISPs and Internet telephony. The impact on ISP costs of recent access-charge reform by the FCC is shown to be limited, while the potential impact of per-minute access charges would be significant.

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to Bessie, Bubba and Tiger

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Introduction

During the past few years the “Internet” has become a household name. Through its ever-changing array of services, this phenomenon is altering the means of communication. The beauty of the Internet is how it facilitates the adoption of new services. The architects of the underlying Internet protocols¹ have designed them with the intent of allowing various applications to run over various types of networks – all communicating via this common set of protocols. One such set of applications is Internet telephony.

The ultimate impact of Internet telephony as a means of communication is still unclear – many technical, financial and policy issues remain to be solved. The goal of this thesis is to elucidate some of the financial and policy issues associated with Internet telephony, and, more generally, with Internet Service Providers (ISPs).

Specifically, this thesis investigates how Internet telephony can impact the costs of Internet service providers. Further, it introduces techniques known as yield management (which are described in Chapter 2) and applies them to the telecommunications industry – specifically to ISPs. These techniques – originally applied to the airline industry – are designed to control costs and/or to increase revenues. Additionally, policy issues studied include U.S. and European decisions on whether and how to regulate ISPs and Internet telephony. The impact on ISP costs of recent access-charge reform by the FCC is quantified as well as the potential impact on ISP costs of per-minute access charges.

To conduct this study a cost model of Internet service providers is developed. This model quantifies technical and non-technical costs of ISPs for two principal scenarios: one of

¹ Such protocols include IP, TCP and UDP. See [CO95b] for further explanation.

current Internet use with relatively little Internet telephony and one of future use with moderate amounts of (computer-to-computer) Internet telephony. Once the ISP's costs are described, a yield management scenario for ISPs is presented that aims to control the high, technical costs of dial-in Internet users.

1. Internet Telephony Overview

The term “Internet telephony” has been broadly applied to a family of applications where (real-time) voice communication occurs over a network using Internet protocols. This is in contrast to traditional telephony (or “Plain Old Telephone Service” – POTS) that occurs solely over a circuit-switched telephone network. However, this distinction between Internet telephony and traditional telephony becomes less clear when one begins to consider telephony services that bridge packet-switched and circuit switched networks. [CL97] presents a visionary analysis of the various types of telephony services that can be realized using these once-disparate networks.

The principal contrast between traditional and Internet telephony is due to the type of network on which a call occurs. Each call of traditional telephony on a circuit-switched network has a fixed amount of bandwidth – a circuit – allocated between the two ends of the call. Any unused bandwidth due to a pause in conversation can not be recovered by the network and allocated to another call.² In contrast, an IP-based network requires all information – be it email, web pages, audio or video – to be broken into discrete elements called packets that are individually routed over the network. Hence, if there is a pause in the conversation of an Internet telephony call, no packets are generated and packets of other users/applications can be sent in this void.

It is this statistical sharing of a potentially constrained resource – bandwidth – that leads one to believe at first thought that Internet telephony is more efficient, and, hence, less expensive than traditional telephony. The existence of an inherent cost advantage of Internet telephony is very debatable and not immediately clear. However, one certain

² However, on certain high-cost, trans-ocean links compression techniques are used that have this effect.

advantage of Internet telephony is its ability to be integrated with other Internet services (such as those described in [CL97]). For example, a user who is browsing a web-based catalog could have a question or desire to place an order via the phone. The person could be connected to a customer service representative merely by clicking on a link in the web page. The user and the representative would then talk via Internet telephony software. Another example could be two (or more) people collaborating on a document from remote locations. Each would have a copy of the document on the computer screen and could edit and discuss the document in real-time. Further examples are limited only by one's imagination.

While packetization is one of the strengths of IP networks, it also presents a technical challenge for implementing real-time services. Because packets are routed individually, they 1) may follow different paths between origin and destination; 2) may be individually delayed along these paths, and 3) may arrive at the destination out of order – if they even arrive at all.³ Such characteristics of the Internet are manifested in a phone conversation as broken speech and as jitter – the end result being a sound quality poorer than that of POTS. Current research into additional protocols (such as, RSVP and RTP) is aimed at eliminating these limits associated with the Internet telephony of today.

The type of Internet telephony represented in the cost model is computer-to-computer Internet telephony. Future forms of Internet telephony that bridge the PSTN and the Internet (as described in [CL97]) will employ devices known as gateways. These devices can serve multiple roles:

- they conduct the translation between Internet and PSTN protocols;
- they convert analog voice into digitized voice to send over the Internet, and they convert digitized voice into analog voice to send over the PSTN;
- they provide directory services so that Internet users can locate PSTN users and vice versa;
- they monitor usage for billing and security purposes.

³ Further, delay from each end-user's computer operating system and voice-digitizing hardware can also add delay to the system.

Because the development of gateways is in a relatively nascent state and the method of their deployment is uncertain, they are not considered in the ISP cost model; the only type of Internet telephony considered in this model is computer-to-computer Internet telephony.

2. Internet Telephony Policy

2.1. U.S. Policy

Telephony has been traditionally one of the most regulated industry segments in the United States. Under FCC rules (specifically, the Computer II Inquiry) ISPs, being classified as “enhanced service providers,” are exempt from regulations imposed on “carriers,” such as long-distance telephone companies.⁴ These carriers must pay per-minute “access charges” on the order of \$0.06 per minute to the local phone companies who terminate each end of a long distance call [WE97]. A trade association of telephone companies – America’s Carriers Telecommunications Association (ACTA) – filed a petition with the FCC asking it to regulate Internet telephony [AC96]. ACTA argued that ISPs providing Internet telephony services should pay access charges to the local telephone companies as do other long-distance service providers.

In May 1997 the FCC unveiled a reformed access-charge system.⁵ The FCC essentially ruled against the ACTA petition by not requiring ISPs to pay per-minute access charges. Instead, the FCC imposed increased phone charges on business users – ISPs included – (and residential users with a second phone line) in the form of an increased Subscriber Line Charge (SLC) and a new Presubscribed Interexchange Carrier Charge (PICC). The impact of these decisions on an ISP’s costs is presented in Chapter 4.

⁴ In its “Computer II Inquiry” [FCC80], the FCC established the definition of (basic and) enhanced service providers and chose not to regulate them for reasons of public interest. Based on this definition, ISPs have always been classified as enhanced service providers [WE97, p.32].

⁵ See [FCC97a], [FCC97b] and [FCC97c].

2.2. European Internet Telephony Policy

Because of the high rate of growth of the Internet in the United States, potential Internet regulation has been focused on at the highest levels of the U.S. government – more than in most other nations. However, the European Commission has also considered regulating Internet telephony. The European Commission’s approach to determining policy for Internet telephony merits attention because of the obvious impact such policies may have in enabling, or inhibiting, the continued growth of a worldwide market for advanced Internet services.

Such communications are subject of a commercial offer.
Such communications are provided for the public.
Such communications are to and from the public switched network termination points on a fixed telephony network.
Such communications involve direct transport and switching of speech in real-time.

Table 1: EU Criteria for Voice Telephony⁶

As discussed in [SH97], the European Commission has established several criteria that Internet telephony must meet before it will be subject to regulation. These criteria, initially published in [EC97], are presented in Table 1.

Based on these criteria, Internet telephony is not considered voice telephony because Internet telephony does not meet the criterion of “real-time” communication due to the current, high levels of delay experienced by Internet telephony users on the public Internet.⁷ Hence, Internet telephony services in Europe are not subject to regulation at this time.

3. Overview of Thesis

Chapter 2 furnishes a survey of yield management and discusses how it can be used within the telecommunications industry. Further, issues regarding policy implications of yield management are addressed. Chapter 3 presents a detailed description of the ISP cost model. Analysis of the cost model results is done in Chapter 4. Additionally, the impact

⁶ [SH97].

⁷ *ibid.*

of regulatory decisions on ISP's costs and a yield management scenario of Internet access are presented in Chapter 4. Conclusions and areas for further research are discussed in Chapter 5.

Telecommunications Yield Management

In this chapter several issues are presented regarding how yield management could be introduced to telecommunications. Some elementary forms of yield management are already being used in telecommunications. These techniques are discussed as well as whether or not more elaborate techniques could be used. Additionally, policy implications for using yield management in telecommunications are discussed.

1. Overview of Yield Management

Yield management (YM) is a group of techniques that has been applied successfully to a variety of industries including airlines, hotels, car and truck rental companies, and sea and land cargo carriers. Among other purposes, yield management has been used to stabilize varying demand for a given service, and thus, to stabilize, and perhaps increase, a service's revenue. An often cited result is American Airlines attributing a \$500 million annual revenue contribution to yield management techniques [SM92].

Generally speaking, yield management is used in a service that has some sort of fixed capacity (e.g., a fixed number of seats on an airplanes, hotel rooms in a hotel, or communications links of a network). Additionally, the cost of adding capacity for these services is usually prohibitive and the service or good is usually perishable.⁸ The policies of yield management offer incentives to increase use of a system when demand is low and to dissuade use of a system when demand is high. A combination of techniques such as pricing, admission control, service definition and resource allocation, among others, can

⁸ For example, an airplane seat for a given flight can not be sold after the plane has flown. Hence, it is considered a perishable good.

be used to attain yield management's goal of efficient use of facilities while maximizing revenue.

The following is a brief overview of how yield management is applied in the airline industry.

1.1. Yield Management in the Context of Airlines

The fundamental business of an airline is to transport people. To do so, the carrier needs to build and maintain a network on which its passengers are transported. In this case the network is composed of fixed-capacity airplanes flying on fixed routes. Because of the large capital investment needed to build this network, the total capacity of the network can be considered as fixed over a short to medium time horizon.⁹

Because the planes must fly according to pre-determined schedules (i.e., the plane can not wait until it is full of passengers before flying) the seats on the airplane can be considered as perishable inventory. If the plane were to take off with any empty seats, what was once a product to sell is no longer available: this particular inventory has perished. Hence, it is in the airline's interest to try to have every seat full on every flight, even if only a fraction of the standard revenue is achieved for an otherwise empty seat. Once a flight's schedule is fixed (i.e., the resources of the airplanes are allocated), the capacity (the number of seats) between any two points on the network is also fixed. The airline then needs to strategically vary its prices in order to fill all seats and hopefully to maximize revenue – which, on a per-seat basis, is termed the “expected marginal seat revenue” – while considering such factors as the number of seats already reserved, the percent of reservations that will actually show up for a flight, competitors' prices, and so on.

The airline's task is further complicated, in part, by having several types of passengers with varying willingness to pay. It is for this reason that airline uses a technique known as “price discrimination.” Passengers can be put into two general categories: business travelers and pleasure travelers. History has shown that pleasure travelers are more price

sensitive than business travelers. Additionally, business travelers tend to make travel plans at the last minute and are not prone to traveling over weekends but rather during the business week. In contrast, the pleasure travelers usually plan a vacation in advance and include some time over the weekend in their travel plans.

Using these passenger characteristics, airlines are able to sell essentially the same service – airline transportation – to different people at different prices. In order to achieve this, the products need to be sufficiently differentiated so that the passengers perceive that they are purchasing different products. Hence, discounted tickets targeted toward the pleasure travelers have such restrictions as a two-week advanced purchase, Saturday night stay-over and nonrefundable fares. Full-fare tickets targeted towards the business travelers are refundable and do not have the advanced-purchase and Saturday-night-stay-over restrictions. Additionally, other classes of airline travel exist such as first class, business and coach. In essence, all classes are simply seats on an airplane, but the carrier is able to further differentiate the products (and charge accordingly) by adding low-cost incentives such as free drinks and a higher quality meal for business and first class than for the coach class.

For each class of travel on each flight of an airline's schedule "booking limits" and prices are established. Often prices are greatly influenced by external factors such as competitors' prices and are not considered to be part of the yield management process. The booking limit corresponds to how many seats of a given fare are available for a particular flight. At any point in time, an airline has prices and booking limits established for travel for up to almost one year. Each evening, the airlines re-compute prices and booking limits based on such factors as the number and type of tickets sold that day and projected demand for the various flights. As previously mentioned, the result of such extensive modeling and computation – in order to near-optimally set prices and booking limits and to define services – has permitted at least one major airline to become profitable.

⁹ However, by reassigning airplanes spatially and/or temporally, each segment of the network can have a varying capacity.

2. Characteristics of Industries Using Yield Management

As mentioned above, certain industries – such as airlines, hotels, car and truck rental companies, and sea and land cargo carriers – are using successfully a combination of yield management techniques to control costs and to stabilize revenue. In this section similar characteristics between these industries are identified and a comparison is made with the telecommunications industry.

2.1. Large Sunk Cost and Low Marginal Cost

Most industries to which yield management has been traditionally applied have shared this characteristic. For instance, in the case of airlines, the number of units available for sale (the seats on an aircraft on a particular route at a particular time) are fixed. To provide one more unit (seat), an additional airplane, or a larger airplane, has to be flown on the same route at the same time. On the other hand, given that capacity is available, the marginal cost of providing service to an additional passenger (such as, food and airplane fuel) is negligible. This results in a wide range of prices over which it is preferable to sell the seat at a deep discount rather than let it go empty.

The hotel industry provides another example. Assuming a room is available, the marginal cost of providing service to an extra occupant may be as little as \$15-25 when the room rate could be in excess of \$100. Thus, a substantial discount is preferable to leaving a room empty. If capacity is unavailable, there is a high fixed cost of adding capacity (i.e., building more rooms).

However, one must mention that the characteristics of large sunk cost and low marginal cost are not essential for yield management to be practical. Yield management has been applied successfully to car and truck rental companies (e.g., Ryder Car and Truck Rental [MC94]) where the incremental cost of adding one more unit of capacity to the whole is relatively lower than in the case of an airline or a hotel.

Weatherford and Bodily [WB92] cite an interesting hypothetical case where even an airline that never sells out – in effect, one that has unlimited capacity – should

nevertheless stimulate demand early and then raise prices for late arrivals. Car and truck rental companies can be considered to have variable capacity because vehicles are rented for varying durations. Having fixed capacities is therefore not essential for the application of yield management techniques to an industry but is common.

The similarities between the airline/hotel scenarios and the telecommunications network scenario is evident. Once a network infrastructure is in place, the marginal cost of establishing a session on the network (assuming the network is session-oriented) is essentially negligible, assuming sufficient capacity is available for this session. However, the fixed cost of increasing the bandwidth of the network or the capacity of the switches is huge compared to the small, marginal cost of one more person using the network.

2.2. Perishable Goods

The distinguishing feature of yield management is that it deals with goods or services that are perishable. There is one and only one date or time at which the good becomes available and has to be used immediately – or within an appropriately small interval of time – otherwise the good “perishes.” The item can be stored either not at all or at least not without significant cost or deterioration. If the item were storable, inventory management techniques would probably be more applicable than yield management techniques. Examples of perishable goods are seats in an aircraft, seats in a theater, rooms in a hotel, and even broadcast advertising time slots.

Similarly, bandwidth on a telecommunications network can be considered a perishable good. A network is sized according to a peak demand. At times when the demand is not at its peak, there is idle capacity. This capacity can not be stored; it can only be used in real-time. Hence, bandwidth can be considered a perishable good. The implications for telecommunications providers is that they should give incentives for use of the network when there is idle capacity.

2.3. Varying but Predictable Demand Patterns

Shifting demand “from the peaks (of high demand) to the valleys (of low demand)” implies that the demand for a given product is varying over time. For example, demand for a movie ticket at 8 p.m. on a Friday night is greater than at noon on a Monday. Similar temporal demand trends exist for many services – especially telecommunications.

The limit of how much demand one can shift to the valleys depends on the nature of the service. Even if a movie theater offered a first-run film for \$1 at 3 a.m., few people would go. However, for certain telecommunications services, one would be more willing to set up a computer/VCR to automatically download a file/movie at 3 a.m. if the price were much cheaper than at a high demand period.

In addition to the demand pattern varying, it must also be predictable. One must be able to reasonably forecast how demand patterns will vary (usually based on current trends), as well as how demand patterns will change with the applications of yield management techniques.

2.4. Capability of Segmenting the Market

A market, as defined by neoclassical economics, is the exchange of currency for a good or service across all people supplying and demanding the service. The market equilibrium is reached at the point where supply equals demand. Individual consumer surplus is the difference in what the consumer is willing to pay – his reservation price – and what the market has set – the equilibrium price. Consumer surplus is the individual consumer surplus summed over all consumers. Similarly, individual supplier surplus is the difference in the supplier’s reservation price and the equilibrium price, and supplier surplus is the individual supplier surplus summed over all suppliers.¹⁰

Price discrimination is the ability to separate consumers such that there is no one equilibrium price for all consumers, but there are separate prices for each consumer or classes of consumers. By separating the demand curve into multiple classes of consumers,

suppliers are able to set multiple equilibrium prices. By doing so, they reduce consumer surplus and increase supplier surplus. In essence, the supplier or suppliers are increasing their profits by separating the aggregate demand curve into separate demand curves. This is price discrimination. As described in [PI95], there are three principal types of price discrimination.

First degree price discrimination is a perfect price discrimination where the demand curve is separated into an individual's demand. The supplier charges each customer his reservation price. This removes all consumer surplus and maximizes supplier surplus.

Second degree price discrimination is non-linear pricing. By setting a price for the good that decreases over the quantity bought, suppliers are able to separate buyers who are buying in high volume and those buying in low volume. Once again, this has the effect of shifting consumer surplus to supplier surplus.

Third degree price discrimination is the type most commonly used by the airlines to segment the market. In this type of price discrimination, users are separated by their buying behavior.

As described in the yield management overview at the beginning of the chapter, airlines realize that there are different groups of people willing to pay different prices for the same product. The airline would like to be able to sell seats to any group who is willing to pay a price that is greater than the marginal cost of the product. The essential step is for the airline to differentiate the product for each group so that a consumer of a given group thinks he is purchasing a different product than one designated for another group. If the products are not sufficiently differentiated, consumers would simply purchase the product with the lowest price.

As previously described, the airlines achieve the product differentiation through restrictions on each type of plane ticket (e.g., two week advance purchase, Saturday night stay-over, and so on). Hence, business travelers and tourist travelers are segmented into

¹⁰ See [PI95] for further discussion on consumer and supplier surplus.

their respective groups – referred to as fare classes. In reality, airlines have segmented the market into many more than two groups; on any given flight, there might be as many as twenty different fare classes.

One should note, however, that because price discrimination is only one of many tools of yield management, it can be implemented without price discrimination. As previously described, the general process of yield management shifts the demand “from the peaks to the valleys.” This has two principal impacts: costs are reduced as a result of the lowered peak demand, and revenue is increased as a result of the overall increased use of the system. Such impacts are still possible without the use of price discrimination through other techniques, such as congestion pricing and admission control. However, given demand patterns conducive to price discrimination, overall revenue would be greater if the firm employed price discrimination than if the firm did not employ it.

2.5. Service Reservations

A characteristic common among services where yield management is employed is that reservations are made. As with hotel rooms and airplane tickets, consumers reserve space in advance so they can be essentially certain that they will be served at the time they would prefer. As previously mentioned, different classes of travelers will have different reservation patterns; for example, tourists generally reserve further in advance than business travelers. The service provider uses the reservation information along with demand forecasts to set the number of available places and prices for each class of service.

Traditionally, in the telecommunications industry, advance reservations are not made. For example, someone making a long-distance telephone call does not call the phone company several days in advance and reserve capacity. Most likely, phone companies give no incentive for such reservation to occur for several reasons: 1) the cost of monitoring such a large number of phone calls would be prohibitive, 2) a phone call takes such little capacity vis-à-vis the total capacity of the network, and 3) even during the high

demand times, the phone network has been sized such that there is available capacity 99.9% of the time.

Even though advance reservations have not been made traditionally in the telecommunications industry, there is plenty of opportunity for this to occur with emerging services. Many new services – especially video services – require much more capacity than a telephone call. Networks that carry currently millions of telephone calls will be more constrained when carrying “video calls.” Hence, service providers can plan for an efficient use of their network capacity by taking advance reservations for certain classes of service to be certain the network is as full as possible at all times.

2.6. Capability of Easily Varying Prices

One characteristic of industries using yield management is the ability to vary easily the prices of service. While yield management techniques were being developed for American Airlines as early as the 1960s, they could not implement the techniques until the deregulation of the airline schedules and prices in 1979 [SM92]. Likewise, in other industries employing yield management, such as hotels and cruise lines, pricing flexibility exists.

In contrast, the telecommunications industry has many of its services regulated. For example, tariffs for local and long-distance telephone service need to be filed with the appropriate regulatory bodies. Any changes to the pricing structures of a service need to be filed and approved. Certainly, the telecommunications industry can not vary its prices as freely as the airline industry. However, there is a current trend of deregulation in the telecommunications industry, and an environment where service providers have more flexibility in varying its prices is certainly perceivable.

3. Existing Yield Management Techniques in Telecommunications

Yield management has not been systematically practiced in the telecommunications industry even though there does exist some rudimentary usage of such techniques. For

instance, long distance telephone rates are varied throughout the day in order to affect demand. Peak usage occurs traditionally during the day, and rates are set higher; when demand drops in the evening and throughout the night, rates are lowered. Hence, only basic, pricing techniques are used. Reasons for this could be due, in part, to current pricing inflexibility as described above.

Because the telephone network has only one class of service, the extent of admission control is based solely on the availability of capacity. If a route from origin to destination exists, the call request is accepted; if no route (of two network links or less) exists, the call is blocked. The public switched telephone networks in the United States are sized such that the probability of a call being blocked is less than some blocking probability threshold – usually on the order of 0.01 or 0.001.¹¹

As another example of yield management, one can look at ISPs. As described in Chapter 3, dial-in subscribers connect to the Internet via the ISP's modems. The number of modems that an ISP uses will vary according to the number of the ISP's dial-in subscribers and to what level of service the ISP wants to offer. At one extreme, the ISP could have one modem for each subscriber; quality of service would be great because no users would be blocked. At the other extreme the ISP could have one modem for all subscribers; service would be rather lousy because the chance of being blocked is high.¹² Hence, the ISP needs to size its modems somewhere between these two extremes. Not all ISPs will size their modems to the same level, and, thus, there will be varying levels of blocking seen by the end users.

ISPs realize that certain end users are willing to pay more than the default \$20 per month if they could be guaranteed a connection when they want it. Hence, some ISPs offer a

¹¹ As just described, from a technical perspective, there is only one class of service. From a pricing perspective, there are actually two broad classes (which are generally unrelated to yield management): business users and residential users, with different prices for each class. This is a form of price discrimination known as “customer-class pricing,” which is based on the theory of Ramsey pricing and rate-of-return regulation [MI91]. This price discrimination is due not to the telephone service providers but rather to regulators who desire business users, with a greater willingness to pay (on average), to subsidize the cost of residential users, who are more sensitive to price (on average).

¹² Of course, the blocking probability would depend on the actual number of subscribers and their usage patterns.

different class of dial-in service where there is a dedicated modem for each subscriber of this service. This could be considered as a form of yield management because the service provider identified a varying willingness-to-pay and created multiple classes of service for its subscribers.

4. Identifying Services for Yield Management

A service provider will have many types of issues to consider when trying to identify the services with which to use yield management. Considerations include technical and non-technical issues as described below.

4.1. Perception of Service

One of the effects of the airlines using yield management is that the passenger's perception of service has changed. Arguably, one could consider the service definition of airlines before yield management to be similar to commercial bus carriers today. For a bus passenger wishing to travel from Boston to New York, for example, the availability of a ticket depends solely on whether or not there remain open seats on the bus. Similarly, in the long distance telephone networks, a call request is admitted solely based on whether or not there exists a route with capacity between the origin and destination. In contrast, the availability of an airline ticket for a certain class of service depends on whether or not there remain any seats for that class on the airplane, not simply whether or not there remain any seats on the airplane. In one scenario, there might remain open seats on the airplane, but no more tickets for a particular fare. In this case, the passenger must choose a ticket from another fare (presumably at a higher price) or choose not to travel on that flight.

Consider the users of the public switched telephone network as an example of a user's perception of a telecommunications service. While the telephone networks have slowly migrated from analog networks to digital networks over the past several decades, the fundamental service of POTS has remained essentially the same since its inception earlier this century. The local (and usually, monopoly) telephone company has defined POTS to

be a single level of quality, known as toll quality – a sort of one-size-fits-all telephone service. Moreover, the user expects the telephone network to have capacity for him to make a phone call when he picks up the telephone. Given this assumption about the user's perception of service, the phone companies spend much effort and money to sufficiently provision the telephone network so that there is a 99.9% chance (which corresponds to a 0.001 afore-mentioned blocking probability) that the network has available capacity for the user to make a phone call at any time during normal conditions.

The service provider (e.g., telephone company) could take a perspective different than that of continually sizing the network to accommodate fluctuations in demand; instead, the service provider could define different levels of service for telephony, such as discounted and standard service, for example. The discounted service could be one that is priced less per minute than standard service and would not necessarily have the toll-quality clarity that the standard service would have. In addition, during times of high demand, the service provider might limit the amount of discounted service that is available. In effect, the user could attempt to make a telephone call with discounted service and find that that service is not currently available at that time; instead, the user would have to pay more and use the standard service. Traditionally, telephone networks have been circuit-switched, and such distinctions in quality-of-service were unachievable, or perhaps not cost-effective. The advent of packet-switched Internet telephony permits more easily such variations in service definition.

Having several levels of quality-of-service for the above example of telephony is not necessarily desirable or cost effective (at least for circuit switched telephony), but having several levels of quality-of-service for other telecommunications service, such as video applications, is potentially beneficial.

Not only will service providers need to define their services from a different perspective, but the end-users will also have to take a different perspective (e.g., growing accustomed to being blocked for a certain discount service but having a higher level of service available – presumably at a higher price).

4.2. Technology and Yield Management

The specific yield management techniques used would depend on the type of services and on the technology employed by the telecommunications provider. For example, one might approach defining yield management techniques for telephony on circuit switched networks differently than for telephony on packet switched networks. Likewise, yield management techniques for broadcast, analog video on a coaxial cable plant vis-à-vis packetized, digital video on the same coaxial plant would be approached differently because of the potential for sharing the bandwidth used by the digital video with other digital services.

5. Policy Considerations for Yield Management in Telecommunications

From a policy maker's perspective, extensive use of yield management in telecommunications could further complicate an already complex decision-making process. Using yield management as described, service providers could be varying prices and blocking call requests for certain types of service. Given the trend in deregulation, the policy maker would have to decide what, if any, services should remain regulated. Responsibilities for policy makers would include not only potentially regulating prices of services, but also availability of services.

The passing of the 1996 Telecommunications Act has spawned a reconsideration of what services to include under the Universal Service umbrella – which has traditionally included only telephone services;¹³ there is now the possibility of including Internet and other enhanced services. Hence, a policy maker might ultimately decide that some service being offered by a telecommunications service provider using yield management should also be included under the Universal Service umbrella. The service provider will then have to consider this policy constraint when defining the yield management techniques in order to meet the minimum requirements (as defined by the policy maker).

¹³ Universal Service is the concept of ensuring that "[c]onsumers in all regions of the Nation, including low-income consumers and those in rural, insular, and high cost areas . . . have access to telecommunications

For example, consider a cable company offering a packet switched telephone service along with other digital video and data services on its coaxial cable plant. The cable company might choose to use yield management techniques to allocate its bandwidth resources. However, regulations might require the cable company to make available at all times the ability of a local telephone call (e.g., a 911 call). Hence, there are certain call requests for some basic level of telephone service (however that is defined by the regulator) that can not be denied. As a result, the cable company will have to consider this when developing its yield management techniques.

6. Summary

Chapter 2 examined how yield management can be applied to many types of telecommunications services. Characteristics common to industries already employing yield management techniques were presented and compared to the telecommunications industry. The specific case for studying yield management in this thesis is for Internet service providers, and the specific scenario presented in Chapter 4 is for dial-in Internet access service.

The next chapter introduces the Internet service provider cost model.

and information services . . . at rates that are reasonably comparable to rates charged for similar services in urban areas” [FCC97a, p. 5].

A Cost Model of Internet Service Providers

This chapter presents a cost model of Internet service providers that was developed for the MIT Internet Telephony Consortium (ITC) and the MIT Research Program on Communications Policy (RPCP). Specifically, the model aims to quantify the impact on an ISP's costs that result from an increased use in Internet telephony. The model contains two scenarios: a baseline scenario representing current ISPs where the principal use of the network is for web browsing and there is essentially no Internet telephony; an Internet telephony (IT) scenario where the ISP sees a substantial increase in use of computer-to-computer Internet telephony by its subscribers.

This model serves several purposes:

- (1) It identifies the costs of end-to-end Internet service for various types of users (e.g. dial-in, leased-line) and how those costs fall into various cost categories. One can then understand an ISP's motivations for targeting certain types of subscribers.
- (2) One can quantify the impact on an ISP's costs for certain "what if" scenarios. For example, what happens to the costs under a substantial increase of computer-to-computer Internet telephony use.
- (3) Using the model results, one can tailor yield management techniques to have the most impact on the high-cost areas of Internet service provision for each type of user.

The model breaks down the ISP's costs into five principal categories:

- *Capital Equipment* – the hardware and software of the network;

- *Transport* – the leased lines of the network and interconnection costs;
- *Customer Service* – staff and facilities for supporting the customers;
- *Operations* – billing, equipment and facilities maintenance, and operations personnel;
- *Other Expenses* – sales, marketing, general, and administrative.

The details of each category are presented later in this chapter. However, before considering the specifics of the cost model, one must first understand which type of telecommunications entity is attempting to be modeled.

1. ISP Market Structure

In building a cost model of an ISP, one must define what type of ISP the model is intended to represent. In order to provide a perspective of this task, note a comment by Bob Metcalfe in his weekly column:

My key fact of the week is that there is no meaningful notion of an “average” ISP [ME97b].

Hence, questions like ‘What is a typical ISP?’ or even ‘What is an ISP?’ are not easily answered. Many entities ranging from national backbone providers – such as MCI – to AOL (who provides access to the Internet as well as to proprietary content) to the local access provider around the corner (who might have only 300 subscribers) all call themselves ISPs because they all provide Internet service. Clearly, a single model can not represent sufficiently all of these entities.

The current structure of ISPs is that there are several national backbone providers such as Sprint, MCI, UUnet, Netcom, and BBN.¹⁴ These network operators have diverse networks that span the country (and internationally in some cases) and interconnect at several points throughout the country. These interconnection points can be at public

¹⁴ The number of ISPs who have these national backbones is growing as other entities who own national telecommunications networks for services other than Internet are considering using some of this capacity for Internet services. For example, as its name would indicate, Cable & Wireless Internet Exchange (CWIX) was initially involved in telecommunications services other than Internet but now operates an international ISP network.

locations –such as NAPs (network access point) or MAEs (metropolitan area ethernet) – or can be at privately arranged peering points.

The types of subscribers that these national backbone ISPs have are (1) business and institutions wanting dedicated, high-bandwidth access and (2) the local and regional ISPs (also referred to as Internet access providers, IAPs). It is from these Internet access providers that many residential users and small businesses obtain their access. Essentially these IAPs are using the larger, upstream provider to interconnect the IAPs' local network with (1) the other local networks of the upstream provider, (2) the individual leased-line subscribers of the upstream provider, and (3) the rest of the Internet that is accessed via one of the NAPs. Hence, there is a clear distinction between the businesses providing end-user access and those providing a nationwide backbone that interconnects the access providers.¹⁵ There are, however, some ISPs that offer both backbone connectivity as well as access service, but this is usually carried out in separate divisions of the ISP, almost as separate business entities.

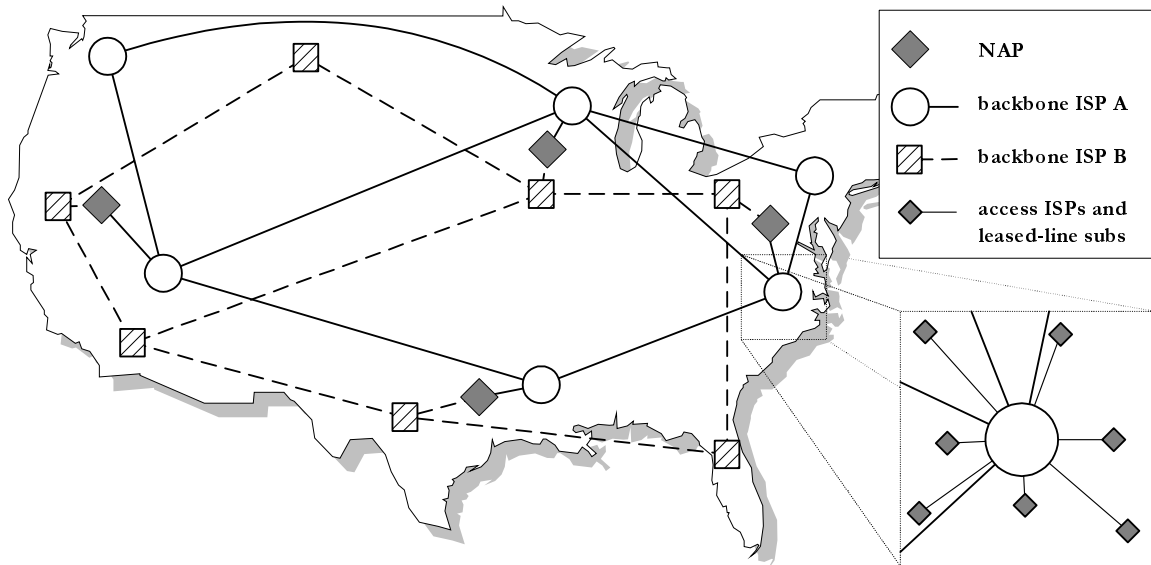


Figure 1. ISP Network Architecture

¹⁵ Several years ago certain ISPs, such as Netcom and PSInet who had national backbones also had over 100,000 dial-in subscribers. They have since left the mass consumer market to concentrate on the more profitable business (leased-line) market.

As an example of ISP structure, Figure 1 shows two hypothetical backbone ISPs. Their networks span the country and interconnect at several NAPs. Additionally each backbone ISP has many access ISP customers and leased-line subscribers that connect at a node, also referred to as a point-of-presence (POP).

Additionally, two important trends are affecting the ISP market structure:

- (1) Because of continued growth of Internet services, the total number of ISPs is growing. Boardwatch Magazine lists 1455 ISPs in its March 1997 directory of ISPs [BO97]; its Fall 1996 directory lists 3068 ISPs in North America [BO96].
- (2) Consolidation among ISPs is also occurring. Because of “acquisitions or attrition,” one analyst put the number of ISPs in the US to be around 1,500 by the year 2000 [LA97].

The effect is that ISP market structure in the US is very dynamic. Developing a model to understand the costs of Internet services that tries to closely imitate current market structure will not necessarily provide additional insight. Moreover, ISP market structure outside the US is less fractured; many countries have just a handful of ISPs, each with substantial market share. Hence, in order to quantify costs of Internet service, one must represent the *end-to-end* costs, not just the costs of a particular access or backbone ISP based on a market structure that is fast changing.

2. Modeling the ISP

In order to quantify these end-to-end costs of Internet service provision, the cost model represents a single backbone ISP and its associated access ISP customers and its leased-line subscribers. It is assumed that the other backbone ISPs (and their subscribers) would have a cost distribution similar to the one being modeled. For descriptive simplicity in the cost model, the aggregated entity of the backbone ISP and the access ISPs will be referred to as a single ISP. Figures 2, 3, and 4 illustrate the topology and technology of this ISP that are discussed in the following sections.

2.1. Defining the Regions Served by the ISP

ISPs generally locate a point-of-presence (POP) in a region that it wants to serve. These POPs can range in size depending on how many subscribers for which the POP is providing service. The model uses a two-level hierarchy of POPs: Tier 1 POPs and Tier 2 POPs. In each urban region, which corresponds to a major city, a Tier 2 POP is located, and in each rural area surrounding a city, a Tier 1 POP is located. Thus, with each Tier 2 POP, there is associated a certain number of Tier 1 POPs. The following list shows the model parameters that define the regions served by the ISP:

- No. of Tier 2 POPs
- No. of Tier 1 POPs / Tier 2 POP
- No. of NAP Interconnection points
- Tier 1 POP average population
- Tier 2 POP average population
- average distance Tier 1 POP to Tier 2 POP (miles)
- average E/W distance between 2 Tier 2 POPs
- average N/S distance between 2 Tier 2 POPs
- average distance Tier 1 POP to closest central office (miles)
- distance to NAP from closest Tier 2 POP.

Using the combination of the number of Tier 1 and Tier 2 POPs and the population served by each POP, the model determines the total population of the region served by the ISP. Additionally, using the distance parameters, the model determines the area of the region being served.

One implied factor that greatly influences the region served by a POP in reality is how one defines the region in which a non-toll call can be made. The main reason for locating multiple POPs throughout a region is that for those users who dial-in over telephone lines, they will most likely not use an ISP for whom they need to make a toll call. The smaller the region in which one can make a non-toll call, the more dispersed the ISP's POPs must be. At one extreme, if a dial-in user can call a POP anywhere in the country without a toll (and the ISP does not have to pay for the call; e.g., 800 numbers), then it is to the ISP's advantage to centralize all equipment in order to save the additional costs of

maintaining POPs dispersed throughout a region and in order to take advantage of statistical multiplexing of certain network equipment (e.g. modems).

Default Values in the Model

The ISP is sized such that it serves 9 major cities throughout the US. The average East-West distance between the cities is 1,500 miles and the average North-South distance is 500 miles so that the ISP essentially spans the US Table 2 indicates the values used for the above mentioned parameters. Because Internet telephony will have no effect on these parameter values, they are the same for both the baseline scenario and the IT scenario.

PARAMETER	BASELINE	IT
No. of Tier 2 POPs	9	9
No. of Tier 1 POPs / Tier 2 POP	50	50
No. of NAP Interconnection points	3	3
Tier 1 POP average population	500,000	500,000
Tier 2 POP average population	2,000,000	2,000,000
average distance Tier 1 POP to Tier 2 POP (miles)	75	75
average E/W distance between 2 Tier 2 POPs	1500	1500
average N/S distance between 2 Tier 2 POPs	500	500
Area of Region Served (sq. mi.)	3,000,000	3,000,000
Total Population of Region	243,000,000	243,000,000
distance to NAP from closest Tier 2 POP (miles)	5	5

Table 2. ISP Size Definition

2.2. ISP Network Topology

This section describes the structure of the network connecting the various POPs. The ISP’s network, which is shown in Figure 2, is similar to that in Figure 1. The Tier 2 POPs are interconnected in a mesh network, and the Tier 1 POPs interconnect in a star network with a Tier 2 POP at the center. The ISP interconnects with other ISPs at three NAPs.¹⁶

The Tier 1 POPs connect to a Tier 2 POP with dedicated T1 circuits. The Tier 2 POPs are interconnected with dedicated OC-3 or T3 circuits, depending on which type of circuit is cheaper. The total number of required circuits depends on the number of POPs and the

¹⁶ An earlier version of the model used a star network instead of a mesh network to interconnect the Tier 2 POPs. As the network was scaled beyond a regional network to one that spans the US, the costs associated with the network (i.e., what are referred to as transport costs in the model) became very high. Updating the model with a mesh network, but maintaining the same level of demand, caused the transport costs to decrease. Hence, for the given demand, the mesh network represents a more efficient backbone topology than a star network.

aggregated amount of traffic. Each Tier 1 and Tier 2 POP has also analog and ISDN dial-in lines over which the dial-in subscribers connect. These are depicted in Figure 3 and Figure 4.

Both Tier 1 and Tier 2 POPs serve analog and ISDN dial-in subscribers. Whereas, leased-line subscribers (56 kb and T1) receive access only at the Tier 2 POPs. Any subscriber located in a Tier 1 region desiring dedicated access will connect via the closest Tier 2 POP. In this way, the Tier 1 POPs are considered as remote POPs serving only dial-in subscribers.

ISPs spend undoubtedly a great amount of effort to optimize their network. Presumably they use techniques from the field of network optimization. The problem of determining an efficient or near-optimal network architecture for the ISP's backbone in this model is known as the two-facility capacitated network loading problem (TFLP). Here the ISP has the choice of two types of facilities, OC-3 and T3 circuits. An OC-3 circuit has essentially the capacity of three T3 circuits, but its cost is less than three times that of a T3 circuit. Hence, at some threshold an OC-3 circuit becomes cheaper than multiple T3 circuits. Additionally, traffic can be routed favorably such that this threshold will be exceeded on a given link warranting the use of an OC-3.

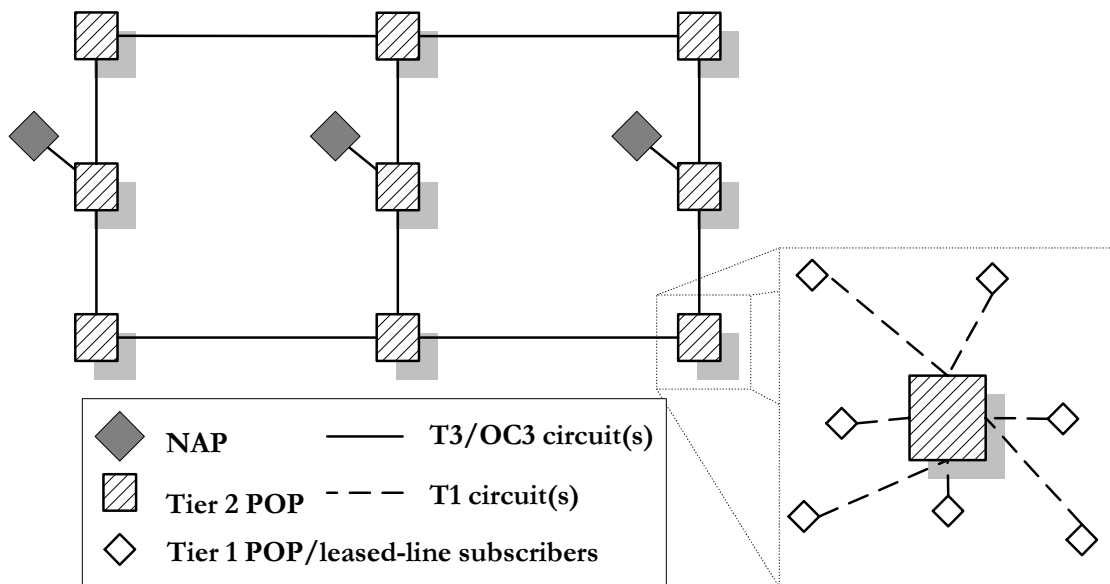


Figure 2. ISP Topology

Solving the TFLP, which can be formulated ultimately as a mixed-integer program, is not a trivial task. Operations researchers use such techniques as Lagrangian relaxation and cutting plane methods to obtain near-optimal solutions. For further study of this problem see MA95.

Because network optimization is not the core of this thesis, attempting to optimize the ISP's network is beyond the scope of this thesis.¹⁷ The mesh network is assumed to be a reasonable topology. Studying the topology of current backbone providers shows that they also have similar mesh networks [BO96].

With the advent of public-switched ATM service, ISPs also have the option of leasing permanent virtual circuits (PVCs) from telecommunications providers. The ISP can then specify the exact amount of bandwidth it requires in each direction between two points. Telecommunications providers are reluctant to discuss the pricing structure because prices are negotiated and are highly competitive. For this reason, PVCs are not considered in this model.

2.3. ISP Service Definition

The following ISP services are included in the model:

- dial-in analog access
- dial-in ISDN access (128 kb)
- 56 kb leased-line access
- T1 leased-line access
- basic web hosting
- enhanced web hosting.

¹⁷ While optimization might yield an improvement, the results of the optimization are highly dependent on the demand inputs and circuit prices. As discussed later in the document, obtaining accurate circuit prices is not simple because they are usually negotiated with the telecommunications provider. Hence, any results of extensive optimization could be easily discounted because of debatable circuit-price inputs. Additionally, current TFLP formulations do not incorporate bulk discounts offered by leased-line providers. With some of these discounts being greater than 50%, solving the TFLP without the discounts would certainly be sub-optimal.

There are two general categories of subscribers: residential subscribers and business subscribers. It is assumed that residential users subscribe only to the analog dial-in service and business users subscribe to all services. Hence, there are seven types of subscribers:

- residential dial-in subscriber
- business dial-in subscriber
- ISDN subscriber
- 56 kb subscriber
- T1 subscriber
- basic web hosting subscriber
- enhanced web hosting subscriber.

ISPs actually offer more than seven classes of service (e.g., fractional T1, frame relay). Instead of trying to incorporate each potential class, it is assumed that the above subset of classes is sufficient to characterize the majority of an ISP's subscribers and its costs.

The residential and business dial-in subscribers receive the same service, but they are differentiated by their usage patterns; residential subscribers are more likely to access the service during the evening and business subscribers are more likely to access the service during the day. Each residential and business analog dial-in subscriber is considered to be an individual, whereas the ISDN and leased-line subscribers are considered to be some sort of institution with multiple users.

For leased-line subscribers some ISPs will sell or lease the end user a router and CSU/DSU, and some will even include the cost of the leased-line in the subscriber's monthly charge. It is assumed that leased-line subscribers will furnish their own router, CSU/DSU, and leased-line. Hence, the costs associated with these are not included in the model.

Even though web hosting is included as part of the model, it is not considered in this thesis because this study of the model is concentrating on the costs of Internet access and Internet telephony. It is assumed that web hosting costs are independent of Internet access and Internet telephony, and, thus, parameters associated with web hosting are set to zero.

2.4. POPs

Figure 3 and Figure 4 show a breakdown of the equipment in the Tier 1 and Tier 2 POPs, respectively. The Tier 1 POP has the analog and ISDN dial-in lines connecting to the modem rack(s) and access router(s), respectively. The modem racks, POP (email/web/news) server(s) and router(s) are all interconnected over a LAN. The technology assumed for the LAN of a Tier 1 POP is 10 Mbps ethernet. The CSU/DSU connects a serial port on the router to a T1 that connects the Tier 1 POP to a Tier 2 POP.

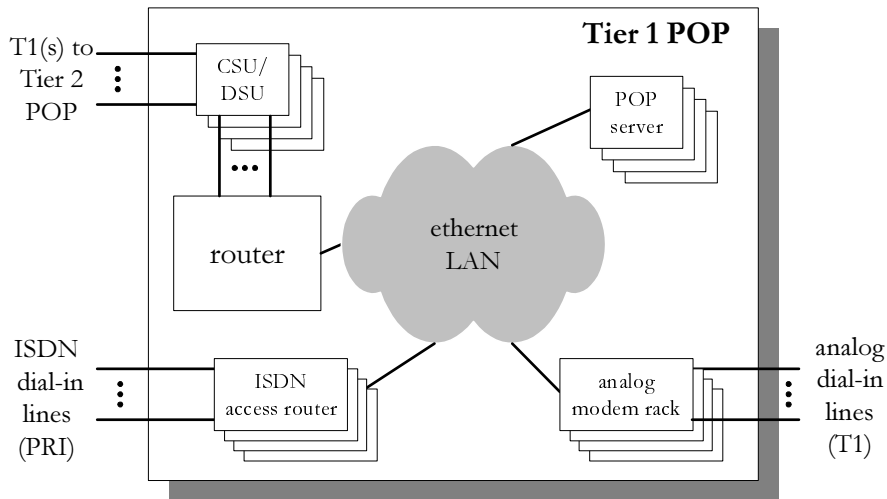


Figure 3. Tier 1 POP

A Tier 2 POP has equipment similar to the Tier 1 POP for connecting the local dial-in users (analog modem racks, ISDN access routers, POP servers, and a LAN). In addition, there is a higher capacity router (than that of the Tier 1 POP) and multiple CSU/DSU's for connecting all Tier 1 POPs, 56 kb, and T1 leased-line subscribers. The router has an ATM card that is connected to the ATM switch in the Tier 2 POP. All Tier 2 POPs are interconnected with T3 or OC-3 links via the ATM switches.

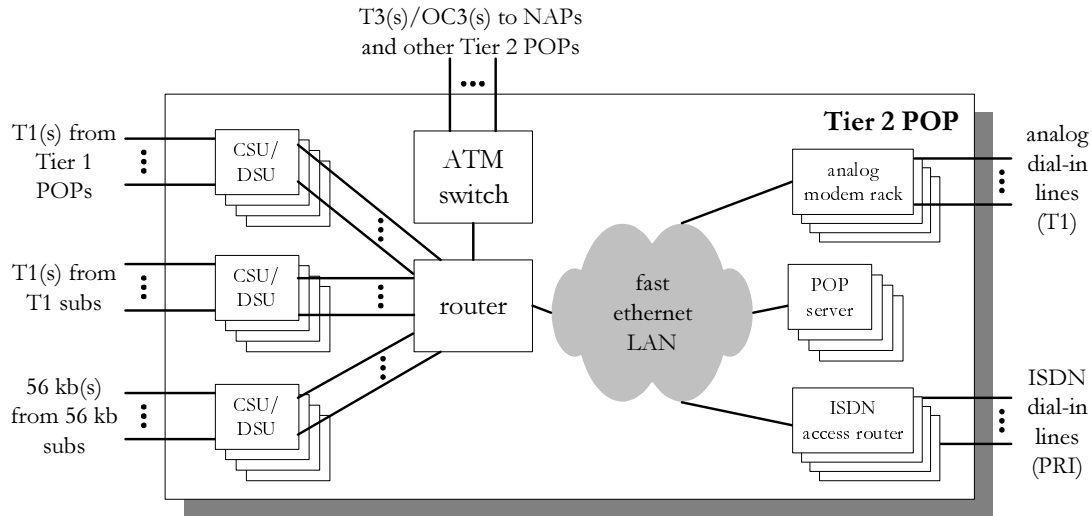


Figure 4. Tier 2 POP

The specific details of how the various equipment in the POPs is sized are found in Section 3.1 (Capital Equipment).

2.5. ISP Market Profile

Once the region that the ISP serves is defined and the ISP's services are defined, one must determine how much demand there is for these services, and how much market share this particular ISP will capture. The following parameters define demand and market share.

Residential

- Ratio of people/household
- % of households with residential dial-in service
- ISP market share of residential dial-in users.

Business

- ratio of online households to online businesses
- % of businesses with dial-in service
- % of businesses with ISDN service
- % of businesses with 56 kb service
- % of businesses with T1 service
- ISP market share of business dial-in users
- ISP market share of ISDN users
- ISP market share of business 56 kb users
- ISP market share of business T1 users

Using these parameters, the number of residential dial-in subscribers for a Tier 1 POP (and similarly for a Tier 2 POP) can be calculated using the following formula:

$$\frac{\text{Tier1 POP avg. population}}{\text{ratio of people/household}} * \% \text{ of households with res. dial - in service} * \text{ISP market share of res. dial - in users}$$

The number of business dial-in subscribers for a Tier 1 POP (and similarly for a Tier 2 POP) can be calculated using the following formula:

$$\frac{\text{Tier 1 POP avg. pop.}}{\text{ratio of people / HH}} * \frac{\% \text{ of HH on - line}}{\text{ratio of on - line HH / on - line bus.}} * \% \text{ online bus. w / dial - in svc.} * \text{ISP market share of bus. dial - in users}$$

Similar formulas are used to determine the number of ISDN subscribers for Tier 1 and Tier 2 POPs. Because of the assumption that leased-line subscribers in Tier 1 and Tier 2 regions connect only at Tier 2 POPs, *Tier 1 POP avg. pop.* is replaced in the above formula with *Tier 1 POP avg. pop. * No. Tier 1 POPs + Tier 2 POP avg. pop.* for determining the number of 56kb and T1 subscribers.

Default Values in the Model

Table 3 is a summary of the values used for the market profile parameters.

PARAMETER	BASELINE	IT
Residential		
ratio of people/household ¹⁸	2.6	2.6
% of households with analog dial-in service ¹⁹	10%	10%
ISP market share of residential dial-in users	10%	10%
Business		
ratio of online households to online businesses ²⁰	65	65
% of businesses with dial-in service	25%	25%
% of businesses with ISDN service	25%	25%
% of businesses with 56 kb service	10%	10%
% of businesses with T1 service	40%	40%
ISP market share of business Dial-in users	10%	10%
ISP market share of business ISDN users	10%	10%
ISP market share of business 56 kb users	10%	10%
ISP market share of business T1 users	10%	10%

Table 3. Online Statistics

Market share parameters are held constant for both scenarios so that cost results can be legitimately compared. The resulting distribution of subscribers is shown in Table 4.

	per Tier 1 POP	per Tier 2 POP	Total (all POPs):	distribution
No. of res. dial-in subscribers	1923	7,692	934,615	98.5%
No. of bus. dial-in subscribers	7	30	3,595	0.4%
No. of ISDN subscribers	7	30	3,595	0.4%
No. of 56 kb subscribers	-	160	1,438	0.2%
No. of T1 subscribers	-	639	5,751	0.6%

Table 4. ISP Subscribers

¹⁸ The U.S. Census Bureau reports that there are approximately 2.65 people/household in the United States. The Census Bureau defines a "household" as a person or group of people who occupy the same housing unit [<http://www.census.gov/prod/2/pop/p20-488.pdf>].

¹⁹ [FI96] reports that 14.7 million (US) households own a PC and use the Internet. This represents approximately 15% of US households. This figure includes households subscribing to ISPs and to commercial online services (COLS) (e.g., AOL, Compuserve). FI96 also reports that 8.9 million households own a PC and subscribe to COLS, with most of these households accessing the Internet. Hence, out of 15 million online households, approximately 60% subscribe to COLS and 40% subscribe to ISPs. However, the distinction between an ISP and a COLS is vague, because some COLS actually lease capacity from ISPs and the COLS subscribers are generating traffic on the Internet. For the purpose of the model, the value of 10% is used so as to take into account the Internet resources consumed by the COLS subscribers.

²⁰ [FO96] reports that this ratio is approximately 100:1; however, FO96 does not define what is considered a business. The ratio of the total number of commercial subscribers to the total number of individual subscribers from 9/94 to 12/95 for four public ISPs [MO96] was found to be approximately 30:1. Again, what is considered a commercial subscriber and an individual subscriber is not defined. Such a discrepancy is most likely due differing definitions of types of subscribers. The value of 65, which is used in the model, is an average of the two cited ratios.

It is assumed that there are approximately ten backbone providers in the United States, each with an equal market share; hence, the ISP represented in the model has a market share of 10%.

Because ISPs are very differentiated, with some targeting business subscribers and some targeting residential subscribers, no current ISP would have an equal distribution of market share across all services. However, because the model represents a backbone ISP and access ISPs, the ensemble is assumed to have an equal market share in all service categories.

Estimates for percent of businesses with analog and ISDN dial-in, 56K, and T1 service are based on 1997 estimates in FO96.²¹

2.6. Revenue

Because this cost model is not intended to represent a business plan for an ISP, revenue is not considered to be a key component. However, revenue estimates are included for two reasons. First, they yield another perspective for comparison of the resulting cost figures. Secondly, sales and marketing expenses are based directly on a percentage of revenue (This is discussed in more detail later in the sales and marketing section). For the model's purposes, the ISP's revenue is derived from monthly charges to the seven types of subscribers listed in the "ISP Market Profile" section.

Default Values in the Model

Regarding revenue results, it is assumed that all customers are current customers; therefore, no installation and other one-time startup charges are included (no concept of customer churn exists in the model).

²¹ In [FO96], analog and ISDN dial-up subscribers are bundled in a single category. In the model, the total amount of this category is split evenly between analog and ISDN subscribers.

INPUT PARAMETER	BASELINE	IT
<i>service charges:</i>		
monthly residential dial-in [BO96], [FO96]	\$20	\$20
monthly business dial-in [BO96], [FO96]	\$20	\$20
monthly ISDN [FO96]	\$100	\$100
monthly 56 kb [FO96]	\$500	\$500
monthly T1 [FO96]	\$1200	\$1200
RESULTING QUANTITY	BASELINE	IT
monthly residential dial-in revenue	\$18,692,000	\$18,692,000
% total revenue	70%	59%
monthly business dial-in revenue	\$72,000	\$72,000
% total revenue	0.3%	0.2%
monthly ISDN revenue	\$359,000	\$359,000
% total revenue	1%	1%
monthly 56 kb revenue	\$719,000	\$1,193,000
% total revenue	3%	4%
monthly T1 revenue	\$6,902,000	\$11,457,000
% total revenue	26%	36%
total monthly revenue ²²	\$26.7 M	\$31.8 M

Table 5. ISP Revenue

Even though there is a constant the number of subscribers for both scenarios, the revenue increases. This is based on the assumption that the leased-line subscribers will keep their circuit(s) at the same level of utilization for both scenarios. For example, if a T1 user is using his line at 60% capacity without Internet telephony, he will purchase enough lines to remain at 60% capacity when he is using Internet telephony; thus the increase in revenue is due to the additional lines purchased by the subscriber. The number of lines per (leased-line) subscriber is directly related to the assumptions about how much bandwidth Internet telephony requires and is discussed in the “Internet Telephony Assumptions” section.

2.7. User Profile

The assumptions regarding user behavior are presented in this section. Based on these assumptions, the model sizes the number of trunks and amount of network equipment required to carry the traffic generated by the users with and without Internet telephony.

²² For comparison, FO96 estimates that Internet access in 1997 will have revenues of \$2.37 billion, which is approximately \$200 million per month. The total monthly revenue for the ISP in the model, which has a 10% market share, is \$26.7 million. Hence, the distribution and magnitude of subscribers seems reasonable.

2.7.1. Residential and Business Dial-in Subscribers

The following parameters are used to determine the traffic generated by all dial-in subscribers:

- average downstream bandwidth per user (kbps)
- % active
- average holding time (minutes)
- % of subscribers requesting service during given hour (for all 24 hours).

The last two parameters are used to determine the number of concurrent dial-in subscribers during a given hour. The number of concurrent dial-in subscribers along with the first parameter, the average downstream bandwidth per user, is used in part to determine the required number of T1 and T3/OC-3 links. This is discussed in more detail in the modem section and in the transport section later in this chapter.

The *% active* parameter allows for one to account for user behavior when dial-in subscribers connect and then spend a certain amount of time idle. For example, certain users might be connected from 9 a.m. until 6 p.m. but only be active 10% of the time. Such users waste resources by tying up a modem.

Default Values in the Model

INPUT PARAMETER	BASELINE	IT
average downstream bandwidth per user (kbps)	5.0	8.3
% active	100%	100%
average holding time (minutes)	30	36
<i>% of subscribers requesting service during given hour</i>	see Figure 5	see Figure 5

Table 6. Analog Dial-in User Assumptions

The default value for the *average downstream bandwidth per user* parameter is based on discussions with MIT ITC members. The Internet-telephony-scenario value is based on assumptions about how bandwidth will increase for that scenario. These assumptions and corresponding formulas are described in the “Internet Telephony Assumptions” section later in this chapter.

Quantifying the effect of users who dial-in for long periods of time and remain idle is beyond the scope of this thesis, and, thus the *% active* parameter is set to 100% so that it has no effect.

Several sources have reported the *average holding time* to be approximately 30 minutes.²³ For the Internet telephony scenario, it is assumed that this holding time increases by 20%.

The usage patterns are based, in part, on discussions with MIT ITC members, and compared against such data published by ISPs.²⁴ In general, for the baseline scenario, residential subscribers are assumed to dial-in principally in the evening, with a peak of 20% requesting service at 10 p.m. Analog and ISDN business subscribers are assumed to have the same usage patterns. In these patterns, the peak requests of 20% occur at 11 a.m. and at 3 p.m. The number of requests seen by a modem pool serving residential and business analog dial-in subscribers will depend on the number of each type of subscriber. This is discussed in further detail in the modem section later in this chapter.

For the Internet telephony scenario, call arrival rates (usage patterns) are assumed to increase by 20% for both the analog and the ISDN subscribers. Because the Internet telephony scenario represents an ISP whose subscribers are embracing Internet telephony, rather than a long distance telephone company using IP technology to complete calls, the call patterns are assumed to remain similar to ISP patterns and not to resemble long-distance-telephone-usage patterns.

²³ For example, the WSJ (*AOL Scales Back Ads, Spends More to Handle Heavy Traffic*, January 17, 1997) reported that AOL subscribers, with flat-rate pricing, spent an average of 32 minutes per day online.

²⁴ For example, see www.iadfw.net/doug/pm-yesterday.html where Internet America, an ISP, publishes its modem usage statistics. See also [MO96b, chapter 4].

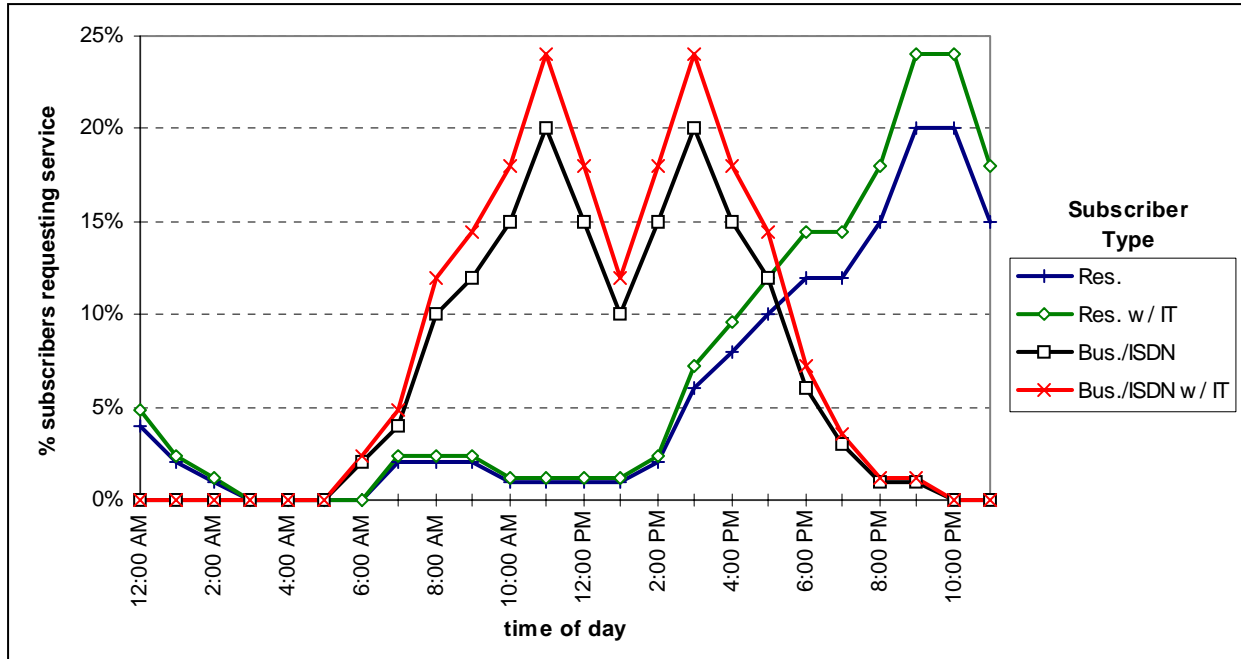


Figure 5. Analog and ISDN Subscriber Usage Patterns

2.7.2. ISDN Subscribers

As for analog dial-in subscribers, ISDN subscribers connect similarly by sharing capacity on an ISDN access router. Here, the units of capacity are B channels, instead of modems.

The parameters for ISDN subscribers are the following:

- ratio of per user ISDN bw to per user dial-in bw
- average holding time (minutes)
- % of subscribers requesting service during given hour (for all 24 hours).

Default values for these parameters are presented in Table 7.

Default Values in the Model

INPUT PARAMETER	BASELINE	IT
ratio of per user ISDN bw to per user dial-in bw	500%	500%
average holding time (minutes)	30	36
% of subscribers requesting service during given hour	see Figure 5	see Figure 5
effective average bw per user (kbps)	25.0	41.5

Table 7. ISDN Dial-in User Assumptions

The *ratio of per user ISDN bw to per user dial-in bw* represents how much more bandwidth an ISDN dial-in subscriber (with a 128 kb connection) consumes than an analog dial-in subscriber. Because the ISDN connection has essentially five times the bandwidth of an analog connection (128 kb v. 28 kb), it is assumed an ISDN subscriber consumes five times the bandwidth of an analog subscriber. As a result of this parameter, the *effective average bw per user* (for ISDN) is derived for both scenarios.

As previously mentioned, ISDN usage patterns and holding time are assumed to be similar to those of analog dial-in usage patterns for businesses, for both the baseline and the Internet telephony scenarios.

2.7.3. 56 kb and T1 Subscribers

The following parameters are used to determine the traffic generated by all leased-line subscribers:

- % that leased line is full during given hour (for all 24 hours)
- Number of leased lines / business.

The value of these parameters is used along with that of the aggregated traffic generated by the dial-in users to determine the capacity of the links connecting the POPs as well as the quantities of certain networking equipment. A more detailed discussion is found in the *Transport* section later in the document.

Default Values in the Model

INPUT PARAMETER	BASELINE	IT
Number of leased lines / business	1	1.66
% leased line is full during given hour	see Figure 6	see Figure 6

Table 8. 2.7.3. 56 kb and T1 Subscribers Assumptions

As described in the revenue section of this chapter, it is assumed that a leased-line subscriber will operate his line at the same capacity for both scenarios. Hence, the *% that leased line is full during given hour* parameter is held constant for both scenarios. For the scenario without Internet telephony, the *number of leased lines / business* is set to one. To account for the impact of Internet telephony, the value of this parameter changes according to the Internet telephony assumptions described later in this chapter.

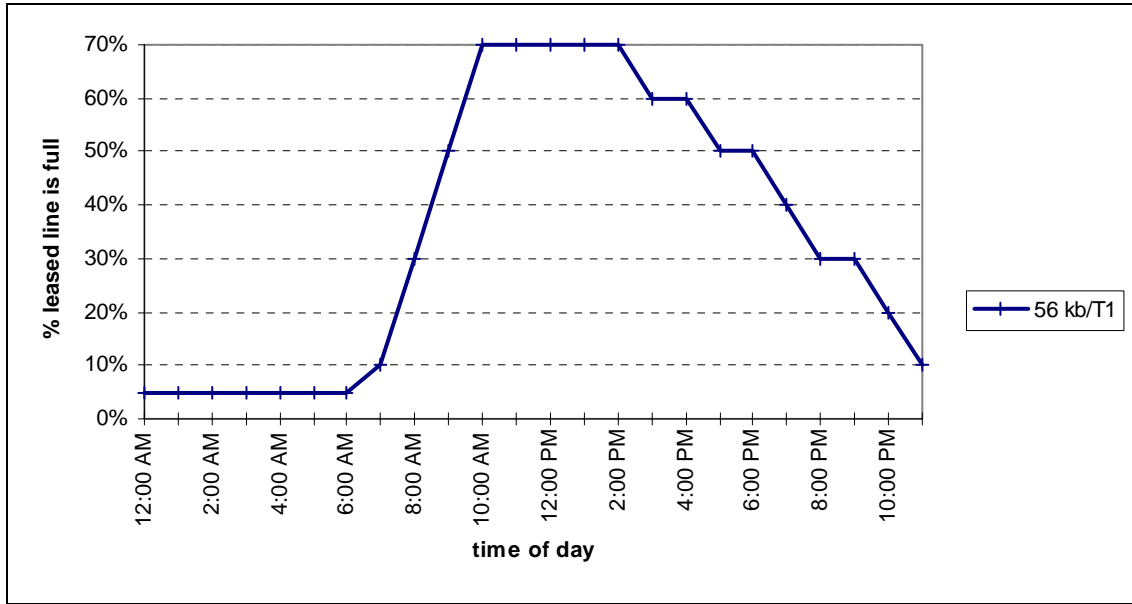


Figure 6. 56 kb and T1 Usage Patterns

The values for the leased-line usage patterns are based, in part, on discussions with ITC members.²⁵ In general, the leased-line peaks at 10 a.m. and tapers off starting in the afternoon. Based on these values, the percent that a leased line is full, on average, during a 24-hour period is 34%.

2.7.4. Internet Telephony Assumptions

The following two parameters are used only in the Internet telephony scenario:

- Internet telephony bw increase vs. web bw
- % using telephony (compared to web).

²⁵ See also [MO96b, chp. 4].

The first parameter represents the increase in the average bandwidth per user when using Internet telephony vis-à-vis surfing the web. The second parameter represents the percent of time a subscriber uses Internet telephony instead of the web. The following formula is used to calculate the average bandwidth for the scenario with Internet telephony.²⁶ The second formula is simply the first formula rearranged and is what is used in the model.

$$\begin{aligned} \text{avg bw with IT} &= (\text{avg bw}) * (1 - \% \text{ tel}) + (\text{avg bw}) * (\text{IT bw inc}) * (\% \text{ tel}) \\ &= (\text{avg bw}) * [1 + (\text{IT bw inc}) * (\% \text{ tel}) - (\% \text{ tel})] \end{aligned}$$

The *number of leased lines / business* parameter (from the *56 kb and T1 subscribers* section above) is based on the ratio of (avg bw with IT)/(avg bw). It is essentially the above formula less the avg bw factor. By using the above formula and the values in Table 9, bandwidth increased by 66%; hence, the *Number of leased lines / business* increased from 1 to 1.66.

Default Values in the Model

INPUT PARAMETER	BASELINE	IT
Internet telephony bw increase vs. web bw	N/A	300%
% using telephony (compared to web)	N/A	33%
<i>Analog dial-in user:</i>		
average downstream bandwidth per user (kbps)	5.0	8.3
<i>ISDN user:</i>		
effective average bw per user (kbps)	25.0	41.5
<i>Leased-line subscriber(56 kb and T1)</i>		
No. of lines per subscriber	1	1.66

Table 9. User Bandwidth Assumptions

Uncompressed telephony requires 64 kbps. Current compression techniques can reduce this by a factor of 5:1, yielding the required bandwidth of a half-duplex Internet telephone conversation to approximately 13 kbps. Including an overhead for packet headers at 10% makes this close to 15 kbps. Compared to the current assumed bandwidth of 5.0 kbps, the ratio of the increase in bandwidth is approximately 300%.

²⁶ In the *avg bw with IT* formula, the following abbreviations apply: *avg bw* in place of *average downstream bandwidth per user*; *% tel* in place of *% using telephony*; and *IT bw inc* in place of *Internet telephony bw increase vs. web bw*.

Assuming that subscribers use Internet telephony 33% of the time (and browse the web the remaining 67% of the time) while connected to the Internet, the required bandwidth per user increases 66% based on the formula described above.

3. Principal Cost Categories

The ISP's costs are separated into five principal categories: capital equipment, transport, customer service, operations, and other expenses (which include sales/marketing and general/administrative). This section goes into substantial detail describing how the costs for each category are determined.

3.1. Capital Equipment

In each subsection below, the method used for determining the appropriate sizing of each piece of capital equipment is described. However, in the "Cost of Capital" section, the conversions of a one-time, fixed cost into a monthly, recurring cost is described.

3.1.1. Cost of Capital

3.1.1.1. Periodic Replacement

One aspect of being an ISP is that there is substantial capital investment. The ISP needs to have the capital equipment in place before it can offer service. Consequently, the ISP sees large, fixed costs. However, once those costs are born and assuming there is sufficient capacity, the marginal costs of this capital are relatively small. In order to account for these fixed, capital costs, they are amortized over the economic life of each piece of capital. Periodic replacement of capital equipment is accounted for by assuming that assets are replaced at the end of their economic lives with equipment having the same real investment cost.

For each piece of capital equipment, there are the following parameters:

- cost per unit (router, modem, etc.);
- economic life (months).

The cost per unit corresponds to the retail price of the unit set by the manufacturer. In reality, one rarely pays the retail price, especially if one is a large entity buying in bulk. Consequently, there is a parameter, called the *discount factor*, that is used to adjust the equipment cost to a value more in line with what is actually being paid.

Default Values in the Model

The value for the discount factor, listed in Table 10; is held constant for both scenarios.

INPUT PARAMETER	BASELINE	IT
Discount Factor	30%	30%

Table 10. Discount Factor

The values for the cost of the individual pieces of capital and their economic life are listed with the description of each piece later in this section.

3.1.1.2. Annualization

Capital investments are converted to a leveled, annual cost by using a cost of capital rate. This rate incorporates the typical real cost of capital to an ISP with a representative mix of debt and equity. It includes interest payments and return on equity, and excludes corporate income taxes and inflation.

To determine the cost of capital rate, the following parameters are used:

- *Debt Percent* – % of company’s value associated with debt (vis-à-vis equity);
- *Cost of Debt* – return that investors expect on debt;
- *Cost of Equity* – return that investors expect on equity.

The following formula is used to compute the cost of capital:

$$\text{Cost of Capital} = \text{Debt Percent} * \text{Cost of Debt} + (1 - \text{Debt Percent}) * \text{Cost of Equity}$$

The values for *Debt Percent* and *Cost of Debt* are directly assumed. However, the value for the *Cost of Equity* is based on the following formula, which is known as the capital asset pricing model (CAPM):

$$\text{Cost of Equity} = r_f + \beta (r_m - r_f)$$

where:

- r_f - the return of a risk free investment
- r_m - the return of a (risky) investment in the market, hence:
- $r_m - r_f$ - the risk premium on the market
- β - relative risk of the company compared to the market.

The cost of equity then takes into account the risk associated with investing in this company, which in this case is an ISP. For more information, see [BR96].

Once the cost of capital is known, it is combined with the unit cost and economic life of a specific piece of capital to determine the leveled, annual cost of that piece of capital.²⁷

The result is the periodic (annual) payment for a piece of capital based on constant payments and a constant interest rate. Monthly costs, which are used in the model, are the based on dividing the annual cost by 12.

Default Values in the Model

Table 11 summarizes the values used to determine the Cost of Equity.

INPUT PARAMETER	BASELINE	IT
r_f ²⁸	6%	6%
$r_m - r_f$ ²⁹	8%	8%
β	2.4	2.4
RESULTING QUANTITY	BASELINE	IT
Cost of Equity	25.2%	25.2%

Table 11. Cost of Equity

Based on betas for public ISPs and other online companies, the average beta is 2.43.³⁰

Using the above formula, the resulting cost of equity is 25.2%. This cost is rather high because of the high risk traditionally associated with the ISP business. Table 12 summarizes the values used to determine the cost of capital.

²⁷ This is accomplished using the PMT function of Excel, which looks like the following:
 monthly cost = PMT(Cost of Capital/12, economic life, -unit cost*(1-discount factor))

²⁸ A risk free investment can be considered as a one-year Treasury bill, whose average return (r_f) during the week ending April 25, 1997 was 6.01% [WSJ, May 6, 1997].

²⁹ [BR96, p. 218] use an estimate of 8.4%.

³⁰ The companies (and associated beta) used to compute this beta are the following: PSInet (3.66), NETcom (2.98), BBN (2.09), MFS/UUnet (1.76) and AOL (1.64) [ME97a].

INPUT PARAMETER	BASELINE	IT
Debt Percent	30%	30%
Cost of Debt	9%	9%
Cost of Equity	25%	25%
RESULTING QUANTITY	BASELINE	IT
Cost of Capital	20.2%	20.2%

Table 12. Cost of Capital

Discussions with people familiar with the telecommunications/ISP industries indicate that assumptions for Debt Percent and Cost of Debt are reasonable for the business being represented in this model.³¹ Sensitivity analysis of the Cost of Capital is presented in Chapter 4.

The economic life of capital equipment can vary greatly depending on the type of equipment and the business in which it is being used. For example, fiber optic cable installed throughout a city might last 20-30 years. However, the laser equipment terminating the fiber might only last five years because of advances in laser technology such that more bandwidth can be obtained from the same fiber.

Similarly for an ISP, its computers and telecommunications equipment change rather rapidly. For the model, it is assumed that the economic life of each piece of capital equipment is 36 months. This is also the value used by BBN for similar assets.³²

Calculations converting a one-time cost into a monthly cost are carried out for each piece of capital, and the results are presented in the section describing the piece of capital.³³

3.1.2. Analog Modems

ISPs generally size the number of modems in their POPs so that there are approximately 8-12 subscribers per modem. A survey in [BO96] reports that the 3086 ISPs had an average of 8.96 subscribers per modem (no standard deviation was reported). This ratio

³¹ For comparison, the Hatfield Model, which calculates costs of local telephony, uses as default values for the cost of equity, 12%, the cost of debt, 7.7% and the debt ratio, 45%. The resulting cost of capital is 10%. These values are indicative of a telephone company, whose business is traditionally less risky than an ISP.

³² BBN reported in its 10K Report (Sept. 9, 1996) that the economic life of computer and data communications equipment is 3 years, of furniture and fixtures is 5 years, and of buildings is 15 - 25 years.

³³ For example, a router with a purchase and installation cost of \$50,000, and 36-month amortization at a cost of capital rate of 11 percent yields a rental cost of approximately \$1,640 per month.

varies depending on how concerned each ISP is with its dial-in subscribers experiencing busy signals when calling.³⁴

Implied in this rule of thumb is a user profile of the average holding time and the average call arrival rate during peak the period (because the number of modems is sized based on the peak demand). If either of these numbers changed (while holding the number of subscribers constant), the required number of modems would need to change to avoid blocking, and hence, the ratio of subscribers per modem would change. Consequently, simply using a subscriber per modem ratio to determine the number of modems is not necessarily accurate if certain assumptions about dial-in behavior change. Instead of the ratio, the Erlang B (also called the Erlang Loss) formula can be used to determine the appropriate number of modems needed to satisfy a blocking probability.

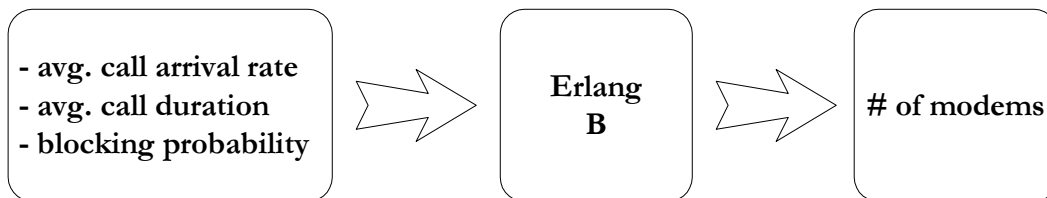


Figure 7. Modem Sizing Process

Let c be the number of modems, ρ be the offered load, $subs$ be the number of subscribers, $percent$ be the percent of subscribers that call during the peak hour and $hold$ be the average holding time per call. Call arrivals are assumed to be Poisson, and holding times are assumed to follow a general distribution (i.e., call lengths are stationary, independent and identically distributed).³⁵ The load is found by the following formula:

$$\rho = subs \times percent \times hold$$

³⁴ For comparison, as of January 1997, AOL had more than 8 million subscribers and simultaneous access for about 260,000 subscribers (*Wall Street Journal*, Jan.17, 1997) that yields a ratio of almost 31 subscribers per modem. This ratio was perhaps sufficient when per-hour usage charges were being assessed on AOL subscribers. However, when AOL went to flat rate pricing, this modem ratio was no longer acceptable because user behavior changed and many call requests were blocked (i.e., busy signals).

³⁵ An example of such a distribution is the negative exponential distribution. However, the Erlang B is valid with any general distribution. Hence, the modem pool can be considered as an M/G/c/c system.

ErlangB(c,ρ) represents the steady state probability of all *c* modems being busy (a.k.a. the blocking probability).³⁶

$$ErlangB(c, \rho) = \frac{\frac{\rho^c}{c!}}{\sum_{k=0}^c \frac{\rho^k}{k!}}$$

For the model, two Excel macros were created: ErB and ErBSlv. ErB(c, ρ) returns the blocking probability while having *c* modems and ρ load. ErBSlv(blockprob, ρ) returns the necessary number of modems given a blocking probability of blockprob and a load of ρ. Essentially, the ErBSlv macro tries different values for the number of modems in the ErB macro until it finds enough modems to satisfy the blocking probability. The macros and corresponding code are described in more detail in Appendix 2.

Default Values in the Model

Table 13 summarizes the values used to determine the cost and sizing of the modems.

INPUT PARAMETER	BASELINE	IT
48 port modem bank ³⁷	\$42,000	\$42,000
blocking probability for sizing equipment ³⁸	1.0%	1.0%

Table 13. Modem Assumptions

To determine the number of required modems, the ErBSlv macro needs inputs for the blocking probability and the load. As seen in the above chart, the blocking probability is a parameter. The load needs to be calculated. Depending on user behavior, load will vary throughout the day. Normally, an ISP would size its modems according to the period of the day when the load is greatest (i.e., modem busy-hour). Because there are both residential and business dial-in users with different demand patterns (which can be varied as input parameters), the modem busy-hour load for each POP needs to be calculated.

³⁶ Hence, for 5000 subscribers, where 10% of them call during peak hour and the average holding time is 1 hour: $ErlangB(489,500) = 0.05$, which means that at least 489 modems are required so that there is no more than a 5% chance that all modems are full (blocking). The corresponding modems/subscriber ratio for this example is 10.225.

³⁷ The list price of a US Robotics Total Control Hub of 48 modems [configured with (1) Dual T1 Card, (12) Quad Digital Modem Cards, (1) Edge Server (NT), (1) Total Control Hub (SNMP Managed), and (1)AC

The call arrival rate for each hour is determined:

$$\text{call arr. rate} = (\# \text{ res. subs.}) * (\% \text{ res. access during hour}) + (\# \text{ bus. subs.}) * (\% \text{ bus. access during hour})$$

The maximum call arrival rate over a 24 hour period is what is used in the ErBSlv formula. Along with the call rate, the average holding time is used to determine the maximum load. It is assumed that the average holding time is the same for residential and business dial-in users.

The results in Table 14 are based on the number of residential and business dial-in subscribers and their call patterns.

RESULTING QUANTITY	BASELINE	IT
leveled cost/modem/month	\$23	\$23
Tier 1 POP modems		
peak combined calls per hour	385	462
Total number of modems per POP	213	298
<i>resulting sub/modem ratio</i>	<i>9.1</i>	<i>6.5</i>
Tier 2 POP modems		
peak combined calls per hour	1,539	1,847
Total number of modems per POP	794	1,131
<i>resulting sub/modem ratio</i>	<i>9.7</i>	<i>6.8</i>

Table 14. Modem Quantities

Cost Allocation

Costs are allocated based on total daily usage (not peak usage) between residential and business analog dial-in subscribers. Of the total number of minutes per day the analog modems are occupied, residential dial-in subscribers account for 99.6% and business dial-in subscribers account for 0.4%. This disparity is due to the large number of residential subscribers relative to the business subscribers.

Power Supply] is \$51,000, which is \$1062 per modem. The list price of an Ascend MAX 4004, which supports 72 analog modems (configured with chassis and [6] 12 port modem modules), is \$50,000, which is \$690 per modem. An average of these prices is \$875 per modem, or \$42,000 for 48 modems.

³⁸ Setting this value is subjective, based on how thoroughly the ISP wants to prevent blocking. The higher the number, the lower the total modem costs, but the higher the number of unhappy dial-in subscribers. Sensitivity analysis is conducted on this parameter in chapter 4.

3.1.3. ISDN Access Routers

ISDN access equipment is sized in a similar manner as analog dial-in modems. The number of concurrent ISDN users at a given POP is determined with the Erlang B based on usage patterns. The number of required B channels is two times the number of concurrent users because each (128 kbps) ISDN user requires two B channels.

The number of access routers needed is sized based on the number of B channels supported by each router.

Default Values in the Model

Table 15 summarizes the values used to determine the cost and sizing of the ISDN access routers.

INPUT PARAMETER	BASELINE	IT
Ascend MAX 4004 access router w/ ISDN software ³⁹	\$18,000	\$18,000
No. of B channels per access router ⁴⁰	92	92
RESULTING QUANTITY	BASELINE	IT
leveled cost/ISDN access router/month	\$470	\$470
leveled cost/B channel/month	\$5	\$5
Total No. of B channels	3,726	6,480

Table 15. ISDN Access Router Quantities

Cost Allocation

ISDN access routers are allocated entirely to ISDN subscribers.

3.1.4. POP servers

In each POP there are servers required to support applications such as email, news, web pages, and domain name resolution (DNS). These servers are sized based on a combination of necessary processing power, in order to handle multiple concurrent requests, and storage space, in order to store email, news, and web pages. To approximate this sizing reasonably, it is assumed that a certain number of each type of subscriber can be supported per server.

The number of servers for each type of subscriber is:

³⁹ List price that includes the chassis and ISDN software.

⁴⁰ The Ascend MAX 4004 supports 4 PRI, with each PRI supporting 23 B channels.

= No. of subscribers/No. of subscribers per server

The number servers for each type of subscriber being served at a particular POP is totaled to determine how many servers are needed for that POP.

Default Values in the Model

By allocating 10 MB per (analog and ISDN) dial-in subscriber for email and web pages, each POP server (with 20 GB of storage) can support 2000 dial-in subscribers. It is assumed that leased-line subscribers will have their own (email and web) servers. They would still need some support from the ISP for such services as news feeds and DNS, but this is considered to be negligible vis-à-vis the server requirements for dial-in subscribers. Hence, the value for the leased-line subscribers is set to 1,000 so that the server requirements are negligible.

INPUT PARAMETER	BASELINE	IT
POP server cost ⁴¹	\$25,000	\$25,000
<i>No. of subscribers supported per POP server</i>		
analog dial-in	2,000	2,000
ISDN dial-in	2,000	2,000
56 kb	1,000	1,000
T1	1,000	1,000
RESULTING QUANTITY	BASELINE	IT
leveled cost/POP server/month	\$652	\$652
Total No. of POP servers	60	87

Table 16. POP Server Quantities

Cost Allocation

POP servers are allocated based on the number of servers needed for each type of subscriber.

3.1.5. LAN - 10 Mbps ethernet

This type of LAN is used in the Tier 1 POPs. It connects the modem banks, POP servers and router(s). It is assumed that 10 Mbps switched ethernet is sufficient for the amount of traffic the modems and POP servers generate and that the actual wiring of the LAN is negligible in cost. The LAN scales based on the number of ethernet ports required.

⁴¹ List price for a Sun Ultra Enterprise 150 server with 128 MB RAM and 20 GB storage (approx. \$20,000) and a Netscape SuiteSpot server (\$5,000).

Allocation is 1 port per POP server, 1 port per modem bank (of 48 modems) and 1 port per router.

Default Values in the Model

Table 17 summarizes the values used to determine the cost and sizing of the 10 Mbps ethernet LAN.

INPUT PARAMETER	BASELINE	IT
10 Mbps ethernet switch per port ⁴²	\$100	\$100
RESULTING QUANTITY	BASELINE	IT
leveled cost/10 Mbps ethernet port/month	\$3	\$3
No. of 10 Mbps ethernet ports per Tier 1 POP	7	9
Total no. of 10 Mbps ethernet ports for all Tier 1 POPs	3,150	4,050

Table 17. 10 Mbps Ethernet LAN Quantities

Cost Allocation

10 Mbps ethernet LAN is allocated in the same proportion as is the T1 transport connecting the Tier 1 Pops to the Tier 2 Pops. Distribution for the baseline scenario is 97.4% to residential dial-in, 0.4% to business dial-in, and 2.2% to ISDN. The disparity is due to the large number of residential dial-in subscribers relative to the other subscribers at a Tier 1 POP.

3.1.6. LAN - 100 Mbps ethernet

This type of LAN is used in the Tier 2 POPs. It connects the modem banks, routers, and POP and content hosting servers. The 100 Mbps switched ethernet LAN is sized similarly to the 10 Mbps ethernet LAN. There is 1 port allocated per network node that attaches to the LAN. The cost of the LAN is based on a per port cost of 100 Mbps switched ethernet.

Default Values in the Model

Table 18 summarizes the values used to determine the cost and sizing of the 100 Mbps ethernet LAN.

⁴² For example, 3Com SuperStack II Switch 1000 (24 ports): \$2400, BayNetworks BayStack 301 Switch (24 ports): \$2500.

INPUT PARAMETER	BASELINE	IT
100 Mbps ethernet switch per port ⁴³	\$500	\$500
RESULTING QUANTITY	BASELINE	IT
leveled cost/100 Mbps ethernet port/month	\$13	\$13
No. of 100 Mbps ethernet ports per Tier 2 POP	19	27
Total no. of 100 Mbps ethernet ports for all Tier 2 POPs	170	241

Table 18. 100 Mbps Ethernet LAN Quantities

Cost Allocation

The allocation of the 100 Mbps ethernet LAN cost is based on the number of ethernet ports required for the different types of equipment.⁴⁴ This allocation yields the following distribution:

residential dial-in	business dial-in	ISDN	56 kb	T1
93%	0.4%	1%	0.2%	0.6%

Table 19. 100 Mbps Ethernet LAN Cost Allocation

3.1.7. 56 kb CSU/DSUs

A 56 kb CSU/DSU is used to connect a leased-line business subscriber. It is assumed that all leased-line subscribers are connected to Tier 2 POPs and none to Tier 1 POPs. There is one CSU/DSU allocated for each subscriber's leased line.

Default Values in the Model

Table 20 summarizes the values used to determine the cost and sizing of the 56 kb CSU/DSUs.

INPUT PARAMETER	BASELINE	IT
56 kb CSU/DSU ⁴⁵	\$500	\$500
RESULTING QUANTITY	BASELINE	IT
leveled cost/56 kb CSU/DSU/month	\$13	\$13
No. of 56 kb CSU/DSUs per Tier 2 POP	160	265
Total no. of 56 kb CSU/DSUs for all Tier 2 POPs	1438	2387

Table 20. 56 kb CSU/DSU Quantities

Cost Allocation

The cost of the 56 kb CSU/DSUs is allocated entirely to the 56 kb subscribers.

⁴³ For example, 3Com SuperStack II Switch 3000 TX (8 ports): \$3,800

⁴⁴ In both scenarios, most ports are needed for analog modems, where the analog modems are principally allocated to residential dial-in subscribers.

⁴⁵ For example, Motorola DDS MR56 Standalone: \$490.

3.1.8. T1 CSU/DSUs

A T1 CSU/DSU is used to connect a leased-line business subscriber as well as to connect the Tier 1 POPs to the Tier 2 POPs. As with the 56 kb subscribers, it is assumed that all T1 subscribers are connected to Tier 2 POPs and none to Tier 1 POPs. Additionally, there is one CSU/DSU allocated for each subscriber’s leased line.

Default Values in the Model

Table 21 summarizes the values used to determine the cost and sizing of the T1 kb CSU/DSUs.

INPUT PARAMETER	BASELINE	IT
T1 CSU/DSU ⁴⁶	\$1,400	\$1,400
RESULTING QUANTITY	BASELINE	IT
leveled cost/T1 CSU/DSU/month	\$37	\$37
No. of T1 CSU/DSUs per Tier 1 POP	1.1	2.5
No. of T1 CSU/DSUs per Tier 2 POP	692	1,186
Total no. of T1 CSU/DSUs for all Tier 1 POPs	476	1,130
Total no. of T1 CSU/DSUs for all Tier 2 POPs	6,228	10,677
Total no. of T1 CSU/DSUs for all POPs	6,704	11,807

Table 21. T1 CSU/DSU Quantities

Cost Allocation

Because the T1 CSU/DSUs connect T1 subscribers and Tier 1 POPs, the costs are distributed among the subscribers of the Tier 1 POPs (residential dial-in, business dial-in and ISDN) and the T1 subscribers. The allocation for the baseline scenario is the following:

residential dial-in	business Dial-in	ISDN	56 kb	T1
14%	0.1%	0.3%	0%	86%

Table 22. T1 CSU/DSU Cost Allocation

3.1.9. Cisco 2500 Routers

This type of router is used in the Tier 1 POPs. Because the model of router used has two serial ports, there is one router allocated for every two T1 connections out of the Tier 1 POP.

⁴⁶ For example, Digital Link 080: \$1400.

For the purposes of this model, it is assumed that the POPs will not grow sufficiently such that there will be a large number of routers per Tier 1 POP.⁴⁷

Default Values in the Model

Table 23 summarizes the values used to determine the cost and sizing of the Cisco 2500 routers.

INPUT PARAMETER	BASELINE	IT
Cisco 2500 ⁴⁸	\$2,800	\$2,800
RESULTING QUANTITY	BASELINE	IT
leveled cost/router/month	\$73	\$73
No. of Cisco 2500 routers per Tier 1 POP	1	2
total No. of Cisco 2500 routers	450	900

Table 23. Cisco 2500 Router Quantities

Cost Allocation

The Cisco 2500 routers are allocated in the same proportion as T1 transport, which is based on the total daily bandwidth originating at the Tier 1 POPs by each type of subscriber.

3.1.10. Cisco 7513 Routers

This type of router is used in the Tier 2 POPs. The methods by which to size routers are not as straight forward as those used to size modems, for example. Router sizing is affected by such parameters as number and type of network connections, routing requirements of packets per second, and routing table size. In addition, certain techniques used on routers (e.g., route caching and on-card-processing) further complicate the task of appropriately sizing the routers.

Because of these complexities, it is assumed that the routers are sized sufficiently based solely on the number and type of network connections needed. This implies that that the packet routing rate is not a limitation. Because the majority of ports on the router are

⁴⁷ In reality, instead of using multiple 2500 routers in a single POP, an ISP would use a different model of router to accommodate a large number of serial connections. This would presumably be cheaper than multiple 2500 routers. Hence, the cost associated with these routers would be an upper bound on the Tier 1 router costs, and cost results show that even at this upper bound, Tier 1 router costs are very small relative to other capital equipment costs.

⁴⁸ Specifically, Cisco 2514A (2 ethernet, 2 WAN) with ISP software: \$2700.

serial ports connecting 56 kb and T1 leased lines, not OC-3 ports, this assumption is not entirely unreasonable.

The sizing for each of the components of the 7513 is discussed in the following subsections.

3.1.10.1. Cisco 7513 serial port card (8 ports per card)

Each leased line (56 kb and T1) that comes from the Tier 1 POPs and the businesses has a CSU/DSU terminating it in the Tier 2 POP. Each of these CSU/DSUs connects via serial port to the router. Hence, the number of required serial ports is equal to the number of CSU/DSUs in the Tier 2 POP. The number of serial port cards is based on the following equation:

$$\# \text{ serial port cards} = \text{roundup}(\# \text{ serial ports} / \# \text{ serial ports per card})^{49}$$

3.1.10.2. Chassis

The chassis of a Cisco 7513 router consists of processor cards, memory, power supplies and the housing, which has slots for thirteen adapter cards. For the model, the chassis is considered to be the ensemble of the chassis itself plus a fast ethernet card and an ATM card.⁵⁰

The following formula is used to determine the number of chassis:

$$\# \text{ chassis} = \text{roundup}(\# \text{ serial port cards} / \# \text{ available slots per chassis})^{51}$$

Default Values in the Model

Table 24 summarizes the values used to determine the cost and sizing of the Cisco 7513 router and its sundry network cards.

⁴⁹ *roundup* is ignored if the *round up lumpy quantities?* parameter is set to N or n.

⁵⁰ Two of the thirteen slots are used by the processors, one by the fast ethernet card (to connect the LAN of the Tier 2 POP); and one by the DS-3 ATM card (to connect the router to the ATM switch); this leaves nine slots for the serial port cards

⁵¹ *roundup* is ignored if the *round up lumpy quantities?* parameter is set to N or n.

INPUT PARAMETER	BASELINE	IT
Cisco 7513 router chassis w/ fast ethernet card and ATM card ⁵²	\$78,000	\$78,000
No. of available slots per chassis	9	9
8 port serial card for 7513, CX-FSIP8	\$16,000	\$16,000
No. of serial ports per card	8	8
RESULTING QUANTITY	BASELINE	IT
leveled cost/Cisco 7513 router chassis/month	\$2,035	\$2,035
leveled cost/Cisco 7513 serial port card/month	\$417	\$417
No. of 7513 serial port cards per Tier 2 POP	107	181
No. of 7513 chassis per Tier 2 POP	12	20
Total no. of 7513 serial port cards for all Tier 2 POPs	958	1,633
Total no. of 7513 chassis for all Tier 2 POPs	106	181

Table 24. Cisco 7513 Router Quantities

Cost Allocation

Because the primary driver of router chassis is the number of serial port cards, the router chassis costs are allocated in the same way as the serial port cards.

The serial port cards are driven by the number of 56 kb and T1 connections, and, hence, the allocation of serial port cards is based on allocation of the 56 kb and T1 CU/DSUs.

The resulting distribution is the shown in Table 25.

residential dial-in	business dial-in	ISDN	56 kb	T1
11%	0.1%	0.2%	19%	70%

Table 25. Cisco 7513 Router Cost Allocation

3.1.11. Fore ASX-200BX ATM Switches

Each Tier 2 POP has an ATM switch through which all Tier 2 POPs are interconnected. Similar to the Cisco 7513 router sizing, the ATM switch is sized solely based on the number of T3/OC-3 connections required. This implies that the ATM switch's cell forwarding capability is not a bottleneck.

Similar to the Cisco 7513 router, the ATM switch has a chassis that can hold a certain number of cards.⁵³ The number of cards required depends on the number of backbone links that need to be terminated, and the number of chassis required depends on the number of cards.

⁵² Configuration includes chassis, redundant power supply, RSP, RSP 2, 32 MB RAM, fast ethernet adapter card (CX-FEIP2TX), ATM adapter card (CX-AIP-DS3), and IP and ATM software.

⁵³ The ATM switch used in the model can hold four cards.

3.1.11.1. ATM switch DS3/OC-3 cards

Because the ISP can use either T3 or OC-3 links, the type of card used in the ATM switches will depend on which type of link can carry the given bandwidth more cheaply.

Each type of these cards has 4 DS3/OC-3 ports on it. The number of cards for each Tier 2 POP is based on the following equation:

$$\text{No. ATM switch cards} = \text{roundup}(\text{no. backbone links into Tier 2 POP} / \text{no. ports per card})^{54}$$

3.1.11.2. ATM switch chassis

Each chassis can hold four cards. The number of chassis for each Tier 2 POP is based on the following equation:

$$\text{No. ATM switch chassis} = \text{roundup}(\text{no. ATM switch cards} / \text{no. slots per chassis})^{55}$$

Default Values in the Model

Table 25 summarizes the values used to determine the cost and sizing of the Fore ATM switches and its DS3/OC-3 cards.

INPUT PARAMETER	BASELINE	IT
Fore 4 port DS3 card ⁵⁶	\$14,000	\$14,000
Fore 4 port OC-3 card ⁵⁷	\$14,000	\$14,000
Fore ATM switch chassis ⁵⁸	\$16,000	\$16,000
No. of slots per switch	4	4
RESULTING QUANTITY	BASELINE	IT
leveled cost/ DS3 card/month	\$365	\$365
leveled cost/ OC-3 card/month	\$365	\$365
leveled cost/ Fore ATM switch chassis /month	\$417	\$417
Total no. of DS3 cards	0	0
Total no. of OC-3 cards	34	98
Total no. of 7513 ATM switch chassis per Tier 2 POP	9	25

Table 26. Fore ASX-200BX ATM Switch Quantities

Cost Allocation

⁵⁴ *roundup* is ignored if the *round up lumpy quantities?* parameter is set to N or n.

⁵⁵ *roundup* is ignored if the *round up lumpy quantities?* parameter is set to N or n.

⁵⁶ Model NM-4/DS3C.

⁵⁷ Model NM-4/155.

⁵⁸ Model ASX-200BX.

All ATM switch equipment is allocated in the same proportion as the T3/OC-3 backbone links, because it is the quantity of these links that drives the quantity of the ATM cards and switches.

3.2. Transport

The transport costs of the ISP are comprised of costs that are due to leased lines to connect the Tier 1 and Tier 2 POPs (T1s, T3s and OC-3s) and costs that are due to incoming analog and ISDN phone lines (T1 and PRI) to connect the dial-in subscribers. In addition, monthly costs for the ISP to interconnect at a network access point (NAP) are included in transport costs.

When designing a network, many issues (such as reliability, spare capacity, and redundancy) arise. Because the ISP is leasing lines from a telecommunications provider – as opposed to owning them itself – it is assumed that reliability and redundancy in the underlying physical network are the responsibility of the telecommunications provider, not of the ISP. It is also assumed that the telecommunications provider has accounted for these additional costs of redundancy in its pricing of the circuits to the ISP. Hence, the ISP sizes its network based solely on the demand between two nodes and does not provision for spare capacity and redundancy.

The network's cost is based on the following parameters:

- Dial-in T1 cost (fixed \$ per month and \$ per mile per month)
- ISDN PRI cost (fixed \$ per month and \$ per mile per month)
- T1 (fixed \$ per month and \$ per mile per month)
- T3 (fixed \$ per month and \$ per mile per month)
- OC-3 (fixed \$ per month and \$ per mile per month)
- Bulk transport discount (monthly cost)
 - \$0 - \$25,000
 - \$25,001 - \$100,000
 - \$100,001 - \$200,000
 - \$200,001 - \$350,000
 - \$350,001 - \$500,000
 - \$500,001 +
- NAP monthly interconnection charges

In general, leased lines have three types of costs: (1) nonrecurring/installation costs, (2) fixed/recurring costs, and (3) per mile costs. Fixed costs and the per mile costs are included in the model, but nonrecurring costs for the leased lines are not included. This is based on the assumption that the lines will be leased over a long period (assumed to be 60 months) and the nonrecurring charges averaged over this period will be negligible vis-à-vis the recurring costs of the leased lines.

Many telecommunications providers offer substantial discounts for a customer, such as an ISP, who leases circuits in bulk. If the customer commits to a certain number of dollars per month, it will receive a discount according to the range in which its commitment falls.

Default Values in the Model

These ranges of bulk discount are estimates based on published tariffs of MCI and Sprint.⁵⁹

INPUT PARAMETER	BASELINE	IT
<i>Bulk transport discount (monthly cost in dollars)</i>	%	%
0 - 25,000	10	10
25,001 - 100,000	20	20
100,001 - 200,000	25	25
200,001 - 350,000	35	35
350,001 - 500,000	45	45
500,001 +	50	50

Table 27. Bulk Transport Discount Assumptions

3.2.1. Data T1 Circuits

Data T1 circuits are used to connect the Tier 1 POPs to the Tier 2 POPs. Because there are only dial-in subscribers at the Tier 1 POPs, the number of data T1s is based on the traffic generated by dial-in subscribers (analog and ISDN) at the Tier 1 POPs. As discussed in the modem sizing section, the number of modems is based on the peak offered traffic by the dial-in users. Similarly, data T1 circuits are based on the peak offered traffic.

⁵⁹ The discounts are specific to each company and product. For example, MCI's discounts for a 60-month lease of a T1 range from 21% to 56%; Sprint's discounts for a 60-month lease of a T1 range from 29% to 53%; and MCI's discounts for a 60 month lease of a T3 range from 8% to 47%. Because only one set of discounts is included in the model, estimates must be made from these ranges.

Because of assumed symmetry, determining the number of T1s needed for one Tier 1/Tier 2 connection is sufficient for all corresponding Tier 1/Tier 2 connections.

The following parameters, along with user profile parameters, which were previously described, are used to size T1 transport:

- % capacity at which to operate transport
- T1 circuit capacity
- % O-D pairs found on ISP's network
- % Tier 1 traffic destined for Tier 2
- % Tier 1 traffic destined for backbone.

In order to account for the bursty nature of Internet traffic, the parameter % capacity at which to operate transport is used for sizing the number of transport circuits. Through experience, an ISP learns that once a link becomes more than a certain percent full packets start to be dropped and latency increases. The ISP thus determines a threshold that when traffic exceeds this threshold, on average, a new link needs to be added. This is the method used in the model to account for the bursty nature of Internet traffic.

It is assumed that all traffic on this network has a single origin and destination (i.e., effects of multicast and broadcast are negligible). The origins are assumed to be the end users on the ISP's network; the destinations are other end users on the ISP's network or on some other ISP's network. The % O-D pairs found on ISP's network parameter represents what percent of destinations of requests are found on this ISP's network.

For traffic (requests) originating at a Tier 1 POP, the destinations can be at (1) the same Tier 1 POP, (2) the upstream Tier 2 POP (and any other Tier 1 POPs connected to this Tier 2 POP, and (3) some other Tier 2 POP on the backbone. The parameters % Tier 1 traffic destined for Tier 2 and % Tier 1 traffic destined for backbone are used to represent the respective destinations.

When sizing the T1 circuits that connect a Tier 1 POP to its upstream Tier 2 POP, one needs to consider cases 2 and 3 in the above paragraph because any traffic terminating at the Tier 1 POP will not be carried on the T1.

The following formula is used to determine the total amount of traffic that originates at a Tier 1 POP:

$$\text{Tier 1 orig. traffic} = \# \text{ analog modems} * \text{avg bw per analog user} + \text{peak \# ISDN users} * \text{avg bw per ISDN user}$$

The following formulas are used to determine the magnitude of the various types of traffic originating at the Tier 1 POP:

$$\text{Tier 1 traffic terminating at Tier 2} = \text{Tier 1 orig. traffic} * \% \text{ O-D} * \% \text{ Tier 1 traffic destined for Tier 2}$$

$$\text{Tier 1 traffic terminating at backbone} = \text{Tier 1 orig. traffic} * \% \text{ O-D} * \% \text{ Tier 1 traffic destined for backbone}$$

$$\text{Tier 1 traffic terminating at NAP} = \text{Tier 1 orig. traffic} * (1 - \% \text{ O-D})$$

The effective traffic that is carried on the T1 is the sum of the above three equations:

$$\text{eff. Tier 1 orig. traffic} = \text{Tier 1 tr. @ Tier 2} + \text{Tier 1 tr. @ backbone} + \text{Tier 1 tr. @ NAP}$$

The number of data T1s between each Tier 1 and Tier 2 POP is then:

$$\# \text{ data T1s} = \text{roundup} \left(\frac{\text{eff. Tier 1 orig. traffic}}{\text{T1 capacity} * \% \text{ operating capacity}} \right)^{60}$$

Based on tariffs filed by telecommunications providers, each T1 has a fixed cost per month (non-distance sensitive) and a distance-based cost per month. The total monthly data T1 cost is determined by the following formula:

$$\text{T1 cost} = (1 - \text{discount}) * (\text{avg. Tier 1 Tier 2 dist.} * \$ \text{ per mile} + \text{fixed } \$ \text{ per mo.}) * \# \text{ T1s per POP} * \# \text{ Tier 1 POPs}$$

Default Values in the Model

Because the Tier 1 POP connects to one of nine Tier 2 POPs, the % Tier 1 traffic destined for Tier 2 parameter is set to 11% (1/9) and the % Tier 1 traffic destined for backbone is set to 89% (8/9). This implies that no traffic remains at the Tier 1 POP (such as a dial-in user browsing a web server located at the same Tier 1 POP). Hence, this is a conservative estimate of the traffic distribution.

⁶⁰ *roundup* is ignored if the *round up lumpy quantities?* parameter is set to N or n.

The values for the fixed and per-mile costs are based on tariffs of Sprint and MCI.⁶¹

INPUT PARAMETER	BASELINE	IT
% capacity at which to operate transport ⁶²	70%	70%
% O-D pairs found on ISP's network ⁶³	10%	10%
% Tier 1 traffic destined for Tier 2	11%	11%
% Tier 1 traffic destined for backbone	89%	89%
T1 capacity (Mbps)	1.536	1.536
<i>T1 (data) cost:</i>		
\$ per month (fixed)	\$3,225	\$3,225
\$ per mile per month	\$3.85	\$3.85
average distance Tier 1 POP to Tier 2 POP (miles)	75	75
RESULTING QUANTITY	BASELINE	IT
No. of data T1s per Tier 1 POP	1.1	2.5
Total data T1 miles	35,712	84,724
Subtotal data T1 cost	\$1.67 M	\$3.97 M
Bulk discount	50%	50%
Total monthly data T1 cost	\$0.84 M	\$1.98 M

Table 28. Data T1 Cost Results

Cost Allocation

Data T1s connect the Tier 1 POPs to the Tier 2 POPs. The only subscribers at the Tier 1 POPs are the dial-in subscribers. Hence, the data T1 costs are split among the residential and business dial-in subscribers (analog and ISDN) according to the relative amount of total traffic they generate.

3.2.2. Backbone T3/OC-3 Circuits

The ISP's backbone consists of a mesh network with NAP connections, which is shown in Figure 8. The network is comprised of T3 and/or OC-3 circuits, depending on which is cheaper.

⁶¹ In the tariffs for a month-by-month, leased T1, MCI charges \$3,234 /mo. and \$3.87 /mile/mo. Sprint charges \$3,214/mo. and \$3.84/mile/mo. Both providers offer substantial discounts for long term commitments up to 60 months and for bulk purchases. These discounts are accounted for in the *Bulk transport discount* parameters described at the beginning of the transport section.

⁶² This value is based on discussions with ITC members.

⁶³ Because the ISP is assumed to have 10% of the U.S. market, only 10% of the O-D pairs are found on this network. All other traffic is routed to the closest NAP where the ISP is presumably interconnected with other ISPs whose end-users represent the remainder of the destinations. A factor that could increase this value is that popular web servers are located on several *different* ISP's networks. Hence, some of the requests would not have to travel through the NAP. On the other hand, because the Internet extends beyond the United States, an ISP with a 10% market share in the United State will have even less than 10% of the O-D pairs when taking an international perspective; hence, assuming these factors essentially cancel each other, a value of 10% is used.

The following parameters, along with user profile parameters, which were previously described, are used to size the backbone (T3 and OC-3) transport:

- % capacity at which to operate transport
- circuit capacity (T3 and OC-3)
- % O-D pairs found on ISP's network
- % Tier 2 traffic destined for backbone
- % backbone traffic going 1 node distance
- % backbone traffic going 2 node distance
- % backbone traffic going 3 node distance
- % backbone traffic going 4 node distance.

The % capacity at which to operate transport and % O-D pairs found on ISP's network parameters are used in the same way as for sizing the T1 circuits. The % Tier 2 traffic destined for backbone parameter represents what percent of originating Tier 2 traffic is destined for the backbone as opposed to some destination at that Tier 2 POP.

Because the backbone is a mesh network, not a star, routing assumptions (between Tier 2 POPs) need to be defined. Generally, one of the strengths of IP is its ability to be routed dynamically over diverse paths. If a node or a link were to fail along a route, assuming there exists multiple paths, a packet would automatically be rerouted over the next "shortest" path. The model, however, assumes a fixed route between any two Tier 2 POPs and NAPs.⁶⁴

The last four parameters listed above are used to determine how far backbone traffic travels. These parameters are needed because of the mesh topology of the backbone.

Using the defined static routes along with the peak amount of Tier 1 and Tier 2 traffic destined for the backbone and the NAPs, the model calculates how much traffic flows on each link between any two nodes (Tier 2 POPs or NAPs).

⁶⁴ This is done for two reasons: (1) If a network is sufficiently provisioned based on the proposed routes, the "shortest" path between any two nodes will be, on average, the route that one used when provisioning the network, and (2) some ISPs are currently using static routes instead of dynamic routes. Routers have packet forwarding rates that are being exceeded at certain congested points in an ISP's network. Ideally, a router will forward each packet independently, based on the shortest path at that time. The computation needed to make this routing decision increases the packet's sojourn time through the router. This leads to increased

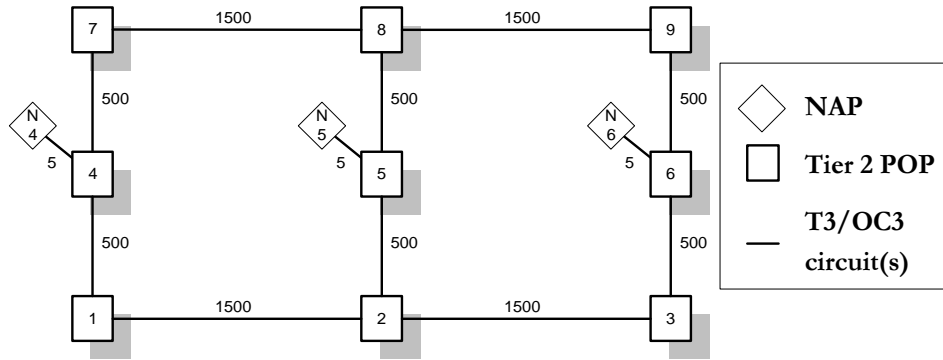


Figure 8. Backbone Network (with distances in miles)

Based on this amount of traffic, the model determines the required number of T3 and OC-3 circuits for each link between two connected nodes. The formula for calculating the number of T3s/OC-3s for each link between nodes “i” and “j” is:

$$\# \text{ T3/OC-3s per } i - j \text{ link} = \text{roundup} \left(\frac{\text{total peak traffic between nodes } i - j}{\text{T3/OC-3 capacity} * \% \text{ operating capacity}} \right)^{65}$$

The number of required circuits is calculated for both technologies, and the cheaper type of circuit is used.⁶⁶

The costs for all (of the cheaper) circuits are summed, and this subtotal is adjusted by the bulk discount factor, which is dependent on the magnitude of the subtotal. This adjusted value is the total monthly cost for the backbone circuits.

Default Values in the Model

The values for the fixed and per-mile costs of T3s are based on tariffs of Sprint and MCI.⁶⁷ OC-3 costs are assumed to be 2.5 times the T3 costs.⁶⁸

congestion in the network. In order to alleviate congestion and, in turn, packet delay, an ISP can define a static route between any two points that a packet must follow.

⁶⁵ *roundup* is ignored if the *round up lumpy quantities?* parameter is set to N or n.

⁶⁶ Theoretically, one should consider both the transport and switching costs. A (pathological) example where this would make a difference is if switching costs were an order of magnitude greater than transport costs. By determining the type of technology based solely on the transport costs, total costs would not necessarily be at a minimum. Based on the cost values used in the model, the inverse is in fact true: transport costs are much greater than switching costs; hence, only transport costs are considered when choosing a technology for the backbone transport.

⁶⁷ In the tariffs for a month-by-month, leased T3, MCI charges \$22,236 /mo. and \$52.07 /mile/mo. Its discounts for long-term commitments of 60 months and bulk purchases range from 8% to 47%. The Sprint tariffs showed \$16,500 /mo. and \$45 /mile/mo. for a month-by-month, leased T3, but in the tariffs obtained

The value for the % Tier 2 traffic destined for backbone parameter is the same as for the T1s. In lieu of having actual data for the distribution of traffic on an ISP's backbone, it is assumed that any traffic on the backbone is equally probable to travel from one to four nodes. Hence, the values for the % backbone traffic going [1,2,3,4] node distance parameters are assumed to be equal (25%).

INPUT PARAMETER	BASELINE	IT
% capacity at which to operate transport	70%	70%
T3 capacity (Mbps)	43.2	43.2
OC-3 capacity (Mbps) ⁶⁹	150	150
% O-D pairs found on ISPs network	10%	10%
% Tier 2 traffic destined for backbone	89%	89%
% backbone traffic going 1 node distance	25%	25%
% backbone traffic going 2 node distance	25%	25%
% backbone traffic going 3 node distance	25%	25%
% backbone traffic going 4 node distance	25%	25%
<i>T3 cost</i>		
\$ per month (fixed)	\$22,000	\$22,000
\$ per mile per month	\$50	\$50
<i>OC-3 cost</i>		
\$ per month (fixed)	\$55,000	\$55,000
\$ per mile per month	\$125	\$125
RESULTING QUANTITY	BASELINE	IT
Average no. of T3s per link	0	0
Average no. of OC-3s per link	7.3	18.6
Subtotal T3/OC-3 transport cost	\$8.16 M	\$28.13 M
Bulk discount	50%	50%
Total monthly T3/OC-3 transport cost	\$4.08 M	\$14.07 M

Table 29. Backbone T3/OC-3 Results

Cost Allocation

T3 transport costs are allocated based on the relative total amount of traffic generated by the five different types of subscribers.⁷⁰

by the author, there were no provisions for bulk or long term discounts. Because the model uses bulk discounts, the values for the T3 costs are similar to the non-discounted MCI tariffs.

⁶⁸ The author was unable to obtain tariffs for OC-3. The values used in the model are based on the reasoning that an OC-3 has approximately three times the capacity of T3, but its cost will be less than three times that of a T3.

⁶⁹ 155 Mbps less the overhead of SONET frames.

⁷⁰ Even though the transport sizing is based on the peak traffic, allocating the costs is not. Doing so would focus the allocation on one point of the day and would miss what else is occurring throughout the day.

3.2.3. T1 (Analog Dial-In) Circuits

These T1 circuits are the lines over which the analog dial-in subscribers connect.⁷¹ These circuits connect a POP to the closest central office of a local telephone company.

The required number of dial-in T1's per POP is directly proportional to the number of analog modems at that POP, whose sizing is described in the capital equipment section of this chapter. One T1 is needed for every 24 modems. Hence, the parameters described at the beginning of the transport section are not used to size these T1 circuits; only the number of modems is used.

Default Values in the Model

Table 30 summarizes the values used to determine the cost and sizing of the dial-in T1 circuits.

INPUT PARAMETER	BASELINE	IT
<i>Dial -in T1 cost</i>		
\$ per month (fixed)	\$370	\$370
\$ per mile per month	\$48	\$48
average distance from POP to closest central office (miles)	1.0	1.0
Total no. of Modems (Tier 1 and Tier 2 POPs)	102,996	144,279
RESULTING QUANTITY	BASELINE	IT
total no. of dial-in T1s required	4,292	6,012
total monthly dial-in T1 cost	\$1.79 M	\$2.51 M

Table 30. Dial-In T1 Cost Results

The values for the costs and per mile costs are based on pricing from NYNEX.

Cost Allocation

Dial-in T1s are solely for the business and residential dial-in subscribers. Hence, the dial-in T1 costs are split among the residential and business dial-in subscribers according to the relative amount of total traffic they generate. This allocation is the same as for the modem cost allocation.

⁷¹ Likewise, an ISP could purchase individual phone lines, but when buying in bulk, the T1s are generally cheaper on a per-line basis.

3.2.4. ISDN PRI (Digital Dial-In) Circuits

As with the analog dial-in T1s, the required number of ISDN PRIs per POP is directly proportional to the required number of B channels at that POP. One PRI is needed for every 23 B channels. Hence, the parameters described at the beginning of the transport section are not used to size the PRI circuits; only the number of B channels is used.

Default Values in the Model

Table 31 summarizes the values used to determine the cost and sizing of the PRI circuits.

INPUT PARAMETER	BASELINE	IT
<i>ISDN PRI cost</i>		
\$ per month (fixed)	\$548	\$548
\$ per mile per month	\$48	\$48
average distance from POP to closest central office (miles)	1.0	1.0
Total no. of B channels (Tier 1 and Tier 2 POPs)	3726	6480
RESULTING QUANTITY	BASELINE	IT
No. of ISDN PRI lines	162	282
total monthly cost of ISDN PRI lines	\$97,000	\$168,000

Table 31. Dial-In T1 Cost Results

The values for the local fixed costs and per mile costs are based on pricing from NYNEX.

Cost Allocation

Costs for the ISDN PRIs are solely for the ISDN subscribers. Hence, the ISDN PRIs are allocated entirely to the ISDN subscribers.

3.2.5. NAP Interconnection Costs

The interconnection with other ISPs is an essential element for any ISP. Some interconnection occurs at private peering points between two ISPs, and some occurs at public interconnection points called NAPs (or MAEs). However, individual peering arrangements must be established between any two ISPs at a NAP. The specific settlement arrangements between these ISPs are individually negotiated and rather privately held. In general, when the two peering ISPs differ greatly in size, the smaller

one usually pays the larger one to interconnect. When the two ISPs are about the same size, no funds are exchanged, and there is what some call a *revenue neutral point*.⁷²

For the purposes of this model, it is assumed that this ISP is large enough that it does not pay other ISPs to interconnect; it only pays the service provider who is managing the equipment at the NAP. The cost to the ISP is based on (1) the number of circuits (DS-3 or OC-3) it wishes to terminate at the NAP and (2) the number of permanent virtual circuits (PVCs) it wishes to establish between itself and other ISPs.

Default Values in the Model

Because there is a large number of ports required, the less expensive OC-3 connections are used instead of DS-3 connections.

INPUT PARAMETER	BASELINE	IT
No. of NAP points ⁷³	3	3
NAP monthly interconnection charges ⁷⁴		
cost per DS-3 port	\$5,500	\$5,500
cost per OC-3 port	\$8,000	\$8,000
RESULTING QUANTITY	BASELINE	IT
Total number of DS-3 ports	0	0
Total number of OC-3 ports	54	90
Total NAP interconnection cost	\$431,000	\$717,000

Table 32. NAP Interconnection Cost Assumptions

Cost Allocation

The allocation of NAP costs is the same as that for the T3/OC-3 backbone transport costs.

3.3. Customer Service

Customer service, which can represent a significant portion of an ISP’s costs, is furnished by representatives who provide technical support over a toll-free call between the ISP and the customer.

⁷² For further discussion of ISP interconnection issues, see *The Economics of Internet Interconnection Agreements* by Joseph P. Bailey in [MC97a].

⁷³ As described in the ISP topology section, it is assumed that the ISP interconnects at three NAPs.

⁷⁴ As of May 1997, the per-port charges by PacBell for the San Francisco NAP are those indicated in the table. In addition, there are PVC charges of \$15 per PVC. It is assumed that the PVC charges are negligible vis-à-vis the per-port charges.

For a telephone company, most customer service calls are prompted by questions about billing, and about establishing, changing or terminating service, but few received calls are due to questions about how to use the telephone. While an ISP will have calls regarding billing and service, most calls will rather be about technical issues, such as “my modem won’t connect” or “I forgot my password.”

It is assumed that all dial-in subscribers (analog and ISDN) will be making calls to customer service. Additionally, technical representatives of subscribers with leased lines will also call customer service, but it is assumed that these subscribers will have their own internal end-user support, so that the end-users are not calling the ISP’s customer service.

For the model, the perspective is taken that customer service is outsourced by the ISP. Hence, instead of determining how large of a staff is needed, one determines how many call-minutes there are and what is the cost per minute charged to the ISP.

The following parameters are used to determine customer service costs for each type of subscriber:

- calls/month/subscriber
- minutes/call
- cost/min.

The following formula is used to determine the customer service cost per subscriber per month:

$$\text{cust svc cost per month} = \text{calls per month per sub} * \text{min per call} * \text{cost per min}^{75}$$

Default Values in the Model

In general, data regarding customer service is difficult to obtain because ISPs consider this information as proprietary. In place of ISP-specific data, related data was used based on discussions the author had with people in the telephone business.

⁷⁵ Note that the cost is a linear combination of all three parameters; that is, if two parameters are held constant, the cost varies linearly with the third parameter. Hence, a change of a certain percent in any of the parameters will yield a change of the same percent in the customer service cost.

Concerning a cost/minute, for outsourcing customer service for standard billing and service questions, a cost of \$1.50/min. is reasonable. However, for technical questions that would come from an ISP's subscribers, a more highly trained representative would be required, and, therefore, the cost/minute would be higher. Moreover, representatives for leased-line subscribers would need to be even more trained; hence, their costs are higher than those for the dial-in subscribers.

INPUT PARAMETER	BASELINE	IT
<i>residential and business dial-in and ISDN customer service</i>		
calls/month/subscriber	0.25	0.30
minutes/call	15	18
cost/min	\$2.00	\$2.00
<i>56 kb and T1 customer service</i>		
calls/month/ subscriber	2	2.40
minutes/call	15	18
cost/min	\$4.00	\$4.00

Table 33. Customer Service Assumptions

It is assumed that dial-in subscribers call, on average, three times per year (which makes 0.25 calls per month) and that leased-line subscribers call two times per month. Additionally, the length of each call is averaged at 15 minutes. Discussions with members of the MIT ITC concluded that these values are reasonable.⁷⁶

Regarding the Internet telephony scenario, it is assumed that per minute costs will stay the same, but that the number of calls to customer service and the duration of each call will increase by 20%. This is due to reasons such as users having increased questions about this new service of Internet telephony (e.g., installing and configuring new software, how to use the software to make calls, why does it sound the way it does, and so on).

Cost Allocation

Cost allocation for customer service costs is straight forward. Because the customer service cost is figured for each type of subscriber, it is allocated 100% to each type of subscriber (i.e., 100% of residential dial-in customer service costs are allocated to residential dial-in subscribers).

⁷⁶ Sensitivity analysis on customer service costs is conducted in Chapter 4.

3.4. Operations

Operations correspond to the routine tasks necessary to keep the ISP functioning.

Operations costs fall into three principal sections:

- Network Operations and Maintenance
- Facilities
- Billing and Collections.

3.4.1. Network Operations and Maintenance

The following parameters are used to quantify the network operations and maintenance costs:

- SW/HW maintenance (% of equipment costs)
- No. of Tier 1 POPs/Operations persons
- No. of Tier 2 POPs/Operations persons
- ops person's salary.

The costs associated with software and hardware maintenance are due to the need to periodically update or repair equipment.⁷⁷ The parameter, SW/HW maintenance, represents the percentage of capital costs that software and hardware maintenance costs will be. This is based on the cost of a service contract to maintain a given piece of capital equipment.

The work of POP personnel includes the day-to-day operations as well as repair tasks and rearrangements of facilities. It is assumed that the smaller Tier 1 POPs will run essentially unattended, monitored by personnel located at an upstream Tier 2 POP. Hence, a single person can maintain multiple Tier 1 POPs.

The total number of operations personnel required to maintain the equipment in the POPs is based on the middle two parameters above. The names of the parameters indicate how they are used:

⁷⁷ This is in contrast to replacing equipment whose economic life has passed. The cost of replacing outdated equipment is built-in to the annualization of the capital equipment by identifying the economic life of each piece of capital equipment.

$$\text{No. of ops. personnel} = \frac{\text{No. of Tier 1 POPs}}{\text{No. Tier 1 POPs / Ops. person}} + \frac{\text{No. of Tier 2 POPs}}{\text{No. Tier 2 POPs / Ops. person}}$$

The total operations personnel cost is then based on the number of operations. persons times the operations person’s salary.

Default Values in the Model

INPUT PARAMETER	BASELINE	IT
SW/HW maintenance (% of equipment costs) ⁷⁸	20%	20%
No. of Tier 1 POPs/Operations persons ⁷⁹	1.7	1.7
No. of Tier 2 POPs/Operations persons ⁸⁰	0.5	0.5
ops person’s salary ⁸¹	\$50,000	\$50,000
RESULTING QUANTITY	BASELINE	IT
SW/HW maintenance costs	\$0.69 M	\$1.04 M
Total no. of Operations persons	283	283
Total POP personnel cost	\$1.18 million	\$1.18 million

Table 34. Network Operation and Maintenance Assumptions

Cost Allocation

Because the operations costs are based primarily on capital equipment costs, they are allocated in the same distribution as the capital equipment costs.

3.4.2. Facilities

Facilities costs are those associated with maintaining a physical space for each POP. Included are such costs as building rent, electricity, and heat. The associated input parameters are the following:

- \$ per Tier 1 POP per month
- \$ per Tier 2 POP per month.

⁷⁸ For example, a Cisco 4500 router (with IP software, 2 fast ethernet cards and a 2 serial port card) costs \$18,000 and, annualized, costs \$470. The SmartNet maintenance for this router costs \$104 per month, which represents approximately 22%.

⁷⁹ The Internet Access Company (www.tiac.com) has 34 POPs and lists 20 operations persons involved with network maintenance, which yields a ratio of 1.7. As listed in its 1996 10K filing, Netcom had 331 POPs (including 80 in the United Kingdom and 22 in Canada), and 163 operations personnel, although the filing does not mention whether these operations personnel maintain all POPs or only the domestic POPs. Based on these numbers, the ratio for Netcom ranges from 1.4 to 2.0. Hence, 1.7 is a reasonable ratio.

⁸⁰ Because the Tier 2 POPs house more equipment, there will be an increased number of required support personnel. The value used represents approximately a three-fold increase over the that required for the Tier 1 POPs.

⁸¹ This value is based on job advertisements and discussions with people in industry. Overhead is added to account for benefits not received as salary.

Default Values in the Model

Because Tier 1 POPs are needed for housing just equipment, they will be substantially smaller than the Tier 2 POPs. Hence, it is assumed that the Tier 1 POPs require an area of 500 sq. ft.⁸² and that Tier 2 POPs will require 2,500 sq. ft. because there will be more equipment and employees to house.

The cost of leasing real estate is assumed to be \$1.65/sq. ft./month.⁸³ This corresponds to the monthly leasing cost of a Tier 1 POP and a Tier 2 POP to be \$830 and \$4125, respectively (see Table 35).

INPUT PARAMETER	BASELINE	IT
\$ per Tier 1 POP per month	\$830	\$830
\$ per Tier 2 POP per month	\$4125	\$4125

Table 35. Facilities Cost Assumptions

3.4.3. Billing and Collections

The costs of billing for Internet service include those of rendering a monthly bill, collecting payment, and maintaining an account. Rendering a monthly bill includes processing the customer’s account and printing a bill or charging a credit card.

The sole input model parameter for each type of subscriber regarding billing charges is:

- billing cost/sub/month.

The total billing cost for each type of subscriber is simply the number of subscribers for each category times the billing cost per subscriber.

Default Values in the Model

Based on discussions ITC members, it is assumed that a bill can be generated for \$1.25, and that this cost is the same for all types of subscribers.

⁸² Netcom’s 1996 10K filing.

⁸³ BBN lists in its 1996 10K filing that it leases an aggregate of approximately 150,000 sq. ft. at an annual cost of \$2.88 million, which corresponds to \$1.60/sq. ft./month. Another BBN lease of 372,000 sq. ft. has an annual cost of \$7.7 million, which corresponds to \$1.72/sq. ft./month. An average of these costs is approximately \$1.65/sq. ft./month. Note that these costs include “taxes and certain operating expenses,” but specific operating expenses are not identified.

INPUT PARAMETER	BASELINE	IT
<i>per subscriber billing cost</i>		
residential dial-in subscribers	\$1.25	\$1.25
business dial-in subs.	\$1.25	\$1.25
ISDN dial-in subs.	\$1.25	\$1.25
56 kb subs.	\$1.25	\$1.25
T1 subs.	\$1.25	\$1.25

Table 36. Billing Assumptions

Because the Internet telephony scenario does not represent the ISP becoming a long-distance phone company, there are no usage-based charges, such as a per-minute charge of Internet telephony use. Hence, there are no additional billing costs that are due to the ISP needing to record activity of individual subscribers.

Cost Allocation

The allocation of billing costs are straight forward because they are calculated independently for each type of subscriber.

3.5. Other Expenses

The remaining costs seen by an ISP are included in an *Other Expenses* category. These costs include sales/marketing and general/administrative. While these costs are not the focus of this thesis, they are nonetheless part of an ISP’s costs and are included to provide a perspective relative to the other cost categories.

3.5.1. Sales and Marketing

Sales and marketing costs can represent a substantial portion of overall costs. However, these costs are rather company/industry specific.

The amount of resources that a company puts into sales and marketing depends on how competitive the industry is and what the company’s sales and marketing strategy is. Identifying general industry and company trends for sales and marketing strategy is beyond the scope of this thesis.

One perspective to determine sales and marketing costs is to consider how much outsourcing these services would cost. For example, salespeople would take a certain

percentage of revenue based on their commission. Similarly, the model quantifies sales and marketing costs by basing them on a percentage of revenue.

This percentage is derived from an average of sales and marketing costs that is extracted from various companies' 10k reports that are submitted to the US Securities and Exchange Commission. In the "Consolidated Statements of Income" section of the 10k reports, *Sales and Marketing Costs* and *Revenues* are listed. The desired number for each company is the ratio of the sales and marketing costs to the revenues. This number is then averaged over the ratio of several companies.

The model parameter that represents this average is:

- sales and marketing (% rev).

Default Values in the Model

Based on 1994, 1995, and 1996 data for several companies (Netcom, PSInet, Uunet, AOL and US Robotics), the average ratio of sales and marketing costs to revenue is 25%. As an indication of how industry/company specific this value is, the standard deviation of the data is 13%.

Over the three-year period, the value for the ISPs ranged from 16% (Uunet, 1996) to 62% (PSInet, 1995). AOL was approximately 20% for all three years and US Robotics varied from 14% to 17%.

Because this model is not a business plan for an ISP, many of whom are investing heavily to expand and, thus, are operating temporarily at a loss, but is rather a model of the cost of end-to-end Internet service, a default value of 20% is chosen to represent the sales and marketing (% rev) parameter (Table 37). This value can be considered conservative for the ISP industry, but somewhat liberal for other industries.⁸⁴

⁸⁴ For comparison, the ratio of sales and marketing costs to *total operating costs*, for the same companies as above, is, on average, 21% with a standard deviation of 4%. Hence, in a competitive industry where costs are close to revenue, using the ratio of sales and marketing costs to *revenue* or to *total operating costs* will yield similar results.

INPUT PARAMETER	BASELINE	IT
sales and marketing (% rev)	20%	20%

Table 37. Sales and Marketing Assumptions

Maintaining the same value for the Internet telephony scenario is based on reasoning that the ISP is not necessarily trying to actively promote a new service (or become a long distance phone company), but rather that the ISP’s subscribers have chosen to embrace the new application of Internet telephony. Hence, the parameter is held constant for both scenarios.

Cost Allocation

Because the sales and marketing costs are based on revenue, they are allocated in the same distribution as the revenue obtained from the various types of subscribers.

3.5.2. General and Administrative

General and administrative (G&A) expenses consist primarily of salaries and occupancy costs for administrative, executive, legal, accounting, and finance personnel.

Determining G&A costs is not as straight forward as determining other costs such as modem or transport costs; there is no simple formula for sizing the number and cost of G&A employees, such as VPs, lawyers, accountants, and support staff.

In order to quantify such costs, an average of G&A costs is extracted from various companies’ 10k reports that are submitted to the US Securities and Exchange Commission. In the Consolidated Statements of Income section of the 10k reports, *General and Administrative* and *Total Operating Costs* are listed. The desired number for each company is the ratio of the G&A costs to the total operating costs. This number is then averaged over the ratio of several companies.

The model parameter that represents this average is:

- general and administrative (% costs).

Default Values in the Model

Using the 1996 values from the 10k reports of multiple companies, G&A costs represent, on average, 11% of total operating costs (Table 38). The standard deviation of the data is 2.6%.⁸⁵

INPUT PARAMETER	BASELINE	IT
general and admin (% costs)	11%	11%

Table 38. G&A Assumptions

Cost Allocation

Because G&A costs scale with the size of the ISP, they are allocated in the same manner that the total costs are distributed.

4. Summary

In this chapter a description of a cost model of Internet service providers is presented. The model puts the ISP’s costs into five categories:

- capital equipment
- transport
- customer service
- operations
- other expenses (sales/marketing and general/administrative).

The model is evaluated with two scenarios: 1) the *baseline scenario* which represents an ISP today where its subscribers use primarily the web; 2) the *Internet telephony scenario*, where the ISP sees a significant rise in the use of computer-to-computer Internet telephony. This scenario is in contrast to another potential Internet telephony scenario where an telephone service provider desires to replicate the PSTN using Internet telephony technology.

Chapter 4 presents the results of the two scenarios along with sensitivity analysis. Subsequently, the cost model is applied to two additional scenarios of ISP regulation and of yield management.

⁸⁵ Companies included in this calculation are: Netcom, PSInet, Uunet, and AOL.

Cost Model Analysis and Interpretation

This chapter presents the results of the cost model for the baseline and Internet telephony scenarios based on the default parameter settings outlined in Chapter 3. Results for the baseline scenario are presented in the first section; results for the Internet telephony scenario are presented in the second section, and sensitivity analysis is discussed in the third section. In addition, the model is extended to compare the cost of the FCC's access charge reform to that of Internet telephony; the results of which are presented in section four. Finally, a yield management example for dial-in subscribers is presented in section five and a summary is in section six.

1. Baseline Scenario Results

As described previously, the baseline scenario represents an ISP whose users are primarily browsing the web. This scenario is intended to represent an ISP in the 1997 time period.

1.1. Total ISP Costs

Table 39 shows the cost results for the baseline scenario. An initial conclusion is that the cost is slightly greater than the revenue. This is not necessarily surprising because many ISPs have had difficulty operating at a profit.

Additionally, both cost and revenue are similarly distributed across the subscriber base. This implies that no type of subscriber is substantially subsidizing the costs of the other types of subscribers.⁸⁶ Because the prices for service (and, consequently, revenues) are

⁸⁶ This is in contrast to the PSTN, for example, where, based on government decisions, the business subscribers subsidize the residential subscribers.

based on US averages and because prices are in-line with the cost results, this indicates that the market for providing Internet access services is relatively efficient.

	magnitude	res.	bus.	ISDN	56 kb	T1
Revenue	\$26.7 M	69.9%	0.3%	1.3%	2.7%	25.8%
Cost	\$30.7 M	69.3%	0.3%	1.0%	2.2%	27.2%

Table 39. Revenue and Cost Comparison

Table 40 shows the cost results across the various cost categories. Capital equipment and operations costs each represent approximately half the costs of the other three categories. In general, however, no particular cost category dominates the ISP's costs. Taken from another perspective, all cost categories play an important role in determining an ISP's costs.

CATEGORY	COST (k \$)	DISTRIBUTION (%)
Capital Equipment	3,349	11
Transport	7,242	24
Customer Service	7,927	26
Operations	3,445	11
Sales, Marketing, G & A	8,725	28
Total Monthly Cost	30,688	

Table 40. Baseline Scenario Cost Summary

1.2. Subscriber Costs

As described in Chapter 3, each cost element is allocated to the various types of subscribers. For example, modem costs are split between the residential and business dial-in subscribers according to the relative amount of calls each type of subscriber makes. Similarly, 56 kb CDU/DSUs are allocated entirely to the 56 kb subscribers. By allocating the costs of each element to each type of subscriber the costs of each type of subscriber are determined.⁸⁷

⁸⁷ The resulting cost allocation for each element can be found in the *Cost Model Tables: Model Outputs of Appendix 5*.

	RES. (\$)	BUS. (\$)	ISDN. (\$)	56 KB. (\$)	T1. (\$)
Capital Equipment	3	3	6	94	115
Transport	3	4	33	27	745
Customer Service	8	8	8	120	120
Operations	3	3	6	65	79
Other Expenses	7	7	33	163	392
Total Monthly Cost	23	24	85	469	1,450

Table 41. Baseline Scenario Subscriber Cost

Table 41 shows the costs of each type of subscriber for each cost category. This information is similarly displayed in Figure 9 where the costs are shown in relative amounts. While it is useful to know the magnitude of costs for each type of subscriber, knowing how each subscriber's cost's distribution compares is also important. As the results show, there is a substantial contrast in cost distribution between the different types of subscribers. For example, customer service costs represent 33% of the residential dial-in subscribers' costs compared to 8% for the T1 subscribers. Transport costs are the opposite; they represent 51% of the T1 subscribers' costs compared to 13% for the residential dial-in subscribers.

Because the ISP has a mix of these various types of subscribers – each of which has a unique cost distribution – the ISP's total cost distribution, as displayed in Table 40, is a weighted average of the distribution for each type of subscriber. Hence, the ISP's total cost distribution will vary with the subscriber mix and the individual cost distribution shown in Figure 9. For example, if an ISP had only T1 subscribers, the ISP's costs would be distributed in the same manner as the T1 subscriber's costs, and if the ISP had only dial-in subscribers, the ISP's costs would be distributed as the dial-in subscriber's costs. Likewise, the cost distribution for a combination of different types of subscribers will be based on a weighted average of the cost distribution for each type of subscriber.

Relating this back to the current market structure of differentiated ISPs, those ISPs who target dial-in users will have a cost distribution different than those who target leased-line users. The cost distribution shown in Table 40 is based on the assumptions for subscriber mix presented in Chapter 3.

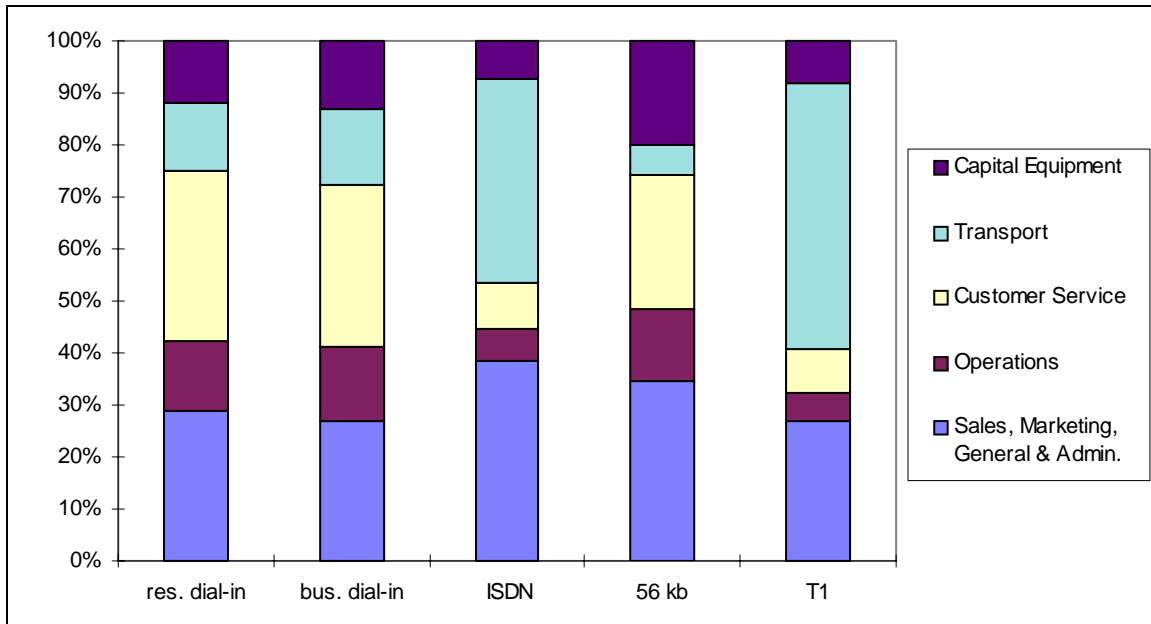


Figure 9. Baseline Scenario Subscriber Cost Distribution

The following five tables break down the costs for each subscriber into more detail. Each table lists the ten-highest cost items for each type of subscriber. For example, previously what was aggregated together as transport is now broken into the various types such as T1, PRI and T3.

1.2.1. Analog Dial-in Subscribers' High-Cost Components

Residential and business dial-in subscribers have essentially the same cost components, with non-technical items (customer service, sales/marketing and general/administrative) being the three highest cost items, which represent 62% of costs. Analog modems represent the only piece of capital equipment on the list. Because there is one phone line needed for each modem, the ensemble of modem and phone line represents more than 20% of total costs. Hence, any changes in usage patterns that require more modems and phone lines will substantially impact the technical portion of user costs.

The important result to note in Table 42 is that the top three elements – comprising 62% of a dial-in subscriber's costs – are non-technical elements. Even though these cost areas are not the focus of this thesis, they obviously can not be ignored. Hence, ISPs who target

dial-in subscribers need to focus substantial resources into controlling the costs of these non-technical areas.

ITEM	RES.	SUBS	BUS.	SUBS
	COST (\$)	%	COST (\$)	%
customer service	7.50	33	7.51	31
sales and marketing	4.00	18	4.01	17
general and administrative	2.52	11	2.53	10
analog modems	2.50	11	2.94	12
analog dial-in T1	1.91	8	2.25	9
billing	1.25	5	1.25	5
POP personnel	0.95	4	1.11	5
T1 transport	0.87	4	1.03	4
s/w and h/w maintenance	0.54	2	0.63	3
facilities	0.33	1	0.39	2
Total of top ten items	22.38	98	23.65	98

Table 42. High-Cost Components for Residential and Business Dial-in Subs. (Baseline Scenario)

1.2.2. ISDN Subscribers' High-Cost Components

The ISDN PRI lines represent the single largest cost component for the ISDN subscribers. The ensemble of PRI and access router represents almost 40% of the total ISDN subscriber costs. Even more so than for the analog dial-in subscribers, changes in usage patterns that require more PRI/routers will greatly impact ISDN user costs. However, similar to the analog dial-in subscribers, non-technical costs also represent a large portion of total costs – 47% for the ISDN subscribers.

ITEM	COST (\$)	%
ISDN PRI	27	32
sales and marketing	20	23
general and administrative	13	15
customer service	8	9
ISDN access router	5	6
T1 transport	5	6
POP personnel	2	3
s/w and h/w maintenance	1	1
billing	1	1
T3/OC-3 transport	1	1
Total of top ten items	83	98

Table 43. High-Cost Components for ISDN Subs. (Baseline Scenario)

1.2.3. 56Kb Subscribers' High-Cost Components

Because 56 kb subscribers – as do T1 subscribers – require a higher level of customer service than dial-in subscribers, customer service represents a large portion of costs. Non-technical components represent 60% of all 56 kb subscriber's costs. The most costly technical element for the 56 kb subscribers is the dedicated serial port on the ISP's router; including serial port and associated router chassis, this ensemble router cost represents 16% of all costs. The high cost of this particular piece of capital equipment is due to the fact that it can not be shared among the 56 kb subscribers. Unlike modems, which are statistically multiplexed among the dial-in users, a serial port is allocated for each leased-line subscriber.

ITEM	COST (\$)	%
customer service	120	26
sales and marketing	100	21
general and administrative	63	13
Cisco 7513 serial port card	52	11
POP personnel	33	7
T3/OC-3 transport	24	5
Cisco 7513 router chassis	22	5
s/w and h/w maintenance	19	4
56 kb CSU/DSU	13	3
facilities	12	2
Total of top ten items	458	98

Table 44. High-Cost Components for 56 kb Subs. (Baseline Scenario)

1.2.4. T1 Subscribers' High-Cost Components

In contrast to the other types of subscribers, a technical component is the highest cost element for the T1 subscribers; it is backbone transport that represents almost half of the costs of a T1 subscriber. However, the non-technical components still represent 35% of all T1 subscriber costs.

ITEM	COST (\$)	%
T3/OC-3 transport	674	46
sales and marketing	240	17
general and administrative	151	10
customer service	120	8
NAP Interconnection cost	71	5
Cisco 7513 serial port card	48	3
POP personnel	40	3
T1 CSU/DSU	37	3
s/w and h/w maintenance	23	2
Cisco 7513 router chassis	20	1
Total of top ten items	1425	98

Table 45. High-Cost Components for T1 Subs. (Baseline Scenario)

1.3. Baseline Scenario Summary

- No particular cost category dominates the ISP's costs. Capital Equipment, Transport and Customer Service each represents a similar fraction of total costs. Additionally, the costs in each of these categories is approximately twice those in Operations and in Sales, Marketing, General and Administrative.
- There is a substantial contrast in cost distribution between the different types of subscribers. For example, dial-in subscribers' costs are distributed very differently across the five cost categories than T1 subscribers' costs.
- The ISP's total cost distribution will vary with the subscriber mix. Because the cost distribution for each type of subscriber varies substantially, the ISP's cost distribution will depend considerably on the relative number of each type of subscriber.
- Non-technical components represent a substantial portion of each subscriber type's costs. This portion ranges from 35% for T1 subscribers to up to more than 60% for analog dial-in subscribers. From a strategy perspective of ISPs, non-technical areas are very important, especially for the mass market of dial-in subscribers. An ISP could gain an advantage from possible economies of scale and/or scope for customer service, reduced sales/marketing and billing by bundling Internet service with other telecommunications services.

2. Internet Telephony Scenario Results

In this section results are presented for the Internet telephony scenario. First the total ISP costs are presented followed by the individual subscriber costs.

2.1. Total ISP Costs

Comparing the Internet telephony scenario to the baseline scenario, there is an increase in all categories; however, some categories are affected more than others. The bottom line is that in the IT scenario the increase in the ISP's costs is double the revenue increase compared to the baseline scenario. Hence, ISPs will need to consider how to minimize the cost impact of Internet telephony or how to recover additional revenue if they plan to ever operate at profitable levels. The comparative results for the baseline and Internet telephony scenarios are shown in Figure 10.

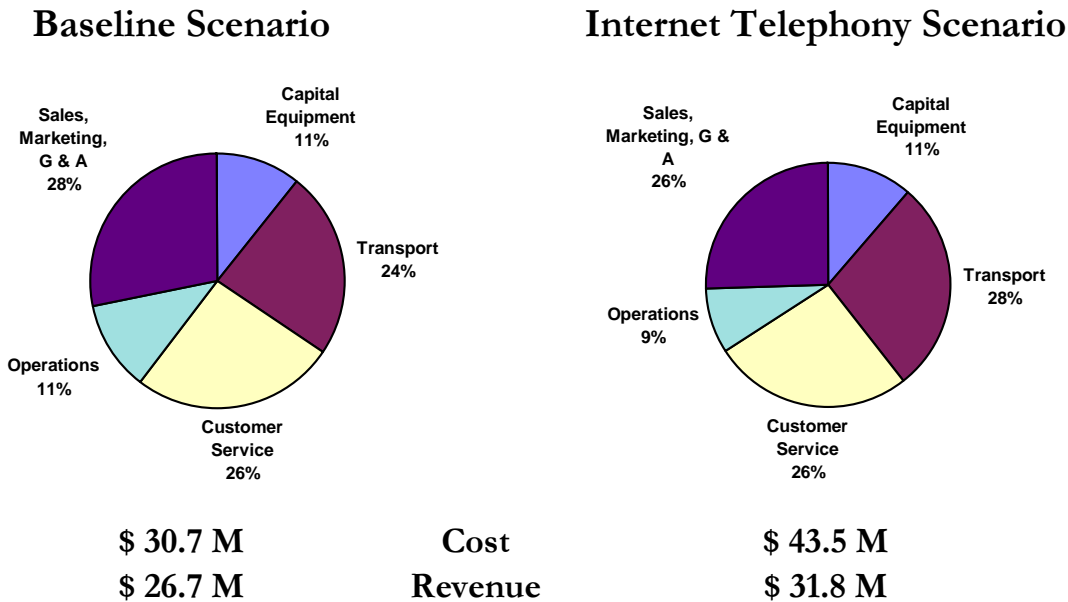


Figure 10. Comparative Cost Results

Table 46 breaks down the overall costs into more detail. At 28% of total costs, transport costs become the largest cost category in the Internet telephony scenario. The implication for ISPs based on this result is that any ISP that operates its network most efficiently will

have a competitive advantage over other ISPs if the Internet telephony scenario takes place.⁸⁸

	BASELINE (k \$)	%	IT (k \$)	%
Capital Equipment	3,349	11	5,002	11
Transport	7,242	24	12,186	28
Customer Service	7,927	26	11,414	26
Operations	3,445	11	3,775	9
Sales, Marketing, G & A	8,725	28	11,148	26
Total Monthly Costs	30,688		43,525	

Table 46. Comparative Cost Results

Even though transport costs increased, the cost distribution has not substantially changed, however. Further insight into the detail of each cost category can be gained by looking at the change in cost for each type of subscriber and by conducting sensitivity analysis on certain parameters.

2.2. Subscriber Costs

Subscriber costs are impacted in different ways. Table 47 shows the percentage increase in each cost category for each subscriber type. For example, transport costs increased by 75% for the analog dial-in subscribers. In general, transport costs are substantially impacted for each subscriber type. Costs in the other expenses category increase for the leased line subscribers (56kb and T1) are due to an increase in sales and marketing costs.⁸⁹

⁸⁸ Such efficiencies could come from scale economies, facilities-based networks or even network optimization techniques. However, if one believes that the market for transport is efficient and that transport is essentially a commodity, then there would be fewer opportunities for competitive advantage by owning a network. Even so, network optimization techniques would prove advantageous whether or not the ISP owns or leases its network

⁸⁹ This is based on the assumption that leased-line subscribers would purchase enough capacity to maintain their circuit at the same level for both scenarios. Hence, additional revenue is received from the leased-line subscribers in the Internet telephony scenario and sales and marketing costs are based on a percentage of revenue.

	RES.	BUS.	ISDN	56 KB	T1
Capital Equipment	45%	45%	80%	66%	63%
Transport	75%	75%	85%	64%	64%
Customer Service	44%	44%	44%	43%	44%
Operations	7%	7%	30%	26%	25%
Other Expenses	7%	7%	7%	78%	78%
Total	33%	34%	48%	59%	64%
Cost	\$30	\$32	\$126	\$745	\$2,375

Table 47. Subscriber Cost Increase

In Figure 11 the increased revenue is incorporated along with the additional costs by considering a cost/revenue ratio for both scenarios. Here one can see that the dial-in subscribers become particularly unprofitable, but the leased-line subscribers remain at about the same level of profitability as in the baseline scenario. This is due to the assumption that the leased-line subscribers would purchase additional capacity in order to keep their circuit at the same level for the Internet telephony scenario.⁹⁰

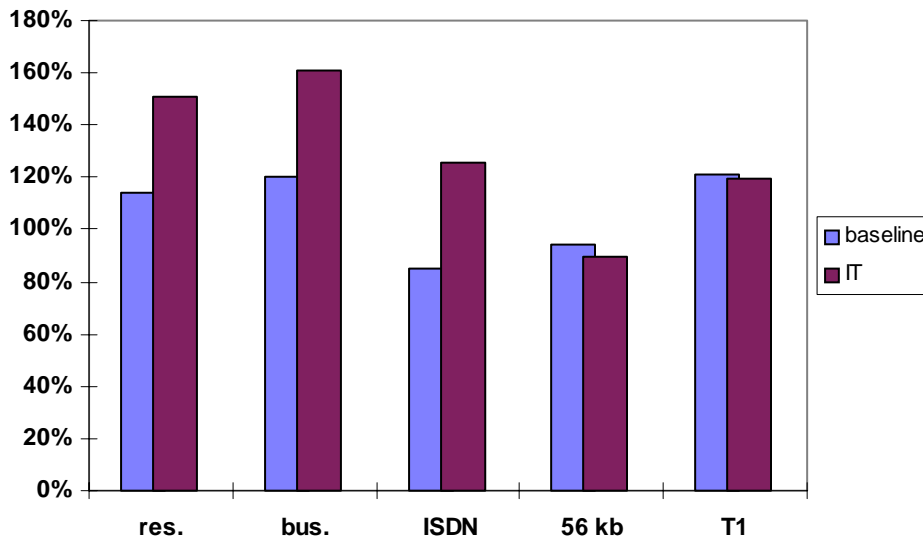


Figure 11. Cost/Revenue Ratio for Baseline and IT Scenarios

2.2.1. Analog Dial-in Subscribers' High-Cost Components

Similar to the baseline scenario, the next five tables show the ten highest cost components for each type of subscriber.

⁹⁰ More specifically, 56 kb and T1 subscribers require 1.66 leased lines per subscriber for the IT scenario. As a result, the 56 kb subscribers pay 1.66 times the original price of \$500 to \$880. Whereas, transport costs increased from \$27 to \$43. In contrast, revenue from a T1 subscriber increased from \$1,200 to \$1,992 compared to transport that increased from \$745 to \$1,219.

ITEM	COST (\$)	% IT	% BASELINE
customer service	10.80	36	33
sales and marketing	4.00	13	18
analog modems	3.51	12	11
general and administrative	3.01	10	11
analog dial-in T1	2.68	9	8
T1 transport	2.07	7	4
billing	1.25	4	5
POP personnel	0.92	3	4
s/w and h/w maintenance	0.78	3	2
T3/OC-3 transport	0.42	1	4
Total of top ten items	29.43	97	

Table 48. High-Cost Components for Residential Dial-in Subs. (IT Scenario)

Both residential and business dial-in subscribers' costs are similarly impacted in the Internet telephony scenario: T1 transport costs make up a larger share of total costs for the Internet telephony scenario. However, customer service and other non-technical cost elements still comprise a large portion of costs for the analog dial-in subscribers.

ITEM	COST (\$)	% IT	% BASELINE
customer service	10.85	34	31
analog modems	4.12	13	12
sales and marketing	4.01	12	17
analog dial-in T1	3.15	10	9
general and administrative	3.02	9	10
T1 transport	2.43	8	4
billing	1.25	4	5
POP personnel	1.08	3	5
s/w and h/w maintenance	0.92	3	3
T3/OC-3 transport	0.49	2	1
Total of top ten items	31.31	97	

Table 49. High-Cost Components for Business Dial-in Subs. (IT Scenario)

2.2.2. ISDN Subscribers' High-Cost Components

Similar to the analog dial-in subscribers, ISDN subscribers have transport costs increase, but the order of the elements has not substantially changed.

ITEM	COST (\$)	% IT	% BASELINE
ISDN PRI	47	37	32
sales and marketing	20	16	23
general and administrative	15	12	15
T1 transport	12	9	6
customer service	11	9	9
ISDN access router	9	7	6
POP personnel	3	2	3
T3/OC-3 transport	2	2	1
s/w and h/w maintenance	2	2	1
billing	1	1	1
Total of top ten items	122	97	

Table 50. High-Cost Components for ISDN Subs. (IT Scenario)

2.2.3. 56 kb Subscribers' High-Cost Components

56 kb subscribers have essentially the same cost distribution as in the baseline scenario. The router serial port card is still the most expensive technical item. However, the top three elements, which now comprise 62% of total costs, are still the same three non-technical elements.

ITEM	COST (\$)	% IT	% BASELINE
customer service	172	23	26
sales and marketing	166	22	21
general and administrative	125	17	13
Cisco 7513 serial port card	87	12	11
T3/OC-3 transport	39	5	5
POP personnel	37	5	7
Cisco 7513 router chassis	36	5	5
s/w and h/w maintenance	31	4	4
56 kb CSU/DSU	22	3	3
facilities	13	2	2
Total of top ten items	728	98	

Table 51. High-Cost Components for 56 kb Subs. (IT Scenario)

2.2.4. T1 Subscribers' High-Cost Components

Similar to the baseline scenario, backbone transport costs are still the highest-cost element for the T1 subscribers in the Internet telephony scenario. Hence, those ISPs targeting T1 subscribers can gain substantial cost savings by having the most efficient network. This is in contrast to ISPs who target analog dial-in subscribers, for example, who would only receive marginal benefit by optimizing their network. For them, more substantial cost savings can be gained by targeting customer service and sales and

marketing areas. One should note, however, that these non-technical costs elements still comprise 37% of costs for a T1 subscriber. Hence, no ISP can afford to ignore such non-technical items regardless of what type of subscriber he is supporting.

ITEM	COST (\$)	% IT	% BASELINE
T3/OC-3 transport	1,103	46	46
sales and marketing	398	17	17
general and administrative	300	13	10
customer service	173	7	8
NAP Interconnection cost	116	5	5
Cisco 7513 serial port card	78	3	3
T1 CSU/DSU	61	3	3
POP personnel	44	2	3
s/w and h/w maintenance	37	2	2
Cisco 7513 router chassis	33	1	1
Total of top ten items	2,343	99	

Table 52. High-Cost Components for T1 Subs. (IT Scenario)

2.3. Internet Telephony Scenario Summary

- In the Internet telephony scenario, the increase in the ISP's costs is double the revenue increase. Hence, ISPs will lose even more money without attempting to recover additional costs.
- Transport costs become the largest cost category in the Internet telephony scenario—28% of total costs. But the overall cost distribution is similar to that of the baseline scenario.
- Non-technical costs still remain a large portion of per-user costs for each type of subscribers, but especially for dial-in subscribers.

3. Sensitivity Analysis

Many assumptions were made in order to arrive at the results of the baseline and Internet telephony scenarios. Sensitivity analysis is conducted in order to determine how varying key parameters will impact these results.

3.1. Dial-in Subscribers per POP

As presented in the results section, modems costs represent 70% of capital equipment costs for the baseline scenario. Seeing that the modem costs are large (as well as the cost of the dial-in lines for each modem), understanding what drives these costs can help an ISP appropriately size its modems.

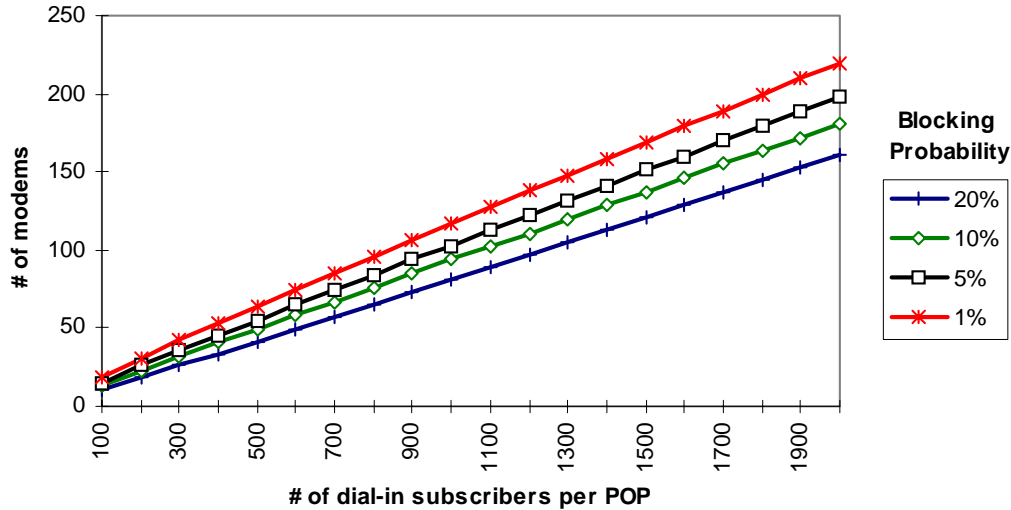


Figure 12. Modem Sizing

As explained in the capital costs section, the modems are sized using the Erlang B formula. The inputs to this formula are the peak offered load and the blocking probability. The offered load is directly proportional to the number of dial-in subscribers and the blocking probability is a parameter set by the ISP depending on the desired grade of service. Figure 12 summarizes how the number of required modems varies with the number of subscribers per POP (which determines the offered load) and the blocking probability. For this chart, it is assumed that 20% of the subscribers call at the peak hour and that the average holding time is 30 minutes.

As intuition would indicate, one can see that the number of modems increases as the number of subscribers per POP increases and as the blocking probability decreases. This increase is not linear, however. Another means to view the trends in Figure 12 is to look at the subscriber to modem ratio, which is commonly used as a guide to size the number

of modems at an ISP. This ratio is depicted in Figure 13. One can see that as the number of subscribers per POP increases the subscriber to modem ratio also increases. This would tend to indicate that there are economies of scale for an ISP specifically regarding modems. However, Figure 13 also indicates that these economies of scale tend to level out as the number of POP subscribers increases.

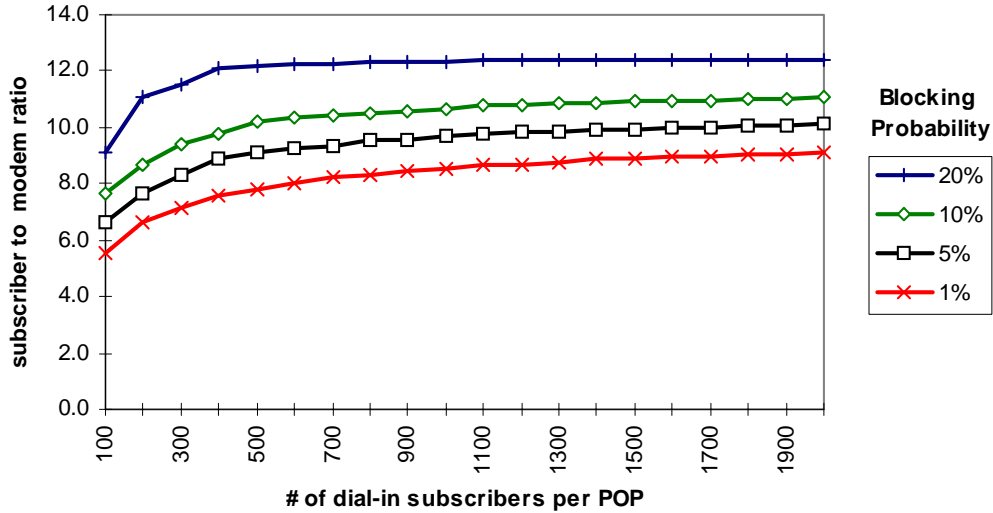


Figure 13. Subscriber to Modem Ratio

Figure 14 shows how a dial-in subscriber's cost varies as the number of subscribers per POP increases. The data in this figure are relative to the baseline scenario. The trend in the chart is that the per-subscriber costs decline as the number of subscribers per POP increases. This is essentially the same result as indicated above.

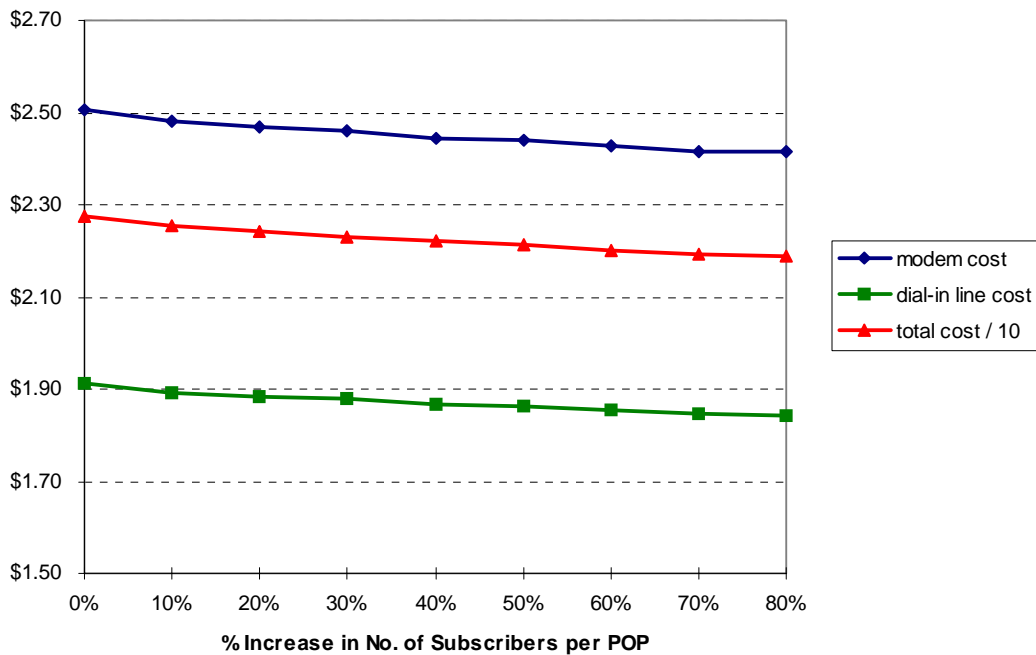


Figure 14. Dial-in Subscriber Cost as Number of Subs. per POP Varies

In general the more subscribers that an ISP can serve from one modem pool (or POP), the fewer modems needed per subscriber. This could be achieved by an ISP gaining market share, an ISP merging or acquiring other ISPs, or an ISP leasing its access equipment to other online services. The ISP could establish agreements with other service providers to allow their subscribers to access the network via the ISP's POP. For example, BBN is an ISP who has agreements with other online service providers. Even though BBN owns access equipment throughout the country, BBN itself does not offer dial-in accounts to individual subscribers. Rather, it has agreements with such service providers as AT&T World Net and AOL to allow their dial-in subscribers to access their respective networks via BBN's modem banks. Similarly, Earthlink has outsourced its dial-in access to Uninet Technologies Inc.⁹¹ Through such contractual arrangements ISPs can reap the benefits of these scale efficiencies without being a huge, facilities-based provider itself.

⁹¹ Data Communications, May 1997, p. 24.

3.2. Internet Telephony Use by Dial-in Subscribers

In addition to being impacted by the number of subscribers per POP, modem costs are also impacted by usage patterns. In the Internet telephony scenario, it was assumed that call arrival rates and holding times each increased by 20% vis-à-vis the baseline scenario.⁹² Additionally, it was assumed that Internet telephony is used 33% of the time that a user is online. These two parameters could be varied independently according to various scenarios. For example, one could assume that Internet telephony is used a given amount, such as 50% of a user's time online, but the total amount of time online does not increase. Likewise, users could continue to do the same activities (without Internet telephony) but simply spend more time online. Figure 15 shows how a dial-in user's total cost would change under these types of scenarios.⁹³

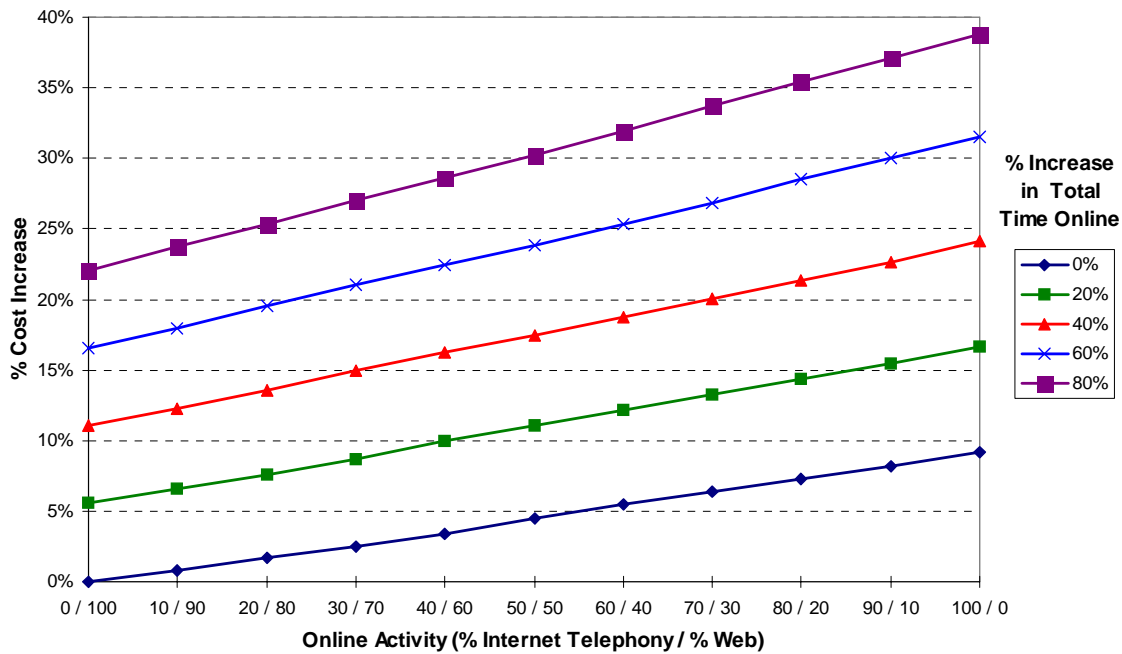


Figure 15. Internet Telephony and Usage Level Impact on Dial-in Subscriber's Costs

⁹² Because the offered load parameter of the Erlang B formula is a linear combination of 1) number of subscribers per POP, 2) percent of subscribers calling during peak hour, and 3) holding time, changing any one of these by a given percent will change the offered load by the same percent. Hence, holding the number of subscribers per POP constant and increasing the other two parameters by 20% each, as in the Internet telephony scenario, offered load is increased by 44% (= 1.2 * 1.2).

⁹³ The cost increase is relative to that of the baseline scenario. Because all other costs are held constant (such as customer service, sales and marketing) the cost increase shown in this figure will not be the same as the for the Internet telephony scenario where other costs were assumed to increase.

For example, a dial-in subscriber's cost would increase by 5% under two scenarios: 1) if she used Internet telephony 55% of the time but did not increase her total time online, or 2) if she didn't use Internet telephony at all but increased her total time online by 20%.

The general trend shown by this chart indicates that dial-in subscribers' costs are more sensitive to a change in usage levels than to a change in usage type. Intuitively this seems appropriate because dial-in subscribers can not generate much bandwidth over a modem, thus having a small impact on (backbone) transport costs, but they can easily influence modem costs by increasing their usage levels.

3.3. Internet Telephony Use by T1 Subscribers

As with the dial-in subscribers, it was assumed that T1 subscribers' end-users would use Internet telephony 33% of the time online. Combining this assumption with one that end-users' bandwidth would increase by 300% when using Internet telephony, the total impact on a T1 subscribers' required bandwidth is a 66% increase.⁹⁴ Figure 16 shows how a T1 subscriber's cost changes as this increase in bandwidth is varied.⁹⁵

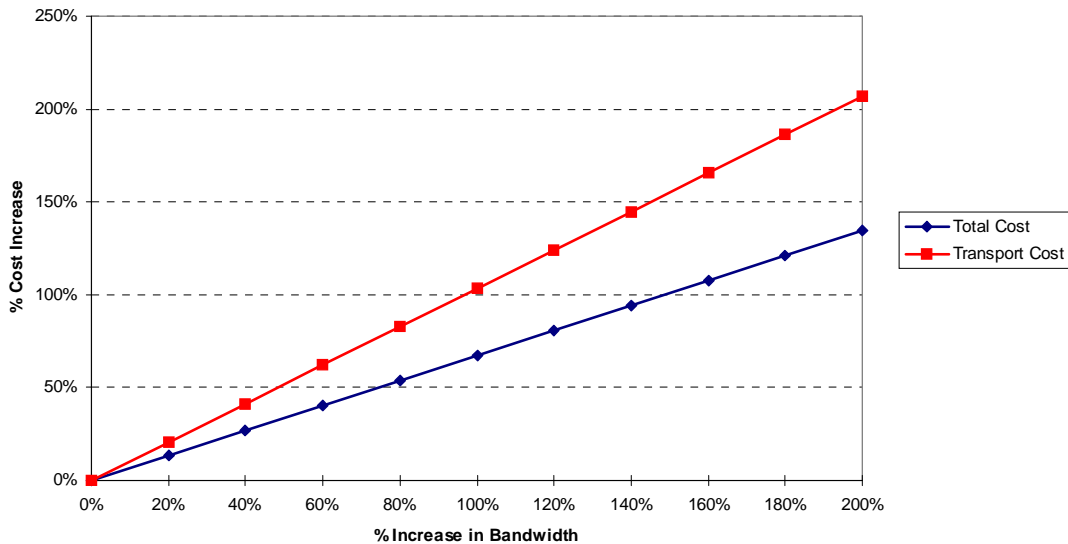


Figure 16. T1 Subscriber's Cost while Varying Bandwidth

⁹⁴ $1 * 66\% + 3 * 33\% = 1.66$.

⁹⁵ As with the prior sensitivity analysis for dial-in subscribers, the cost increase is relative to that of the baseline scenario. All other costs are held constant.

The general trend as indicated in this chart is that the total cost varies essentially linearly with the change in required bandwidth. Hence, there are no economies of scale present in this model interpretation. This does not mean that economies of scale do not exist. For, if the ISP were facilities-based, it might see such efficiencies. However, the costs used in this model are based on tariffs of telecommunications providers, and because these tariffs show no further discounts once the ISP has reached the top tier of discounts, the results in the model will indeed show no economies of scale for the backbone transport costs.

As intuition would indicate, holding all costs constant and varying the bandwidth requirement for a T1 subscriber will simply increase the transport portion of a T1 subscriber's total costs. These results are shown in Figure 17.

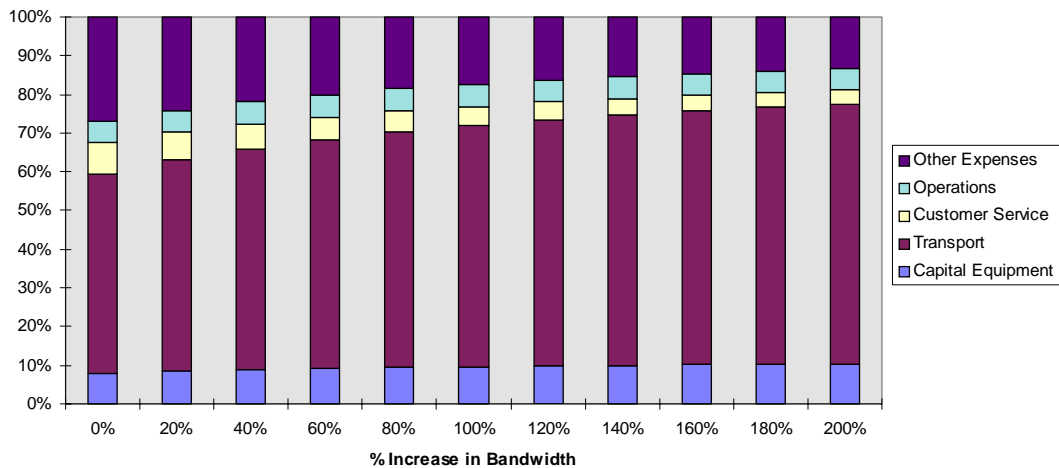


Figure 17. T1 Subscriber's Cost Distribution while Varying Bandwidth

3.4. Customer Service Costs

The overall cost distribution shows that customer service represents a substantial portion of costs. Comparing the cost distribution for each type of subscriber shows that customer service represents the greatest relative amount for dial-in users. Because of the large number of dial-in users in the baseline scenario, customer service thus represents a large portion of total costs.

As described in Chapter 3, monthly customer service costs are based on assumptions about (1) how often each subscriber calls, (2) the duration of each call, and (3) the per

minute cost to the ISP for each call. The per-subscriber customer service cost is a linear combination of these three parameters. Changing any of these parameters by a given factor will change the resulting cost by the same factor. With customer service costs being a large portion of dial-in subscribers' costs, the end results will be rather sensitive to all three of these parameters.

Figure 18 shows the results as any one of the three parameters is varied. The values are relative to the baseline scenario. Based on these results, any combination of changes in per-minute customer service costs or usage that results in a doubling of the per-user customer service costs (corresponding to the 100% increase on the chart) will result in the total cost per dial-in subscriber to increase by 35% with almost half of the costs being customer service costs.

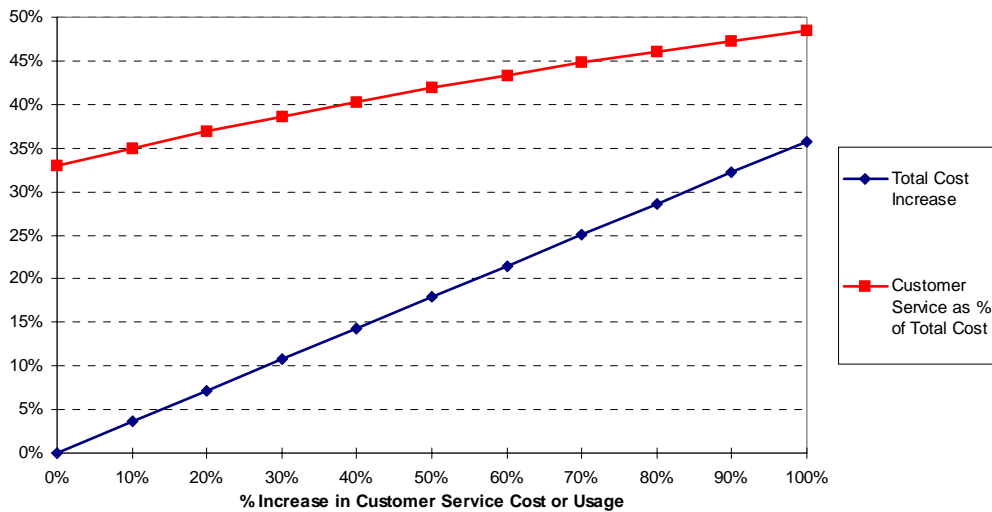


Figure 18. Dial-in Subscriber Customer Service Costs

With customer service costs being substantial in the baseline scenario and sensitive to parameter values as indicated in Figure 18, any ISP should be conscious of any factors that will influence these costs. Internet telephony is indeed one factor that could impact these costs.

With the introduction of any new application, end-users will have many issues to resolve to make the application function properly. This is certainly the case with Internet telephony where many factors – some which are beyond the end-user's direct control, like

network congestion – can influence the quality of an Internet telephone conversation. Hence, ISPs can expect an increase in customer service requests as Internet telephony is adopted. The extent to which the increase occurs depends partially on how quickly Internet telephony is adopted and on how user-friendly its applications are.

Hence, in the near term, if Internet telephony were to be adopted rather quickly, ISPs would want to do as much as possible to circumvent subscribers' calls for customer service. This could be accomplished partially by having extensive support via web servers and fax back services.

Further, adoption rates of Internet telephony are not independent of the ease of use of the software. Pervasive use of Internet telephony might only occur when it is almost as easy to use as POTS. Hence, ISPs might see their customer service costs controlled if software were user-friendly and if the quality of the calls were stable.

The cost model described in the previous chapters has been extended to two specific scenarios that are presented here. The first scenario compares an ISP's costs with Internet telephony versus the costs due to the FCC's increase in access charges. The second scenario presents an example of how ISPs could employ yield management by defining different types of dial-in services that could reduce an ISP's costs.

4. Impact of Access Charge Reform on ISP Costs

The Internet telephony scenario represents a case in which moderate use of Internet telephony creates a large cost increase to an ISP. For comparative purposes one might wonder how other changing factors would affect an ISP's costs. One such factor is the FCC's recent revamping of access charge rules.

Under the new rules ISPs will see an increase in cost of their analog dial-in lines.⁹⁶ Two principal changes cause this increase: increased subscriber line charge (SLC) and presubscribed interexchange carrier charge (PICC). The SLC goes from a cap of \$5.60

⁹⁶ While the change in cost will be specific to the LEC that serves each ISP, an average change in cost based on [FCC97c] is used when carrying out the subsequent calculations presented here.

per-line per-month to \$9.00 on Jan. 1, 1998 (although few LECs will be able to charge as high as the cap; the average has been calculated to be \$7.61), and the PICC goes from \$0.53 to \$2.75 per-line per-month. Using the average charges, the impact on ISPs (or any multi-line business) will be a \$4.23 per month increase for each analog line.⁹⁷ Plugging these updated costs into the ISP cost model yields an increase for the analog dial-in subscribers' cost for both the baseline and IT scenarios. Table 53 shows the initial results for the two scenarios compared to the results for the two scenarios with the access reform. Note that while the cost increases due to access reform, this increase is minor in comparison to the potential increase due to Internet telephony.

	BASELINE	BASELINE W/ ACCESS REFORM	IT	IT W/ ACCESS REFORM
Capital Equipment	\$2.70	\$2.70	\$3.90	\$3.90
Transport	\$2.98	\$3.44	\$5.21	\$5.86
Customer Service	\$7.50	\$7.50	\$10.80	\$10.80
Operations	\$3.07	\$3.07	\$3.27	\$3.27
Other Expenses	\$6.52	\$6.57	\$7.01	\$7.06
<i>Total</i>	\$22.77	\$23.27	\$30.19	\$30.89

Table 53. Analog Dial-in Subscriber Costs for 4 Scenarios

An alternative method of access reform could have been to implement per-minute access charges for ISPs – as proposed in the ACTA petition. The effect of such reform is shown in Figure 19. This analysis is based on the residential dial-in subscriber of the baseline scenario who spends 1233 minutes per month online (approximately 41 minutes per day). The dial-in subscriber monthly cost is displayed as the per-minute access charge is varied. The result is that access charges quickly become the dominating cost element for a dial-in subscriber. ISPs would surely have to pass this cost increase on to the end-user which would have the effect of greatly impeding the continued growth in dial-in Internet services.

⁹⁷ $(\$7.61 - \$5.60) + (\$2.75 - \$0.53) = \$4.23.$

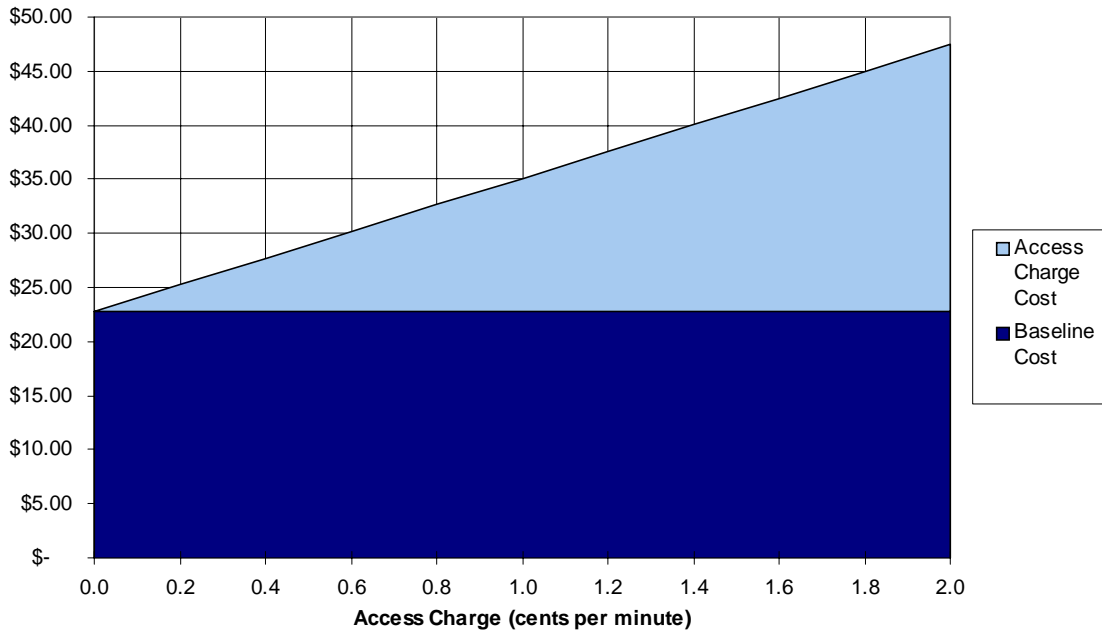


Figure 19. Access Charge Impact on Dial-in User Cost

While no cost increase is advantageous to ISPs, the recent FCC actions should be considered much less threatening than the potential impact of Internet telephony or of per-minute access charges.

5. Yield Management Example for Dial-in Subscribers

As discussed in this chapter, each type of subscriber has a unique cost distribution seen by the ISP. Recall that transport costs do not represent a large percent of dial-in subscribers' costs but do so for T1 subscribers. For the ISP to consider yield management techniques, it should take into consideration such distinctions so that the correct incentives are directed to the correct type of subscriber.

For technical costs of dial-in subscribers, modems and their associated phone lines are the two most costly elements. The goal of the yield management example presented in this section is to reduce the costs of these two items. An ISP could offer several types of dial-in accounts to control these costs, while maintaining flat-rate pricing. Currently the most popular type of dial-in account (in the United States) is a flat-rate account where the user pays a fixed amount each month (e.g. \$20) and has essentially unlimited access during the

month. Additionally, other types of dial-in accounts exist. These usually have a fixed monthly cost that includes a limited number of hours per month online. Any time spent beyond this limit is generally charged on a per-hour basis.

As an alternative to a type of account that has usage-based pricing, an ISP could define different classes of accounts, all having flat-rate pricing. For example, an ISP could define the “Gold Subscribers” as those who would have unlimited access at any time of the day, similar to current dial-in subscribers, whereas a discount class, called the “Bargain Subscribers,” would have access limited during the peak dial-in hours. For example, the Bargain Subscribers could either not be allowed access during certain peak hours or be allowed only a maximum amount of time per hour during these peak hours. Presumably, this limited time would be enough to download email, read it off-line and then send any replies. However, substantial web browsing and FTPing would have to be done during the off-peak hours.

Analysis of such a system is no longer possible with the Erlang B formula because there are multiple classes of arrivals to the system, each with potentially different holding times. A more general version of the Erlang B formula exists that can be applied to such a system as proposed here. In fact this formula is applicable to networks, not just single servers, with multiple classes of arrivals and multiple routes for each type of arrival. However, for this case, there is only one server (the modem pool), two classes of arrivals (one for the Gold Subscribers and one for the Bargain Subscribers) and a single route for each class of arrival.

The general version of the formula [RO95] is the following, where the probability of blocking a class- k call is

$$B_k = 1 - \frac{G_k}{G}$$

where G and G_k are normalization constants, defined by

$$G_k = \sum_{n \in S_k} \prod_{l=1}^2 \frac{\rho_l^{n_l}}{n_l!}$$

and

$$G = \sum_{n \in S} \prod_{k=1}^2 \frac{\rho_k^{n_k}}{n_k!}.$$

The Erlang B is a special case of this formula where there is only one class of user (i.e., $k=1$), and the state of the system is defined by a scalar representing how many modems are occupied at a given time. For the proposed example of two classes of subscribers, the state of the system (modem pool) is defined by the vector $n = (n_1, \dots, n_k)$ where n_k is the current number of calls for the class k subscriber.

S is the set of all states in which the modem pool can be, and S_k , a subset of S , is the set of states where there is remaining capacity for another call of class k . For the proposed example, all classes of arrivals require the same amount of capacity (i.e., one modem), and all classes of arrivals follow the same routes; hence, $S_1 = S_2 = S_k$ and, thus, $B_1 = B_2 = B_k$.

Solving this formula using brute calculations to determine blocking probabilities for networks is very cumbersome and potentially intractable. For studies of alternative numerical methods for solving this formula, see [RO95]. However, for the simple case of two classes, straight-forward calculation is possible. The code for doing so is included in Appendix 3.

Given the two classes of subscribers, the ultimate impact on the reduction in modems depends on how many of the current subscribers (soon to be classified as Gold Subscribers) shift to the Bargain Subscriber category, which is a function of the price that the Bargain Subscribers are being charged as well as the limit on the hours that they can access the network. To illustrate numerical results, an assumption was made that 30% of the current subscribers changed over to the Bargain Subscribers.

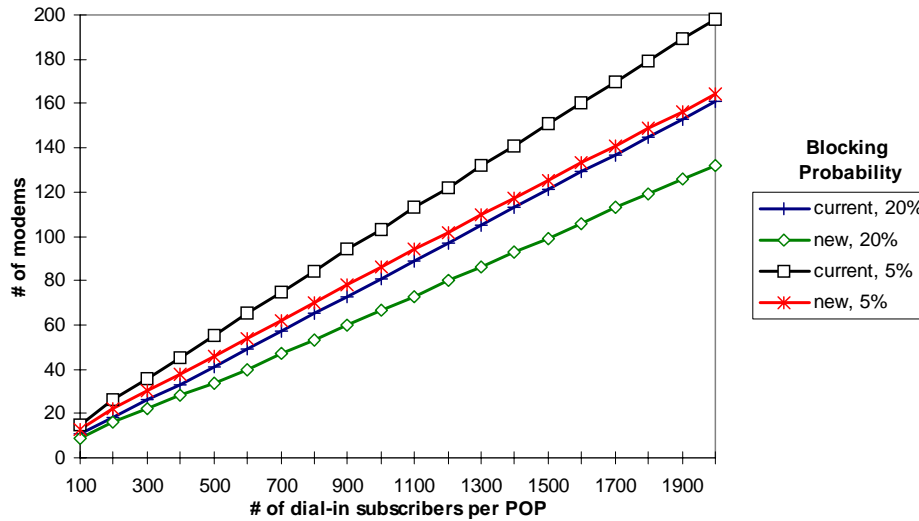


Figure 20. Modem Sizing (2)

The same analysis was done as before to size the modems, but using the general formula this time. The number of required modems was calculated to meet a certain blocking probability, specifically 5% and 20%. The results are shown in Figure 20. Note that for all values of the number of subscribers per POP, the number of modems required to maintain a 5% blocking probability for the new scenario of yield management is approximately the same as the number of modems required to maintain a 20% blocking probability for the original scenario of one class of dial-in user.

Viewing this from another perspective, Figure 21 shows how the number of subscribers per modem varies for the different scenarios. With one class of subscriber, the ISP would need roughly 9 modems per subscriber to maintain a 5% blocking probability. In the yield management scenario (and the assumptions about the holding time and take rate for the two classes), this ratio approaches 12 modems per subscriber when the number of subscribers per POP approaches 2,000. Note that according to the chart, a ratio of 12 modems per subscriber with one class of subscriber would yield a blocking probability of ~20%. From either perspective, the ISP is able to offer a better grade of service with the same amount of capital equipment, or, probably more importantly, the ISP is able to maintain a good grade of service with less capital equipment.

Of course, the reduction in capital costs would have to be weighed against the reduction in revenue to determine whether such an approach is profitable. Additional factors to consider are whether a large enough subscription to the bargain class would actually shift the peak of the access period to a time outside of what was considered the peak hours. Doing so would result in the ISP having to size its modems at a different peak while taking in less revenue – a rather counterproductive result.

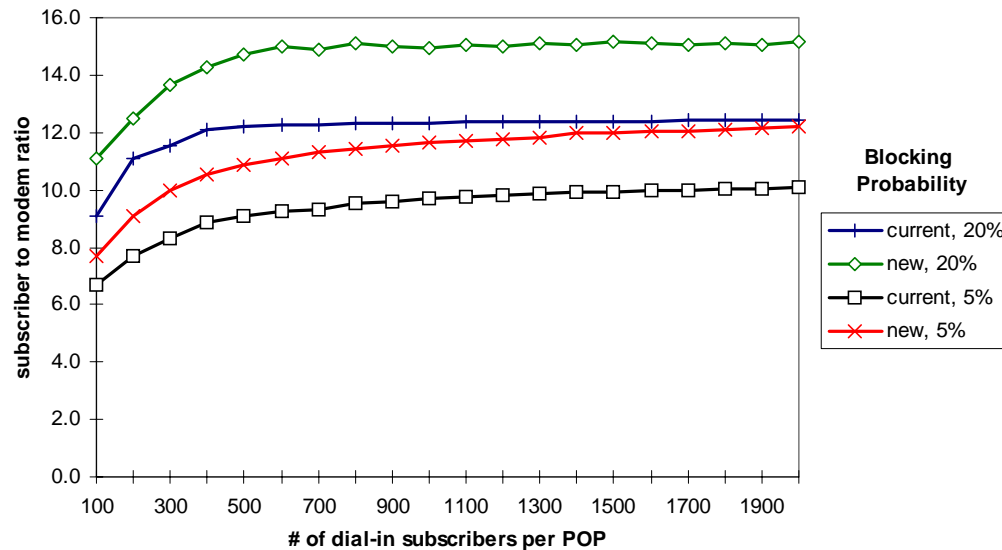


Figure 21. Subscriber to Modem Ratio (2)

A general goal of yield management is to offer incentives for users to modify their usage patterns that are beneficial to the service provider, the ISP in this case. Currently dial-in subscribers could be put in two principal groups: residential users and business users. While this distinction is not explicitly made by ISPs in the form of specific accounts for dial-in users and residential users, as is the case for telephony, these two general groups would exhibit very different usage patterns. Depending on the mix of residential and business dial-in subscribers, the ISP could see the modem traffic peaking during the day (presumably by a large number of business dial-in subscribers) or during the evening (presumably by a large number of residential subscribers).

If the mix of business and residential subscribers were such that the day and evening peaks were rather similar, then implementing the previously described yield management technique might have the result of the causing the majority of one type of dial-in

subscriber (business or residential) to shift to the bargain class. The result is that the yield management did not necessarily change user behavior. For example, if the peak modem hours were in the evening and the ISP offered the Gold and Bargain Subscriber classes, the result would be that most of the business dial-in users would become Bargain Subscribers. This is mainly due to the fact that the business peak is during the day; hence, the business subscribers can receive service at the bargain price and not necessarily change their usage patterns. Hence, the ISP must know the types of subscribers it has on its system and their usage patterns so that it can effectively segment the market before when introducing yield management techniques.

6. Chapter Summary

This chapter presented the model results for the baseline and Internet telephony scenarios. Total ISP costs as well as individual subscriber costs were presented for each scenario. In general, ISPs were found to be operating at a slightly unprofitable level, and with the introduction of Internet telephony, an ISP's costs could increase substantially making it extremely unprofitable if the ISP does nothing to recover the additional costs. Further, non-technical costs such as customer service, sales and marketing represent a large portion of an ISP's costs.

In addition to the baseline and Internet telephony scenarios, two other scenarios were presented: one considered the ISP's costs under revised access charge rules by the FCC and a second scenario considered how the modem requirements would vary with the use of yield management techniques.

The next chapter presents the conclusions of the thesis and areas for further research.

Conclusions

Results from this thesis include findings on: Internet service provider costs, impact of Internet telephony on an ISP's costs, the applicability of yield management techniques to the telecommunications industry and the policy implications of these results.

1. ISP Costs

The following results are drawn from the ISP cost model:

- Based on the subscriber mix for the baseline scenario, no particular cost category dominates the ISP's costs. Capital Equipment, Transport and Customer Service each represents a similar fraction of total costs. Additionally, the costs in each of these categories is approximately twice those in Operations and in Sales, Marketing, General and Administrative.
- Per-subscriber costs are developed for five types of ISP subscribers: 1) residential dial-in, 2) business dial-in, 3) 128 kb ISDN dial-in, 4) 56 kb leased-line, and 5) T1 leased-line. Model results show that there is a substantial contrast in cost distribution between the different types of subscribers. For example, dial-in subscribers' costs are distributed very differently across the five cost categories than T1 subscribers' costs. Most notable are the high customer service costs and low transport costs for dial-in subscribers and high transport costs and low customer service costs for T1 subscribers.
- The highest-cost technical element for dial-in subscribers is the modem. On an aggregate level modems account for 70% of total capital costs of the baseline scenario. Further, phone-line costs are directly related to modem costs. The

combination of modems and phone lines represents almost 20% of costs on a per-subscriber basis. Sensitivity analysis shows that these costs can vary substantially by varying usage levels and the number of dial-in subscribers served per modem pool. The implication of this result is that changes in user behavior – brought on, perhaps, by new Internet applications – can greatly impact the ISP's costs.

- Non-technical components represent a substantial portion of each subscriber type's costs. This portion ranges from 35% for T1 subscribers to up to more than 60% for analog dial-in subscribers. Most prevalent are the customer service, sales and marketing costs. Sensitivity analysis of customer service costs for dial-in subscribers shows that a change in call requests can greatly impact the per-user cost. From a strategy perspective, ISP's can gain a competitive advantage by controlling these costs. Extensive online support services could be used to help obviate calls to customer service, and service contracts that tie a subscriber to an ISP could help reduce the need for high marketing costs to constantly attract new subscribers.
- The ISP's cost distribution across the five cost categories will vary with the subscriber mix. Because the cost distribution for each type of subscriber varies substantially, the ISP's cost distribution will depend considerably on the relative number of each type of subscriber. Hence, the baseline scenario results of no cost category dominating the ISP's costs will change substantially if the subscriber mix is varied.

2. Internet Telephony

The initial result of the Internet telephony scenario is that the increase in the ISP's costs (42%) is double the revenue increase (19%). Hence, ISPs – many of whom are operating currently at the margin of profitability – will lose even more money without attempting to recover these additional costs. Transport costs become the largest cost category in the Internet telephony scenario – 28% of total costs. But all cost categories increase and the overall cost distribution is similar to that of the baseline scenario. The implication of this result is that Internet telephony has the potential to impact an ISP on all fronts – technical

and non-technical. New pricing techniques – such as, yield management and those found in [MC97a] – may be required for the ISP to recover the costs associated with Internet telephony.

On an individual subscriber basis, non-technical costs still remain a large portion of costs for each type of subscriber. This is especially so for dial-in subscribers where the total of customer service, sales, marketing, general and administrative costs represent approximately 60% of the per-user costs. While these non-technical costs are not the focus of this thesis, their impact can not be ignored. Obviously any ISP that can reduce these costs will gain a competitive advantage.

The ultimate impact of Internet telephony will depend of course on user behavior.⁹⁸ Sensitivity analysis showed that the dial-in subscribers' costs can vary substantially if usage patterns change. This is due to increased modem and phone line costs. Further, customer service costs for dial-in subscribers are also very sensitive. Should Internet telephony applications be difficult to install or use, ISP's will see a rise in their customer service costs.

2.1. Policy Issues for Internet Telephony

As described in the “Internet Telephony Policy” section in Chapter 1, a petition filed with the FCC by ACTA called for the regulation of ISPs and Internet telephony. Specifically, ACTA argued that ISPs providing Internet telephony services should pay access charges to the local telephone companies as do other long-distance service providers. The FCC essentially ruled against the ACTA petition in the FCC's May 1997 access-charge-reform decision by not requiring ISPs to pay per-minute access charges.⁹⁹ Instead, the FCC imposed increased, fixed charges (SLC and PICC) on each phone line for business users – ISPs included. As presented in Chapter 4, the impact on an ISP's costs of these increased charges is limited, whereas the potential impact of per-minute access charges would be significant.

⁹⁸ Work on user behavior and Internet telephony is underway within the ITC. See [OD97].

The European Commission has recently also decided against regulating Internet telephony at this time. In [EC97] the Commission has established several criteria that Internet telephony must meet before it will be subject to regulation. Currently, Internet telephony does not meet these criteria in the eyes of the Commission and, thus, is not regulated.

As Internet telephony evolves into a service that can compete directly with POTS, policy makers will continue to be challenged to not quash this nascent industry while also not permitting regulatory asymmetry. However, Internet telephony applications will also evolve into services that go beyond POTS – further complicating the policy maker’s task.

Interconnection among ISPs will also become an important issue just as it is currently with POTS providers. For example, a local ISP wanting to offer long distance telephony services will be unable to do so if quality-of-service can not be guaranteed across heterogeneous networks. Whereas, a nation-wide ISP controlling its own network can offer such guarantees. Hence standards for interconnection must be developed – much like Bellcore has done for the PSTN – and means or incentives for adhering to these standards must also exist.

3. Yield Management

Yield management is a technique that has been applied successfully to several industries to stabilize revenue in the face of highly fluctuating demand. In this thesis it is shown that many characteristics common to these industries are also shared by the telecommunications industry. Further, a yield management scenario of controlling modem costs for dial-in subscribers is presented. The conclusion of this scenario is that the costs can be reduced, but the ultimate savings rely heavily on the ISP’s understanding of its subscribers’ behavior. A careless implementation could result in no change in costs but a decrease in revenue.

Successful adoption of yield management by the telecommunications industry hinges on its understanding of the many issues – technical and non-technical – surrounding yield

⁹⁹ See [FCC97a], [FCC97b] and [FCC97c].

management. For example, service providers must be able to 1) predict accurately demand patterns, 2) segment effectively the market in various classes of service, and 3) have the flexibility to easily vary prices.

From a policy maker's perspective, extensive use of yield management in telecommunications could further complicate an already complex decision-making process. Using yield management as described, service providers could be varying prices and blocking call requests for certain types of service. Given the trend in deregulation, the policy maker would have to decide what, if any, services should remain regulated. Responsibilities for policy makers would include not only potentially regulating prices of services, but also availability of services.

4. Areas for Further Research

The ISP model is based on the transport being leased. If one believes that transport is essentially a commodity, then the transport prices should approach costs. If it is not a commodity, then ISP costs can be more accurately modeled using a facilities-based network. Here one would have to account for the installation and maintenance costs of a country-wide network. The difficulty of doing this is in finding the appropriate data for such items as trenching costs per mile, fiber and SONET equipment costs as well as an understanding of the opportunity cost of installing a network and using it for ISP services.

Alternatively, other model extensions could include additional access types such as cable modems, ADSL and wireless technologies as well as additional services such as virtual private networks and video conferencing.

The Internet telephony model could include the use of gateways as part of the Internet telephony service. One would then need to define how the services employ the gateways (i.e., who can call whom with the gateways, will traffic from other ISPs be carried, and so on). However, with or without gateways, one could also consider the impact on an ISP's costs if Internet telephony were used principally for long-distance calls versus local calls. Local calls would require the ISPs to interconnect at more points in order to reduce backhaul; whereas, current network topologies would be sufficient for long-distance calls.

Policy decisions at the federal level regarding Internet telephony have been made, but policy makers at the local and state levels must also decide whether and how to regulate Internet telephony. These policy makers might not be as concerned if Internet telephony is used principally for long distance (which is the jurisdiction of the FCC), but its use for local service will most likely cause concern. Further, these policy makers will be challenged by the multiple forms of service which Internet telephony can take and how to apply appropriate regulations to these services.

Many issues remain regarding the application of yield management to telecommunications. Models need to be developed for specific scenarios – such as, voice services on circuit-switched and packet-switched networks and video services on circuit-switched and packet-switched networks. At a high level airline analogies show similarities, but the application of airline yield management models to telecommunications is not necessarily immediate. For example, while an airplane passenger takes only one seat on one airplane during a flight, telecommunications services can concurrently occupy resources on a variable number of network links. Additional characteristics unique to telecommunications will require new models to be developed for that industry.

List of Acronyms

ATM	asynchronous transfer mode
CSU	channel service unit
DNS	domain name service
DSU	data service unit
FCC	Federal Communications Commission
IAP	Internet access provider
ISDN	integrated services digital network
IP	Internet Protocol
ISP	Internet service provider
ITC	Internet Telephony Interoperability Consortium
LAN	local area network
MAE	metropolitan area ethernet
NAP	network access point
PICC	Presubscribed Interexchange Carrier Charge
POP	point-of-presence
POTS	plain old telephone service
PSTN	public switched telephone network
PVC	permanent virtual circuit
RPCP	Research Program on Communications Policy
RSVP	Resource Reservation Protocol
RTP	Real Time Protocol
SVC	switched virtual circuit
SLC	Subscriber Line Charge
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
YM	yield management

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Network Loss and Erlang B Formulae

1. General Network Loss Formula

The following code returns the blocking probability for the network loss formula, specifically for the case of two service classes, a single route and single unit of capacity required per arrival of either class. As mentioned previously, because of the specific conditions, the blocking probability for each of the two classes is the same. Hence, the same formula can be used for both classes.

```
Function BlockProb(c As Integer, p1 As Double, p2 As Double) As Double
Dim top As Double
Dim bot As Double
Dim i As Integer
Dim j As Integer
'
top = 0
bot = 0
For i = 0 To c
    j = c - i
    If (i <> 0) And (j <> 0) Then
        top = top + Exp(i * Log(p1) + j * Log(p2) - 0.5 * Log(i) - 0.5 *
Log(j) - i * Log(i) - j * Log(j) + i + j - Log(6.2832))
    ElseIf i = 0 Then
        top = top + Exp(j * Log(p2) - 0.5 * Log(j) - j * Log(j) + j - 0.5 *
Log(6.2832))
    ElseIf j = 0 Then
        top = top + Exp(i * Log(p1) - 0.5 * Log(i) - i * Log(i) + i - 0.5 *
Log(6.2832))
    End If
Next i
For i = 0 To c
    For j = 0 To c - i
        If (i <> 0) And (j <> 0) Then
            bot = bot + Exp(i * Log(p1) + j * Log(p2) - 0.5 * Log(i) - 0.5 *
Log(j) - i * Log(i) - j * Log(j) + i + j - Log(6.2832))
        ElseIf (i = 0) And (j <> 0) Then
            bot = bot + Exp(j * Log(p2) - 0.5 * Log(j) - j * Log(j) + j -
0.5 * Log(6.2832))
        ElseIf (i <> 0) And (j = 0) Then
            bot = bot + Exp(i * Log(p1) - 0.5 * Log(i) - i * Log(i) + i -
0.5 * Log(6.2832))
        Else
            bot = bot + 1
        End If
    Next j
Next i
BlockProb = top / bot
End Function
```

The following code uses the above function to find the appropriate number of channels (modems) given the offered traffic for each service class and the blocking probability.

```
Function BPSlv(BlockPb As Double, p1 As Double, p2 As Double) As Integer
Dim c As Integer
Dim oldc As Integer
Dim temp As Integer
Dim try As Double
'
try = 1
c = Abs((p1 + p2) * (1 - BlockPb))
oldc = temp = 0
While (Abs(try - BlockPb) > 0.3 * BlockPb)
    try = BlockProb(c, p1, p2)
    If try > BlockPb Then
        c = c + 1
    ElseIf try < BlockPb Then
        c = c - 1
    End If
Wend
BPSlv = c
End Function
```

2. Erlang B Formula

The Erlang B is a special case of the general network loss formula where there is only one service class. Instead of using the general network loss formula, which is computationally intensive, the Erlang B can be more easily calculated. As described in the modem section in Chapter 3, the Erlang B formula is the following:

$$ErlangB(c, \rho) = \frac{\frac{\rho^c}{c!}}{\sum_{k=0}^c \frac{\rho^k}{k!}}$$

The function for the Erlang B is modified from the above formula because of the computational limits of the PC. However, even with the modifications values too large will still cause the macro to overflow. Stirling's approximation for factorials¹⁰⁰ is used along with manipulations of exponential and natural logarithm functions to yield the following equation for the Erlang B:

$$ErB(c, \rho) = e^{[\ln(c^{-0.5}) + c * (1 + \ln(\rho) - \ln(c)) - c - \ln(e^{-c} + \sum_{i=1}^c i^{-0.5} * e^{i * (1 + \ln(\rho) - \ln(i) - c)})]}$$

The corresponding code for the above formula is the following:

```
Function ErB(c As Integer, p As Double) As Double
Dim numerator As Double
Dim series As Double
Dim Fucn As Double
Dim i As Integer
,
series = 0
For i = 1 To c
    series = series + i ^ (-0.5) * Exp(i * (1 + Log(p) - Log(i)) -
Fucn(c))
Next i
    ErB = Exp(Log(c ^ (-0.5)) + c * (1 + Log(p) - Log(c)) - Fucn(c) -
    Log(Exp(-Fucn(c)) + series))
End Function
,
```

Fucn(c) is a user-determined function that can be modified to prevent the computer from overflowing. The following formula is used.

```
Function Fucn(l As Integer) As Double
Fucn = l ^ 1 / 2
End Function
```

¹⁰⁰ $x! \approx stir(x) = \sqrt{2\pi x} * e^{x * \ln(x) - x}$

The following code uses the Erlang B function to find the appropriate number of channels (modems) given the offered traffic for the single service class and the blocking probability.

```
Function ErBSlv(BlockProb As Double, trafficload As Double) As Integer
Dim c As Integer
Dim try As Double
Dim inc As Boolean
Dim dec As Boolean
'
try = 1
c = Abs(trafficload * (1 - blockprob))
inc = False
dec = False
While ((Abs(try - blockprob) > 0.3 * blockprob) And (Not (inc And dec)))
    try = ErB(c, trafficload)
    If try > blockprob Then
        c = c + 1
        inc = True
    ElseIf try < blockprob Then
        c = c - 1
        dec = True
    End If
Wend
ErBSlv = c
End Function
'
```

Appendix Four

Cost Model Tables: User Inputs

User Inputs

This worksheet shows all user-modifiable inputs. Values in italics are computed; do not change these.
 You may change values in blue and then set the "use default" option to "N" to see the effect of the change on the outputs.

Input Name	Scenario Without Internet Telephony				Scenario With Internet Telephony		
	Default (from mod)	Manual (from user)	Use Default (Y or N)	Input	Manual (from user)	Use other scenario input (Y or N)	Input
Geographic							
# of Tier2 POPs	9			9			9
# of Tier1 POPs / Tier2 POP	50	50	Y	50			50
# of Tier1 POPs				450			450
# of NAP Interconnection points	3			3			3
Tier1 POP avg. population	500,000	500,000	Y	500,000			500,000
Tier2 POP avg. population	2,000,000	2,000,000	Y	2,000,000			2,000,000
avg. dist. Tier1 POP to Tier2 POP (miles)	75	75	Y	75			75
avg. E/W dist. between 2 Tier2 POPs	1500	1500	Y	1500			1500
avg. N/S dist. between 2 Tier2 POPs	500	500	Y	500			500
avg. dist. from POP to closest central office (miles)	1.0	1.0	Y	1.0			1.0
distance to NAP from closest Tier 2 POP	5	5	Y	5			5
Market Profile							
Residential							
ratio of people/household	2.6	2.6	Y	2.6			2.6
% of households with analog dial-in service	10.0%	10.0%	Y	10.0%			10%
ISP market share of analog dial-in users	10.0%	0.0%	Y	10.0%			10%
Business							
ratio of on-line households to on-line businesses	65	65	Y	65			65
% of on-line businesses with dial-in service	25.0%	25.0%	Y	25.0%			25%
% of on-line businesses with ISDN service	25.0%	25.0%	Y	25.0%			25%
% of on-line businesses with 56K service	10.0%	10.0%	Y	10.0%			10%
% of on-line businesses with T1 service	40.0%	40.0%	Y	40.0%			40.0%
ISP market share of bus. dial-in users	10.0%	0.0%	Y	10.0%			10%
ISP market share of bus. ISDN service	10.0%	0.0%	Y	10.0%			10%
ISP market share of bus. 56K users	10.0%	0.0%	Y	10.0%			10%
ISP market share of bus. T1 users	10.0%	0.0%	Y	10.0%			10%
Content Hosting							
% bus. dial-in subscribers w/ basic Web hosting	0%	0%	Y	0%			0%
% bus. dial-in subscribers w/ enhanced Web hosting	0%	0%	Y	0%			0%
% 56K subscribers w/ basic Web hosting	0%	0%	Y	0%			0%
% 56K subscribers w/ enhanced Web hosting	0%	0%	Y	0%			0%
% T1 subscribers w/ basic Web hosting	0%	0%	Y	0%			0%
% T1 subscribers w/ enhanced Web hosting	0%	0%	Y	0%			0%
Service Prices							
monthly residential dial-in	\$20	\$20	Y	\$20	\$20	Y	\$20
monthly business dial-in	\$20	\$20	Y	\$20	\$20	Y	\$20
monthly ISDN	\$100	\$100	Y	\$100	\$100	Y	\$100
monthly 56k	\$500	\$500	Y	\$500	\$500	Y	\$500
monthly T1	\$1,200	\$1,200	Y	\$1,200	\$2,100	Y	\$1,200
basic content hosting	\$0	\$0	Y	\$0	\$100	Y	\$0
enhanced content hosting	\$0	\$0	Y	\$0	\$3,000	Y	\$0
currency conversion multiplier	1	1	Y	1			1
Internet Telephony Assumptions							
Internet telephony b/w increase vs. Web b/w					300%		300%
% using telephony (compared to Web)					33%		33%

Capital Equipment (cost installed)						
round up lumpy quantities (transport and related capital eqpt.)?	N	N	Y	N		N
Discount factor (received from vendors for bulk purchase)	30%	30%	Y	30%		30%
concurrent analog dial-in users per POP server	2000	2000	Y	2000		2000
concurrent ISDN dial-in users per POP server	2000	2000	Y	2000		2000
# of 56 kb businesses per POP server	1000	1000	Y	1000		1000
# of T1 businesses per POP server	1000	1000	Y	1000		1000
48 port analog modem banks	\$42,000	\$42,000	Y	\$42,000		\$42,000
economic life (months)	36	36	Y	36		36
Ascend Max 4004 access router w/ ISDN software	\$18,000	\$18,000	Y	\$18,000		\$18,000
# of B channels per 4004	92	92	Y	92		92
economic life (months)	36	36	Y	36		36
blocking probability for sizing # of modems	1.00%	1.00%	Y	1.00%		1.00%
POP server (Web/news/email)	\$25,000	\$25,000	Y	\$25,000		\$25,000
economic life (months)	36	36	Y	36		36
Content Hosting server	\$10,000	\$10,000	Y	\$10,000		\$10,000
economic life (months)	36	36	Y	36		36
10 Mbps ethernet switch per port	\$100	\$100	Y	\$100		\$100
economic life (months)	36	36	Y	36		36
100 Mbps ethernet switch per port	\$500	\$500	Y	\$500		\$500
economic life (months)	36	36	Y	36		36
56 kb CSU/DSU	\$500	\$500	Y	\$500		\$500
economic life (months)	36	36	Y	36		36
T1 CSU/DSU	\$1,400	\$1,400	Y	\$1,400		\$1,400
economic life (months)	36	36	Y	36		36
Cisco 2500 router	\$2,800	\$2,800	Y	\$2,800		\$2,800
economic life (months)	36	36	Y	36		36
8 port serial card for Cisco 7513, CX-FSIP8	\$16,000	\$16,000	Y	\$16,000		\$16,000
economic life (months)	36	36	Y	36		36
# of serial ports per card	8	8	Y	8		8
ATM adapter card for Cisco 7513, CX-AIP-DS3	\$18,000	\$18,000	Y	\$18,000		\$18,000
economic life (months)	36	36	Y	36		36
Cisco 7513 router chassis w/ fast ethernet card	\$60,000	\$60,000	Y	\$60,000		\$60,000
economic life (months)	36	36	Y	36		36
# of available slots per chassis	9	9	Y	9		9
Fore 4 port DS3 card	\$14,000	\$14,000	Y	\$14,000		\$14,000
economic life (months)	36	36	Y	36		36
# of DS3 ports per card	4	4	Y	4		4
Fore 4 port OC-3 card	\$14,000	\$14,000	Y	\$14,000		\$14,000
economic life (months)	36	36	Y	36		36
# of OC-3 ports per card	4	4	Y	4		4
Fore ASX-200BX ATM switch chassis	\$16,000	\$16,000	Y	\$16,000		\$16,000
economic life (months)	36	36	Y	36		36
# of slots per switch	4	4	Y	4		4
Transport						
% capacity at which to operate transport	70%	70%	Y	70%		70%
56 kb capacity (kbps)	56	56	Y	56		56
T1 capacity (Mbps)	1.5	1.5	Y	1.5		1.5
T3 capacity (Mbps)	44.2	44.2	Y	44.2		44.2
OC-3 capacity (Mbps)	150	150	Y	150		150
% O-D pairs found on ISP's network	10%	10%	Y	10%		10%
% Tier 1 traffic destined for Tier 2	11%	11%	Y	11%	11%	Y
% Tier 1 traffic destined for backbone	89%	89%	Y	89%	89%	Y
% Tier 2 traffic destined for backbone	89%	89%	Y	89%	89%	Y
% backbone traffic going 1 node distance	25%	25%	Y	25%	25%	Y
% backbone traffic going 2 node distance	25%	25%	Y	25%	25%	Y
% backbone traffic going 3 node distance	25%	25%	Y	25%	25%	Y
% backbone traffic going 4 node distance	25%	25%	Y	25%	25%	Y
NAP monthly interconnection charges						
cost per DS-3 port	\$5,500	\$5,500	Y	\$5,500	\$5,500	Y
cost per OC-3 port	\$8,000	\$8,000	Y	\$8,000	\$8,000	Y
T1 - analog dial-in lines						
\$ per month (fixed)	\$370	\$370	Y	\$370		\$370
\$ per mile per month	\$48	\$48	Y	\$48		\$48
ISDN PRI - digital dial-in lines						
\$ per month (fixed)	\$548	\$548	Y	\$548		\$548
\$ per mile per month	\$48	\$48	Y	\$48		\$48
T1 (data)						
\$ per month (fixed)	\$3,225	\$3,225	Y	\$3,225		\$3,225
\$ per mile per month	\$3.85	\$3.85	Y	\$3.85		\$3.85

T3							
\$ per month (fixed)	\$22,000	\$22,000	Y	\$22,000			\$22,000
\$ per mile per month	\$50	\$50	Y	\$50			\$50
OC-3							
\$ per month (fixed)	\$55,000	\$55,000	Y	\$55,000			\$55,000
\$ per mile per month	\$125	\$125	Y	\$125			\$125
Bulk transport discount (monthly cost)							
\$0 - \$25,000	10%	10%	Y	10%	10%	Y	10%
\$25,001 - \$100,000	20%	20%	Y	20%	20%	Y	20%
\$100,001 - \$200,000	25%	25%	Y	25%	25%	Y	25%
\$200,001 - \$350,000	35%	35%	Y	35%	35%	Y	35%
\$350,001 - \$500,000	45%	45%	Y	45%	45%	Y	45%
\$500,001 +	50%	50%	Y	50%	50%	Y	50%
Customer Service							
residential dial-in customer service							
calls/month/customer	0.25	0.25	Y	0.25	0.30	n	0.30
minutes/call	15	15	Y	15	18	n	18
cost/min	\$2.00	\$2.00	Y	\$2.00	\$1.50	Y	\$2.00
business dial-in customer service							
calls/month/business	0.25	0.25	Y	0.25	0.30	n	0.30
minutes/call	15	15	Y	15	18	n	18
cost/min	\$2.00	\$2.00	Y	\$2.00	\$1.50	Y	\$2.00
ISDN customer service							
calls/month/business	0.25	0.25	Y	0.25	0.30	n	0.30
minutes/call	15	15	Y	15	18.00	n	18
cost/min	\$2.00	\$2.00	Y	\$2.00	\$2.40	Y	\$2.00
56 kb customer service							
calls/month/customer	2	2	Y	2	2.4	n	2.40
minutes/call	15	15	Y	15	18	n	18
cost/min	\$4.00	\$4.00	Y	\$4.00	\$1.50	Y	\$4.00
T1 dial-in customer service							
calls/month/business	2	2	Y	2	2.4	n	2.40
minutes/call	15	15	Y	15	18	n	18
cost/min	\$4.00	\$4.00	Y	\$4.00	\$1.50	Y	\$4.00
basic Web hosting customer service							
calls/month/customer	0	0	Y	0	0.00	y	0.00
minutes/call	0	0	Y	0	0	y	0
cost/min	\$0.00	\$0.00	Y	\$0.00	\$0.00	Y	\$0.00
enhanced Web hosting customer service							
calls/month/business	0	0	Y	0	0	y	0
minutes/call	0	0	Y	0	0	y	0
cost/min	\$0.00	\$0.00	Y	\$0.00	\$0.00	Y	\$0.00
Operations							
network operations							
SW/HW maint. (% of equipment costs)	20%	20%	Y	20%	20%	Y	20%
# of Tier 1 POPs/Operations persons	1.7	1.7	Y	1.7	1.7	Y	1.7
# of Tier 2 POPs/Operations persons	0.5	0.5	Y	0.5	0.5	Y	0.5
ops person's salary	\$50,000	\$50,000	Y	\$50,000	\$50,000	Y	\$50,000
web hosting operations							
# of basic sites / web person	0	0	Y	0			0
# of enhanced / web person	0	0	Y	0			0
web person's salary	\$0	\$0	Y	\$0			\$0
facilities							
\$ per Tier 1 POP per month	\$830	\$500	Y	\$830	\$830	Y	\$830
\$ per Tier 2 POP per month	\$4,125	\$4,125	Y	\$4,125	\$4,125	Y	\$4,125
billing and collections							
residential dial-in subs.	\$1.25	\$1.25	Y	\$1.25	\$1.25	Y	\$1.25
business dial-in subs.	\$1.25	\$1.25	Y	\$1.25	\$1.25	Y	\$1.25
ISDN dial-in subs.	\$1.25	\$1.25	Y	\$1.25	\$1.25	Y	\$1.25
56 kb subs.	\$1.25	\$1.25	Y	\$1.25	\$1.25	Y	\$1.25
T1 subs.	\$1.25	\$1.25	Y	\$1.25	\$1.25	Y	\$1.25
basic Web hosting subs.	\$1.25	\$1.25	Y	\$1.25	\$1.25	Y	\$1.25
enhanced Web hosting subs.	\$1.25	\$1.25	Y	\$1.25	\$1.25	Y	\$1.25
Other Expenses							
sales and marketing (% rev)	20%	20%	Y	20%	20%	Y	20%
general and admin (% costs)	11%	11%	Y	11%	11%	Y	11%
Cost of Capital Factors							
Debt Percent	30.0%	30.0%	Y	30.0%			30.0%
Cost of Debt	9.0%	9.0%	Y	9.0%			9.0%
Cost of Equity	25.0%	25.0%	Y	25.0%			25.0%
Cost of Capital	20.2%	26.0%	Y	20.2%			20.2%

Residential dial-in user profile							
avg. downstream bandwidth per user being 100% active (kbps.)	5.0	5.0	Y	5.0			8.3
% active (applies to all analog and ISDN dial-in)	100%	100%	Y	100%	100%	n	100%
effective avg. bandwidth per user				5.0			8.3
avg. holding time (minutes)	30	30	n	30	36	n	36
# of residential subs per Tier 1 POP				1923			1923
# of residential subs per Tier 2 POP				7692			7692
% of subscribers requesting service during given hour:							
12:00 AM	4%	0%	Y	4%	5%	n	5%
1:00 AM	2%	0%	Y	2%	2%	n	2%
2:00 AM	1%	0%	Y	1%	1%	n	1%
3:00 AM	0%	0%	Y	0%	0%	n	0%
4:00 AM	0%	0%	Y	0%	0%	n	0%
5:00 AM	0%	0%	Y	0%	0%	n	0%
6:00 AM	0%	0%	Y	0%	0%	n	0%
7:00 AM	2%	0%	Y	2%	2%	n	2%
8:00 AM	2%	0%	Y	2%	2%	n	2%
9:00 AM	2%	0%	Y	2%	2%	n	2%
10:00 AM	1%	0%	Y	1%	1%	n	1%
11:00 AM	1%	0%	Y	1%	1%	n	1%
12:00 PM	1%	30%	Y	1%	1%	n	1%
1:00 PM	1%	0%	Y	1%	1%	n	1%
2:00 PM	2%	0%	Y	2%	2%	n	2%
3:00 PM	6%	0%	Y	6%	7%	n	7%
4:00 PM	8%	0%	Y	8%	10%	n	10%
5:00 PM	10%	0%	Y	10%	12%	n	12%
6:00 PM	12%	0%	Y	12%	14%	n	14%
7:00 PM	12%	0%	Y	12%	14%	n	14%
8:00 PM	15%	0%	Y	15%	18%	n	18%
9:00 PM	20%	0%	Y	20%	24%	n	24%
10:00 PM	20%	0%	Y	20%	24%	n	24%
11:00 PM	15%	0%	Y	15%	18%	n	18%
average % of subscriber access				6%			7%
Business dial-in user profile							
effective avg. bw per user (kbps.)-must be same as for res. dial-in				5.0			8.3
avg. holding time (minutes)-must be same as for res. dial-in				30			36
# of business dial-in subs per Tier 1 POP				7			7
# of business dial-in subs per Tier 2 POP				30			30
% of subscribers requesting service during given hour:							
12:00 AM	0%	0%	Y	0%	0%	n	0%
1:00 AM	0%	0%	Y	0%	0%	n	0%
2:00 AM	0%	0%	Y	0%	0%	n	0%
3:00 AM	0%	0%	Y	0%	0%	n	0%
4:00 AM	0%	0%	Y	0%	0%	n	0%
5:00 AM	0%	0%	Y	0%	0%	n	0%
6:00 AM	2%	2%	Y	2%	2%	n	2%
7:00 AM	4%	4%	Y	4%	5%	n	5%
8:00 AM	10%	10%	Y	10%	12%	n	12%
9:00 AM	12%	12%	Y	12%	14%	n	14%
10:00 AM	15%	15%	Y	15%	18%	n	18%
11:00 AM	20%	20%	Y	20%	24%	n	24%
12:00 PM	15%	15%	Y	15%	18%	n	18%
1:00 PM	10%	10%	Y	10%	12%	n	12%
2:00 PM	15%	15%	Y	15%	18%	n	18%
3:00 PM	20%	20%	Y	20%	24%	n	24%
4:00 PM	15%	15%	Y	15%	18%	n	18%
5:00 PM	12%	12%	Y	12%	14%	n	14%
6:00 PM	6%	6%	Y	6%	7%	n	7%
7:00 PM	3%	3%	Y	3%	4%	n	4%
8:00 PM	1%	1%	Y	1%	1%	n	1%
9:00 PM	1%	1%	Y	1%	1%	n	1%
10:00 PM	0%	0%	Y	0%	0%	n	0%
11:00 PM	0%	0%	Y	0%	0%	n	0%
average % of subscriber access				7%			8%

ISDN dial-in user profile							
ratio of per user ISDN bw to per user dial-in bw	500%	500%	Y	500%	500%	n	500%
effective avg. bw per user (kbps.)				25.0			41.5
avg. holding time (minutes)	30	30	Y	30	36	n	36
# of business dial-in subs per Tier 1 POP				7			7
# of business dial-in subs per Tier 2 POP				30			30
% of subscribers requesting service during given hour:							
12:00 AM	0%	0%	Y	0%	0%	n	0%
1:00 AM	0%	0%	Y	0%	0%	n	0%
2:00 AM	0%	0%	Y	0%	0%	n	0%
3:00 AM	0%	0%	Y	0%	0%	n	0%
4:00 AM	0%	0%	Y	0%	0%	n	0%
5:00 AM	0%	0%	Y	0%	0%	n	0%
6:00 AM	2%	2%	Y	2%	2%	n	2%
7:00 AM	4%	4%	Y	4%	5%	n	5%
8:00 AM	10%	10%	Y	10%	12%	n	12%
9:00 AM	12%	12%	Y	12%	14%	n	14%
10:00 AM	15%	15%	Y	15%	18%	n	18%
11:00 AM	20%	20%	Y	20%	24%	n	24%
12:00 PM	10%	10%	Y	10%	12%	n	12%
1:00 PM	12%	12%	Y	12%	14%	n	14%
2:00 PM	15%	15%	Y	15%	18%	n	18%
3:00 PM	20%	20%	Y	20%	24%	n	24%
4:00 PM	15%	15%	Y	15%	18%	n	18%
5:00 PM	12%	12%	Y	12%	14%	n	14%
6:00 PM	6%	6%	Y	6%	7%	n	7%
7:00 PM	3%	3%	Y	3%	4%	n	4%
8:00 PM	1%	1%	Y	1%	1%	n	1%
9:00 PM	1%	1%	Y	1%	1%	n	1%
10:00 PM	0%	0%	Y	0%	0%	n	0%
11:00 PM	0%	0%	Y	0%	0%	n	0%
average % of subscriber access				7%			8%
56 kb user profile							
# of 56 kb subs per Tier 2 POP				160			160
Number of leased lines / business	1	1	Y	1			1.66
% that leased line is full during given hour							
12:00 AM	5%	1%	Y	5%			5%
1:00 AM	5%	5%	Y	5%			5%
2:00 AM	5%	5%	Y	5%			5%
3:00 AM	5%	5%	Y	5%			5%
4:00 AM	5%	5%	Y	5%			5%
5:00 AM	5%	5%	Y	5%			5%
6:00 AM	5%	5%	Y	5%			5%
7:00 AM	10%	10%	Y	10%			10%
8:00 AM	30%	30%	Y	30%			30%
9:00 AM	50%	50%	Y	50%			50%
10:00 AM	70%	70%	Y	70%			70%
11:00 AM	70%	70%	Y	70%			70%
12:00 PM	70%	70%	Y	70%			70%
1:00 PM	70%	70%	Y	70%			70%
2:00 PM	70%	70%	Y	70%			70%
3:00 PM	60%	60%	Y	60%			60%
4:00 PM	60%	60%	Y	60%			60%
5:00 PM	50%	50%	Y	50%			50%
6:00 PM	50%	50%	Y	50%			50%
7:00 PM	40%	40%	Y	40%			40%
8:00 PM	30%	30%	Y	30%			30%
9:00 PM	30%	30%	Y	30%			30%
10:00 PM	20%	20%	Y	20%			20%
11:00 PM	10%	10%	Y	10%			10%
average % that leased lin is full				34%			34%

T1 user profile						
# of T1 subs per Tier 2 POP					639	639
Number of leased lines / business	1	1	Y		1	1.66
% that leased line is full during given hour						
12:00 AM	5%	0%	Y		5%	5%
1:00 AM	5%	0%	Y		5%	5%
2:00 AM	5%	0%	Y		5%	5%
3:00 AM	5%	0%	Y		5%	5%
4:00 AM	5%	0%	Y		5%	5%
5:00 AM	5%	0%	Y		5%	5%
6:00 AM	5%	0%	Y		5%	5%
7:00 AM	10%	0%	Y		10%	10%
8:00 AM	30%	0%	Y		30%	30%
9:00 AM	50%	0%	Y		50%	50%
10:00 AM	70%	0%	Y		70%	70%
11:00 AM	70%	0%	Y		70%	70%
12:00 PM	70%	100%	Y		70%	70%
1:00 PM	70%	0%	Y		70%	70%
2:00 PM	70%	0%	Y		70%	70%
3:00 PM	60%	0%	Y		60%	60%
4:00 PM	60%	0%	Y		60%	60%
5:00 PM	50%	0%	Y		50%	50%
6:00 PM	50%	0%	Y		50%	50%
7:00 PM	40%	0%	Y		40%	40%
8:00 PM	30%	0%	Y		30%	30%
9:00 PM	30%	0%	Y		30%	30%
10:00 PM	20%	0%	Y		20%	20%
11:00 PM	10%	0%	Y		10%	10%
average % that leased lin is full					34%	34%
Basic Web Hosting						
# of basicWeb hosting subs per Tier 2 POP	0	0	Y		0	0
# of basic subscribers per server	0	0	Y		0	0
Enhanced Web Hosting						
# of enhanced Web hosting subs per Tier 2 POP	0	0	Y		0	0
# of enhanced subscribers per server	0	0	Y		0	0

Cost Model Tables: Model Outputs

Regional ISP - without Internet Telephony

Market Summary			
Population of Tier 1 Region	500,000 people	Area of Region Served	3,000,000 sq. mi.
Population of Tier 2 Region	2,000,000 people	Total Population of Region	243,000,000 people
# of Tier 1 POPs	450	Avg. Population Density	81 /sq.mi.
# of Tier 2 POPs	9	Total # of Businesses	3,738,462
Subscriber type:	# per Tier 1 POP:	# per Tier 2 POP:	Total (all POPs):
res. dial-in	1,923	7,692	934,615
bus. dial-in	7	30	3,595
ISDN dial-in	7	30	3,595
56 kb	-	160	1,438
T1	-	639	5,751
basic Web hosting	-	-	-
enhanced Web hosting	-	-	-
			Total # of Subscribers
			948,994

Monthly Revenue	# lines/sub	Quantity	Price	Revenue	% revenue
residential dial-in		934,615	\$ 20	\$ 18,692,000	70.01%
business dial-in		3,595	\$ 20	\$ 72,000	0.27%
ISDN dial-in		3,595	\$ 100	\$ 359,000	1.34%
56 kb	1	1,438	\$ 500	\$ 719,000	2.69%
T1	1	5,751	\$ 1,200	\$ 6,902,000	25.85%
basic Web hosting		-	\$ -	\$ -	0%
enhanced Web hosting		-	\$ -	\$ -	0%
Total Revenue				\$ 26,700,000	100%

Monthly Costs - Scenario without Internet telephony

Category	Quantity	Unit Cost	Cost	% cost	% allocation					\$/subscriber												
					res.	bus.	ISDN	56 kb	T1	basic host.	enh. host.	res.	bus.	ISDN	56 kb	T1	basic host.	enh. host.				
Capital Equipment																						
analog modems	102996	\$ 23	\$ 2,351,000	70%	100%	0%	0%	0%	0%	0%	0%	0%	\$ 2.50	\$ 2.94	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -		
ISDN access router	3726	\$ 5	\$ 19,000	1%	0%	0%	100%	0%	0%	0%	0%	0%	-	-	\$ 5.29	-	-	-	-	-		
POP server	60	\$ 652	\$ 39,000	1%	86%	0.4%	2%	2%	10%	0%	0%	\$ 0.04	\$ 0.04	\$ 0.17	\$ 0.65	\$ 0.65	\$ -	\$ -	\$ -	\$ -		
content hosting server	0	\$ 261	\$ -	0%	0%	0%	0%	0%	0%	0%	0%	-	-	-	-	-	-	-	-	-		
LAN - 10 Mbps ethernet	3150	\$ 3	\$ 8,000	0%	97%	0%	2%	0%	0%	0%	0%	\$ 0.01	\$ 0.01	\$ 0.05	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -		
LAN - 100 Mbps ethernet	170	\$ 13	\$ 2,000	0%	93%	0%	1%	0%	1%	0%	0%	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.00	\$ -	\$ -	\$ -	\$ -		
56 kb CSU/DSU	1438	\$ 13	\$ 19,000	1%	0%	0%	0%	100%	0%	0%	0%	-	-	-	\$ 13.21	-	-	-	-	-		
T1 CSU/DSU	6704	\$ 37	\$ 245,000	7%	14%	0%	0%	0%	86%	0%	0%	\$ 0.04	\$ 0.04	\$ 0.21	\$ -	\$ 36.55	\$ -	\$ -	\$ -	\$ -		
Cisco 2500 router	450	\$ 73	\$ 33,000	1%	97%	0%	2%	0%	0%	0%	0%	\$ 0.03	\$ 0.04	\$ 0.20	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -		
Cisco 7513 serial port card	958	\$ 417	\$ 400,000	12%	11%	0%	0%	19%	70%	0%	0%	\$ 0.05	\$ 0.06	\$ 0.28	\$ 52.18	\$ 48.48	\$ -	\$ -	\$ -	\$ -		
Cisco 7513 ATM card	106	\$ 470	\$ 50,000	1%	11%	0%	0%	19%	70%	0%	0%	\$ 0.01	\$ 0.01	\$ 0.03	\$ 6.52	\$ 6.06	\$ -	\$ -	\$ -	\$ -		
Cisco 7513 router chassis	106	\$ 1,565	\$ 167,000	5%	11%	0%	0%	19%	70%	0%	0%	\$ 0.02	\$ 0.02	\$ 0.12	\$ 21.79	\$ 20.24	\$ -	\$ -	\$ -	\$ -		
Fore 4 port DS3 card	0	\$ 365	\$ -	0%	4%	0%	0%	1%	95%	0%	0%	-	-	-	-	-	-	-	-	-		
Fore 4 port OC-3 card	34	\$ 365	\$ 12,000	0%	4%	0%	0%	1%	95%	0%	0%	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.07	\$ 1.98	\$ -	\$ -	\$ -	\$ -		
Fore ASX-200BX ATM switch chassis	9	\$ 417	\$ 4,000	0%	4%	0%	0%	1%	95%	0%	0%	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.02	\$ 0.66	\$ -	\$ -	\$ -	\$ -		
Total capital equipment costs				\$ 3,349,000	100%	75%	0%	1%	4%	20%	0%	0%	\$ 2.70	\$ 3.17	\$ 6.35	\$ 94.45	\$ 114.62	\$ -	\$ -	\$ -	\$ -	
Transport																						
analog dial-in T1 (# of T1 lines)	4292	\$	\$ 1,794,000	25%	100%	0%	0%	0%	0%	0%	0%	\$ 1.91	\$ 2.25	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -		
ISDN dial-in PRI (# of PRI lines)	162	\$	\$ 97,000	1%	0%	0%	100%	0%	0%	0%	0%	-	-	\$ 26.98	-	-	-	-	-	-		
T1 transport		\$	\$ 837,000	12%	97%	0%	2%	0%	0%	0%	0%	\$ 0.87	\$ 1.03	\$ 5.03	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -		
NAP Interconnection cost		\$	\$ 431,000	6%	4%	0%	0%	1%	95%	0%	0%	\$ 0.02	\$ 0.02	\$ 0.11	\$ 2.53	\$ 71.17	\$ -	\$ -	\$ -	\$ -		
T3/OC-3 transport		\$	\$ 4,083,000	56%	4%	0%	0%	1%	95%	0%	0%	\$ 0.18	\$ 0.21	\$ 1.03	\$ 24.00	\$ 674.21	\$ -	\$ -	\$ -	\$ -		
Total transport costs				\$ 7,242,000	100%	38%	0%	2%	1%	59%	0%	0%	\$ 2.98	\$ 3.50	\$ 33.15	\$ 26.54	\$ 745.38	\$ -	\$ -	\$ -	\$ -	
Customer Service																						
Residential dial-in customer service		\$	\$ 7,010,000	88%	100%	0%	0%	0%	0%	0%	0%	\$ 7.50	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -		
Business dial-in customer service		\$	\$ 27,000	0%	0%	100%	0%	0%	0%	0%	0%	-	\$ 7.51	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -		
ISDN dial-in customer service		\$	\$ 27,000	0%	0%	0%	100%	0%	0%	0%	0%	-	-	\$ 7.51	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -		
56 kb customer service		\$	\$ 173,000	2%	0%	0%	0%	100%	0%	0%	0%	-	-	-	\$ 120.32	\$ -	\$ -	\$ -	\$ -	\$ -		
T1 customer service		\$	\$ 690,000	9%	0%	0%	0%	0%	100%	0%	0%	-	-	-	\$ -	\$ 119.97	\$ -	\$ -	\$ -	\$ -		
basic Web hosting customer service		\$	\$ -	0%	0%	0%	0%	0%	0%	100%	0%	-	-	-	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -		
enhanced Web hosting customer service		\$	\$ -	0%	0%	0%	0%	0%	0%	100%	0%	-	-	-	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -		
Total customer service costs				\$ 7,927,000	100%	88%	0%	0%	2%	9%	0%	0%	\$ 7.50	\$ 7.51	\$ 7.51	\$ 120.32	\$ 119.97	\$ -	\$ -	\$ -	\$ -	
Operations																						
Network Operations and Maintenance:																						
software and hardware maintenance		\$	\$ 670,000	19%	75%	0%	1%	4%	20%	0%	0%	\$ 0.54	\$ 0.63	\$ 1.27	\$ 18.90	\$ 22.93	\$ -	\$ -	\$ -	\$ -		
POP personnel		\$	\$ 1,178,000	34%	75%	0%	1%	4%	20%	0%	0%	\$ 0.95	\$ 1.11	\$ 2.23	\$ 33.22	\$ 40.32	\$ -	\$ -	\$ -	\$ -		
Web hosting personnel		\$	\$ -	0%	0%	0%	0%	0%	0%	0%	0%	-	-	-	-	-	-	-	-	-		
Facilities		\$	\$ 411,000	12%	75%	0%	1%	4%	20%	0%	0%	\$ 0.33	\$ 0.39	\$ 0.78	\$ 11.59	\$ 14.07	\$ -	\$ -	\$ -	\$ -		
Billing and Collections		\$	\$ 1,186,000	34%	98%	0%	0%	0%	1%	0%	0%	\$ 1.25	\$ 1.25	\$ 1.25	\$ 1.25	\$ 1.25	\$ -	\$ -	\$ -	\$ -		
Total operations costs				\$ 3,445,000	100%	83%	0%	1%	3%	13%	0%	\$ 3.07	\$ 3.39	\$ 5.53	\$ 64.96	\$ 78.56	\$ -	\$ -	\$ -	\$ -	\$ -	
Other Expenses																						
Sales and Marketing	20% of revenue	\$	\$ 5,340,000	61%	70%	0%	1%	3%	26%	0%	0%	\$ 4.00	\$ 4.01	\$ 19.97	\$ 100.01	\$ 240.01	\$ -	\$ -	\$ -	\$ -		
General and Administrative:	11% of total costs	\$	\$ 3,375,000	39%	70%	0%	1%	3%	26%	0%	0%	\$ 2.53	\$ 2.53	\$ 12.62	\$ 63.21	\$ 151.69	\$ -	\$ -	\$ -	\$ -		
Total other expenses				\$ 8,715,000	100%	70%	0%	1%	3%	26%	0%	\$ 6.53	\$ 6.54	\$ 32.60	\$ 163.22	\$ 391.70	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Cost Summary																						
Capital Equipment		\$	\$ 3,349,000	11%	12%	13%	7%	20%	8%	0%	0%	\$ 3	\$ 3	\$ 6	\$ 94	\$ 115	\$ -	\$ -	\$ -	\$ -		
Transport		\$	\$ 7,242,000	24%	13%	15%	39%	6%	51%	0%	0%	\$ 3	\$ 4	\$ 33	\$ 27	\$ 745	\$ -	\$ -	\$ -	\$ -		
Customer Service		\$	\$ 7,927,000	26%	33%	31%	9%	26%	8%	0%	0%	\$ 8	\$ 8	\$ 8	\$ 120	\$ 120	\$ -	\$ -	\$ -	\$ -		
Operations		\$	\$ 3,445,000	11%	13%	14%	6%	14%	5%	0%	0%	\$ 3	\$ 3	\$ 6	\$ 65	\$ 79	\$ -	\$ -	\$ -	\$ -		
Other Expenses		\$	\$ 8,715,000	28%	29%	27%	38%	35%	27%	0%	0%	\$ 7	\$ 7	\$ 33	\$ 163	\$ 392	\$ -	\$ -	\$ -	\$ -		
Total Monthly ISP Costs without internet telephony				\$ 30,678,000	100%	69.4%	0.3%	1.0%	2.2%	27.2%	0.0%	0%	\$ 23	\$ 24	\$ 85	\$ 469	\$ 1,450	\$ -	\$ -	\$ -	\$ -	\$ -

Regional ISP - with Internet Telephony

Market Summary			
Population of Tier 1 Region	500,000 people	Area of Region Served	3,000,000 sq. mi.
Population of Tier 2 Region	2,000,000 people	Total Population of Region	243,000,000 people
# of Tier 1 POPs	450	Avg. Population Density	81 /sq.mi.
# of Tier 2 POPs	9	Total # of Businesses	3,738,462
Subscriber type: # per Tier 1 POP: # per Tier 2 POP: Total (all POPs):			
res. dial-in	1,923	7,692	934,615
bus. dial-in	7	30	3,595
ISDN dial-in	7	30	3,595
56 kb	-	160	1,438
T1	-	639	5,751
basic Web hosting	-	-	-
enhanced Web hosting	-	-	-

Monthly Revenue	no lines/sub	Quantity	Price	Revenue	% revenue
residential dial-in		934,615	\$ 20	\$ 18,692,000	59%
business dial-in		3,595	\$ 20	\$ 72,000	0%
ISDN dial-in		3,595	\$ 100	\$ 359,000	1%
56 kb	1.7	2,387	\$ 500	\$ 1,193,000	4%
T1	1.7	9,547	\$ 1,200	\$ 11,457,000	36%
basic Web hosting		-	\$ -	\$ -	0%
enhanced Web hosting		-	\$ -	\$ -	0%
Total Revenue				\$ 31,800,000	100%

Monthly Costs - Scenario with Internet telephony

Capital Equipment	Quantity	Unit Cost	Cost	% cost	% allocation							\$/subscriber							
					res.	bus.	ISDN	56 kb	T1	basic host.	enh. host.	res.	bus.	ISDN	56 kb	T1	basic host	enh. host.	
analog modems	144279	\$ 23	\$ 3,293,000	66%	100%	0%	0%	0%	0%	0%	0%	\$ 3.51	\$ 4.12	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
ISDN access router	6480	\$ 5	\$ 33,000	1%	0%	0%	100%	0%	0%	0%	0%	\$ -	\$ -	\$ 9.18	\$ -	\$ -	\$ -	\$ -	\$ -
POP server	86	\$ 652	\$ 56,000	1%	84%	0%	2%	3%	11%	0%	0%	\$ 0.05	\$ 0.06	\$ 0.29	\$ 1.08	\$ 1.08	\$ -	\$ -	\$ -
content hosting server	0	\$ 261	\$ -	0%	0%	0%	0%	0%	0%	0%	0%	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
LAN - 10 Mbps ethernet	4050	\$ 3	\$ 11,000	0%	97%	0%	2%	0%	0%	0%	0%	\$ 0.01	\$ 0.01	\$ 0.07	\$ -	\$ -	\$ -	\$ -	\$ -
LAN - 100 Mbps ethernet	240	\$ 13	\$ 3,000	0%	94%	0%	1%	0%	1%	0%	0%	\$ 0.00	\$ 0.00	\$ 0.01	\$ 0.00	\$ 0.00	\$ -	\$ -	\$ -
56 kb CSU/DSU	2387	\$ 13	\$ 31,000	1%	0%	0%	0%	100%	0%	0%	0%	\$ -	\$ -	\$ -	\$ 21.56	\$ -	\$ -	\$ -	\$ -
T1 CSU/DSU	11807	\$ 37	\$ 431,000	9%	19%	0%	0%	0%	81%	0%	0%	\$ 0.09	\$ 0.10	\$ 0.50	\$ -	\$ 60.60	\$ -	\$ -	\$ -
Cisco 2500 router	900	\$ 73	\$ 66,000	1%	97%	0%	2%	0%	0%	0%	0%	\$ 0.07	\$ 0.08	\$ 0.40	\$ -	\$ -	\$ -	\$ -	\$ -
Cisco 7513 serial port card	1633	\$ 417	\$ 682,000	14%	15%	0%	0%	18%	68%	0%	0%	\$ 0.11	\$ 0.13	\$ 0.64	\$ 86.66	\$ 78.37	\$ -	\$ -	\$ -
Cisco 7513 ATM card	181	\$ 470	\$ 85,000	2%	15%	0%	0%	18%	68%	0%	0%	\$ 0.01	\$ 0.02	\$ 0.08	\$ 10.80	\$ 9.77	\$ -	\$ -	\$ -
Cisco 7513 router chassis	181	\$ 1,565	\$ 284,000	6%	15%	0%	0%	18%	68%	0%	0%	\$ 0.05	\$ 0.05	\$ 0.27	\$ 36.09	\$ 32.63	\$ -	\$ -	\$ -
Fore 4 port DS3 card	0	\$ 365	\$ -	0%	6%	0%	0%	1%	93%	0%	0%	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Fore 4 port OC-3 card	57	\$ 365	\$ 21,000	0%	6%	0%	0%	1%	93%	0%	0%	\$ 0.00	\$ 0.00	\$ 0.01	\$ 0.12	\$ 3.41	\$ -	\$ -	\$ -
Fore ASX-200BX ATM switch chassis	14	\$ 417	\$ 6,000	0%	6%	0%	0%	1%	93%	0%	0%	\$ 0.00	\$ 0.00	\$ 0.00	\$ 0.03	\$ 0.97	\$ -	\$ -	\$ -
Total capital equipment costs					resulting cost distribution					\$/subscriber									
					73%	0%	1%	4%	21%	0%	0%	\$ 3.90	\$ 4.58	\$ 11.44	\$ 156.35	\$ 186.83	\$ -	\$ -	\$ -
Transport					% allocation					% allocation									
analog dial-in T1 (# of T1 lines)	6012	\$ 2,513,000	\$ 2,513,000	21%	100%	0%	0%	0%	0%	0%	0%	\$ 2.68	\$ 3.15	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
ISDN dial-in PRI (# of PRI lines)	282	\$ 168,000	\$ 168,000	1%	0%	0%	100%	0%	0%	0%	0%	\$ -	\$ -	\$ 46.74	\$ -	\$ -	\$ -	\$ -	\$ -
T1 transport		\$ 1,985,000	\$ 1,985,000	16%	97%	0%	2%	0%	0%	0%	0%	\$ 2.07	\$ 2.43	\$ 11.93	\$ -	\$ -	\$ -	\$ -	\$ -
NAP Interconnection cost		\$ 717,000	\$ 717,000	6%	6%	0%	0%	1%	93%	0%	0%	\$ 0.04	\$ 0.05	\$ 0.25	\$ 4.14	\$ 116.26	\$ -	\$ -	\$ -
T3/OC-3 transport		\$ 6,803,000	\$ 6,803,000	56%	6%	0%	0%	1%	93%	0%	0%	\$ 0.42	\$ 0.49	\$ 2.42	\$ 39.27	\$ 1,103.06	\$ -	\$ -	\$ -
Total transport costs					resulting cost distribution					\$/subscriber									
					40%	0%	2%	1%	58%	0%	0%	\$ 5.21	\$ 6.12	\$ 61.34	\$ 43.41	\$ 1,219.32	\$ -	\$ -	\$ -
Customer Service					% allocation					% allocation									
Residential dial-in customer service		\$ 10,094,000	\$ 10,094,000	88%	100%	0%	0%	0%	0%	0%	0%	\$ 10.80	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Business dial-in customer service		\$ 39,000	\$ 39,000	0%	0%	100%	0%	0%	0%	0%	0%	\$ -	\$ 10.85	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
ISDN dial-in customer service		\$ 39,000	\$ 39,000	0%	0%	0%	100%	0%	0%	0%	0%	\$ -	\$ -	\$ 10.85	\$ -	\$ -	\$ -	\$ -	\$ -
56 kb customer service		\$ 248,000	\$ 248,000	2%	0%	0%	0%	100%	0%	0%	0%	\$ -	\$ -	\$ -	\$ 172.48	\$ -	\$ -	\$ -	\$ -
T1 customer service		\$ 994,000	\$ 994,000	9%	0%	0%	0%	0%	100%	0%	0%	\$ -	\$ -	\$ -	\$ -	\$ 172.83	\$ -	\$ -	\$ -
basic Web hosting customer service		\$ -	\$ -	0%	0%	0%	0%	0%	0%	100%	0%	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
enhanced Web hosting customer service		\$ -	\$ -	0%	0%	0%	0%	0%	0%	100%	0%	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Total customer service costs					resulting cost distribution					\$/subscriber									
					88%	0%	0%	2%	9%	0%	0%	\$ 10.80	\$ 10.85	\$ 10.85	\$ 172.48	\$ 172.83	\$ -	\$ -	\$ -
Operations					% allocation					% allocation									
Network Operations and Maintenance: software and hardware maintenance		\$ 1,000,000	\$ 1,000,000	26%	73%	0%	1%	4%	21%	0%	0%	\$ 0.78	\$ 0.92	\$ 2.29	\$ 31.26	\$ 37.35	\$ -	\$ -	\$ -
POP personnel		\$ 1,178,000	\$ 1,178,000	31%	73%	0%	1%	4%	21%	0%	0%	\$ 0.92	\$ 1.08	\$ 2.69	\$ 36.82	\$ 44.00	\$ -	\$ -	\$ -
Web hosting personnel		\$ 411,000	\$ 411,000	11%	0%	0%	0%	0%	0%	0%	0%	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Facilities		\$ 411,000	\$ 411,000	11%	73%	0%	1%	4%	21%	0%	0%	\$ 0.32	\$ 0.38	\$ 0.94	\$ 12.85	\$ 15.35	\$ -	\$ -	\$ -
Billing and Collections		\$ 1,186,000	\$ 1,186,000	31%	98%	0%	0%	0%	1%	0%	0%	\$ 1.25	\$ 1.25	\$ 1.25	\$ 1.25	\$ 1.25	\$ -	\$ -	\$ -
Total operations costs					resulting cost distribution					\$/subscriber									
					81%	0%	1%	3%	15%	0%	0%	\$ 3.27	\$ 3.62	\$ 7.17	\$ 82.18	\$ 97.95	\$ -	\$ -	\$ -
Other Expenses					% allocation					% allocation									
Sales and Marketing	20% of revenue	\$ 6,360,000	\$ 6,360,000	57%	59%	0%	1%	4%	36%	0%	0%	\$ 4.00	\$ 4.01	\$ 19.97	\$ 165.94	\$ 398.40	\$ -	\$ -	\$ -
General and Administrative:	11% of total costs	\$ 4,788,000	\$ 4,788,000	43%	59%	0%	1%	4%	36%	0%	0%	\$ 3.01	\$ 3.02	\$ 15.04	\$ 124.92	\$ 299.93	\$ -	\$ -	\$ -
Total other expenses					resulting cost distribution					\$/subscriber									
					59%	0%	1%	4%	36%	0%	0%	\$ 7.01	\$ 7.02	\$ 35.01	\$ 290.86	\$ 698.33	\$ -	\$ -	\$ -
Cost Summary					% Cost					% Cost									
Capital Equipment		\$ 5,002,000	\$ 5,002,000	11%	13%	14%	9%	21%	8%	0%	0%	\$ 4	\$ 5	\$ 11	\$ 156	\$ 187	\$ -	\$ -	\$ -
Transport		\$ 12,186,000	\$ 12,186,000	28%	17%	19%	49%	6%	51%	0%	0%	\$ 5	\$ 6	\$ 61	\$ 43	\$ 1,219	\$ -	\$ -	\$ -
Customer Service		\$ 11,414,000	\$ 11,414,000	26%	36%	34%	9%	23%	7%	0%	0%	\$ 11	\$ 11	\$ 11	\$ 172	\$ 173	\$ -	\$ -	\$ -
Operations		\$ 3,775,000	\$ 3,775,000	9%	11%	11%	6%	11%	4%	0%	0%	\$ 3	\$ 4	\$ 7	\$ 82	\$ 98	\$ -	\$ -	\$ -
Other Expenses		\$ 11,148,000	\$ 11,148,000	26%	23%	22%	28%	39%	29%	0%	0%	\$ 7	\$ 7	\$ 35	\$ 291	\$ 698	\$ -	\$ -	\$ -
Total Monthly ISP Costs with Internet telephony					% Cost					% Cost									
					65%	0%	1%	2%	31%	0%	0%	\$ 30	\$ 32	\$ 126	\$ 745	\$ 2,375	\$ -	\$ -	\$ -

Monthly Costs	Scenario without Int. tel.		Scenario with Int. tel.		% change							
	Cost	% cost	Cost	% cost	res.	bus.	ISDN	56 kb	T1	basic host	enh. host.	
Capital Equipment												
analog modems	\$ 2,351,000	70%	\$ 3,293,000	66%	40%	40%	0%	0%	0%	0%	0%	
ISDN access router	\$ 19,000	1%	\$ 33,000	1%	0%	0%	74%	0%	0%	0%	0%	
POP server	\$ 39,000	1%	\$ 56,000	1%	40%	40%	74%	66%	66%	0%	0%	
content hosting server	\$ -	0%	\$ -	0%	0%	0%	0%	0%	0%	0%	0%	
LAN - 10 Mbps ethernet	\$ 8,000	0%	\$ 11,000	0%	0%	0%	37%	0%	0%	0%	0%	
LAN - 100 Mbps ethernet	\$ 2,000	0%	\$ 3,000	0%	0%	0%	0%	0%	0%	0%	0%	
56 kb CSU/DSU	\$ 19,000	1%	\$ 31,000	1%	0%	0%	0%	63%	0%	0%	0%	
T1 CSU/DSU	\$ 245,000	7%	\$ 431,000	9%	137%	137%	137%	0%	66%	0%	0%	
Cisco 2500 router	\$ 33,000	1%	\$ 66,000	1%	100%	100%	100%	0%	0%	0%	0%	
7513 serial port	\$ 400,000	12%	\$ 682,000	14%	131%	131%	131%	66%	62%	0%	0%	
7513 ATM card	\$ 50,000	1%	\$ 85,000	2%	0%	0%	130%	66%	61%	0%	0%	
Cisco 7513 routers	\$ 167,000	5%	\$ 284,000	6%	130%	130%	130%	66%	61%	0%	0%	
Fore 4 port DS3 card	\$ -	0%	\$ -	0%	0%	0%	0%	0%	0%	0%	0%	
Fore 4 port OC-3 card	\$ 12,000	0%	\$ 21,000	0%	0%	0%	0%	72%	72%	0%	0%	
Fore ASX-200BX ATM switch chassis	\$ 4,000	0%	\$ 6,000	0%	0%	0%	0%	47%	47%	0%	0%	
<i>Total capital equipment costs</i>	<i>\$ 3,349,000</i>	<i>100%</i>	<i>\$ 5,002,000</i>	<i>100%</i>	<i>45%</i>	<i>45%</i>	<i>80%</i>	<i>66%</i>	<i>63%</i>	<i>0%</i>	<i>0%</i>	
Transport												
analog dial-in T1 (# of T1 lines)	\$ 1,794,000	25%	\$ 2,513,000	21%	40%	40%	0%	0%	0%	0%	0%	
ISDN dial-in PRI (# of PRI lines)	\$ 97,000	1%	\$ 168,000	1%	0%	0%	73%	0%	0%	0%	0%	
T1 transport	\$ 837,000	12%	\$ 1,985,000	16%	137%	137%	137%	0%	0%	0%	0%	
NAP Interconnection cost	\$ 431,000	6%	\$ 717,000	6%	135%	135%	135%	63%	63%	0%	0%	
T3 transport	\$ 4,083,000	56%	\$ 6,803,000	56%	136%	136%	136%	64%	64%	0%	0%	
<i>Total transport costs</i>	<i>\$ 7,242,000</i>	<i>100%</i>	<i>\$ 12,186,000</i>	<i>100%</i>	<i>75%</i>	<i>75%</i>	<i>85%</i>	<i>64%</i>	<i>64%</i>	<i>0%</i>	<i>0%</i>	
Customer Service												
Residential dial-in customer service	\$ 7,010,000	88%	\$ 10,094,000	88%	44%	0%	0%	0%	0%	0%	0%	
Business dial-in customer service	\$ 27,000	0%	\$ 39,000	0%	0%	44%	0%	0%	0%	0%	0%	
ISDN dial-in customer service	\$ 27,000	0%	\$ 39,000	0%	0%	0%	44%	0%	0%	0%	0%	
56 kb customer service	\$ 173,000	2%	\$ 248,000	2%	0%	0%	0%	43%	0%	0%	0%	
T1 customer service	\$ 690,000	9%	\$ 994,000	9%	0%	0%	0%	0%	44%	0%	0%	
basic Web hosting customer service	\$ -	0%	\$ -	0%	0%	0%	0%	0%	0%	0%	0%	
enhanced Web hosting customer service	\$ -	0%	\$ -	0%	0%	0%	0%	0%	0%	0%	0%	
<i>Total customer service costs</i>	<i>\$ 7,927,000</i>	<i>100%</i>	<i>\$ 11,414,000</i>	<i>100%</i>	<i>44%</i>	<i>44%</i>	<i>44%</i>	<i>43%</i>	<i>44%</i>	<i>0%</i>	<i>0%</i>	
Operations												
Network Operations and Maintenance:												
software and hardware maintenance	\$ 670,000	19%	\$ 1,000,000	26%	45%	45%	80%	65%	63%	0%	0%	
POP personnel	\$ 1,178,000	34%	\$ 1,178,000	31%	-3%	-3%	21%	11%	9%	0%	0%	
Web hosting personnel	\$ -	0%	\$ -	0%	0%	0%	0%	0%	0%	0%	0%	
Facilities	\$ 411,000	12%	\$ 411,000	11%	-3%	-3%	21%	11%	9%	0%	0%	
Billing and Collections	\$ 1,186,000	34%	\$ 1,186,000	31%	0%	0%	0%	0%	0%	0%	0%	
<i>Total operations costs</i>	<i>\$ 3,445,000</i>	<i>100%</i>	<i>\$ 3,775,000</i>	<i>100%</i>	<i>7%</i>	<i>7%</i>	<i>30%</i>	<i>26%</i>	<i>25%</i>	<i>0%</i>	<i>0%</i>	
Other Expenses												
Sales and Marketing	\$ 5,340,000	61%	\$ 6,360,000	57%	0%	0%	0%	66%	66%	0%	0%	
General and Administrative:	\$ 3,375,000	39%	\$ 4,788,000	43%	19%	19%	19%	98%	98%	0%	0%	
<i>Total other expenses</i>	<i>\$ 8,715,000</i>	<i>100%</i>	<i>\$ 11,148,000</i>	<i>100%</i>	<i>7%</i>	<i>7%</i>	<i>7%</i>	<i>78%</i>	<i>78%</i>	<i>0%</i>	<i>0%</i>	
Cost Summary												
Capital Equipment	\$ 3,349,000	11%	\$ 5,002,000	11%	45%	45%	80%	66%	63%	0%	0%	
Transport	\$ 7,242,000	24%	\$ 12,186,000	28%	75%	75%	85%	64%	64%	0%	0%	
Customer Service	\$ 7,927,000	26%	\$ 11,414,000	26%	44%	44%	44%	43%	44%	0%	0%	
Operations	\$ 3,445,000	11%	\$ 3,775,000	9%	7%	7%	30%	26%	25%	0%	0%	
Other Expenses	\$ 8,715,000	28%	\$ 11,148,000	26%	7%	7%	7%	78%	78%	0%	0%	
Total Monthly ISP Costs	\$ 30,678,000	100%	\$ 43,525,000	100%	33%	34%	48%	59%	64%	0%	0%	

Appendix Six

Cost Model Tables: Capital Equipment

Capital Equipment Costs

Equipment	cost - inc. install	effective capacity	units	economic life (month)	discount factor	annualized block cost/month	annualized cost/unit/ month
48 port analog modem banks	\$42,000	48 modems		36	30%	\$1,096	\$23
Ascend Max 4004 access router w/ ISDN sw	\$18,000	92 B channels		36	30%	\$470	\$5
POP server	\$25,000	1 server		36	30%	\$652	\$652
content hosting server	\$10,000	1 server		36	30%	\$261	\$261
LAN - 10 Mbps ethernet	\$100	1 port		36	30%	\$3	\$3
LAN - 100 Mbps ethernet	\$500	1 port		36	30%	\$13	\$13
56 kb CSU/DSU	\$500	1 box		36	30%	\$13	\$13
T1 CSU/DSU	\$1,400	1 box		36	30%	\$37	\$37
Cisco 2500	\$2,800	1 router		36	30%	\$73	\$73
7513 serial port card	\$16,000	1 card		36	30%	\$417	\$417
7513 ATM card	\$18,000	1 card		36	30%	\$470	\$470
Cisco 7513	\$60,000	1 router		36	30%	\$1,565	\$1,565
Fore 4 port DS3 card	\$14,000	1 card		36	30%	\$365	\$365
Fore 4 port OC-3 card	\$14,000	1 card		36	30%	\$365	\$365
Fore ASX-200BX ATM switch chassis	\$16,000	1 switch		36	30%	\$417	\$417

Scenario without Internet telephony

Cost Summary Capital Equipment	unit cost/month	Tier 1 POPs		# of POPs: 450		Tier 2 POPs		# of POPs: 9		Total for all POPs		
		Quantity per POP	Quantity all POPs	Cost	(%cost)	Quantity per POP	Quantity all POPs	Cost	(%cost)	Quantity all POPs	Cost	(%cost)
analog modems	\$23	213	95850	\$2,187,792	95%	794	7146	\$163,109	16%	102996	\$2,350,900	70%
ISDN access router	\$5	8	3600	\$18,374	1%	14	126	\$643	0%	3726	\$19,017	1%
POP server	\$652	0.1	49	\$31,841	1%	1	11	\$7,039	1%	60	\$38,880	1%
content hosting server	\$261	0	0	\$0	0%	0	0	\$0	0%	0	\$0	0%
LAN - 10 Mbps ethernet	\$3	7	3150	\$8,217	0%	0	0	\$0	0%	3150	\$8,217	0%
LAN - 100 Mbps ethernet	\$13	0	0	\$0	0%	18.9	170	\$2,217	0%	170	\$2,217	0%
56 kb CSU/DSU	\$13	0	0	\$0	0%	160	1438	\$18,754	2%	1438	\$18,754	1%
T1 CSU/DSU	\$37	1.1	476	\$17,389	1%	692	6228	\$227,435	22%	6704	\$244,824	7%
Cisco 2500 router	\$73	1	450	\$32,868	1%	0	0	\$0	0%	450	\$32,868	1%
Cisco 7513 serial port card	\$417	0	0	\$0	0%	106.5	958	\$399,923	38%	958	\$399,923	12%
Cisco 7513 ATM card	\$470	0	0	\$0	0%	11.8	106	\$49,990	5%	106	\$49,990	1%
Cisco 7513 router chassis	\$1,565	0	0	\$0	0%	11.8	106	\$166,635	16%	106	\$166,635	5%
Fore 4 port DS3 card	\$365	0	0	\$0	0%	0	0.0	\$0	0%	0	\$0	0%
Fore 4 port OC-3 card	\$365	0	0	\$0	0%	0	34.1	\$12,463	1%	34	\$12,463	0%
Fore ASX-200BX ATM switch	\$417	0	0	\$0	0%	0	8.5	\$3,561	0%	9	\$3,561	0%
<i>Total capital costs per tier</i>				\$2,296,481	100%			\$1,051,769	100%		\$3,348,250	100%

Capital Equipment Quantities

Tier 1 POP

analog modems:		
peak combined calls per hour	385	taken from 'Tier 1 and Tier 2 call rate calculations' chart on Transport page
avg holding time (min.)	30	
Total number of modems per POP	213	= to the peak # of concurrent users
resulting sub/modem ratio	9.1	(just for reference - result is not used anywhere)
ISDN access router:		
peak calls per hour	1	taken from 'Tier 1 and Tier 2 call rate calculations' chart on Transport page
avg holding time (min.)	30	
Peak # of concurrent ISDN users	4	= to the peak # of concurrent users
Total number of B channels required	8	# of concurrent users * 2 B channels per user
POP server		
# for analog dial-in users	0.11	
# for ISDN dial-in users	0.00	
Total POP servers	0.11	
LAN sizing - # of 10 Mbps ethernet ports	7	allocate 1 switch port per 48 modems + router and server cxns
T1 CSU/DSU	1.1	
Cisco 2500 router	1	1 for every 2 T1s

Tier 2 POPs

analog modems:

peak combined calls per hour	1539	taken from 'Tier 1 and Tier 2 call rate calculations' chart on Transport page
avg holding time (min.)	30	
Total number of modems per POP	794	= to the peak # of concurrent users
resulting sub/modem ratio	9.7	(just for reference - result is not used anywhere)

ISDN access router:

peak calls per hour	6	taken from 'Tier 1 and Tier 2 call rate calculations' chart on Transport page
avg holding time (min.)	30	
Peak # of concurrent ISDN users	7	= to the peak # of concurrent users
Total number of B channels required	14	# of concurrent users * 2 B channels per user

POP server:

# for analog dial-in users	0.40
# for ISDN dial-in users	0.00
# for 56K users	0.16
# for T1 users	0.64
Total POP servers	1.20

content hosting server

	0
--	---

LAN sizing - # of 100 Mbps ethernet ports

allocate 1 switch port per 48 modems + router and server cxns

# for analog modems	16.5
# for ISDN	0.1
# for router	1.0
# for POP servers	1.2
# for content hosting servers	0.0
Total 100 Mbps ethernet ports	18.9

56 kb CSU/DSU

1 for each 56 kb sub. connecting here (from tier 1 and tier 2 areas)* # of leased lines/sub

T1 CSU/DSU

1 for each T1 sub. * # leased lines/sub + no Tier 1 POPs / Tier 2 POP * no T1s per POP

# for Tier 1 POPs	53
# for T1 subs	639
Total T1 CSU/DSU	692

Cisco 7513 router:

# of serial port cards	106.5
# of chassis	11.8
# of ATM cards	11.8

1 port for each business connecting here (from tier 1 and tier 2 areas) + 1 port for each Tier 1 POP/# of ports per card
total # of required ATM and serial port cards/# of available slots per chassis

1 card for each router chassis to connect to the ATM switch

ATM Switches

	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8	Node 9	
# of T3s per node	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
# of OC-3s per node	7.3	7.8	7.3	30.9	30.7	31.1	7.0	7.5	7.1	Total
# of DS3 cards required	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
# of OC-3 cards required	1.8	1.9	1.8	7.7	7.7	7.8	1.7	1.9	1.8	34.1
# of ATM switch chassis	0.5	0.5	0.5	1.9	1.9	1.9	0.4	0.5	0.4	8.5

Scenario with Internet telephony

Cost Summary Capital Equipment	unit cost/month	Tier 1 POPs				Tier 2 POPs				Total for all POPs			
		Quantity per POP	Quantity all POPs	Cost	(%cost)	Quantity per POP	Quantity all POPs	Cost	(%cost)	Quantity all POPs	Cost	(%cost)	
analog modems	\$23	298	134100	\$3,060,854	94%	1131	10179	\$232,337	13%	144279	\$3,293,191	66%	
ISDN access router	\$5	14	6300	\$32,154	1%	20	180	\$919	0%	6480	\$33,072	1%	
POP server	\$652	0.2	69	\$44,754	1%	2	17	\$11,131	1%	86	\$55,885	1%	
content hosting server	\$261	0	0	\$0	0%	0	0	\$0	0%	0	\$0	0%	
LAN - 10 Mbps ethernet	\$3	9	4050	\$10,565	0%	0	0	\$0	0%	4050	\$10,565	0%	
LAN - 100 Mbps ethernet	\$13	0	0	\$0	0%	27	240	\$3,130	0%	240	\$3,130	0%	
56 kb CSU/DSU	\$13	0	0	\$0	0%	265	2387	\$31,132	2%	2387	\$31,132	1%	
T1 CSU/DSU	\$37	2.5	1130	\$41,255	1%	1186	10677	\$389,931	22%	11807	\$431,186	9%	
Cisco 2500 router	\$73.04	2	900	\$65,736	2%	0	0	\$0	0%	900	\$65,736	1%	
Cisco 7513 serial port card	\$417.37	0	0	\$0	0%	181.4	1633	\$681,571	39%	1633	\$681,571	14%	
Cisco 7513 ATM card	\$469.55	0	0	\$0	0%	20.2	181	\$85,196	5%	181	\$85,196	2%	
Cisco 7513 router chassis	\$1,565.15	0	0	\$0	0%	20.2	181	\$283,988	16%	181	\$283,988	6%	
Fore 4 port DS3 card	\$365.20	0	0	\$0	0%	0	0.0	\$0	0%	0	\$0	0%	
Fore 4 port OC-3 card	\$365.20	0	0	\$0	0%	0	56.9	\$20,767	1%	57	\$20,767	0%	
Fore ASX-200BX ATM switch	\$417.37	0	0	\$0	0%	0	14.2	\$5,933	0%	14	\$5,933	0%	
<i>Total capital costs per tier</i>				\$3,255,318	100%					\$1,746,036	100%	\$5,001,353	100%

Capital Equipment Quantities

Tier 1 POP

analog modems:		
peak combined calls per hour	462	taken from 'Tier 1 and Tier 2 call rate calculations' chart on Transport page
avg holding time (min.)	36	
Total number of modems per POP	298	= to the peak # of concurrent users
resulting sub/modem ratio	6.5	(just for reference - result is not used anywhere)
ISDN access router:		
peak calls per hour	2	taken from 'Tier 1 and Tier 2 call rate calculations' chart on Transport page
avg holding time (min.)	36	
Peak # of concurrent ISDN users	7	
Total number of B channels required	14	# of concurrent users * 2 B channels per user
POP server		
# for analog dial-in users	0.15	
# for ISDN dial-in users	0.00	
Total POP servers	0.15	
LAN sizing - # of 10 Mbps ethernet ports	9	allocate 1 switch port per 48 modems + router and server cxns
T1 CSU/DSU	2.5	
Cisco 2500 router	2	1 for every 2 T1s

Tier 2 POPs

analog modems:

peak combined calls per hour	1847	taken from 'Tier 1 and Tier 2 call rate calculations' chart on Transport page
avg holding time (min.)	36	
Total number of modems per POP	1131	= to the peak # of concurrent users
resulting sub/modem ratio	6.8	(just for reference - result is not used anywhere)

ISDN access router:

peak calls per hour	7	taken from 'Tier 1 and Tier 2 call rate calculations' chart on Transport page
avg holding time (min.)	36	
Peak # of concurrent ISDN users	10	= to the peak # of concurrent users
Total number of B channels required	20	# of concurrent users * 2 B channels per user

POP server:

# for analog dial-in users	0.57
# for ISDN dial-in users	0.01
# for 56K users	0.27
# for T1 users	1.06
Total POP servers	1.90

content hosting server

	0
--	---

LAN sizing - # of 100 Mbps ethernet ports

allocate 1 switch port per 48 modems + router and server cxns

# for analog modems	23.6
# for ISDN	0.2
# for router	1.0
# for POP servers	1.9
# for content hosting servers	0.0
Total 100 Mbps ethernet ports	26.7

56 kb CSU/DSU

	265
--	-----

1 for each 56 kb sub. connecting here (from tier 1 and tier 2 areas)* # leased lines/sub

T1 CSU/DSU

1 for each T1 sub. * # leased lines/sub + no Tier 1 POPs / Tier 2 POP * no T1s per POP

# for Tier 1 POPs	126
# for T1 subs	1061
Total T1 CSU/DSU	1186

Cisco 7513 router:

# of serial port cards	181.4
# of chassis	20.2
# of ATM cards	20.2

1 port for each business connecting here (from tier 1 and tier 2 areas) + 1 port for each Tier 1 POP/# of ports per card
total # of required serial port cards/# of available slots per chassis

1 card for each router chassis

ATM Switches

	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8	Node 9	
# of T3s per node	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
# of OC-3s per node	12.1	13.0	12.2	51.5	51.2	51.7	11.6	12.5	11.7	Total
# of DS3 cards required	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
# of OC-3 cards required	3.0	3.2	3.0	12.9	12.8	12.9	2.9	3.1	2.9	56.9
# of ATM switch chassis	0.8	0.8	0.8	3.2	3.2	3.2	0.7	0.8	0.7	14.2

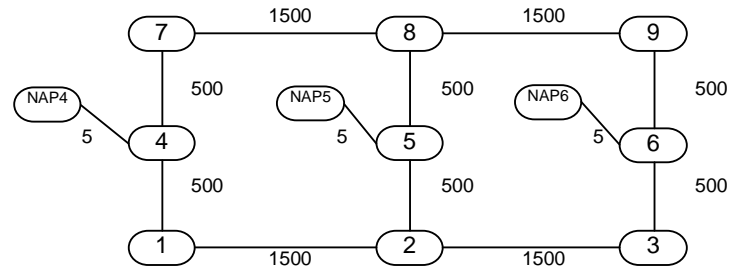
Cost Model Tables: Transport

Transport Costs

Tier 2 Node Layout

Node	X coord	Y coord
1	0	0
2	1500	0
3	3000	0
4	0	500
5	1500	500
6	3000	500
7	0	1000
8	1500	1000
9	3000	1000
NAP 1	5	500
NAP 2	1505	500
NAP 3	3005	500

Network Diagram (distance in miles)



Distance Matrix

	1	2	3	4	5	6	7	8	9	NAP 4	NAP 5	NAP 6
1	0	1500	3000	500	1581	3041	1000	1803	3162	500	1586	3046
2	1500	0	1500	1581	500	1581	1803	1000	1803	1576	500	1586
3	3000	1500	0	3041	1581	500	3162	1803	1000	3036	1576	500
4	500	1581	3041	0	1500	3000	500	1581	3041	5	1505	3005
5	1581	500	1581	1500	0	1500	1581	500	1581	1495	5	1505
6	3041	1581	500	3000	1500	0	3041	1581	500	2995	1495	5
7	1000	1803	3162	500	1581	3041	0	1500	3000	500	1586	3046
8	1803	1000	1803	1581	500	1581	1500	0	1500	1576	500	1586
9	3162	1803	1000	3041	1581	500	3000	1500	0	3036	1576	500
NAP 4	500	1576	3036	5	1495	2995	500	1576	3036	0	1500	3000
NAP 5	1586	500	1576	1505	5	1495	1586	500	1576	1500	0	1500
NAP 6	3046	1586	500	3005	1505	5	3046	1586	500	3000	1500	0

Scenario without Internet telephony

Tier 1 and Tier 2 call rate calculations	Tier 1 average calls per hour				Tier 2 average calls per hour			
	Analog modems			ISDN	Analog modems			ISDN
	res. dial-in	bus. dial-in	total	total	res. dial-in	bus. dial-in	total	total
12:00 AM	77	0	77	0	308	0	308	0
1:00 AM	38	0	38	0	154	0	154	0
2:00 AM	19	0	19	0	77	0	77	0
3:00 AM	0	0	0	0	0	0	0	0
4:00 AM	0	0	0	0	0	0	0	0
5:00 AM	0	0	0	0	0	0	0	0
6:00 AM	0	0	0	0	0	1	1	1
7:00 AM	38	0	39	0	154	1	155	1
8:00 AM	38	1	39	1	154	3	157	3
9:00 AM	38	1	39	1	154	4	157	4
10:00 AM	19	1	20	1	77	4	81	4
11:00 AM	19	1	21	1	77	6	83	6
12:00 PM	19	1	20	1	77	4	81	3
1:00 PM	19	1	20	1	77	3	80	4
2:00 PM	38	1	40	1	154	4	158	4
3:00 PM	115	1	117	1	462	6	467	6
4:00 PM	154	1	155	1	615	4	620	4
5:00 PM	192	1	193	1	769	4	773	4
6:00 PM	231	0	231	0	923	2	925	2
7:00 PM	231	0	231	0	923	1	924	1
8:00 PM	288	0	289	0	1154	0	1154	0
9:00 PM	385	0	385	0	1538	0	1539	0
10:00 PM	385	0	385	0	1538	0	1538	0
11:00 PM	288	0	288	0	1154	0	1154	0
subtotal	2635	12	2647	12	10538	48	10586	47
% modem and T1 allocation per user type	100%	0%			100%	0%		
max # of calls and b/w @ busy hour			385	1			1539	6

Tier 1 and 2 originating b/w calculations	Tier 1 (Mbps)				Tier 2 (Mbps)					
	res. dial-in	bus.dial-in	ISDN	Total	res. dial-in	bus.dial-in	ISDN	56 k	T1	Total
12:00 AM	0.2	0.0	0.0	0.2	0.8	0.0	0.0	0.4	49.1	50.3
1:00 AM	0.1	0.0	0.0	0.1	0.4	0.0	0.0	0.4	49.1	49.9
2:00 AM	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.4	49.1	49.7
3:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	49.1	49.5
4:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	49.1	49.5
5:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	49.1	49.5
6:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	49.1	49.5
7:00 AM	0.1	0.0	0.0	0.1	0.4	0.0	0.0	0.9	98.2	99.4
8:00 AM	0.1	0.0	0.0	0.1	0.4	0.0	0.0	2.6	294.5	297.5
9:00 AM	0.1	0.0	0.0	0.1	0.4	0.0	0.0	4.4	490.8	495.6
10:00 AM	0.0	0.0	0.0	0.1	0.2	0.0	0.1	6.1	687.1	693.5
11:00 AM	0.0	0.0	0.0	0.1	0.2	0.0	0.1	6.1	687.1	693.5
12:00 PM	0.0	0.0	0.0	0.1	0.2	0.0	0.0	6.1	687.1	693.5
1:00 PM	0.0	0.0	0.0	0.1	0.2	0.0	0.0	6.1	687.1	693.5
2:00 PM	0.1	0.0	0.0	0.1	0.4	0.0	0.1	6.1	687.1	693.7
3:00 PM	0.3	0.0	0.0	0.3	1.1	0.0	0.1	5.2	589.0	595.4
4:00 PM	0.4	0.0	0.0	0.4	1.5	0.0	0.1	5.2	589.0	595.8
5:00 PM	0.5	0.0	0.0	0.5	1.9	0.0	0.0	4.4	490.8	497.1
6:00 PM	0.6	0.0	0.0	0.6	2.3	0.0	0.0	4.4	490.8	497.4
7:00 PM	0.6	0.0	0.0	0.6	2.3	0.0	0.0	3.5	392.6	398.4
8:00 PM	0.7	0.0	0.0	0.7	2.8	0.0	0.0	2.6	294.5	299.9
9:00 PM	0.9	0.0	0.0	0.9	3.8	0.0	0.0	2.6	294.5	300.9
10:00 PM	0.9	0.0	0.0	0.9	3.8	0.0	0.0	1.7	196.3	201.8
11:00 PM	0.7	0.0	0.0	0.7	2.8	0.0	0.0	0.9	98.2	101.8
subtotal	6.4	0.0	0.1	6.6	25.7	0.1	0.6	72.1	8098.1	8196.6
% backbone allocation per user type	97%	0%	2%		0%	0%	0%	1%	99%	
busy hour avg. b/w (Mbps)			0.9						693.7	

Tier 1 and 2 backbone b/w calculations Time of day	Tier 1 (Mbps)			Tier 2 (Mbps)					Total traffic destined for backbone						
	res. dial-in	bus.dial-in	ISDN	res. dial-in	bus.dial-in	ISDN	56 k	T1	res. dial-in	bus.dial-in	ISDN	56 k	T1	Total	
12:00 AM	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	4.4	0.9	0.0	0.0	0.0	4.4	5.3
1:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.5	0.0	0.0	0.0	4.4	4.9
2:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.2	0.0	0.0	0.0	4.4	4.6
3:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.0	0.0	4.4	4.4
4:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.0	0.0	4.4	4.4
5:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.0	0.0	4.4	4.4
6:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.0	0.0	4.4	4.4
7:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.1	8.7	0.5	0.0	0.0	0.1	8.7	9.3	
8:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.2	26.2	0.5	0.0	0.0	0.2	26.2	26.9	
9:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.4	43.7	0.5	0.0	0.1	0.4	43.7	44.6	
10:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.5	61.2	0.2	0.0	0.1	0.5	61.2	62.0	
11:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.5	61.2	0.2	0.0	0.1	0.5	61.2	62.0	
12:00 PM	0.0	0.0	0.0	0.0	0.0	0.0	0.5	61.2	0.2	0.0	0.0	0.5	61.2	62.0	
1:00 PM	0.0	0.0	0.0	0.0	0.0	0.0	0.5	61.2	0.2	0.0	0.1	0.5	61.2	62.0	
2:00 PM	0.0	0.0	0.0	0.0	0.0	0.0	0.5	61.2	0.5	0.0	0.1	0.5	61.2	62.2	
3:00 PM	0.0	0.0	0.0	0.1	0.0	0.0	0.5	52.4	1.4	0.0	0.1	0.5	52.4	54.3	
4:00 PM	0.0	0.0	0.0	0.1	0.0	0.0	0.5	52.4	1.8	0.0	0.1	0.5	52.4	54.8	
5:00 PM	0.0	0.0	0.0	0.2	0.0	0.0	0.4	43.7	2.3	0.0	0.1	0.4	43.7	46.4	
6:00 PM	0.1	0.0	0.0	0.2	0.0	0.0	0.4	43.7	2.7	0.0	0.0	0.4	43.7	46.8	
7:00 PM	0.1	0.0	0.0	0.2	0.0	0.0	0.3	34.9	2.7	0.0	0.0	0.3	34.9	38.0	
8:00 PM	0.1	0.0	0.0	0.3	0.0	0.0	0.2	26.2	3.4	0.0	0.0	0.2	26.2	29.8	
9:00 PM	0.1	0.0	0.0	0.3	0.0	0.0	0.0	26.2	4.5	0.0	0.0	0.2	26.2	31.0	
10:00 PM	0.1	0.0	0.0	0.3	0.0	0.0	0.2	17.5	4.5	0.0	0.0	0.2	17.5	22.1	
11:00 PM	0.1	0.0	0.0	0.3	0.0	0.0	0.1	8.7	3.4	0.0	0.0	0.1	8.7	12.2	
subtotal										30.9	0.1	0.7	6.4	720.7	758.9
% T3/OC-3 b/w allocated per user type										4%	0%	0%	1%	95%	62.2
													busy hour avg. b/w (Mbps)	62.2	

Tier 1 and 2 NAP b/w calculations Time of day	Tier 1 (Mbps)			Tier 2 (Mbps)					Total traffic destined for NAP					
	res. dial-in	bus.dial-in	ISDN	res. dial-in	bus.dial-in	ISDN	56 k	T1	res. dial-in	bus.dial-in	ISDN	56 k	T1	Total
12:00 AM	0.2	0.0	0.0	0.7	0.0	0.0	0.4	44.2	9.1	0.0	0.0	0.4	44.2	53.7
1:00 AM	0.1	0.0	0.0	0.3	0.0	0.0	0.4	44.2	4.6	0.0	0.0	0.4	44.2	49.1
2:00 AM	0.0	0.0	0.0	0.2	0.0	0.0	0.4	44.2	2.3	0.0	0.0	0.4	44.2	46.8
3:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.4	44.2	0.0	0.0	0.0	0.4	44.2	44.6
4:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.4	44.2	0.0	0.0	0.0	0.4	44.2	44.6
5:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.4	44.2	0.0	0.0	0.0	0.4	44.2	44.6
6:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.4	44.2	0.0	0.0	0.1	0.4	44.2	44.7
7:00 AM	0.1	0.0	0.0	0.3	0.0	0.0	0.8	88.3	4.6	0.0	0.2	0.8	88.3	93.9
8:00 AM	0.1	0.0	0.0	0.3	0.0	0.0	2.4	265.0	4.6	0.1	0.4	2.4	265.0	272.5
9:00 AM	0.1	0.0	0.0	0.3	0.0	0.0	3.9	441.7	4.6	0.1	0.5	3.9	441.7	450.8
10:00 AM	0.0	0.0	0.0	0.2	0.0	0.0	5.5	618.4	2.3	0.1	0.7	5.5	618.4	627.0
11:00 AM	0.0	0.0	0.0	0.2	0.0	0.1	5.5	618.4	2.3	0.2	0.9	5.5	618.4	627.2
12:00 PM	0.0	0.0	0.0	0.2	0.0	0.0	5.5	618.4	2.3	0.1	0.4	5.5	618.4	626.8
1:00 PM	0.0	0.0	0.0	0.2	0.0	0.0	5.5	618.4	2.3	0.1	0.5	5.5	618.4	626.8
2:00 PM	0.1	0.0	0.0	0.3	0.0	0.0	5.5	618.4	4.6	0.1	0.7	5.5	618.4	629.3
3:00 PM	0.3	0.0	0.0	1.0	0.0	0.1	4.7	530.1	13.7	0.2	0.9	4.7	530.1	549.5
4:00 PM	0.3	0.0	0.0	1.4	0.0	0.0	4.7	530.1	18.3	0.1	0.7	4.7	530.1	553.8
5:00 PM	0.4	0.0	0.0	1.7	0.0	0.0	3.9	441.7	22.8	0.1	0.5	3.9	441.7	469.1
6:00 PM	0.5	0.0	0.0	2.0	0.0	0.0	3.9	441.7	27.4	0.1	0.3	3.9	441.7	473.3
7:00 PM	0.5	0.0	0.0	2.0	0.0	0.0	3.1	353.4	27.4	0.0	0.1	3.1	353.4	384.1
8:00 PM	0.6	0.0	0.0	2.5	0.0	0.0	2.4	265.0	34.2	0.0	0.0	2.4	265.0	301.7
9:00 PM	0.8	0.0	0.0	3.4	0.0	0.0	2.4	265.0	45.6	0.0	0.0	2.4	265.0	313.1
10:00 PM	0.8	0.0	0.0	3.4	0.0	0.0	1.6	176.7	45.6	0.0	0.0	1.6	176.7	223.9
11:00 PM	0.6	0.0	0.0	2.5	0.0	0.0	0.8	88.3	34.2	0.0	0.0	0.8	88.3	123.4
subtotal									312.6	1.4	6.9	64.9	7288.3	7674.1
% T3/OC-3 b/w allocated per user type									4%	0%	0%	1%	95%	629.3
													busy hour avg. b/w (Mbps)	629.3

T1 - analog dial-in lines

# of modems / Tier1 POP	213
# of Tier1 POPs	450
# of modems / Tier2 POP	794
# of Tier2 POPs	9
Total # of Modems	30296
# of dial-in T1s required	4292

Total Cost T1 Dial-In **\$1,793,847**

ISDN PRI - digital dial-in lines

# of B channels required / Tier 1 POP	8
# of Tier1 POPs	450
# of B channels required / Tier 2 POP	14
# of Tier2 POPs	9
Total # of B channels	3726
# of ISDN PRI	162

Total Cost ISDN PRI **\$96,552**

Tier 1 - Tier 2 Connections

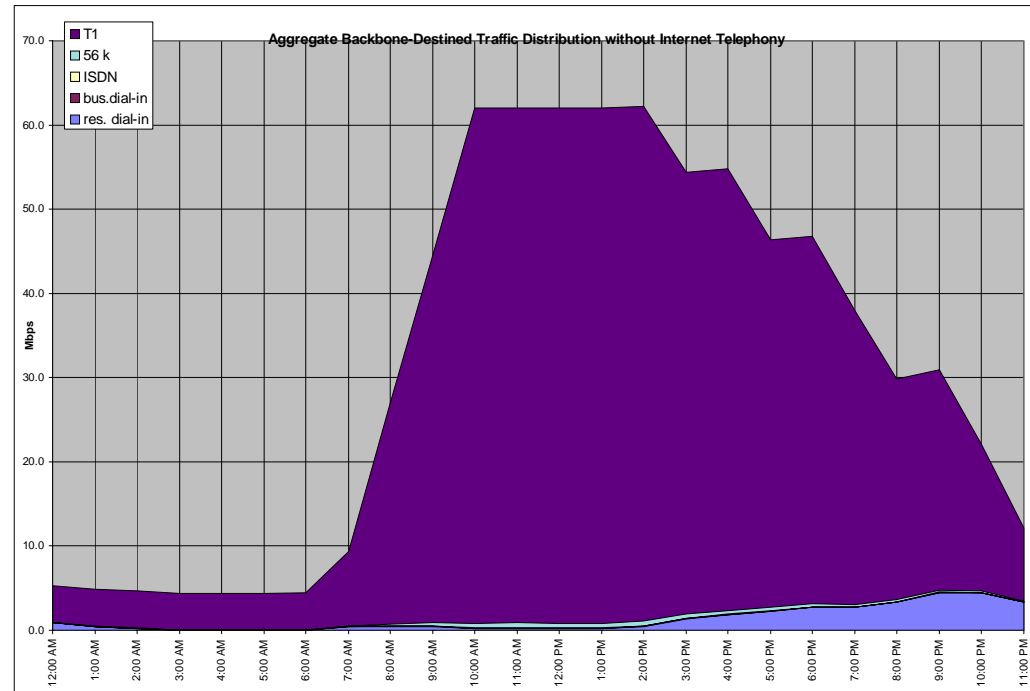
# of Tier 1 analog modems	213
avg b/w per analog dial-in user (kbps)	5.00
# of Tier 1 concurrent ISDN users	4
avg b/w per ISDN dial-in user (kbps)	25.00
peak traffic originating at Tier 1 (Mbps)	1.14
Tier 1 traffic terminating at Tier 1	0.00
Tier 1 traffic terminating at Tier 2	0.01
Tier 1 traffic destined for backbone	0.10
Tier 1 traffic destined for NAP	1.02
Total traffic on Tier 1/Tier 2 link (Mbps)	1.1
avg dist Tier1-Tier2 (miles)	75
round up to integer quantity?	N
# of data T1s per Tier 1 POP	1.06
# of Tier1 POPs	450
Total Miles T1 transport	35,712
subtotal T1 cost	\$1,673,093
Bulk discount	50%

Total T1 transport cost **\$836,547**

% capacity at which T1s are being used 70%

Tier 2 - Tier 2 T3/OC-3 Connections

Tier 1 and 2 traffic destined for backbone	62.2
Tier 1 and 2 traffic destined for NAP	629.3
% backbone traffic going 1 node distance	25%
% backbone traffic going 2 node distance	25%
% backbone traffic going 3 node distance	25%
% backbone traffic going 4 node distance	25%



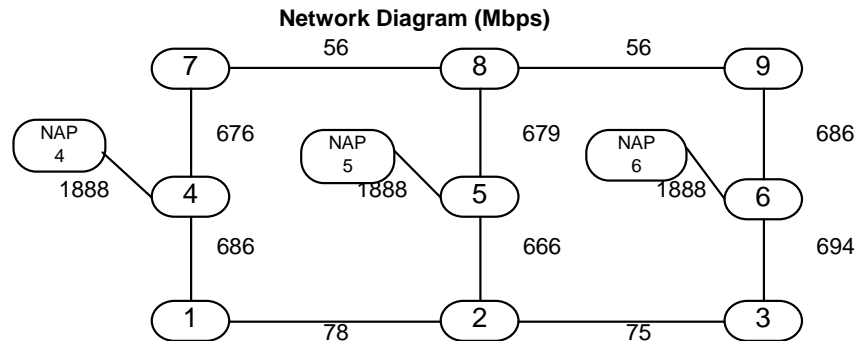
Demand Matrix - demand assumed to be symmetric

Node representing O-D pair	1	2	3	4	5	6	7	8	9	NAP 4	NAP 5	NAP 6
1	0.0	7.8	5.2	7.8	5.2	7.8	5.2	7.8	15.6	629.3	0.0	0.0
2		0.0	5.2	5.2	5.2	5.2	7.8	5.2	7.8	0.0	629.3	0.0
3			0.0	7.8	5.2	7.8	15.6	7.8	5.2	0.0	0.0	629.3
4				0.0	5.2	15.6	7.8	7.8	5.2	629.3	0.0	0.0
5					0.0	7.8	3.9	7.8	3.9	0.0	629.3	0.0
6						0.0	5.2	7.8	7.8	0.0	0.0	629.3
7							0.0	7.8	5.2	629.3	0.0	0.0
8								0.0	5.2	0.0	629.3	0.0
9									0.0	0.0	0.0	629.3
NAP 4										0.0	0.0	0.0
NAP 5											0.0	0.0
NAP 6												0.0

Link i-j	total traffic on i-j (Mbps)	distance of link	# of circuits			min # of circuits			
			T3	OC-3	T3 cost	OC-3 cost	T3	OC-3	min cost
1-2	78	1500	2.5	0.7	\$ 243,804	\$ 179,240	0.0	0.7	\$ 179,240
1-4	686	500	22.2	6.5	\$ 1,042,305	\$ 766,283	0.0	6.5	\$ 766,283
2-3	75	1500	2.4	0.7	\$ 235,678	\$ 173,266	0.0	0.7	\$ 173,266
2-5	666	500	21.5	6.3	\$ 1,010,803	\$ 743,124	0.0	6.3	\$ 743,124
3-6	694	500	22.4	6.6	\$ 1,054,118	\$ 774,968	0.0	6.6	\$ 774,968
4-NAP4	1888	5	61.0	17.9	\$ 1,357,262	\$ 997,834	0.0	17.9	\$ 997,834
4-7	676	500	21.8	6.4	\$ 1,026,554	\$ 754,704	0.0	6.4	\$ 754,704
5-NAP5	1888	5	61.0	17.9	\$ 1,357,262	\$ 997,834	0.0	17.9	\$ 997,834
5-8	679	500	21.9	6.4	\$ 1,030,492	\$ 757,599	0.0	6.4	\$ 757,599
6-NAP6	1888	5	61.0	17.9	\$ 1,357,262	\$ 997,834	0.0	17.9	\$ 997,834
6-9	686	500	22.2	6.5	\$ 1,042,305	\$ 766,283	0.0	6.5	\$ 766,283
7-8	56	1500	1.8	0.5	\$ 174,727	\$ 128,456	0.0	0.5	\$ 128,456
8-9	56	1500	1.8	0.5	\$ 174,727	\$ 128,456	0.0	0.5	\$ 128,456
					\$ 11,107,299	\$ 8,165,880		95.2	\$ 8,165,880

subtotal T3/OC-3 cost \$8,165,880
 Bulk discount 50%
 Total T3/OC-3 transport cost **\$4,082,940**

NAP Interconnection Cost
 type of connection OC-3
 cost per port @ NAP \$8,000
 # of ports 53.8
 Total NAP Interconnection cost **\$430,526**



Scenario with Internet telephony

Time of day	Tier 1 and Tier 2 call rate calculator				Tier 1 average calls per hour				Tier 2 average calls per hour					
	res. dial-in		bus. dial-in		Analog modems		ISDN total	res. dial-in		bus. dial-in		Analog modems		ISDN total
12:00 AM	92	0	0	92	0	369	0	369	0	0	0	0	0	
1:00 AM	46	0	0	46	0	185	0	185	0	0	0	0	0	
2:00 AM	23	0	0	23	0	92	0	92	0	0	0	0	0	
3:00 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	
4:00 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	
5:00 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	
6:00 AM	0	0	0	0	0	0	1	1	1	1	1	1	1	
7:00 AM	46	0	0	47	0	185	1	186	1	186	1	186	1	
8:00 AM	46	1	0	47	1	185	4	188	4	188	4	188	4	
9:00 AM	46	1	0	47	1	185	4	189	4	189	4	189	4	
10:00 AM	23	1	0	24	1	92	5	98	5	98	5	98	5	
11:00 AM	23	2	0	25	2	92	7	99	7	99	7	99	7	
12:00 PM	23	1	0	24	1	92	5	98	4	98	4	98	4	
1:00 PM	23	1	0	24	1	92	4	96	4	96	4	96	4	
2:00 PM	46	1	0	47	1	185	5	190	5	190	5	190	5	
3:00 PM	138	2	0	140	2	554	7	561	7	561	7	561	7	
4:00 PM	185	1	0	186	1	738	5	744	5	744	5	744	5	
5:00 PM	231	1	0	232	1	923	4	927	4	927	4	927	4	
6:00 PM	277	1	0	277	1	1108	2	1110	2	1110	2	1110	2	
7:00 PM	277	0	0	277	0	1108	1	1109	1	1109	1	1109	1	
8:00 PM	346	0	0	346	0	1385	0	1385	0	1385	0	1385	0	
9:00 PM	462	0	0	462	0	1846	0	1847	0	1847	0	1847	0	
10:00 PM	462	0	0	462	0	1846	0	1846	0	1846	0	1846	0	
11:00 PM	346	0	0	346	0	1385	0	1385	0	1385	0	1385	0	
subtotal	3162	14	0	3176	14	12646	57	12703	56	12703	56	12703	56	
% modem and T1 allocation per user t	100%	0%				100%	0%							
max # of calls and b/w @ busy hour				462	2			1847	7					

Time of day	Tier 1 (Mbps)				Tier 2 (Mbps)					
	res. dial-in	bus. dial-in	ISDN	Total	res. dial-in	bus. dial-in	ISDN	56 k	T1	Total
12:00 AM	0.4	0.0	0.0	0.4	1.8	0.0	0.0	0.7	81.5	84.0
1:00 AM	0.2	0.0	0.0	0.2	0.9	0.0	0.0	0.7	81.5	83.1
2:00 AM	0.1	0.0	0.0	0.1	0.4	0.0	0.0	0.7	81.5	82.6
3:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	81.5	82.2
4:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	81.5	82.2
5:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	81.5	82.2
6:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	81.5	82.2
7:00 AM	0.2	0.0	0.0	0.2	0.9	0.0	0.0	1.5	162.9	165.3
8:00 AM	0.2	0.0	0.0	0.3	0.9	0.0	0.1	4.4	488.8	494.2
9:00 AM	0.2	0.0	0.0	0.3	0.9	0.0	0.1	7.3	814.7	823.0
10:00 AM	0.1	0.0	0.0	0.2	0.4	0.0	0.1	10.2	1140.6	1151.4
11:00 AM	0.1	0.0	0.0	0.2	0.4	0.0	0.2	10.2	1140.6	1151.4
12:00 PM	0.1	0.0	0.0	0.1	0.4	0.0	0.1	10.2	1140.6	1151.3
1:00 PM	0.1	0.0	0.0	0.1	0.4	0.0	0.1	10.2	1140.6	1151.3
2:00 PM	0.2	0.0	0.0	0.3	0.9	0.0	0.1	10.2	1140.6	1151.8
3:00 PM	0.7	0.0	0.0	0.7	2.7	0.0	0.2	8.7	977.7	989.3
4:00 PM	0.9	0.0	0.0	0.9	3.6	0.0	0.1	8.7	977.7	990.1
5:00 PM	1.1	0.0	0.0	1.2	4.5	0.0	0.1	7.3	814.7	826.6
6:00 PM	1.3	0.0	0.0	1.4	5.4	0.0	0.1	7.3	814.7	827.4
7:00 PM	1.3	0.0	0.0	1.4	5.4	0.0	0.0	5.8	651.8	663.0
8:00 PM	1.7	0.0	0.0	1.7	6.7	0.0	0.0	4.4	488.8	499.9
9:00 PM	2.2	0.0	0.0	2.2	9.0	0.0	0.0	4.4	488.8	502.2
10:00 PM	2.2	0.0	0.0	2.2	9.0	0.0	0.0	2.9	325.9	337.8
11:00 PM	1.7	0.0	0.0	1.7	6.7	0.0	0.0	1.5	162.9	171.1
subtotal	15.4	0.1	0.3	15.8	61.5	0.3	1.4	119.7	13442.8	13625.6
% backbone allocation per user type	97%	0%	2%		0%	0%	0%	1%	99%	
busy hour avg. b/w (Mbps)				2.2						1151.8

Tier 1 and 2 backbone b/w calculations Time of day	Tier 1 (Mbps)			Tier 2 (Mbps)					Total traffic destined for backbone					
	res. dial-in	bus.dial-in	ISDN	res. dial-in	bus.dial-in	ISDN	56 k	T1	res. dial-in	bus.dial-in	ISDN	56 k	T1	Total
12:00 AM	0.0	0.0	0.0	0.2	0.0	0.0	0.1	7.3	2.2	0.0	0.0	0.1	7.3	9.5
1:00 AM	0.0	0.0	0.0	0.1	0.0	0.0	0.1	7.3	1.1	0.0	0.0	0.1	7.3	8.4
2:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.1	7.3	0.5	0.0	0.0	0.1	7.3	7.9
3:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.1	7.3	0.0	0.0	0.0	0.1	7.3	7.3
4:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.1	7.3	0.0	0.0	0.0	0.1	7.3	7.3
5:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.1	7.3	0.0	0.0	0.0	0.1	7.3	7.3
6:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.1	7.3	0.0	0.0	0.0	0.1	7.3	7.3
7:00 AM	0.0	0.0	0.0	0.1	0.0	0.0	0.1	14.5	1.1	0.0	0.0	0.1	14.5	15.8
8:00 AM	0.0	0.0	0.0	0.1	0.0	0.0	0.4	43.5	1.1	0.0	0.1	0.4	43.5	45.1
9:00 AM	0.0	0.0	0.0	0.1	0.0	0.0	0.6	72.5	1.1	0.0	0.1	0.6	72.5	74.4
10:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.9	101.5	0.5	0.0	0.2	0.9	101.5	103.1
11:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.9	101.5	0.5	0.0	0.2	0.9	101.5	103.2
12:00 PM	0.0	0.0	0.0	0.0	0.0	0.0	0.9	101.5	0.5	0.0	0.1	0.9	101.5	103.1
1:00 PM	0.0	0.0	0.0	0.0	0.0	0.0	0.9	101.5	0.5	0.0	0.1	0.9	101.5	103.1
2:00 PM	0.0	0.0	0.0	0.1	0.0	0.0	0.9	101.5	1.1	0.0	0.2	0.9	101.5	103.7
3:00 PM	0.1	0.0	0.0	0.2	0.0	0.0	0.8	87.0	3.2	0.0	0.2	0.8	87.0	91.3
4:00 PM	0.1	0.0	0.0	0.3	0.0	0.0	0.8	87.0	4.3	0.0	0.2	0.8	87.0	92.3
5:00 PM	0.1	0.0	0.0	0.4	0.0	0.0	0.6	72.5	5.4	0.0	0.1	0.6	72.5	78.7
6:00 PM	0.1	0.0	0.0	0.5	0.0	0.0	0.6	72.5	6.5	0.0	0.1	0.6	72.5	79.7
7:00 PM	0.1	0.0	0.0	0.5	0.0	0.0	0.5	58.0	6.5	0.0	0.0	0.5	58.0	65.0
8:00 PM	0.1	0.0	0.0	0.6	0.0	0.0	0.4	43.5	8.1	0.0	0.0	0.4	43.5	52.0
9:00 PM	0.2	0.0	0.0	0.8	0.0	0.0	0.4	43.5	10.8	0.0	0.0	0.4	43.5	54.7
10:00 PM	0.2	0.0	0.0	0.8	0.0	0.0	0.3	29.0	10.8	0.0	0.0	0.3	29.0	40.0
11:00 PM	0.1	0.0	0.0	0.6	0.0	0.0	0.1	14.5	8.1	0.0	0.0	0.1	14.5	22.7
subtotal									73.9	0.3	1.6	10.6	1196.4	1282.9
% T3/OC-3 b/w allocated per user type									6%	0%	0%	1%	93%	103.7
												busy hour avg. b/w (Mbps)		

Tier 1 and 2 NAP b/w calculations Time of day	Tier 1 (Mbps)			Tier 2 (Mbps)					Total traffic destined for NAP					
	res. dial-in	bus.dial-in	ISDN	res. dial-in	bus.dial-in	ISDN	56 k	T1	res. dial-in	bus.dial-in	ISDN	56 k	T1	Total
12:00 AM	0.4	0.0	0.0	1.6	0.0	0.0	0.7	73.3	21.8	0.0	0.0	0.7	73.3	95.8
1:00 AM	0.2	0.0	0.0	0.8	0.0	0.0	0.7	73.3	10.9	0.0	0.0	0.7	73.3	84.9
2:00 AM	0.1	0.0	0.0	0.4	0.0	0.0	0.7	73.3	5.5	0.0	0.0	0.7	73.3	79.4
3:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.7	73.3	0.0	0.0	0.0	0.7	73.3	74.0
4:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.7	73.3	0.0	0.0	0.0	0.7	73.3	74.0
5:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.7	73.3	0.0	0.0	0.0	0.7	73.3	74.0
6:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.7	73.3	0.0	0.0	0.2	0.7	73.3	74.2
7:00 AM	0.2	0.0	0.0	0.8	0.0	0.0	1.3	146.6	10.9	0.1	0.4	1.3	146.6	159.4
8:00 AM	0.2	0.0	0.0	0.8	0.0	0.1	3.9	439.9	10.9	0.2	1.0	3.9	439.9	456.0
9:00 AM	0.2	0.0	0.0	0.8	0.0	0.1	6.5	733.2	10.9	0.3	1.3	6.5	733.2	752.2
10:00 AM	0.1	0.0	0.0	0.4	0.0	0.1	9.1	1026.5	5.5	0.3	1.6	9.1	1026.5	1043.0
11:00 AM	0.1	0.0	0.0	0.4	0.0	0.2	9.1	1026.5	5.5	0.4	2.1	9.1	1026.5	1043.7
12:00 PM	0.1	0.0	0.0	0.4	0.0	0.1	9.1	1026.5	5.5	0.3	1.0	9.1	1026.5	1042.5
1:00 PM	0.1	0.0	0.0	0.4	0.0	0.1	9.1	1026.5	5.5	0.2	1.3	9.1	1026.5	1042.6
2:00 PM	0.2	0.0	0.0	0.8	0.0	0.1	9.1	1026.5	10.9	0.3	1.6	9.1	1026.5	1048.5
3:00 PM	0.6	0.0	0.0	2.4	0.0	0.2	7.8	879.9	32.7	0.4	2.1	7.8	879.9	923.0
4:00 PM	0.8	0.0	0.0	3.2	0.0	0.1	7.8	879.9	43.6	0.3	1.6	7.8	879.9	933.2
5:00 PM	1.0	0.0	0.0	4.0	0.0	0.1	6.5	733.2	54.5	0.3	1.3	6.5	733.2	795.8
6:00 PM	1.2	0.0	0.0	4.8	0.0	0.0	6.5	733.2	65.5	0.1	0.6	6.5	733.2	806.0
7:00 PM	1.2	0.0	0.0	4.8	0.0	0.0	5.2	586.6	65.5	0.1	0.3	5.2	586.6	657.6
8:00 PM	1.5	0.0	0.0	6.1	0.0	0.0	3.9	439.9	81.8	0.0	0.1	3.9	439.9	525.8
9:00 PM	2.0	0.0	0.0	8.1	0.0	0.0	3.9	439.9	109.1	0.0	0.1	3.9	439.9	553.1
10:00 PM	2.0	0.0	0.0	8.1	0.0	0.0	2.6	293.3	109.1	0.0	0.0	2.6	293.3	405.0
11:00 PM	1.5	0.0	0.0	6.1	0.0	0.0	1.3	146.6	81.8	0.0	0.0	1.3	146.6	229.8
subtotal									747.2	3.4	16.6	107.7	12098.5	12973.4
% T3/OC-3 b/w allocated per user type									6%	0%	0%	1%	93%	1048.5
												busy hour avg. b/w (Mbps)		

T1 - analog dial-in lines

# of modems / Tier1 POP	298
# of Tier1 POPs	450
# of modems / Tier2 POP	1131
# of Tier2 POPs	9
Total # of Modems	144279
# of dial-in T1s required	6012

Total Cost T1 Dial-In \$2,512,859

ISDN PRI - digital dial-in lines

# of B channels required / Tier 1 POP	14
# of Tier1 POPs	450
# of B channels required / Tier 2 POP	20
# of Tier2 POPs	9
Total # of B channels	6480
# of ISDN PRI	282

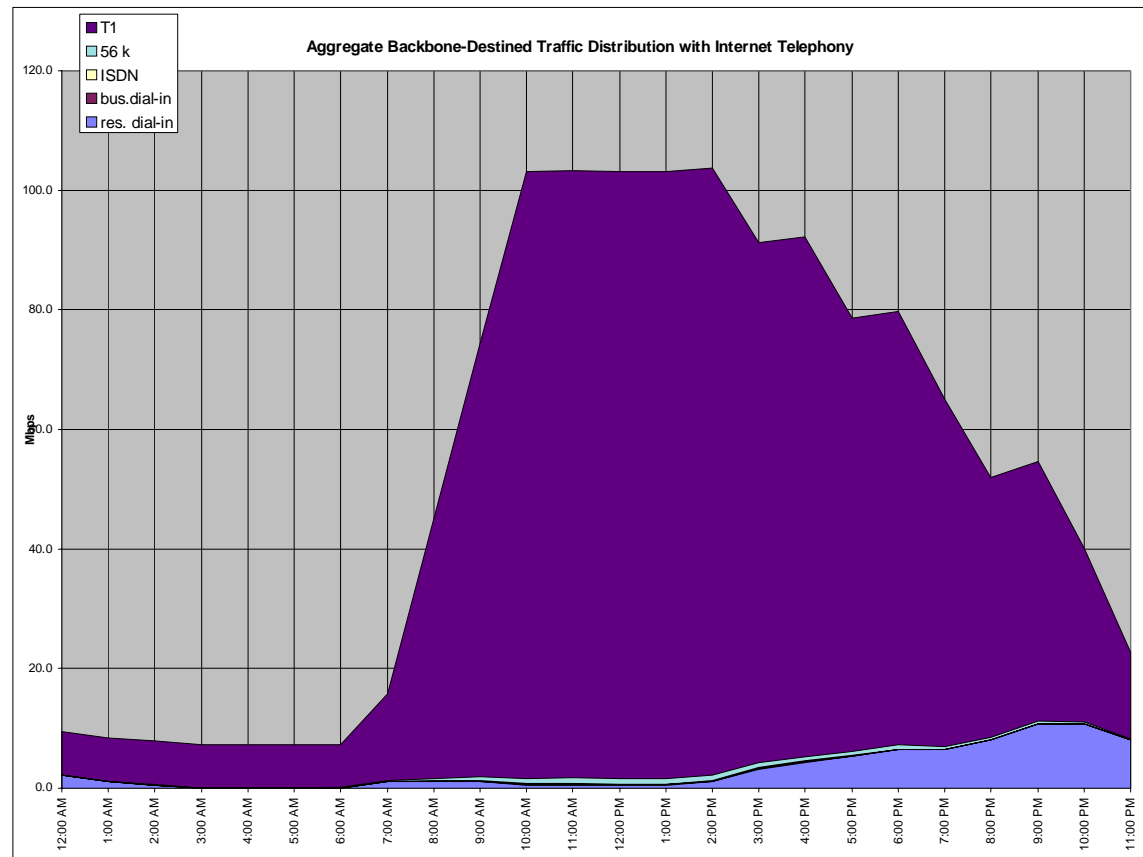
Total Cost ISDN PRI \$167,917

Tier 1 - Tier 2 Connections

# of Tier 1 analog modems	298
avg b/w per analog dial-in user (kbps)	8.30
# of Tier 1 concurrent ISDN users	7.0
avg b/w per ISDN dial-in user (kbps)	41.50
peak traffic originating at Tier 1 (Mbps)	2.70
Tier 1 traffic terminating at Tier 1	0.00
Tier 1 traffic terminating at Tier 2	0.03
Tier 1 traffic destined for backbone	0.24
Tier 1 traffic destined for NAP	2.43
Total traffic on Tier 1/Tier 2 link (Mbps)	2.7
avg dist Tier1-Tier2 (miles)	75
Total traffic on Tier 1/Tier 2 link (Mbps)	2.7
round up to integer quantity?	N
# of data T1s per Tier 1 POP	2.5
# of Tier1 POPs	450
Total Miles T1 transport	84,724
subtotal T1 cost	\$3,969,323
Bulk discount	50%
Total T1 transport cost	\$1,984,662
% capacity at which T1s are being used	70%

Tier 2 - Tier 2 T3/OC-3 Connections

Tier 1 and 2 traffic destined for backbone	103.7
Tier 1 and 2 traffic destined for NAP	1048.5
% backbone traffic going 1 node distance	25%
% backbone traffic going 2 node distance	25%
% backbone traffic going 3 node distance	25%
% backbone traffic going 4 node distance	25%



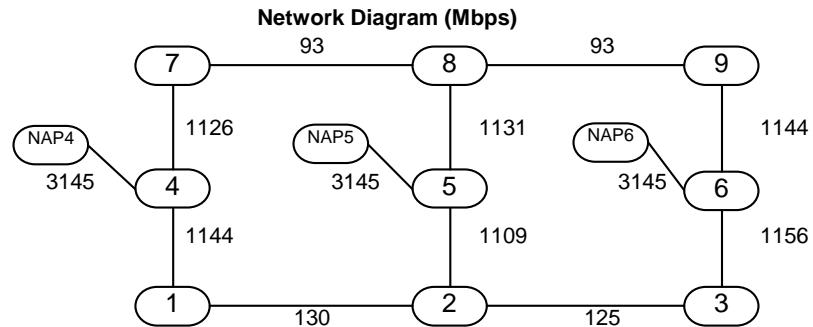
Demand Matrix - demand assumed to be symmetric

Node representing O-D pair	1	2	3	4	5	6	7	8	9	NAP 4	NAP 5	NAP 6
1	0.0	13.0	8.6	13.0	8.6	13.0	8.6	13.0	25.9	1048.5	0.0	0.0
2		0.0	8.6	8.6	8.6	8.6	13.0	8.6	13.0	0.0	1048.5	0.0
3			0.0	13.0	8.6	13.0	25.9	13.0	8.6	0.0	0.0	1048.5
4				0.0	8.6	25.9	13.0	13.0	8.6	1048.5	0.0	0.0
5					0.0	13.0	6.5	13.0	6.5	0.0	1048.5	0.0
6						0.0	8.6	13.0	13.0	0.0	0.0	1048.5
7							0.0	13.0	8.6	1048.5	0.0	0.0
8								0.0	8.6	0.0	1048.5	0.0
9									0.0	0.0	0.0	1048.5
NAP 4										0.0	0.0	0.0
NAP 5											0.0	0.0
NAP 6												0.0

Link i-j	total traffic on i-j (Mbps)	distance of link	# of circuits			min # of circuits			
			T3	OC-3	T3 cost	OC-3 cost	T3	OC-3	min cost
1-2	130	1500	4.2	1.2	\$ 406,230	\$ 298,653	0.0	1.2	\$ 298,653
1-4	1144	500	37.0	10.9	\$ 1,736,703	\$ 1,276,792	0.0	10.9	\$ 1,276,792
2-3	125	1500	4.0	1.2	\$ 392,689	\$ 288,698	0.0	1.2	\$ 288,698
2-5	1109	500	35.8	10.5	\$ 1,684,214	\$ 1,238,203	0.0	10.5	\$ 1,238,203
3-6	1156	500	37.4	11.0	\$ 1,756,387	\$ 1,291,263	0.0	11.0	\$ 1,291,263
4-NAP4	3145	5	101.6	29.9	\$ 2,261,488	\$ 1,662,604	0.0	29.9	\$ 1,662,604
4-7	1126	500	36.4	10.7	\$ 1,710,459	\$ 1,257,498	0.0	10.7	\$ 1,257,498
5-NAP5	3145	5	101.6	29.9	\$ 2,261,488	\$ 1,662,604	0.0	29.9	\$ 1,662,604
5-8	1131	500	36.5	10.7	\$ 1,717,020	\$ 1,262,321	0.0	10.7	\$ 1,262,321
6-NAP6	3145	5	101.6	29.9	\$ 2,261,488	\$ 1,662,604	0.0	29.9	\$ 1,662,604
6-9	1144	500	37.0	10.9	\$ 1,736,703	\$ 1,276,792	0.0	10.9	\$ 1,276,792
7-8	93	1500	3.0	0.9	\$ 291,132	\$ 214,035	0.0	0.9	\$ 214,035
8-9	93	1500	3.0	0.9	\$ 291,132	\$ 214,035	0.0	0.9	\$ 214,035
					\$18,507,135	\$13,606,102		158.6	\$13,606,102

subtotal T3/OC-3 cost \$13,606,102
 Bulk discount 50%
Total T3/OC-3 transport cost \$6,803,051

NAP Interconnection Cost
 type of connection OC-3
 cost per port @ NAP \$8,000
 # of ports 89.7
Total NAP Interconnection cost \$717,348



Cost Model Tables: Customer Service

Scenario without Internet telephony

Customer Service

	calls/sub/mo	min/call	cost/min	# of subs	cost/month
residential dial-in subs.	0.3	15.0	\$2.00	934,615	\$7,009,615
business dial-in subs.	0.3	15.0	\$2.00	3,595	\$26,960
ISDN dial-in subs.	0.3	15.0	\$2.00	3,595	\$26,960
56 kb subs.	2.0	15.0	\$4.00	1,438	\$172,544
T1 subs.	2.0	15.0	\$4.00	5,751	\$690,178
basic Web hosting subs.	0.0	0.0	\$0.00	0	\$0
enhanced Web hosting subs.	0.0	0.0	\$0.00	0	\$0
<i>Total customer service cost</i>					\$7,926,257

Scenario with Internet telephony

Customer Service

	calls/sub/mo	min/call	cost/min	# of subs	cost/month
residential dial-in subs.	0.3	18.0	\$2.00	934,615	\$10,093,846
business dial-in subs.	0.3	18.0	\$2.00	3,595	\$38,822
ISDN dial-in subs.	0.3	18.0	\$2.00	3,595	\$38,822
56 kb subs.	2.4	18.0	\$4.00	1,438	\$248,464
T1 subs.	2.4	18.0	\$4.00	5,751	\$993,856
basic Web hosting subs.	0.0	0.0	\$0.00	0	\$0
enhanced Web hosting subs.	0.0	0.0	\$0.00	0	\$0
<i>Total customer service cost</i>					\$11,413,811

Cost Model Tables: Operations

Scenario without Internet telephony

Billing and Collections

	\$/sub/mo	# of subs	cost/month	allocation
residential dial-in subs.	\$1.25	934,615	\$1,168,269	98%
business dial-in subs.	\$1.25	3,595	\$4,493	0%
ISDN dial-in subs.	\$1.25	3,595	\$4,493	0%
56 kb subs.	\$1.25	1,438	\$1,797	0%
T1 subs.	\$1.25	5,751	\$7,189	1%
basic Web hosting subs.	\$1.25	0	\$0	0%
enhanced Web hosting subs.	\$1.25	0	\$0	0%
<i>Total billing and collections</i>			\$1,186,243	

Network Operations and Maintenance

software and hardware maintenance	
total capital equipment cost	\$3,348,250
operations and maint. % of cost	20%
<i>Total Operations and Maint.</i>	\$669,650
POP personnel	
# of Tier 1 POPs	450
# of Tier 1 POPs/Operations persons	1.7
# of Tier 2 POPs	9
# of Tier 2 POPs/Operations persons	0.5
Total # of Operations persons	283
Ops person's monthly salary	\$4,167
<i>Total POP personnel cost</i>	\$1,177,941
Web hosting personnel	
Total # of basic sites	0
# of basic sites / web person	0
Total number basic site personnel	0
Total # of enhanced sites	0
# of enhanced / web person	0
Total number enhanced site personnel	0
Web person's monthly salary	\$0
<i>Total web hosting personnel</i>	\$0
facilities	
Total # of Tier 1 POPs	450
\$ per Tier 1 POP per month	\$830
Total # of Tier 2 POPs	9
\$ per Tier 2 POP per month	\$4,125
<i>Total facilities cost</i>	\$410,625

Scenario with Internet telephony**Billing and Collections**

	\$/sub/mo	# of subs	cost/month	allocation
residential dial-in subs.	\$1.25	934,615	\$1,168,269	98%
business dial-in subs.	\$1.25	3,595	\$4,493	0%
ISDN dial-in subs.	\$1.25	3,595	\$4,493	0%
56 kb subs.	\$1.25	1,438	\$1,797	0%
T1 subs.	\$1.25	5,751	\$7,189	1%
basic Web hosting subs.	\$1.25	0	\$0	0%
enhanced Web hosting subs.	\$1.25	0	\$0	0%
<i>Total billing and collections</i>			\$1,186,243	

Network Operations and Maintenance

software and hardware maintenance	
total capital equipment cost	\$5,002,000
operations and maint. % of cost	20%
<i>Total Operations and Maint.</i>	\$1,000,400
POP personnel	
<i># of Tier 1 POPs</i>	450
# of Tier 1 POPs/Operations persons	1.7
<i># of Tier 2 POPs</i>	9
# of Tier 2 POPs/Operations persons	0.5
Total # of Operations persons	283
Ops person's monthly salary	\$4,167
<i>Total POP personnel cost</i>	\$1,177,941
Web hosting personnel	
Total # of basic sites	0
# of basic sites / web person	0
Total number basic site personnel	0
Total # of enhanced sites	0
# of enhanced / web person	0
Total number enhanced site personnel	0
Web person's monthly salary	\$0
<i>Total web hosting personnel</i>	\$0
facilities	
Total # of Tier 1 POPs	450
\$ per Tier 1 POP per month	\$830
Total # of Tier 2 POPs	9
\$ per Tier 2 POP per month	\$4,125
<i>Total facilities cost</i>	\$410,625