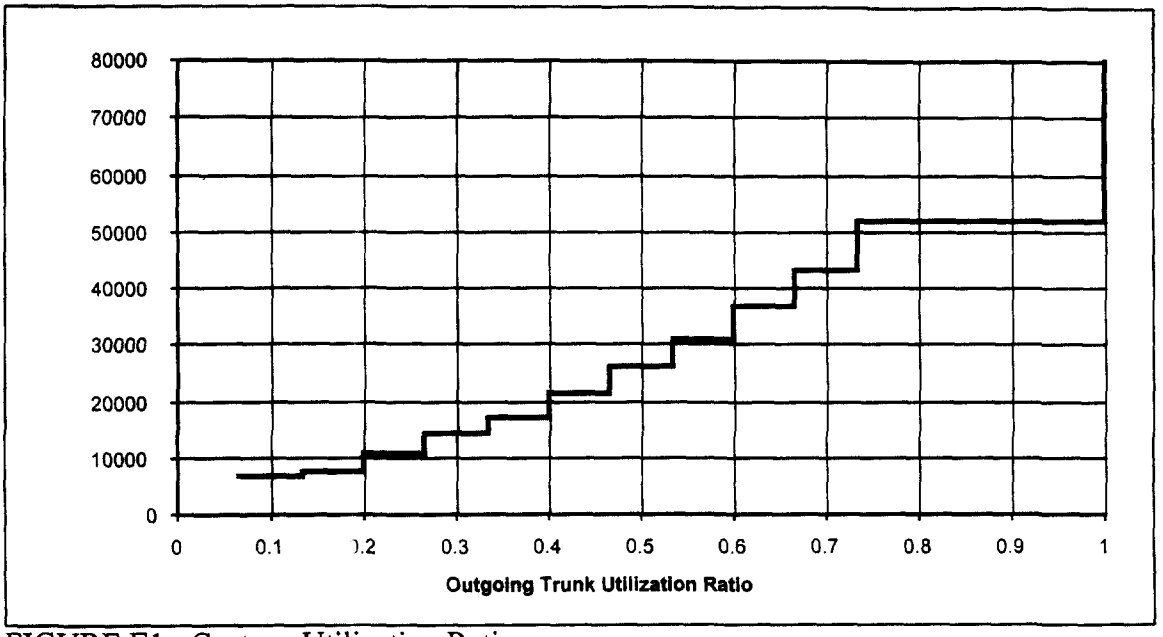


FIGURE E1: Cost vs. Utilization Ratio

- At some level of increased outgoing bandwidth it is more economical for the IAP/gateway to utilize T3 rather than T1 lines. This level is defined as the T1-T3 threshold.
- The IAP/gateway provides an outgoing bandwidth to the ISP equal to a fraction of its maximum incoming bandwidth defined as the overflow ratio.

DISCUSSION OF RESULTS

This model of the upstream components of Internet Telephony provides:

1) The total costs (per month and per minute) to the IAP/gateway of an upstream connection.
2) The percentage of the total costs for Internet Telephony related to upstream.

The costs of the upstream component fall within a range, depending on the value assumed for the input variables. For a final numerical value one should refer to the summed price model. These are not exact numbers, but they provide a feel for the range of values that apply and fall within a range which can be considered reasonable. The range of cost to the IAP/gateway for the upstream component can be loosely stated as $0.05 to $0.30 per simultaneous user per hour. A further feel for the results can be deduced from the sensitivity analysis, which should be referred to for a more complete understanding of the effects of different variables.

SENSITIVITY ANALYSIS

The sensitivity analysis provides an understanding of which variables strongly affect the upstream cost. The influence of specific variables on the total monthly and per minute costs of upstream connection to the ISP were analyzed. These variables included number of incoming lines, number of subscribers per line, and compression ratio.

Each of the following headings describes the variable that is altered within the section below it. As in the previous cases, the variables not altered were kept at the following default values:

- # of Simultaneous Users = 120 (1560 subscribers)
- Distance between CO and IAP/ISP = 5 miles
- Distance between IAP and ISP = 20 miles
- Line Leasing Period = 40 months
- Compression Ratio = 2.67
- T1 - T3 Threshold = 4

OF INCOMING LINES (SIMULTANEOUS USERS)

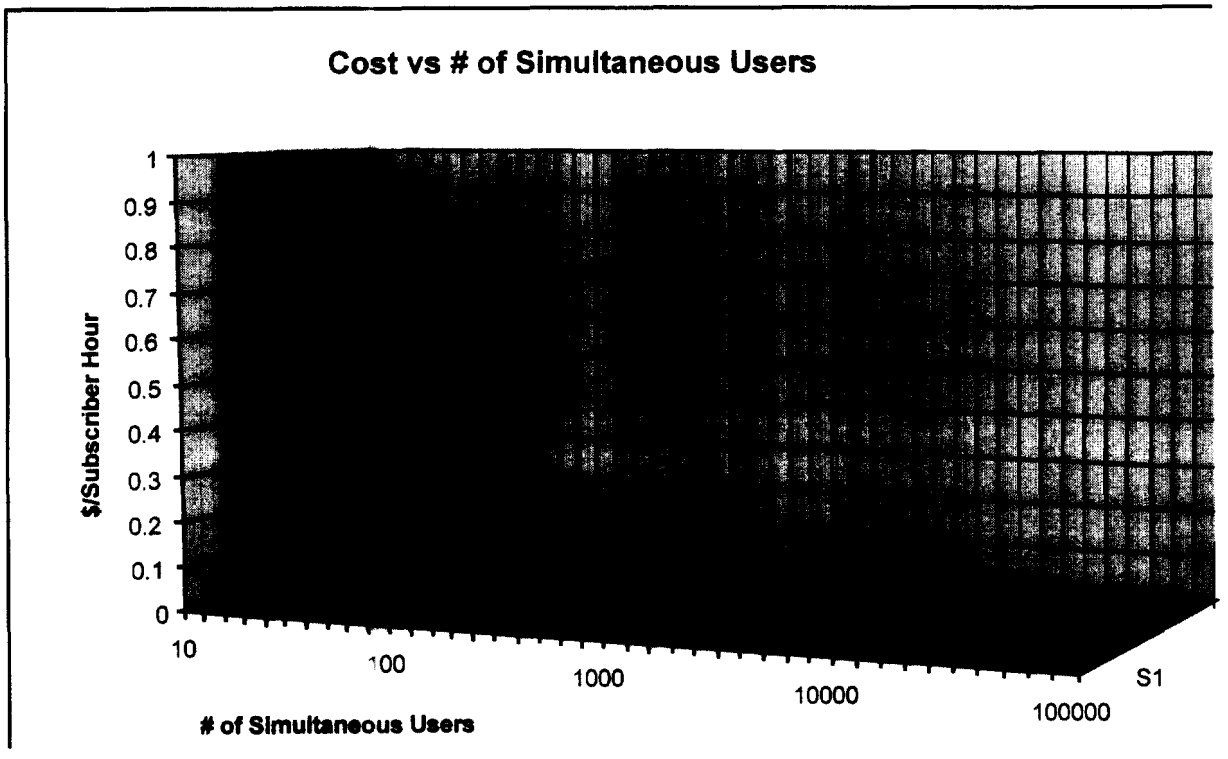


Figure E2 Cost vs. # of Simultaneous Users

As was the case with the local and gateway components, economies of scale are also present in the upstream as shown by the Figure E2. The first two jumps seen in the figure are due to the increased costs of adding another T1 line to handle the increased bandwidth. The third small increase seen around 30,000 users is caused by replacement

of the T1 lines with T3 lines. Little additional savings per subscriber hour are achievable beyond approximately 80,000 simultaneous users. The general trend is that costs are reduced because larger capacity lines necessary for serving many subscribers are more cost effective than the smaller lines.

COMPRESSION RATIO

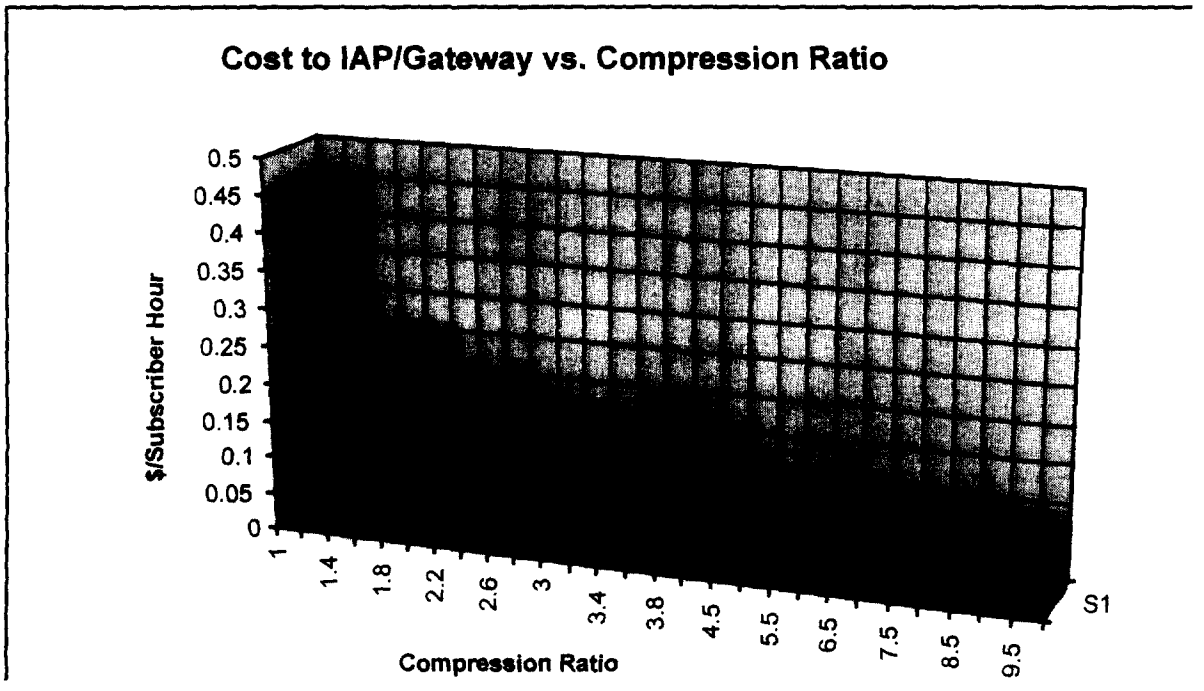


Figure E3 Cost/Subscriber-Hour vs. Compression Ratio

Variation of the compression ratio, as shown in Figure E3, results in a series of steps in the cost/subscriber hour function. This results because the number of outgoing lines decreases in integer units. At a compression ratio of approximately 5, the reduced required outgoing bandwidth allows for a T1 line to be eliminated. However, in the range of compression ratio of interest for Internet Telephony, namely 2-5, the cost is seen to be essentially constant. Therefore, a compression ratio equal to 2.67 is an acceptable assumption to produce a high degree of confidence in the resulting upstream costs to the IAP.

T1 - T3 THRESHOLD

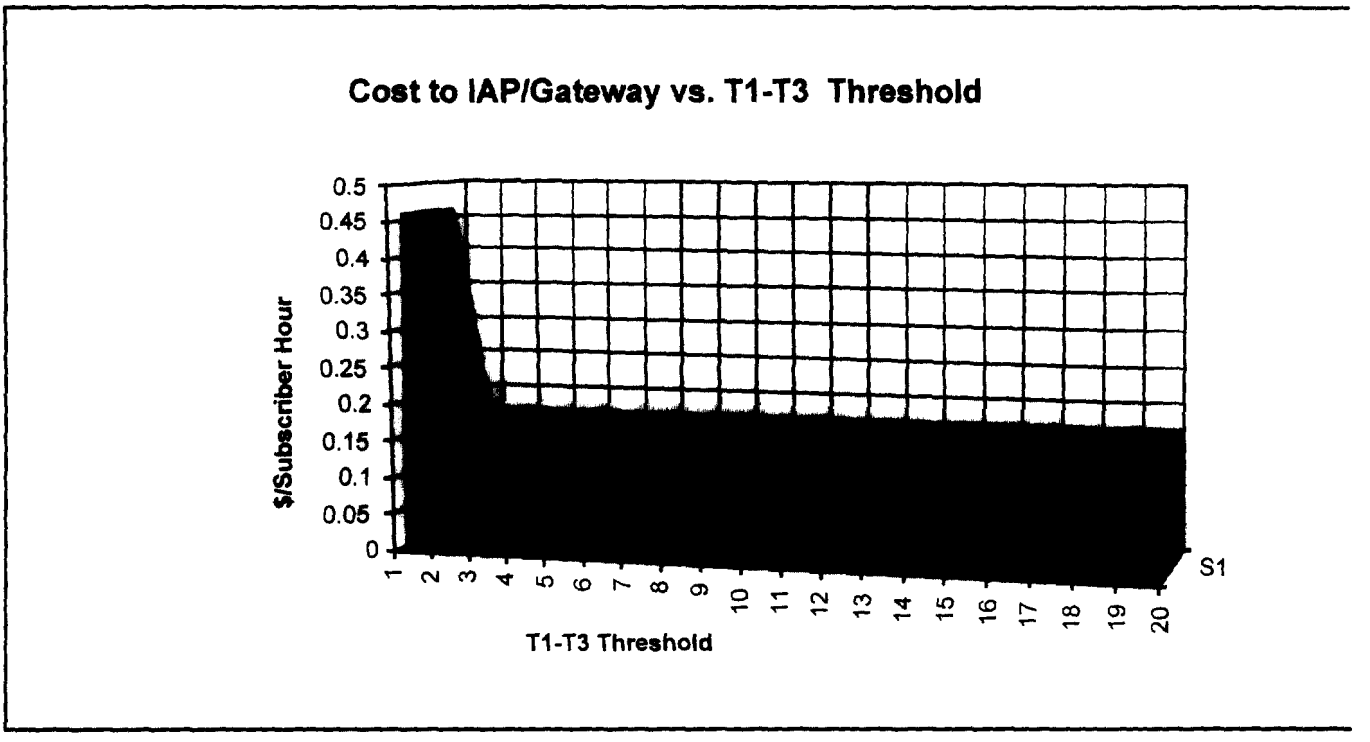


Figure E4: Cost to IAP/Gateway vs. T1-T3 Threshold

This upstream analysis assumes that the number of T1 lines that are equivalent to T3 lines (i.e. T1-T3 threshold) is equal to 4. Figure E4 indicates that altering the T1-T3 threshold has no effect on the upstream costs per subscriber-hour beyond a threshold of 2. Therefore, a T1-T3 threshold value of 4 is an acceptable assumption to produce a high degree of confidence in the resulting upstream costs to the IAP.

Appendix F: Assumptions and Results of Overall Models

IAP Model: Key Assumptions

All costs in the model will be the current costs seen by the Internet Access Provider. This will mean that the local cost component will simply be the monthly price from the LEC for the local lines, and the upstream cost component will simply be the monthly price charged by the upstream ISP. These assumptions come from the fact that this is a price model rather than a cost model.

$$C_{local} = P_{incoming} + P_{outgoing} \qquad C_{upstream} = P_{upstream}$$

The IAP market is fairly competitive, which means that the cost of providing Internet Access to one user is fairly close to current prices.

$$C_{total\ per\ user} = P_{user}$$

The IPOP considered in this model is the average IPOP for a large IAP, which for this model was Netcom.[1]

Calls are made from one computer to another computer. Although the total cost of a call includes the costs at both ends, the cost seen by the IAP is only the cost of providing the service to one end because each user splits the total cost of the call. The costs used for the IPOP include all operational costs including advertising, billing, labor, equipment, etc. It is important to note that this is not the marginal cost of placing a call.

		(monthly)	(per user)	(per hour)	(per min)	%
Local Costs	=	$ 2,103	$ 1.348	$ 0.090	$0.0015	11.5%
IPOP Costs	=	$ 14,166	$ 9.081	$ 0.605	$0.0101	77.5%
Upstream Costs	=	$ 2,000	$ 1.28	$ 0.085	$0.001	10.9%
Local Access Fee	=	$ -	$ -	$ -	$0.000	0.0%
Total Cost	=	**$ 18,269**	**$ 11.71**	**$ 0.781**	**$0.013**	

Table F1: Results of IAP Pricing Model

Gateway Model: Key Assumptions

The Internet telephony gateway provider will most likely be an IAP. It is assumed that they would follow a similar business model for providing this gateway service, and would have similar operational costs.

[1] Cohen and Pankopf, Dec. 11, 1995.

The equipment costs for a gateway are similar to the equipment cost of an IAP's modem bank. This assumption is further explained in Appendix D.
The only significant cost difference between an IAP and a Gateway Provider will be the required bandwidth of the outgoing line. The bandwidth for a call using Internet telephony will be 24 kbps, which gives a compression ratio of 2.67:1. This compression ratio is the maximum possible using Dialogic cards, which could be used for an Internet telephony gateway.

All other assumptions from the IAP price model are the same for this model.

		(monthly)	(per user)	(per hour)	(per min)	%
Local Costs	=	$ 2,748	$ 1.761	$ 0.117	$0.0020	12.5%
IPOP Costs	=	$ 15,316	$ 9.818	$ 0.655	$0.0109	69.4%
Upstream Costs	=	$ 4,000	$ 2.56	$ 0.171	$0.003	18.1%
Local Access Fee	=	$ -	$ -	$ -	$0.000	0.0%
Total Cost	**=**	**$ 22,064**	**$ 14.14**	**$ 0.943**	**$0.016**	

Table F2: Results of Gateway Price Model

Regulatory Model: Key Assumptions

- A local subsidy of 2.5 cents per minute is charged at both ends of the call, adding a total of 5 cents per minute
- A local subsidy is not charged for the leased lines from the IAP to connect to the upstream ISP to avoid "double" charging the subsidy.
- All other assumptions from the IAP price model are the same for this model.
- From previous assumptions, economic analysis shows that consumers will bear the cost of the access fee. This is because one of the assumptions used earlier was that the IAP market is fairly competitive, which means that if IAPs were to bear the access fee they would no longer be able to offer any type of Internet access profitably.

		(monthly)	(per user)	(per hour)	(per min)	%
Local Costs	=	$ 2,103	$ 1.348	$ 0.090	$0.0015	3.9%
IPOP Costs	=	$ 14,166	$ 9.081	$ 0.605	$0.0101	26.5%
Upstream Costs	=	$ 2,000	$ 1.28	$ 0.085	$0.001	3.7%
Local Access Fee	=	$ 35,100	$ 23	$ 1.500	$0.025	65.8%
Total Cost	**=**	**$ 53,369**	**$ 34.21**	**$ 2.281**	**$0.038**	

Table F3. Results of Regulatory Model

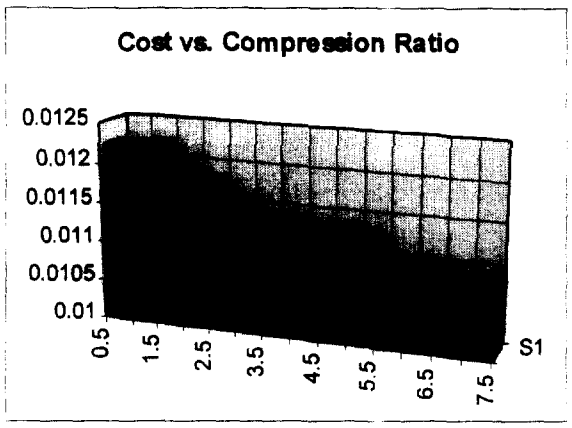
Appendix G: Overall Model Sensitivity Analysis

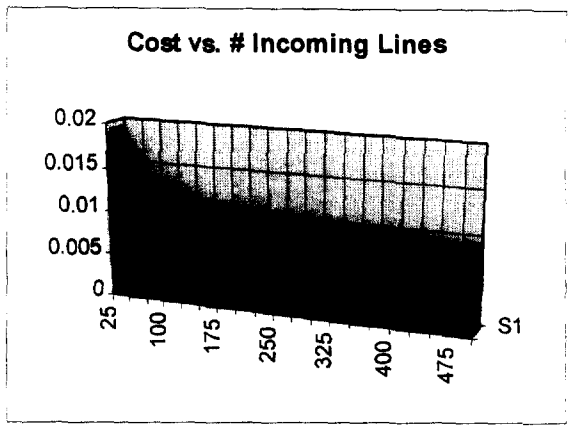
COMPUTER TO COMPUTER SCENARIO

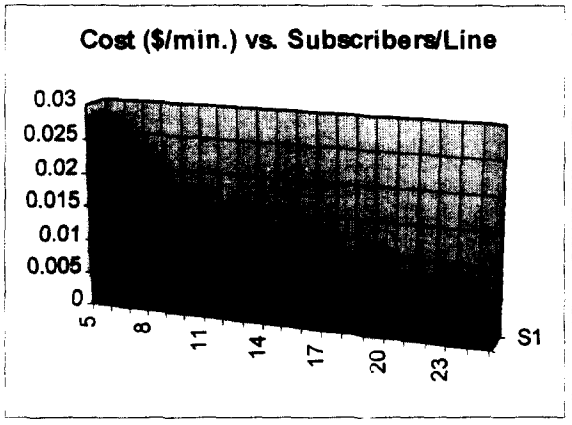
Although costs increase linearly with distance, the effect on total costs is minimal for both the distances to the central offices and the distance between the IAP and ISP. Changes in the former result in cost differentials of no more than $0.00001 per user-minute; while changes in the latter result in cost differences on the order of $0.0001 per user-min. The line leasing period likewise has minimal effect on total costs; its greatest effect occurs for periods of less than 48 months, but even in this range the effect is only $0.0001 per user-min. Changing the price threshold between T1 and T3 lines also has only a small effect on total cost (also along the lines of $0.0001/user-min.); this threshold simply determines at what capacity the more cost-efficient (in terms of cost/bandwidth) T3 lines can be used.

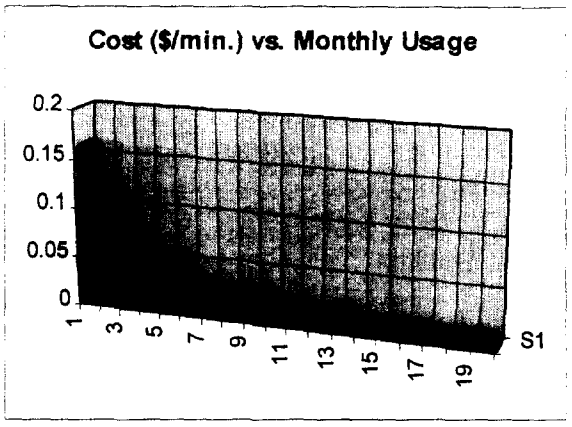
The model is somewhat more sensitive to the compression ratio; costs decrease in discrete steps (of $0.00046/user-min.) at points where increased compression allows one less line to be used. The total number of incoming lines has a significant effect on costs. Costs drop off rapidly as the number of incoming lines is increased, until the line count reaches 100 lines or so, when the decrease levels off significantly. At 25 lines, costs are $0.019/user-min; at 100 lines, $0.011/user-min. The number of subscribers per line has an even more significant effect on costs. At 5 subscribers/line the cost per user-minute is $0.028. At 10 subscribers/line cost drops to $0.014/user-min. and at 20 subscribers/line, costs are $0.007/user-min. Total costs are also highly dependent on the monthly usage per user. At 1 hour, costs are $0.163; by 5 hours/month, costs decrease to $0.032 and by 10 hrs/mo. costs are $0.016. Note that increases in subscribers/line and on usage/user are limited by the available incoming lines; the subscriber-usage product cannot exceed the available bandwidth-hours.

In summary, the model is most sensitive to usage characteristics: how many subscribers the provider is serving, and how heavy their usage. Decreases in cost/user-minute with increasing usage indicate economies of scale are available in providing Internet access/Internet telephony services.


Cost vs. Compression Ratio
0.0125
0.012
0.0115
0.011
0.0105
0.01
0.5
1.5
2.5
3.5
4.5
5.5
6.5
7.5
S1


Cost vs. # Incoming Lines
0.02
0.015
0.01
0.005
0
25
100
175
250
325
400
475
S1


Cost ($/min.) vs. Subscribers/Line
0.03
0.025
0.02
0.015
0.01
0.005
0
5
8
11
14
17
20
23
S1


Cost ($/min.) vs. Monthly Usage
0.2
0.15
0.1
0.05
0
1
3
5
7
9
11
13
15
17
19
S1