Internet Telephony or Circuit Switched Telephony:

Which is Cheaper?

Martin B.H. Weiss
{mbw+@pitt.edu}
Telecommunications Program
University of Pittsburgh
Pittsburgh PA 15260

Junseok Hwang
{hwang@tele.pitt.edu}
Telecommunications Program
University of Pittsburgh
Pittsburgh PA 15260

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Running heading: Internet vs. Circuit Telephony Cost

Abstract

Telephony is an Internet application that has the potential to radically alter the telecommunications environment. This application may affect traditional regulatory structures, subsidy structures, business models, *etc*. Today, users can transmit telephone-like voice traffic over the Internet at zero incremental price, unlike circuit switched telephony, which has a per-minute incremental price. This research was carried out to determine whether Internet Telephony (Itel) was a fundamentally cheaper approach to the interoffice transmission and switching of voice, or whether the price difference was the result of an implicit regulatory subsidy.

This paper is intended to be a first estimate of the switching and interoffice transmission costs for Itel and circuit switched networks. To evaluate these costs, we

build a properly dimensioned "green fields" network for an area and a population equivalent to the US state of Rhode Island in both technologies and compared the costs.

We find that the switching and transmission costs for Itel are approximately 50% lower than the costs for circuit switching. We further find that this cost difference is largely due to the reduced interoffice transmission capacity required by Itel and *not* due to assymetrical regulatory treatment.

1 Introduction

One of the most challenging developments in telecommunications in recent years has been the emergence of Internet Telephony (Itel)[1]. In the U.S., Internet Service Providers (ISPs) are exempt from the access charge system that is used to support local service. Internationally, ISPs are often outside of the traditional regulatory structures because they are Value Added Networks (VANs), which have historically been less regulated than providers of public switched service. Furthermore, the international accounting and settlements process is substantially challenged in the face of Itel, because the benefits of arbitrage are substantial. Even if including Itel under the normal regulatory framework was a social goal, it is far from clear how [Frieden,1997].

One of the questions that has arisen is whether the per call price difference between Itel and the public switched telephone network occurs because Itel fundamentally more cost effective than the traditional public switched telephone network, or if is due to a regulatory artifact[2]. If it is the former, it implies a pending revolution in

[1] We would like to thank the people at Cisco Systems, Inc., Hyperion Telecommunications, Inc. and NPT Systems, Inc. for their time and willingness to help.

[2] This sentiment has recently been expressed by Jack Grubman, a well known telecom analyst with Salomon Smith Barney (in [Stuck,1998]).

the design, organization, and operation of the public network infrastructure. If it is the latter, Itel will be a marginal phenomenon in the long run, requiring little if any attention from public regulators[3].

In this paper, we begin to address this question by constructing networks (on paper) and evaluating their costs. This is not intended to be a complete or final design, but rather one that captures the major switching and transmission cost elements of the interoffice network needed to address the question articulated in the previous paragraph. This is intended to be a "first order" analysis; there are many assumptions, the relaxation of which may result in further insights.

2 Technological Overview

The purpose of this section is to outline the key distinctions between these two technologies. More definitive discussions can be found elsewhere.

2.1 Assumptions and Simplifications

As this is a first order analysis, there are some simplifying assumptions that we wish to make. These include:

- *The focus will be on the costs of switching, signaling and trunking.* Thus, we will assume that similar access and transmission technologies will be used. An actual Itel-based network might well consider alternatives to the current local loop technology. In terms of transmission, this assumption is not unreasonable, as the higher speed aggregate transmission links probably would use the same technology.

[3] Investments by carriers such as Qwest Communications suggests that the cost may be lower.

- *We will assume current technologies.* We considered compressed voice and silence suppression technologies for the Itel access networks and fast IP router switches for Itel switching functions.
- *We will assume equal levels of demand for both technologies.*
- *We will assume that the services are perfect substitutes for each other.* That is, we will assume that the user will not be able to tell the difference between Itel and traditional telephone service from the point of view of major functions. Today, many consumers report poorer service quality with Itel as well as limitations surrounding the PC [Clark,1997]. On the other hand, Itel allows a level of service integration that is difficult or costly to achieve with circuit switched telephony.
- *We will assume that neither service is subject to line charges for regulatory purposes.*
- *We assume this network is only connected to similar networks.* As a result, we make no allowance for gateway or interconnection facilities.
- *We assume that the cost of transmission is constant over the life of the study*.

2.2 The Public Switched Telephone Network

The public switched telephone network has evolved into its present form over its 100 year history. The network was initially optimized to handle low bandwidth (4kHz) channels using manual technology (no mean feat, as illustrated by Mueller [Mueller,1997]). As technology evolved, so did the way in which switching was performed. The digitization of the network allowed for high speed data services. Advances in packet switching technology allowed for the transformation of the signaling network to support a wide array of enhancements to basic service. Despite these advances, the circuit switched telephone network can be characterized by the following:

- It is capable of handling many dedicated low bandwidth channels (64kbps or 4kHz). Adaptive Differential PCM (ADPCM) was developed to transmit "toll quality" voice over 32kbps, but this technology has not been widely installed.
- It is independent of content - once the channel has been allocated, it remains allocated whether it is used or not; that bandwidth cannot be used by others during idle periods.
- Network attachments (*i.e.*, telephones) are cheap because their functionality is specialized and limited.

Numerous other characteristics also exist; the above list attempts to capture those of relevance to this study.

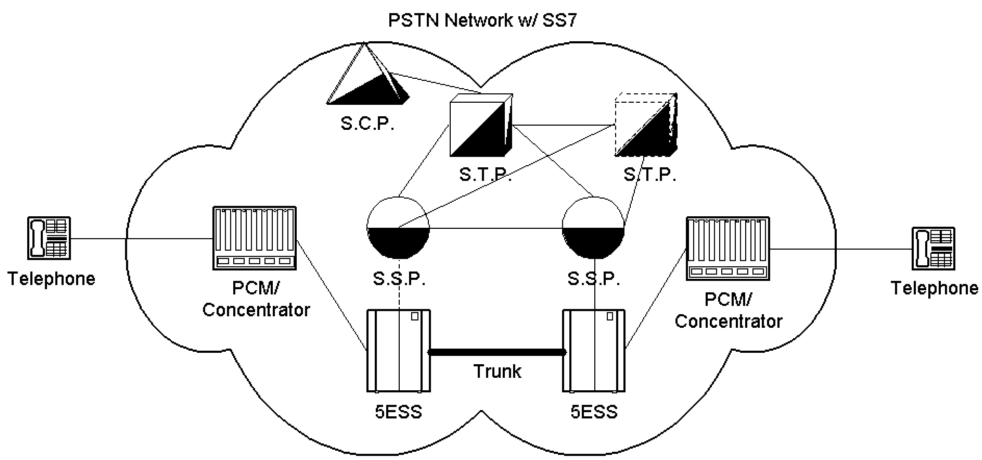

Figure 1: Circuit Switched Architecture

2.3 Internet Telephony

Internet telephony has grown as a specialized application of the Internet. A dominant characteristic of TCP/IP, as with most packet networks, is that most resources are shared (as opposed to dedicated). Thus, the bandwidth of a transmission channel is dynamically allocated to those who are using it at the moment. If their use disappears for a time, no system resources are dedicated to that user. The system was not designed to support services that require guaranteed timely packet arrivals. In summary, the essential characteristics of TCP/IP networks are:

- It is capable of handling many application types, and allocating bandwidth dynamically between them on demand. This makes the development of integrated services particularly easy.
- It cannot easily make performance guarantees, especially arrival time guarantees. This leads to quality of service degradation if the network is used for voice traffic. Note that this can be substantially mitigated if the network is engineered to low utilization, which increases cost.

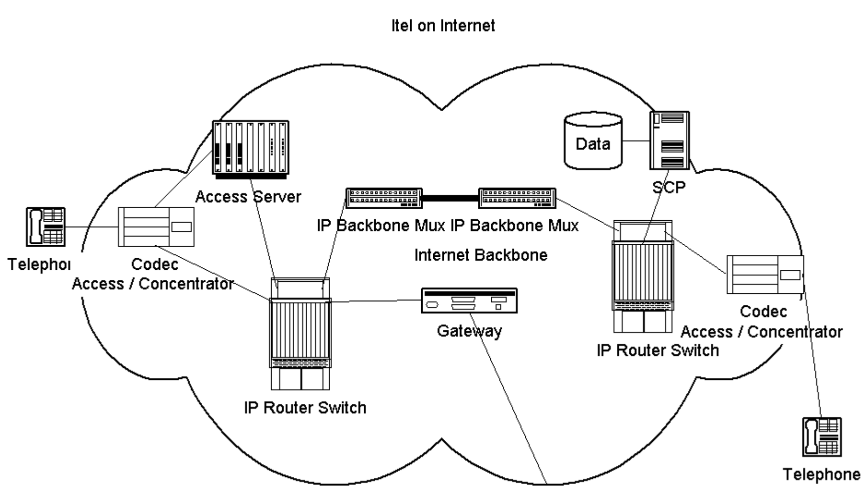

Figure 2: Internet Telephony Architecture

2.4 Architecture of Internet Telephony

In this subsection, we discuss the different feature components of Itel from the circuit switched network. Followings are the key components of Itel architecture.

Loop Interface Since we assumed only that the copper wires in the loop were constant, we configured the Itel approach with xDSL. As a result, the Itel configuration includes DSLAMs, which raises the capital cost of Itel significantly. We also assume that the users have an Itel "appliance"[4] that performs the G.729A compression and packetization using RTP/UDP/IP.

IP router switches IP router switches operates at the much higher performance than the traditional IP routers. It is also interoperable with the conventional IP routers and have faster packet processing and forwarding capability with the combination of layer-2 switching and layer 3 routing. Many of recent IP switches provides packet processing rates of more than millions of packets per sec and internal switching bus more than Gbps speed. Some of the IP products support multiple upgradeable switching processors and Virtual Circuit (VC) layer 2 switching will enable the high speed switching bus to act like the fast space switching fabric. Implementation of IP switch is vendor dependent. In our simulation, we mainly assumed Cisco equipment (See [Kumar, 1998] for more discussion).

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[4] See, for example, http://www.selsius.com: Selsius phone 12S Series' price is ranging from $200 to $400 currently.

Backbone OC-3 Trunk carrying IP IP over SONET technology is being implemented in many of IP backbone router switches. Some of the variant can be IP over ATM over SONET. IP over ATM over SONET solution might be attractive when the volume of traffic is integrated service and protocol based. However, if IP traffic becomes dominant as would be the case for Itel carriers, direct IP over SONET would be the more efficient solution [Manchester,1998]. The Itel model evaluated in this paper will already have 50 byte packets (40 bytes of RTP/UDP/IP overhead and 10 bytes for the voice payload) and the cell-based ATM transmission will increase significant amount of overhead again for transmission. Figure 6 shows the protocol stack of Itel central switching office example. In our model, typical OC-3 SONET trunks among COs provide enough capacity utilizing a utilization of less than 40% for most of the trunks.

Backbone Itel Gateway supporting SS7 In the case of Hybrid packet and circuit switched network would require the gateway solution to provide the signaling interface and routing. Numbering-to-IP conversion function may be implemented in this gateway.

Call Processor We included a single processor Sun UltraSPARC to process calls. This may well be to small to handle the required processing loads. Since the carrier-level call processing software for Itel is not yet available, we were unable to size this correctly. Information on the processing capablility of 5ESS or DMS100 processors was not available to us. Thus, the cost of this element may end up being higher.

2.5 RTP/UDP/IP Protocol Stack in Itel

The dominant standard for transmitting real time data in packet switched networks is ITU standard H.323 which uses RTP/UDP/IP encapsulation. RTP (Real-Time Transport Protocol) supports end-to-end delivery services of applications transmitting real-time data over IP networks. RTP is defined in in RFC 1889 [Casner, 1996] and applied to audio and video in RFC 1890 [Schulzrinne, 1994]. RTP does not guarantee timely delivery or quality of service. RTP typically runs over UDP to utilize its multiplexing and checksum services. RTP provides the sequence number and time stamp information needed to assemble a real time data stream from packets. RTP also specifies the payload type to assign multiple data and compression types[5].

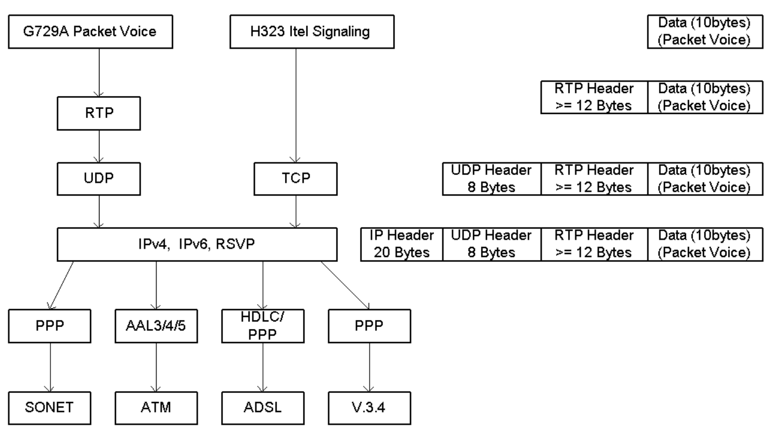

Figure 3: RTP Protocol Stack

[5] G.723 , G.729, and G.729A are the popular compression types for the codecs in Voice Over IP (VIOP). The VOIP standard committee proposed a subset of H.323 for audio over IP. Many Internet Telephony vendors developed the products based on this standard.

3 Model Description

In this section, we describe the parameters of the simulation model. The network parameters for the circuit switched case and the Itel case are presented in their respective sections along with the summary results from the simulation.

3.1 The Service Area

To estimate the cost for each system, we constructed a "green field" system of each type for the same service area (a population of 1 million people uniformly distributed over an area of 3140 square kilometers -- equivalent to the U.S. State of Rhode Island). To simplify the calculation, we make the following assumptions:

- An average population density of 2.2 person per household
- Square service area (56km per side)
- No geographical barriers
- Households uniformly distributed over the service area (constant population density)
- Homogeneity of users
- Consistency of a user's behavior between systems (*i.e.*, we assume away price and demand issues)

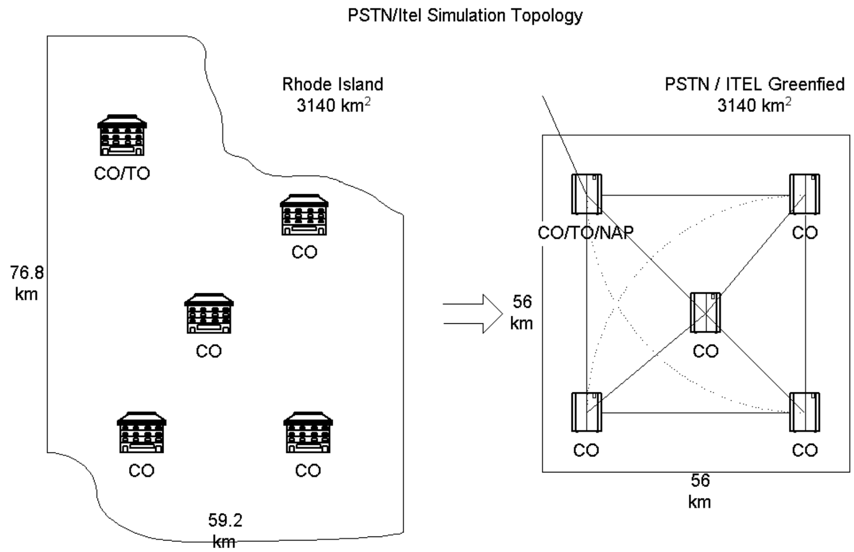

Figure 4: Simulation Topology

We assumed the local loop with with 19 gauge copper twisted pairs which can be extended up to 30 k-ft[6]. We use five local switching locations because a 5ESS-2000 can support up to 100,000 loop lines. If we assume one line per household, then each local switching location (CO) terminates 90,909 lines. We further assume that all originating traffic is distributed as 10% for outgoing from its service region and the remainder evenly among the five COs. The incoming traffic from the other service regions is assumed to be same as the amount of outgoing traffic, passing through the Tandem (or NAP).

3.2 Circuit Switched Model

In addition to the general assumptions described above, we have made following additional assumptions (summarized in Table 1) that pertain specifically to the circuit switched network:

- A 5ESS-2000 switch supports100,000 lines at 3.6 CCS/line (0.1 Erlang) in the busy hour. Therefore, each switch carries 9090.9 Erlangs of traffic from its local loops.
- We assumed the most of the blocking occurs not in the switches but at the trunk side at one percent blocking probability.
- Since we have only five switches within the given service region, we assumed each switch will have a direct trunk to each other.
- The signaling network (SS7 Signaling System 7) is configured so that each local switch is equipped with SSP (Service Switching Points) and connects to two STPs (Signal Transfer Points) and additional two STPs, forming a quadruple mesh STP network to access SCPs and external STPs (illustrated in Figure 5). Each signaling link (between SSP and STP) is engineered to have 40% utilization, so that if a failure occurred, the expected utilization would be 80% per link [Bellcore, 1987]. The data rate for each signaling link is 64 kbps. We assume that each call generates average 3.5 signaling messages from an originating party and 3.5 signaling messages from the terminating party. The average packet length is 15 octets per message.

Based on the above assumptions we dimensioned circuit switched network as follows:

- The capacity of the trunks between any two normal COs and between a CO and Tandem will be bi-directional 210,816 Kbps (for each direction) and 326,400 Kbps respectively. With this configuration, the COMNET III simulation produced a P.01 grade of service.

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[6] We realize that nobody actually uses 19 AWG cable. However, this allowed us to assume "home runs," avoiding the complications introduced by loop carrier systems. Since we are not costing this portion of the network, this assumption is inconsequential.

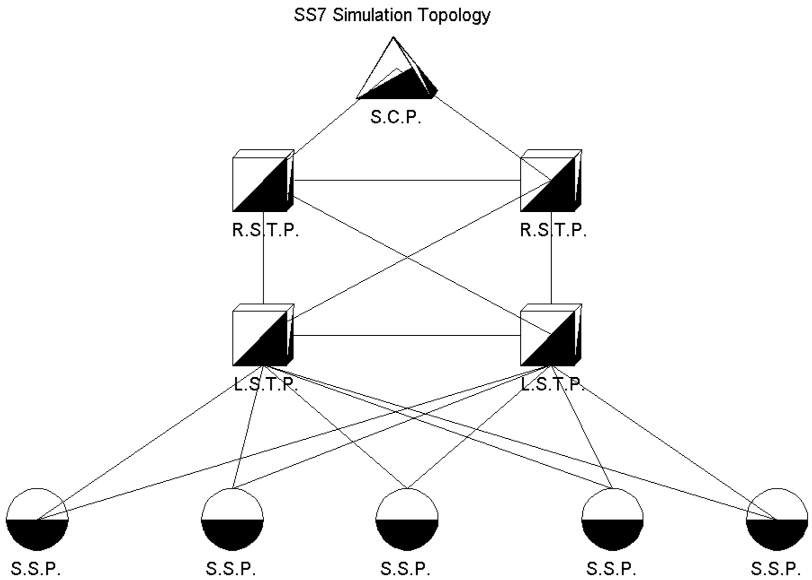

Figure 5: SS7 Network Simulation Topology

Circuit Switched and SS7 Network Parameters	**Values**
Circuit Switched Parameters	
Data Rate per Channel	64 *Kbps*
Local Loop	19 guage twisted pair
Citcuit Switch	5ESS-2000
Fraction of outgoing call	0.1
Originated Traffic per line	0.1 Erlangs
No. of loop lines per CO	90909
Inter Arrival Time for CO	0.0264 sec
Inter Arrival Time for Toll Office	0.0176 sec
Average Call Duration	240 sec
SS7 Parameters	
No. of SSP	5
No. of LSTP	2
No. of RSTP	2
No. of SCP	1
Engineering Utilization	40 %
Unit of SS7 link group	8 DS0s
Average signaling messages per call	7
Average signaling message size	15 octets

Table 1: Assumptions for Circuit Switched Model

- The capacity of the signaling links between a SSP and a Local STP; between two local STPs; between a Local STP and Remote STP and between two Remote STPs are bi-directional 326 Kbps (326 Kbps for each direction), 1,630 Kbps, 111 Kbps and 222 Kbps respectively.

Circuit Switched and SS7 Network Requirement	Values
Circuit Switched Parameters	
Four Trunks between each CO and a Toll	4 X (2 OC-3 and 1 OC-1)
Six Trunks between each CO	6 X (1 OC-3 and 1 OC-1)
Blocking Probability	0.01
Call Attempted per Hour	750299
Call Carried per Hour	742454
SS7 Parameters	
SS7 Links between SSP and LSTP	80 DS0
SS7 Links between LSTPs	32 DS0
SS7 Links between LSTPs and RSTP	8 DS0
SS7 Links between RSTPs	8 DS0

Table 2: Summary of Simulation Output for Circuit Switched Network

The summary of circuit switched network simulation output is in Table 2 . The simulated trunk capacity (211 Mbps) between each CO and Toll Office requires two OC-3 and one OC-1 SONET leased trunks[7]. The trunk capacity (327 Mbps) between each CO requires one OC-3 and one OC-1 SONET Trunks[8]. The OC-1s shown in the table are the separate trunks between each CO, which cannot be aggregated to OC-3s.

[7] Total 4 apirs of this type are required in the simulated service are networks.
[8] Total 6 pairs of this type trunks are required in the simulated service area networks.

3.3 Itel Model

The Itel simulation model assumed in our analysis is based on RTP/UDP/IP standardized in ITU H.323. In this protocol, sequence numbers and time stamps are used to reassemble the real time voice traffic, although this provides no quality guarantee. TCP/IP is used to control the call (like SS7 in the circuit switched model). The simulated Itel model would provide functionality comparable to the circuit switched network, but it will not necessarily provide quality and reliability comparable to circuit switching.

Figure 6 represents the Itel architecture model in our simulation. The simulation uses IP router switching and trunking. The IP Access Server and Edge Concentrator in the figure represent DLSAMs (Digital Subscriber Line Access Multiplexer) which do not have much effect on delay in the simulation.

The assumptions made for Itel simulation model are specified below and in Table 3.

- All voice traffic would be compressed from 64 Kbps PCM voice to 8 Kbps compressed data using G.729A codec.
- Silence suppression will be enabled in each codec, with 60% of a session being silent in one way.
- On the suppressed codec output, RTP, UDP and IP overhead will make actual average throughput around 14 Kbps.
- Each voice is packetized every 10 msec making 10 bytes voice packet through compression codec and two voice packets (20 bytes payload) are enveloped in the 40

bytes RTP/UDP/IP header. The operational details of the RTP/UDP/IP is described in the previous Internet Telephony section.

- For the packet voice, the burst packet voice is modeled with average 350 msec exponentially distributed active state and 650 msec exponentially distributed silence state[9].
- The Itel call is modeled as a connectionless UDP/IP session with exponentially distributed session lengths with a mean of 240 sec.

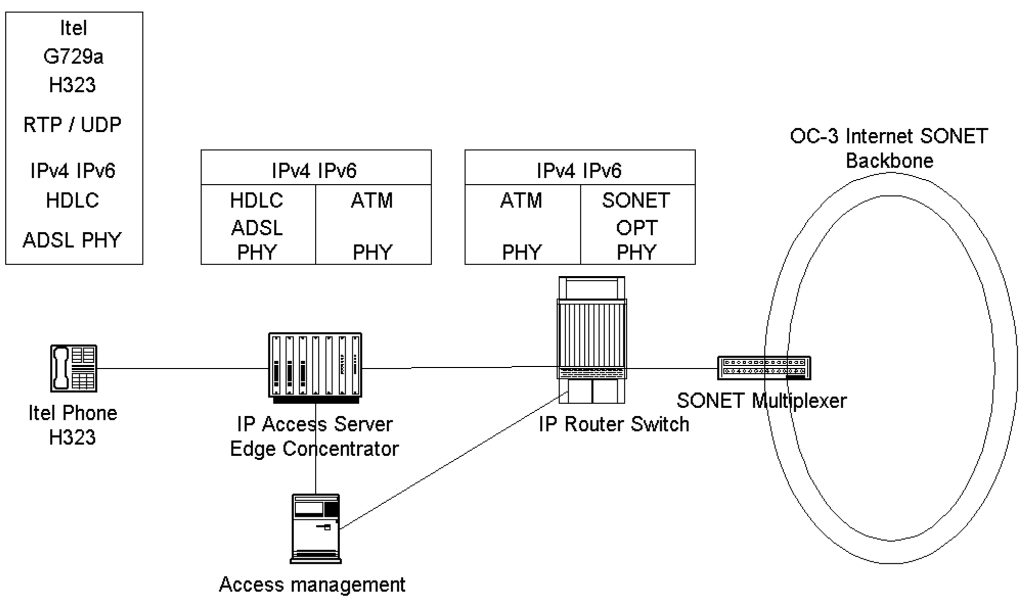

Figure 6: Internet Telephony Central Switching Office Protocol Stack

[9] See Figure 7.

Itel Networks Parameters	Values
Compressed Peak Data Rate per Channel	8 *Kbps* (G.729A)
Local Loop	19 guage twisted pair, ADSL
Packet Switch	IP Switch (>10 Gbps and 1 MPPS)
Fraction of outgoing call	0.1
Originated Traffic per line	0.1 Erlangs
No. Of loop lines per CO	90909
Packet Voice Size	10 bytes (10 msec)
Packet Payload Size	20 bytes
Protocol Overhead	40 byes (RTP/UDP/IP)
Packet Voice Burst Distribution	Burst 350 msec, silence 650 msec
Packet Delay Constraint	Less than 250 msec
Itel Call (RTP Session) Setup Delay Constraint	Less than 1 sec

Table 3: Assumptions for Itel Simulation Model

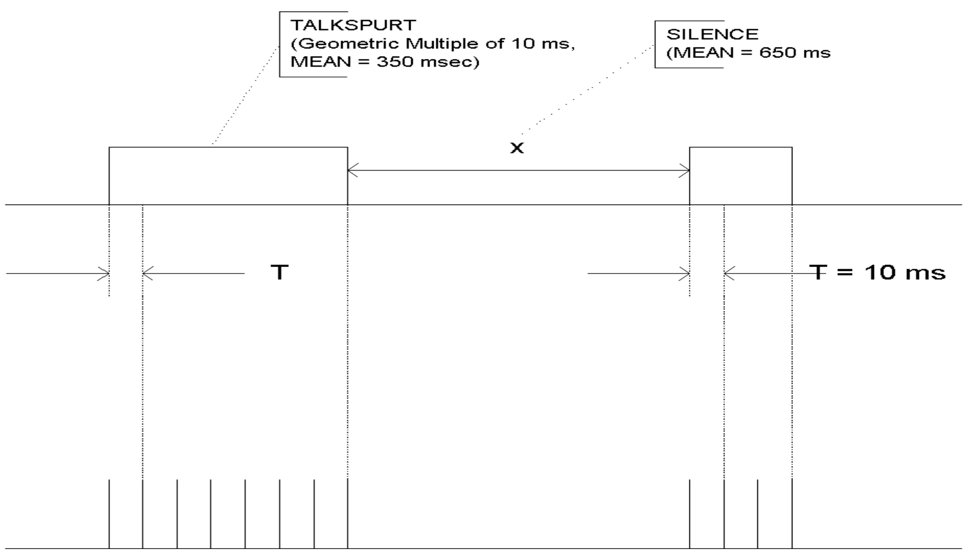

Figure 7: Packetized Voice Distribution

In the simulation, we found the average and 95 percentile delays for packets through the network. This delay was modelled using the delay budgets in Table 5. We assumed that this would provide a connection equality that was approximately equivalent to circuit switched voice [10] (Table 4 shows the ITU recommendations). The source was initially modelled using an "on-off" speaker model. We found that, when aggregated, these could be modelled reasonably well by an exponential distribution, so that is what we used to reduce the running time of the simulation.

One Way Delay	Description
0-150	Acceptable for most user applications.
150-400	Acceptable provided that administrations are aware of the transmission time impact on the transmission quality of user applications.
400-	Unacceptable for general network planning purposes; however it is recognized that in some exceptional cases this limits will be exceeded.

Table 4: ITU Delay Recommendation

Itel Network Requirement	Values
Itel Networks	
Trunk among Cos	OC-3 Sonet Ring (=10 OC-3)
Local interface of each IP Switch	12 DS-3 ATM
Major Network Components	Itel Access Server Concentrator IP Switch Sonet Mux
Itel Delay Budget	
Average Switch Utilization	0.62
Average Variable Packet Delay	3.41 msec
95 Percentile Variable Packet Delay	18.44 msec
Access, Lookahead, Encoding, Dejitter G729A	77 msec
Average End-to-End Packet Delay	80.41 msec
95 Percentile End-to-End Packet Delay	95.44 msec
Average Delay Jitter	8.45 msec

Table 5: Summary of Simulation Output for Itel

[10] Total delay is a function of operating system and sound device delay in the end devices as well as network delay. Informal measurements suggest that these delays can be very high in WinTel PCs using standard sound cards.

Unlike a conventional ISP, which terminates the user line through CSU and DSU on LAN (10 Mbps or 100 Mbps), the Itel user access line for the carrier solution is terminated through a DSL Access Multiplexer (DSLAM), which is connected to the IP switches via internal OC3 or T3 circuits. Figure 6 shows the operational architecture of the Itel CO model. The simulation shows that 12 DS3 interfaces are required for the local interface with the concentrator from the IP switches and OC-3 line can support all trunk connection between any COs with more than 50% spare capacity. With OC-1, the trunks are so fully utilized that it increases the packet delay significantly in the simulation. Therefore, one SONET OC-3 Ring provides enough capacity for the assumed Itel trunk traffic among the ISP COs. In this simulation model, SS7 call setup functions is simulated as session setup using TCP/IP. Therefore, no additional capacity dimensioning is required for each links. The output of simulation for Itel is summarized in Table 5.

4 Estimated System Costs

With these design in hand, we consulted with vendors to review the "reasonableness" of the design and to estimate the cost of the switches routers. The cost estimates we used were based on the information from extracted from the literature (circuit switched network) and from Cisco (Itel network). The cost of the transmission links is based on leased line costs from AT&T.

The cost shown here is only focused on switching and trunking for circuit and packet switching technologies. We did not include loop-related cost elements such as main distribution frames (MDFs) or line cards.

The cost difference of the switching technology is composed of two parts; initial investment costs and annual recurring costs. Most of the switching equipment in a CO will be considered the initial capital investment costs and transmission links (OC-3, *etc*.) will be considered the recurring costs. The life of telephone Central Office equipment can be determined in several ways. According to IRS documents, the product life of telephone switching equipment (Class 48.12) is 18 years[11]. Given the pace of technological change, we are doubtful that such long depreciation schedules will be sustainable in the future. Using the cost data, we have conducted sensitivity analysis of the monthly subscriber line costs in terms of the product life varying 3 years to 20 years and MARR (Minimum Attractive Rate of Return)[12] ranging from 5% to 50%.

4.1 Circuit Switched Costs

The simulation results indicate that a total of 14 OC-3's and 12 OC-1's would be needed, resulting in a $1.454 million monthly cost of trunking. The bulk price with discount rate of 50% of the cost yields $727 thousand per month. A 5ESS switching system costs around 2.94 million dollars[13] (switching only) [Schulzrinne, 1997]. Figure 8 is a sensitivity analysis of monthly per line costs[14] (dashed lines in the figure). Our result shows that the total local switching cost is $16.03 Million (initial switching investment cost) and that the monthly cost (switching and trunking) per subscriber line is $2.3 when

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[11] From IRS Publication 534, Depreciation

[12] MARR is frequently used in engineering economic analysis to represent the investors' expecting Rate of Return. Investors use MARR, instead of Interest Rate, when they convert the NPV of initial capital investment to the average recurring cost with their return over a given life time of the capital assests. MARR may vary depending on the technology change and the riskiness of industry investors are involved or interested in.

[13] The switching cost $2.7 per kbps for 5ESS is used.

[14] This is bottom line cost because we counted a 5ESS switch in all the CO locations and required leased trunks only.

the 5-year product life and 5% MARR are assumed. $1.6 out of $2.3 comes from the cost of trunking per month[15]. The major cost factor of the circuit switched network is in trunking cost.

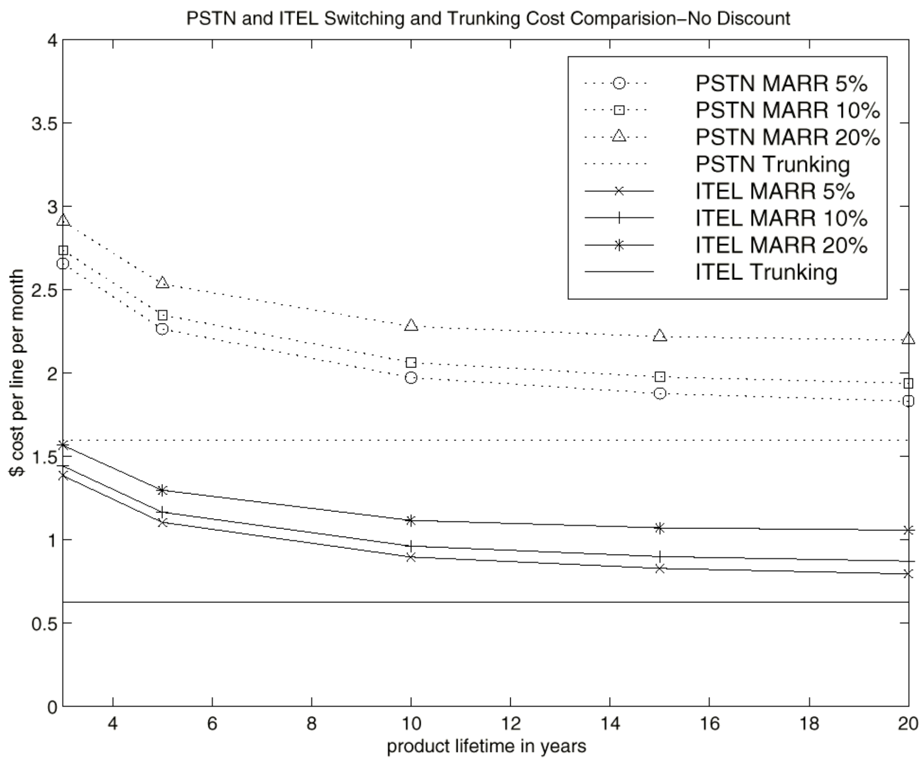

Figure 8: Network Costs (In dollars per line per month)

4.2 Itel Costs

For the Itel network, we used the same number of "CO's" so that the local loops between the two networks would be identical. While this might yield a sub-optimal Itel design, it was necessary so that we could ignore local loop costs in our analysis. The cost for Itel switching and trunking was the NPV of $26.6 Million with high portion of those costs

[15] The figures shown here are the cost figures for the circuit switched network, which dose not include the access and signaling equipment. We will see this cost is still high enough to top the Itel cost analyzed in the section 4.2.

being the DSLAM cost when the 5-year product life and 5% MARR are assumed. The monthly discounted bulk rate trunking price is $286 thousand dollars. The monthly Itel subscriber line cost for switching and trunking is $ 1.1 when the 5-year product life and 5% MARR are assumed. As with circuit switched network, the dominant cost component is the trunking cost which comprises $0.63 out of the $1.1 monthly Itel subscriber line cost for switching and trunking. Figure 8 (solid lines) shows the cost per line per month for varying product lifetime and MARR. We included a Sun UltraSPARC-2 2300[16] at $20,000 for call processing; this may not be sufficient to handle the call processing load, so the actual capital costs for Itel may be a bit higher. Given the dominance of recurring costs in the results, we do not believe that the impact of this will be large.

5 Discussion and Conclusions

The results of this analysis shows that the interoffice transmission and switching costs for Itel approach are lower than for the circuit switched approach for a modestly sized circuit switched network by about $1.00 per month (or 50%)[17] using a 5% MARR and a capital equipment life of 10 years. The dominant cost factor is the cost of interoffice transmission; the compression and silence suppression enabled the use of 29% less transmission capacity[18] in Itel[19].

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[16] This is in the same price range as the Sun Netra-1 1125, which is sold to telephone companies for this purpose. We have not been able to determine how many of these systems would be necessary for a CO of the size that we have configured.

[17] This cost advantage obtained even though we used a more expensive access approach in xDSL than in the circuit switched network.

[18] The Itel network required 10 OC-3s *vs*. the 14 required for circuit switching.

[19] It would not be as simple to implement the compression technology in circuit switched networks, as they would have to be assoicated with trunks, which are application blind. Compression is optimized for voice, and will not work with fax or modem traffic, so a compression system for circuit switching would have to

This suggests that the regulatory issues raised by Itel will not go away, and that regulators will have to continue to confront them. It also suggests an imminent technology conversion for telephone companies as they continue to seek lower costs of delivering their services.

Still, these results do need to be put into perspective. Generally speaking, the transmission and switching costs of an IXC are around 22% of their total cost structure [Stuck,1998]. Some of the largest unknown costs for Itel are the OA&M costs and billing costs[20]. These systems are highly developed for circuit switched networks and are of major importance to carriers. Finally, we did not consider operations cost differences between the two technologies, or their relative reliability, security *etc*. There is no reason to believe that these would be constant across the technologies.

The costs cited above assume a 50% discount off of retail for the trunks. Since the capital cost of the circuit switched network exceeds the capital cost of Itel, Itel is cheaper at *all* levels of discount. When line cards and MDFs are added in, the NPV costs of Itel and circuit switching are approximately the same at a trunking discount of 50%. Recall that we configured Itel using DSL, which explains this high cost. If a lower cost access technology were to be used, this result would change, of course.

Also, we did not account for loop termination equipment or terminal devices. The total system costs must include the cost of these systems. At a high level, analog telephones are inexpensive, ranging in price from about $30 to about $150, which amounts to $0.50 to $2.50 per month over five years. Internet telephones are likely to be considerably more costly.

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be able to distinguish among the various applications of a trunk, and then would have to be able to aggregate compressed traffic into 64kbps channels.

Another important factor is the ability to deliver integrated services. We did not consider the incremental cost of developing and deploying integrated services in both networks. The relative cost of this (and the relative revenue opportunities based on the capabilities of the terminal device) could be an important factor in determining a carrier's choice of switching and transmission technology.

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