Economic Impact on T1 Infrastructure of VoIP-Enabled IAD

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Executive Summary

This paper compares the operational and economic impact of traditional TDM-based IADs with VoIP-enabled IADs, and identifies and quantifies the benefits of moving from TDM to VoIP. It examines the Total Cost of Ownership (TCO) and revenue opportunities of a Future Mode of Operations (FMO) using VoIP with that of the Present Mode of Operations (PMO) that uses TDM to assign POTS services to individual DS0 channels and Internet Access to bonded DS0 channels.

CAPX for the VoIP-enabled IAD mode is shown to be 71% to 75% lower than the PMO when all 24 DS0 channels are filled with revenue producing services and 61% to 65% lower when only one-half of the available voice channels are used. This large cost difference is primarily due to the use of a Softswitch rather than a Class 5 Circuit Switch for delivery of POTS services.

Annual recurring operating costs to operate and maintain the Class 5 Circuit Switch versus the Softswitch also are analyzed. These costs include environment expenses—floor space, power, cooling, battery & re-generation, maintenance and sparing expense. These expense items overwhelmingly favor the VoIP design over the circuit switched one—Softswitch expenses are 12% of Circuit Switch expense. This is so because the very smallest Circuit Switch occupies several equipment cabinets each of which is 50% larger than the standard telecom rack while a Softswitch capable of supporting 100,000s of subscribers requires 1/3 of a standard rack. Consequently, resources requirements such as floor space, power, etc. are greater for the PMO. This cost item alone offers payback for conversion to a VoIP-enabled IAD in less than a year.

VoIP-enabled IADs support two to three times the revenue generating service capacity of the PMO using the same T1 line. This creates the opportunity to extend T1-based services to larger customers and the opportunity to up-sell existing TDM-based IAD customer sites by converting them to VoIP. This improved utilization of the T1 line is achieved by employing 2:1 voice compression protocols, exploiting the statistical multiplexing capability of the VoIP-enabled IAD and by applying its QoS capabilities. Both classic voice trunking and IP over-subscription economies contribute to the improved line utilization.

The VoIP-enabled IAD enables faster and lower cost provisioning of new services and adds, moves, and changes to existing services than the PMO. It does this by supporting automated service provisioning and customer web-driven service orders rather than the PMO's use of manual configuration for each of the T1 line's 24 DS0 channels. This reduces new service installation times and cost by one-half and service change costs by more than 10:1. In addition, many voice feature changes can be done by the customer with minimal service provider involvement or associated cost.

Finally, IAD capable of remote conversion from TDM mode to VoIP offer the further advantage of upgrade to VoIP without a truck roll. Once converted, the operating cost savings and increased revenue opportunities of the VoIP-enabled IAD quickly payback the cost of

conversion. In addition, the load on legacy Digital Cross Connect systems and Class 5 Circuit Switches is reduced.

Introduction

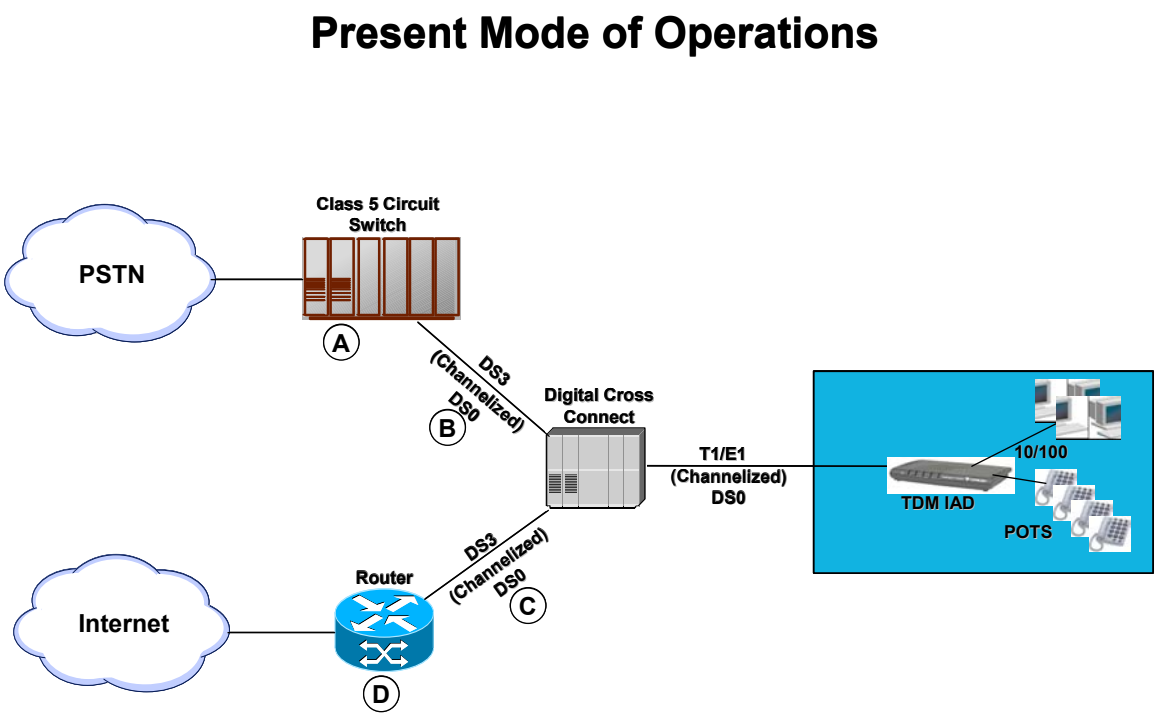
Integrated access services offering voice and Internet access over a T1 line are the mainstay of service provider small and medium business solutions. Even very large enterprises make heavy use of these offerings because their retail, field service, and branch offices greatly outnumber very large enterprise locations. Integrated access services are enabled by Integrated Access Devices (IADs) that traditionally have been used to multiplex circuit switched voice calls onto DS0 digital channels while bonding several DS0s to provide IP transport for Internet access or other data applications.

An IAD with VoIP-enabled capability further enhances integrated access service offerings by increasing service flexibility and revenue opportunities, and decreasing service provider total cost of ownership (TCO). This paper compares traditional TDM-based IADs with VoIP-enabled IADs, and identifies and quantifies the benefits of moving from TDM.

Present versus Future Mode of Operations

Figure 1 is a schematic of the present mode of operations (PMO) for a business subscriber to integrated access service.

Figure 1



A typical service configuration for the Present Mode of Operations (PMO) (Figure 1) consists of 1-20 analog voice lines and an Internet access service operating at data speeds between 256 Kbps and 768 Kbps. The PMO dedicates each of the 24 DS0 channels within the T1 line to either voice or data so available Internet access capacity goes down as the number of analog voice lines increases. A service order is required to add or remove each voice line and to change the data speed of the Internet access service. Two to three weeks may be required to process each order. Much of the capacity of the T1 line, consequently, goes unused because each DS0 channel assigned to voice service is only used when someone is talking on the telephone number assigned to that channel. It cannot be freed up to temporarily increase the data speed of the Internet access service nor used in a trunk pool by another telephone service user. This means that the full 1.544 Mbps capacity of the T1 line will be rarely utilized. Many desirable combinations of Internet access data speeds and numbers of voice lines will be excluded due to the rigid assignment of DS0 channels and long order intervals to make changes.

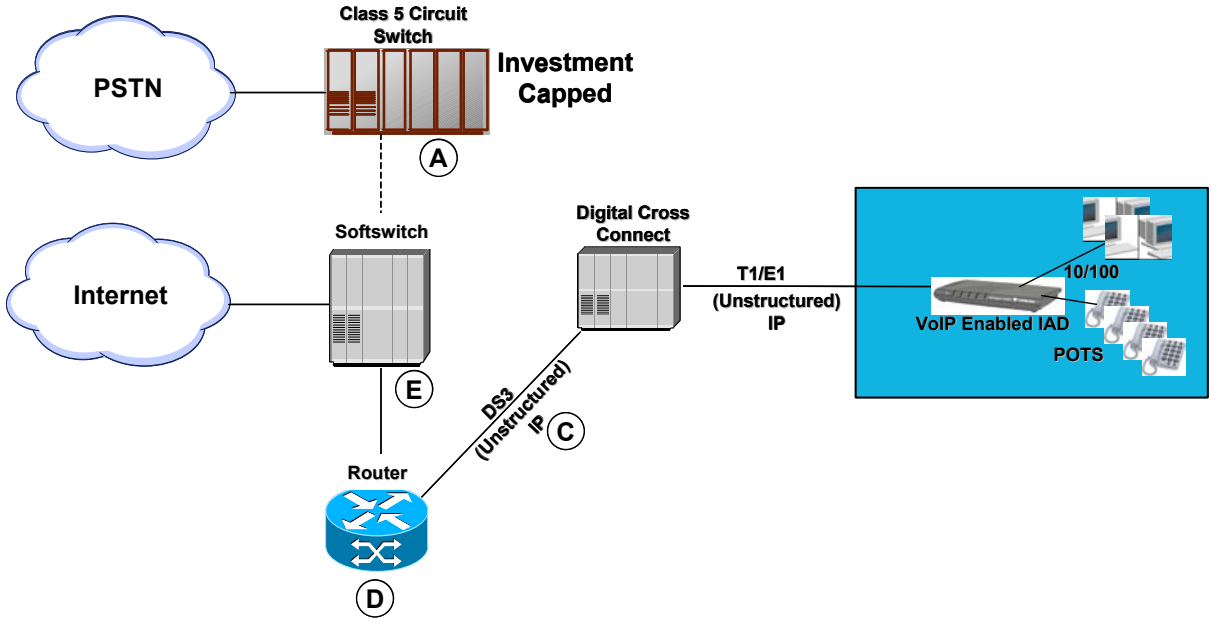
The left-hand side of Figure 1 shows the central office equipment and connections (Labeled A-D) that are required to connect the voice lines to the PSTN and the data channel to the Internet.

The separation of traffic into dedicated DS0 channels is maintained until the voice lines are terminated in the Class 5 Circuit Switch and the data traffic is terminated in the Router. A digital cross connect system is used to provide the necessary DS0 level channel interconnections.

Figure 2 is a schematic of the Future Mode of Operations (FMO). (An additional network element, E, the Softswitch has been added to the diagram.)

Figure 2

Future Mode of Operations



The FMO utilizes a VoIP-enabled IAD at the customer premise. End users need not perceive any differences in the services they are using—telephone service continues to be analog voice lines (POTS) and the same 10/100 Ethernet connection is made to the LAN. The view is quite different from the PMO, however, from the service provider Central Office (CO) looking into the IAD. Neither the T1 line nor any of the connections within the CO are made with DS0 channelized circuits. No direct connection is made between the Digital Cross Connect system and the Class 5 Circuit Switch and no connection must necessarily be made between the Softswitch and the Class 5 Circuit Switch in this particular CO. The voice and data services have been converged onto a single IP network. There is no technical requirement, furthermore, for the 0:1 Digital Cross Connect function though it will likely remain until most TDM services are converted to IP.

Once established the FMO customers may make web enabled service changes that involve little or no service provider work and the order interval is reduced to one day, at most. Elimination of the DS0 channelized lines also allows much more efficient use of the T1 lines full capacity as well as eliminating most of the capital and operating expense associated with the Digital Cross Connect system.

Benefits of VoIP-enabled IAD

The VoIP-enabled IAD has four primary advantages over the TDM-based IAD.

1. CAPX is reduced by convergence of voice and data onto a single network and by simplifying the network through elimination of channelized DS0 facilities and DS0 cross connect switching.

2. Recurring operating costs are reduced through network convergence and the cost advantages of Softswitches as compared to Circuit Switches

3. Total cost of ownership is reduced and unit revenue potential is increased through better capacity utilization of the IAD and associated T1 line

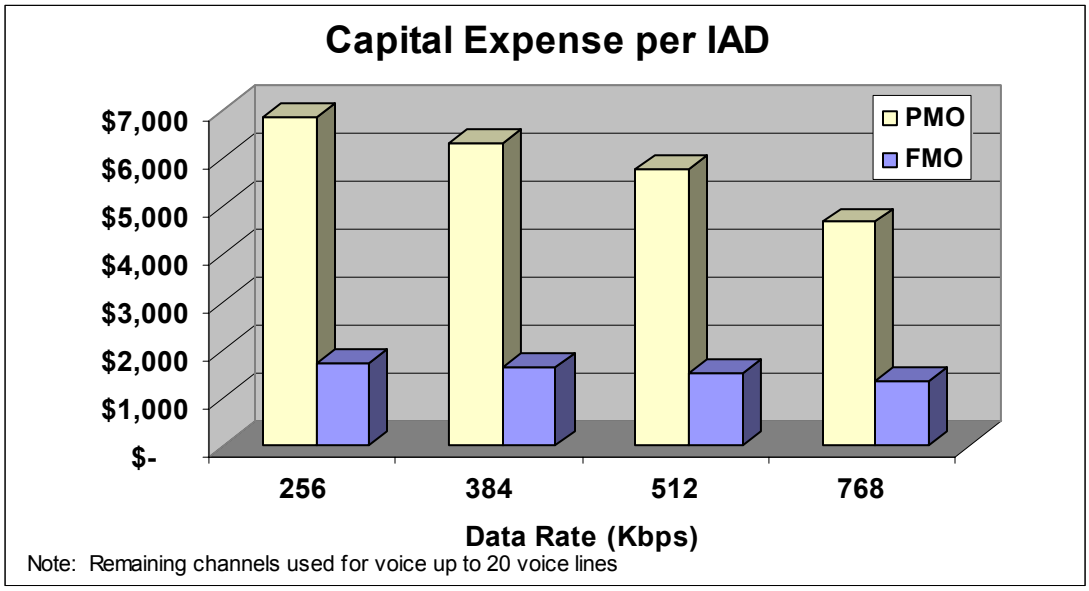
4. Operating expense and the time to provision services are reduced through simpler move, add, and change processes.

In addition, Verilink's 8000 Series IAD possesses additional advantages because it can be upgraded from the PMO to the FMO without a truck roll and it provides the flexibility of interworking with both SIP and MGCP based VoIP networks.

Lower CAPX through Network Convergence

Figure 3 compares the capital expense of the Future Mode of Operations to that of the Present Mode of Operations. The comparison is made on a per IAD basis and assumes that the 24 DS0 capacity of the PMO solution is fully used and that the FMO carries the identical traffic. In addition, all voice traffic is carried on the IP network—no gateway to the Class 5 switch is used.

Figure 3



The FMO CAPX is 71% to 75% less than that of the PMO. If one-half of the PMO's voice capacity is utilized then FMO CAPX is 61% to 65% less. The FMO's CAPX advantage is derived from its use of a Softswitch rather than a Class 5 Circuit Switch for local voice switching and through elimination of the parallel voice and data transport networks in the Central Office. Table 1 details the CAPX comparison.

Table 1

CAPX per IAD
(20 POTS lines and 256 Kbps data)

Network Element	Description	PMO Cost	FMO Cost
A	Class 5 Switch	$ 6,251	$ -
B	DCS to Class 5 Switch	$ 375	$ -
C	DCS to Router	$ 75	$ 450
D	Router	$ 156	$ 285
E	Softswitch	$ -	$ 1,000
	Total CAPX per IAD	**$ 6,857**	**$ 1,735**

The primary source of the FMO's CAPX advantage is the high cost of the Class 5 Switch ($6,251) as compared to the Softswitch ($1,000) plus the additional router capacity ($129) needed to support the FMO's VoIP traffic. Some of the FMO's higher router cost is offset by the

FMO's use of lower cost unstructured TDM interfaces as compared to the PMO's use of higher cost channelized interfaces.

Also, the FMO does not strictly require the DCS, however, the analysis assumes that most service providers will use the DCS until converged traffic dominates their networks.

Additional CAPX savings are captured through the FMO to the extent that interoffice traffic remains on the IP network rather than connecting to the circuit-switched PSTN through a gateway.

The capacity utilization advantages of the FMO versus the PMO are examined in a subsequent section. This extends the FMO's CAPX advantage even further as service demand approaches the hard limits imposed by the PMO's 24 DS0 framework.

Lower Recurring Operating Cost through Softswitching

Table 2 compares the recurring operating cost for PMO versus FMO voice switching equipment on a per IAD basis where 20 POTS lines are in service for both the PMO and FMO.

Table 2

Annual Recurring Operating Cost per IAD
(Voice Switching System Only – 20 POTS Lines)

	Annual Cost per IAD	
Operating Cost Item	**PMO**	**FMO**
Floorspace	$ 360	$ 22
Power	$ 583	$ 65
Cooling	$ 465	$ 52
Battery & Regen	$ 132	$ 15
Maintenance	$ 750	$ 120
Spares	$ 63	$ 10
Total Annual Cost	**$ 2,353**	**$ 284**

Notes:

- Floor space allocates 9 square feet per rack as per GR63 @ $85 Square Feet per Month
- Power is average power measured in Amps @ $45 Amp per Month
- Cooling is measured in BTUs where BTUs = 3.41 X average power measured in Watts @ $3 per 10,000 BTU per Hour
- Battery and Re-Gen uses the "Power Rating" measured in Watts @ $0.29 Kilo Watt Hour
- Maintenance is for vendor software support and hardware repairs @ 12% of equipment cost
- Spare policy is 5% spares with a five year life

Recurring costs are simply the costs to keep the switching systems up and running. They include floor space, power, cooling, battery and generator backup, vendor provided software and

hardware maintenance, and the cost of spares. Operations costs to manage the systems and effect adds, moves and changes are addressed in a subsequent section.

Recurring costs alone easily justify the FMO versus the PMO. They are $2,069/year per IAD less for the FMO as compared to the PMO or a $172/month savings. The allocated CAPX of the Softswitch to support the 20 POTS lines in this example is $1,000. Payback on recurring cost of switching alone is 5.8 months.

The dramatic cost difference between the Circuit Switch and the Softswitch is most easily seen by visual inspection. A Softswitch chassis fits into 1/3 of a standard telco rack while a single compact Circuit Switch, meant for deployment in small Central Offices, requires multiple cabinets each of which is 50% larger than a standard telco rack in the smallest configuration. Clearly much more space, power, cooling, and backup power are required to support this volume of Circuit Switch equipment.

The underlying architectural differences of the Circuit Switch versus the Softswitch as well as the use of much more modern electronic packaging in the Softswitch account for the dramatic difference in resource consumption. Softswitches are ideally suited for VoIP-based IAD services because they set behind the IP Router and need only one or two Gigabit Ethernet interfaces to switch calls. The router is very cost effective in terminating the TDM trunks. Circuit Switches, in contrast, require large numbers of DS3 Digital Line Trunk Unit Cards on the line-side as interfaces into the Class 5 switch.

Softswitches employ Call Agent software to perform call-processing functions including service intelligence, call routing logic, lawful interception, control of subtended media/signaling gateways, and billing. The Call Agent software is capable of up to 1 million busy hour call attempts (Sufficient to support 250,000 subscribers) running in a server that is just two Rack Units high. In contrast, the Circuit Switch requires different shelves for each different function consuming several cabinets to do the same job.

Maintenance expense (see Table 2) refers to system vendor annual fees for software support and hardware repairs. Switch manufacturers typically have several software upgrades or releases per year that need to be purchased and installed on switches. In addition to software upgrades, maintenance includes manufacturer site visits, technical support and equipment replacements for technical problem resolution. Industry practice is to tie annual maintenance fees to the initial equipment cost (5% of cost the first year and 12% of cost for each subsequent year.) Since Softswitches have much lower CAPX than Circuit Switches annual maintenance cost is lower.

Service providers also must keep spare parts on hand to effect quick repairs. In this analysis the cost of spares is treated as an expense item and they are written off over five years. The PMO clearly will have much higher sparing cost than the FMO because the Circuit Switch requires many more unique parts than does the Softswitch.

Capacity Utilization Advantages of VoIP-enabled IADs

The TDM-based IAD's capacity is constrained by the requirement to dedicate each of the 24 available DS0 channels to either voice or data. So for example, if 20 distinct POTS lines (Telephone Numbers) are required at the customer premise then no more than 256 Kbps of data service can be provided even if the POTS lines are only used for an hour or so each day. VoIP-enabled IADs, in contrast, can use idle capacity for either voice or data calling instantaneously and because they typically employ 2:1 voice compression technology they can at least double the number of supported telephone lines with no probability of blocking. Therefore, 40 POTS lines and 256 Kbps symmetrical data service can be supported on the same T1 line using a VoIP-enabled IAD.

This advantage of VoIP technology over the PMO can be pushed even further by exploiting the statistical nature of both data packets and circuit switched telephone calls.

Circuit Switching Efficiencies

The PMO uses no switching at the customer premises whatsoever—each POTS line is dedicated to a particular DS0 channel. The VoIP-enabled IAD, however, employs statistical multiplexing so that the amount of bandwidth within the T1 line dedicated to voice traffic can be thought of as a set of telephone trunks. This is analogous to a PBX where circuit switching permits a larger number of telephone extensions to be supported than there are available trunks connecting the PBX to the Central Office. The trunking capacity needed to support the customer site can be estimated using Erlang formulas that use number of telephone extensions, number of calls per day per telephone extension, call holding time, percentage of calls during the busy hour and a target call blocking probability as inputs to the calculation. For example, a small office with ten telephone extensions will require six trunks to the Central Office to limit the probability of blocking a call during the busy hour to 0.01.

Data Traffic Efficiencies

Data communications traffic is very bursty and asymmetrical. This is especially true for web-based traffic. Typically, users submit a short query to a web page that is followed by a somewhat longer response from a web server. Outbound traffic is typically ¼ that of inbound traffic for these types of applications. So each user's pattern is to think about and compose a query that is then sent in an instant by clicking on a web button. Similarly the web server's response is sent as a short burst upon processing of the user's web form. Sustained traffic loads on even highly aggregated links are typically 10% to 15% of capacity. This is why many broadband vendors are able to use oversubscription ratios as high as 50:1.

This web-based traffic pattern is becoming the norm for essentially all enterprise data communications because web front ends are now common for ERP systems and even legacy transaction processing applications.

Whereas simple voice compression algorithms can increase the utilization of the T1 line by 50% to 100% depending on the proportion of total traffic that is voice, use of the IAD's QoS capabilities can double or even triple the service delivery capacity of the T1 line. For example,

VBR-rt can be used for VoIP traffic to maximize voice capacity while UBR for data assures that all unused capacity is available for data.

The PMO (TDM-based IAD) will rarely use all of the 1.5 Mbps capacity of a T1 line because it must dedicate each DS0 to either a single voice line or to fixed rate data service. In contrast, the FMO's IP routing, VoIP, and QoS capabilities can support revenue producing services equivalent to that delivered by more than three T1 lines under the PMO. (As an extreme example, 48 POTS lines and 384 Kbps Internet Access Service can be delivered by using 2:1 voice compression and exploiting trunking and statistical multiplexing efficiencies.)

This creates the opportunity to extend IAD-based services to larger customer sites at a per service cost point that is ½ to 2/3 less than that delivered to existing sites because the same IAD and T1 line configuration is used as for the smaller sites. Viewed another way, additional revenue can be generated at existing customer sites with zero incremental cost.

Faster and Lower Cost Provisioning and Moves, Adds and Changes

Fast, flexible, and cost-effective service provisioning is essential to sustaining service provider competitive advantage. Long intervals between receiving a customer order and turning up service not only delays revenue recognition (Time-to-Revenue) but makes services less competitive compared to alternatives that can be delivered more quickly. Furthermore, operating costs are much more important than CAPX in driving profitability—large ILECs incur $3 of operating cost for every $1 of depreciation and amortization expense. The effect on profitability is multiplied because the long interval is due to the many manual steps required to establish service. Consequently, revenue is delayed, potential sales are lost, and operating expenses are increased which impacts both the top line and bottom line.

Long delays due to complex manual provisioning processes are even more problematic for moves, adds and changes to existing services. Opportunities to upgrade services are lost if fees are charged for the change and if the order interval is too long. However, if service can be changed quickly and easily—perhaps by using a customer facing web interface—then subscribers will pay a premium for the convenience. This, again, has a doubling effect on profitability. The elimination of the manual processes simultaneously contributes to lower operating costs and more sales.

<u>Provisioning of a New IAD-based Service</u>

Under the PMO initial service installation is a time consuming and laborious project requiring the following tasks.

1. Install IAD on customer premise
2. Terminate IAD on loop plant
3. Reserve DS0's on Class 5 switch
4. Reserve DS0's on Router
5. Establish 3:0 connections on DCS

6. Assign call register value (Telephone Numbers) on Class 5 Switch
7. Assign IP address(es) for Internet Service
8. Test each DS0 connection
9. Authorize and verify billing

These tasks require three to four weeks to complete and 120 hours of installation technicians' and network engineers' time plus the cost of a truck roll for an OPEX cost of $12,180 per installation ($180 for the truck roll, $84/hr. for installation technician, and $109/hr. for network engineer).

Under the FMO initial service installation is much quicker and simpler requiring the following tasks.

1. Install IAD on customer premise
2. Terminate IAD on loop plant
3. Establish 3:1 connection on DCS
4. Provision 1 voice PVC and 1 data PVC
5. Authorize and verify billing

These tasks require one to two weeks to complete and 60 hours of installation technicians' and network engineers' time plus the cost of a truck roll for an OPEX of $6,180 per installation ($180 for the truck roll, $84/hr. for installation technician, and $109/hr. for network engineer).

Under the FMO many customer details such as setting up individual telephone numbers, and features such as call waiting, FAX, and message waiting indicators are handled by automated provisioning by the customer using a web page.

Consequently, FMO initial service installation takes about ½ the time and OPEX as the PMO.

Adds, Moves & Changes to Existing IAD Services

Once installed the VoIP-enabled IAD enjoys a very substantial time-to-revenue and OPEX advantage over the PMO. For example, the addition of a single POTS line under the PMO requires the following steps:

1. Reserve DS0's on Class 5 switch
2. Establish 3:0 connections on DCS
3. Assign call register value (Telephone Numbers) on Class 5 Switch
4. Test each DS0 connection
5. Authorize and verify billing

The order interval is at least one week and requires 20 hours of the time of a network engineer ($2,180).

In contrast, under the FMO the customer initiates the service order through a web page and it is automatically executed. Between 1 to 2 hours of clerical time ($120) is required by the service provider to check the billing authorization and verify the order. The service is turned up within one day.

Converting a 8000 Series IAD from the PMO to the FMO

In those situations where an existing Verilink 8000 Series IAD is operating in TDM mode (PMO) it can be quickly and economically converted to VoIP service (FMO) without a truck roll ($180 savings) because the necessary functionality resides in the 8000 Series software. The service provider simply provisions an unstructured DS1 channel through the DCS to the IP router and performs the billing authorization and verification as discussed above. The customer then has a great deal of control in establishing or changing service features. This process can be accomplished in one week and requires about 10 hours of working time at a cost of $990.

Once established, the operating cost savings and increased revenue opportunities quickly payback the cost of conversion. An additional benefit, also, is realized by freeing up capital equipment within the DSC and Class 5 Switch.

Conclusion

The VoIP-enabled IAD enjoys many economic advantages over the TDM-based IAD. Its use of a Softswitch rather than a Class 5 Circuit Switch provides a very substantial Total Cost of Ownership advantage. Softswitch equipment is an order of magnitude less expensive than the Circuit Switch because the IP statistical multiplexing technique requires much less hardware than does circuit switching. The Softswitch's CAPX advantage is further enhanced because it contains up-to-date electronic components while Circuit Switches being at the end of the product cycle use older component technology. The dramatic difference in the hardware also yields an order of magnitude difference in the floor space, power, cooling, backup power, and maintenance costs of the Softswitch compared to the Circuit Switch. Elimination of the high cost of powering a Circuit Switch alone justifies conversion to VoIP.

VoIP-enabled IADs extend by a factor of two to three the number of revenue producing services that can be supported on a single T1 line as compared to TDM-based IADs. This creates the opportunity to reach larger customer sites with a low cost T1 line as well as opens up new opportunities to up-sell services within existing customer sites.

VoIP-enabled IADs are capable of much more rapid implementation of moves, adds and changes at greatly lower OPEX than are TDM based IADs. This has a doubling effect on profitability by increasing revenue while simultaneously reducing OPEX.

Finally, a 8000 Series IAD can be quickly converted to VoIP operation at a cost of about $990 that will be quickly paid back by the TCO reduction and revenue enhancement advantages of the VoIP-enabled IAD as compared to the TDM alternative.