

PBX vs. Centrex Comparison

Summary

While the basic differences between private branch exchange (PBX) and Centrex, whether conventional or IP-based in nature, are relatively clear, the subtleties can be quite confusing. Therefore, the decision process can be difficult for many user organizations.

Note

Service provider aggressiveness in protecting and increasing public network revenues over the past few years has helped renew interest in Centrex services. State regulators have been more responsive to arguments for revised Centrex rate structures. These factors have helped position Centrex to compete more effectively with premises-based PBX and key-system alternatives. At the same time, IP-based client/server platforms have developed to the point that they now are positioned to seriously challenge the traditional circuit-switched platforms in both the PBX and Centrex domains.

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Making the Decision— Key Differences

When deciding between purchasing a PBX or subscribing to Centrex service, the decision-maker must consider the alternatives in the context of a multidimensional business problem. Certain aspects of the problem are relatively easily quantifiable, including functionality, cost, flexibility, support, security, and points of contact.

Other elements of the decision are more subjective, but no less important. In fact, these issues may well determine the ultimate success or failure of the decision. Such factors are oriented toward the very nature of the user organization and include organizational structure, responsibility/control, and style of the organization.

Functionality— Current and Future

When deciding between PBX and Centrex, the business problem and applications must be carefully examined to identify the range of features necessary to address the functional requirements of the end-user organization. Additionally, one must consider the levels of both frequency and intensity with which individual users and user groups access the features.

PBX manufacturers continue to enhance their systems with highly sophisticated features for supporting increasingly demanding applications such as automatic call distribution (ACD), voice over IP (VoIP), voice/unified messaging, Web chat/collaboration, and e-mail distribution, among others. PBX manufacturers have focused on providing integrated and highly transparent access to desirable and specialized networks and network services such as T-carrier/E-carrier, local area networks (LANs), frame relay networks, asynchronous transfer mode (ATM) networks, and IP-based networks. More recent developmental efforts have gone into positioning the PBX in support of VoIP, as well LAN traffic, both within the customer premises and across the WAN.

Centrex systems have the inherent capability to provide a level of functionality similar to that of PBXs. Service providers are increasingly offering a wider range of features and functions on central office (CO) platforms; however, the offerings tend to be more limited for several reasons. First, conventional circuit-switched COs have finite limits to the level of processing power and memory available. Although conventional COs are much more substantial platforms and, therefore, are far less limited than are PBXs, their resources must be spread across a much greater and much more diverse population of end users.

As a CO typically serves a large number of local-loop connections (10,000 to 20,000) involving thousands of subscribers, there are limits to the extent in which the switch can be committed to providing certain processor-demanding and memory-intensive Centrex services. As has always been the case in the incumbent local exchange carrier (ILEC) domain, in general, and the Centrex domain, in specific, the emphasis clearly is on providing high-quality and highly reliable basic voice grade services.

Second, the ILECs remain constrained by lengthy, cumbersome, and limiting regulatory processes. As a result, they tend to offer only those services for which they are convinced there exists a strong, broad, and profitable market. Additionally, the regulators are not likely to encourage the ILECs to overbuild the Centrex CO, inflating the rate base in the process; rather, they increasingly take the position that the rates for such services must be cost-based. In many regulatory jurisdictions, telcos can negotiate special customer contracts to include additional features of more limited appeal; the associated regulatory process to reach a broader market, however, might be lengthy. In some states (e.g., Nevada), Centrex has been detariffed, and it is now available only on a contract basis. Notably, competitive carriers and service providers are not so constrained.

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Nonetheless, the range of Centrex features offered satisfies the needs of many small- and medium-size businesses. Even many large businesses find Centrex to be an attractive alternative to a premises-based system, unless their needs are unusual. In fact, service providers are increasingly successful in tariffing Centrex services such as call conferencing, ACD, voice processing, Custom Local Area Signaling Services (CLASS), and newer services such as IP Centrex.

Cost

In evaluating PBX versus Centrex alternatives, costs must be considered along multiple dimensions. At the minimum, these include the following:

- Acquisition
 - Switch
 - Terminal Equipment
 - Cable and Wire
- Network Access
 - Line/Trunk Charges
 - Access Charges
- Maintenance
- Facilities
 - Floor Space
 - Power
 - Insurance
- Security
 - Physical
 - Logical
- Predictability

Acquisition Costs

Acquisition costs include the costs of acquiring the switch, terminal equipment, and inside/outside cable and wire system.

Switch Acquisition: While the acquisition costs associated with a premises-based switch can be significant— easily in the range of \$650 to \$750 per PBX port, plus associated adjuncts such as voice mail, ACD, and other applications processors— Centrex services require minimal capital outlay, if any, for common equipment (e.g., telephone sets). On the other hand, the monthly cost of subscribing to Centrex lines and features, which can typically fall in the \$15 per line/per month range for basic call service up to \$60 per line/per month (or more) for advanced Centrex services for call centers, is never-ending and can be quite substantial over time. However, the ongoing costs of adjuncts, enhancements, upgrades, additions, and maintenance may push the long-term cost of a PBX off the chart, particularly as new

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technologies develop in support of ever more demanding emerging applications. But a truly fair cost comparison must consider the longevity and total cost of ownership of both solutions.

Additionally, one must consider the cost of system replacement, which is an issue for PBXs, but not for Centrex COs. Some years ago, numerous end-user organizations were shocked by the cost of PBX upgrades required to support area code changes to the North American Numbering Plan (NANP), as older PBXs that could not be upgraded required full replacement. Year 2000 issues and problems also posed a significant threat and involved even more significant potential PBX costs. Universal International Freephone Numbers (UIFN) and other changes to international and national numbering plans are fairly frequent occurrences. All of these changes and compatibility issues weigh more heavily on the PBX owner than they do on the Centrex user.

The level of competition for the specific PBX hardware/software configuration desired clearly affects the cost of acquisition. Such costs vary by manufacturer, system size, and system capability. The size and number of systems involved have clear and present impacts on total cost. Additionally the nature of manufacturer distribution channels impacts acquisition costs, with some PBX systems, for example, available through numerous distributors, while others are available on a more restricted basis.

Terminal Equipment Acquisition: Regardless of the platform chosen (PBX or Centrex), the terminal equipment currently must be purchased or leased, rather than “rented” under telco tariff. Telcos can offer such equipment through separate, nonregulated subsidiaries or business units, with the transactions being separate and distinct. Centrex customer premises equipment (CPE) can be provided by competitive local exchange carriers (CLECs) on any basis they choose. Acquiring PBX terminal equipment generally involves the same switch vendor and could, therefore, provide the client company with additional leverage relative to this one aspect of the cost equation. Additionally, a number of terminal equipment distributors, system integrators, consultants, and supply houses can provide users with the necessary terminal equipment. The secondary market often provides an attractive alternative in the form of reconditioned or refurbished equipment.

Equipment standardization also is a key issue for large, multisite user organizations. PBXs can offer consistency of features, functions, and user interfaces because the user can “standardize” on equipment from a single manufacturer, and often can use the same electronic sets across multiple sites and switch versions. Centrex is not nearly so predictable and controllable as the CO type might vary from location to location. Since many of the service providers support only station sets that are proprietary to the CO switch, terminal equipment acquisition is problematic in a multisite environment involving Centrex systems of disparate origin.

Cable and Wire: The service provider is required by regulation to terminate at the demarcation point (demarc). Therefore, providing inside wire and cable systems must always involve either a nonregulated vendor (i.e., an unregulated telco subsidiary or a third-party vendor) or internal technical staff, or at least must be treated by the ILEC as a nonregulated activity. Generally speaking, the Centrex demarcation point is called a Minimum Point of Entry (MPOE) and is located just inside the point where the entrance cable enters the building or property.

In a campus environment, outside plant facilities are often a significant issue. Careful planning and a thorough understanding of applicable state tariffs might well lead to the most advantageous placement of the demarcation point by virtue of the physical/technical location of the local loop termination.

FCC Docket #88-57 (14 June 1990) capped a multiyear process that suggested quite strongly that premises cable and wire be transferred from the service provider to the user, although individual service

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providers and state regulatory bodies (Public Utilities Commissions/Public Service Commissions [PUCs/PSCs]) have moved at distinctly different paces and directions in this regard.

In California, for example, the California Public Utilities Commission (CPUC) determined that an MPOE be established (effective 8 August 1993). The entrance cable is demarcated by the service provider typically 12 inches from the inside wall; all inside facilities past that point are the property of the user (read *building owner*). But feedback indicated that building owners were unprepared for this responsibility and were, in many cases, even unaware of the proposed transfer of the asset and the accompanying responsibilities and opportunities. The tenants were similarly unaware of this change in ownership and management and its many significant implications.

California typically defined the demarcation point at the jack for Centrex subscribers and at the PBX termination for PBX users, with PBX inside wire being the user's responsibility. As of 8 August 1993, the building owner entered the equation with the responsibility for cable and wire provisioning, management, and security from the MPOE to the Centrex jack or PBX. The building owners' responsibilities are significant, and the tenants are now dependent on yet another party— one which may charge for the use of the asset and which might manage it poorly.

The Chesapeake & Potomac (C&P) telephone company and Bell of Pennsylvania (Bell of PA), both of which previously were Bell Atlantic Bell operating companies (BOCs) and are now part of Verizon, moved in the same general direction as did Pacific Bell several years earlier. Regulations vary widely on a state-by-state basis. In New York, for example, Verizon (previously Bell Atlantic/NYNEX) still takes the demarcation to the individual tenant, usually terminating in a tenant-level wiring closet.

Network Access Costs

Line/Trunk Charges: The cost of the local-loop connection to the CO varies widely across telco jurisdictions. Generally speaking, the raw monthly costs of Centrex lines are well below those of PBX trunks. Depending on the distance of the user from the serving CO, however, mileage charges could have a significant impact on the monthly cost of either alternative. Centrex lines generally are provided on a single-loop basis with any mileage charges applied to each Centrex line, while PBX mileage charges are applied to PBX trunks, which are shared by multiple stations. It should also be noted that, in some jurisdictions and usually only under contract, multiple Centrex stations can share a single high-capacity (multichannel) local loop connection, thereby mitigating such differences in both local-loop and mileage charges.

The CLECs, of course, are free to price network access according to any formula they choose. Certainly, Centrex lines and PBX trunks can be provisioned over unbundled local loops rented by the CLEC from the ILEC. This approach is considered only to serve customers who are off-net (i.e., the premises are not connected directly to the CLEC network via CLEC facilities). A much more attractive alternative is for the CLEC to bypass ILEC facilities and provide direct connectivity to an on-net building, either by a direct optical fiber connection or via Wireless Local Loop (WLL) technology. A WLL link typically would involve a radio technology in the form of either point-to-point microwave or Local Multipoint Distribution Services (LMDS). Multitenant units (MTUs), also known as multidwelling units (MDUs), such as high-rise office buildings, condominiums, or mixed-use buildings, often can justify the expenditures necessary to support an on-net approach.

Equal Access Charges: The cost of the local-loop connection also includes charges associated with equal access. While the access charges that apply to both PBX and Centrex often are equal, once again one must consider the fact that PBX trunks are shared by multiple stations. Centrex lines, on the other hand, generally are subject to access charges on a line-by-line basis.

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At this point, one must remember that the purpose of access charges is to reimburse the LEC for the cost of providing access to the various InterExchange Carriers (IECs) with equal ease through the local CO and cable plant. Since Centrex is a CO-based service, all IEC connections are provided on that basis. PBX users, on the other hand, have the advantage of accessing the IEC POP (Point of Presence) via alternative means. Such means include leased-line circuits provided by the ILEC for connection directly to the IEC, facilities bypass via microwave, and facilities bypass through facilities-based CLECs. Such CLECs typically offer SONET fiber-optic facilities for this purpose, although some make use of short-haul point-to-point microwave or LMDS. Infrared (Ir), also known as free space optics (FSO), is a developing alternative bypass technology. CLECs, many of which were originally Competitive Access Providers (CAPs), serve as both LECs and IECs. Assuming that the customer premises is in reasonable proximity to the CLEC's backbone network and that the volume of traffic generated by the customers within a building or campus is sufficient, such a CLEC often can address all requirements, including PBX trunks and Centrex service.

Large PBX users certainly can eliminate much of the cost of access charges by avoiding switched connection to the IEC through the CO. In the process, the PBX user gains the additional advantage of interexchange access diversity and, thereby, the advantage of protection against catastrophic failure at the CO level. CLEC connections provided over SONET fiber-optic facilities offer the advantages of additional and readily available channel capacity, improved transmission quality, and redundancy. In its most complete form, the SONET standard specifies a four-fiber, bidirectional line-switched ring (4FBLSR) architecture. This redundant dual counter-rotating ring architecture provides inherent redundancy and, therefore, network resiliency.

Maintenance Costs

System acquisition and network access costs can be identified more easily than system maintenance costs, but are not significantly greater in the long term. Centrex offers the advantage of bundled switch maintenance—at no additional cost. The serving LECs either staff or remotely monitor all major central offices on a 24x7 basis. As a result, service-affecting problems with the switching system typically are resolved very quickly—often before they are even detected at the user level.

PBX systems, on the other hand, involve additional operating expense for maintenance personnel, as well as the capital expense for certain common equipment spare parts. Whether technical and supervisory personnel are provided internally or by a vendor (either the system provider or a third party), the costs can be significant and can increase over time at an unpredictable rate.

The cost of maintaining both terminal equipment and inside wire and cable plant is roughly equivalent, in either case.

Facilities Costs

The total cost of the switching system also must include the cost of the facilities that house the core system and ancillary systems, associated environmental systems (e.g., air conditioners, humidifiers or dehumidifiers, fire suppression systems, and uninterruptible power supplies), and the power they consume. Additionally, the cost of insuring the systems against loss and damage must be considered.

While such costs are the full and complete responsibility of the PBX owner, they are borne entirely by the service provider on behalf of the Centrex user. Although such costs are not extraordinary in magnitude, they must be considered in order that a valid comparison be made between PBX and Centrex alternatives.

Security Costs

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The costs of securing the system must be considered, especially given the significant and highly publicized potential for catastrophic security breaches. Although CO Centrex is not perfectly secure, it can be considered to be virtually so. As COs are locked and often staffed on a 24x7 basis, physical security is not an issue. Further, as LEC technicians monitor such systems continuously, the likelihood of an electronic security breach is remote. Should such breaches occur, they are quickly resolved by the LEC, and at the LEC's own cost, including the cost of any toll fraud committed. PBX owners, on the other hand, are much more susceptible to security breaches, both physical and logical, and are completely responsible for protecting the systems against unsavory characters who might wish either to cause damage to the systems or to use the customer's network fraudulently.

Predictability of Costs

The commitment to a PBX or Centrex system is usually for a long term. Therefore, the predictability of the various cost elements must be considered.

PBX acquisition is definitely a long-term proposition. The acquisition cost of the initial system configuration (i.e., common equipment, terminal equipment, and cable and wire) is fixed and is expensed according to standard depreciation schedules. The costs of system additions and enhancements are subject to higher markups and will increase over time at unpredictable rates, unless the initial contract specifies otherwise. The costs associated with changes in the NANP and Y2K compatibility are more recent examples. Network access costs will vary at an unpredictable rate according to the rates and tariffs of the service providers.

ILEC Centrex rates generally are difficult to predict because they are subject to state regulation. In some jurisdictions, however, Centrex rate predictability assurances are offered by contract. In other jurisdictions, Centrex has been detariffed and is available only under contract. CLECs, once again, are free to price Centrex any way they choose.

Scalability of Costs

Scalability refers to the relationship between capacity and capability (e.g., hardware and software configuration), and associated costs. A perfectly scalable system would maintain an exactly proportionate relationship between these two factors, whereas a far less desirable relationship would exist with a system that involved quantum leaps in cost for relatively slight improvements in performance or feature content.

Centrex systems are highly scalable, and in both directions. As more user sites are added to a Centrex network, the associated costs increase accordingly for circuits, features, terminal equipment, and cabling. As an individual site expands, the costs of that expansion can be characterized as bearing a reasonably graceful relationship to the increases in performance. Perhaps more importantly, many Centrex cost elements decrease as the size of the user network decreases. As sites are eliminated or as the number of station users decreases, the costs of the associated Centrex services decrease accordingly. The acquisition costs of station equipment and cabling, of course, are sunk costs and do not decrease. Seasonal businesses find this scalability characteristic of Centrex to be highly desirable, as many elements of their communications cost equation closely match their communications requirements, which can vary considerably during the course of a year.

PBX systems vary widely in terms of their scalability and the specifics of the performance breakpoints at which additional hardware (e.g., processors and cabinets) is required. Similarly, the cost of maintenance and operation generally will increase as the size of the system increases. Should the user organization eliminate sites or reduce staff, the cost of the system does not decrease accordingly, with the possible exception of maintenance cost.

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Responsibility/Control

Clearly more subjective, but no less significant, are the issues of responsibility and control over one's environment and destiny. While some choose to classify such concerns merely as a matter of "style," others believe that the issues are quite significant, and even palpable.

PBXs provide the user organization with virtually total control over the system environment. Within current and future constraints of both the PBX system capabilities and the user organization's financial resources, the system can be configured to provide the exact level of functionality required and desired. Along with this dimension of control, the user company must consider the associated responsibilities that must be borne.

Centrex system management and control, on the other hand, are the responsibility of the serving LEC. Centrex system functional capabilities are enhanced largely on the basis of both perceived market demand and long-term infrastructure investment priorities of the serving telco. While the very large user organization sometimes can influence such priorities, the decision, ultimately, is that of the telco and the regulators.

The discussion of "control" would not be complete without considering the fact that telecom managers and consultants generally tend to favor PBX solutions, sometimes for reasons which are less than fully objective. Consultants usually reject Centrex out-of-hand because of its inherent simplicity; the clear perception is that user organizations simply do not expect high-priced outside experts to come up with simple, obvious solutions. Further, telecom managers do not view Centrex solutions as contributing to increased departmental budget, staff, responsibility, and overall span of control; therefore, Centrex defeats the personal goals of telecom managers whose levels of compensation and prestige are based on such factors.

Flexibility

In an increasingly dynamic business environment, issues of network flexibility are a substantial concern. PBX and Centrex systems offer distinctly different capabilities in regard to expansion/contraction, configuration management, and feature content and assignment via Class of Service (COS) assignment.

PBX systems, because they are owned and managed by the enterprise, are endowed with the functionality desired and required by the user. Literally hundreds of features typically are available, and multiple applications processors (e.g., voice processors, ACDs, and protocol converters) can be applied to specific business problems. User access to features and functions can be managed relatively easily by COS through proprietary software system interfaces. PBX systems, however, have finite limits in terms of port, traffic, processor, and memory capacities. Additionally, PBXs must be engineered and equipped to support a high Grade of Service (GOS) during periods of peak load, with the level of capital investment required being proportionate.

Conventional Centrex systems generally provide the level of functionality offered by the telco on a tariffed basis, although special features can be made available on a contract basis for very large subscribers—with the cooperation of the telco and the PUC/PSC. CLECs, of course, are unencumbered by state regulation in this regard. Configuration management and feature assignment/reassignment are also available through software interfaces to Centrex configuration management systems, although this capability is not universally available.

For example, such configuration service is provided by the telco as an electronic interface to the Centrex system for purposes of accomplishing move, add, and change (MAC) activity. Marketed under a variety of names, most systems of this type are based on technology developed either by Telcordia Technologies

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(previously Bellcore), through its Centrex Customer Rearrangement System (CCRS), or CommTech (Macstar). These systems allow the telco to accept MAC requests from the user terminal, write them to temporary memory at the CO level, and perform edits prior to their being posted to the system database. Such changes generally are posted to the system during the evening hours, as scheduled by the subscriber, and thus are not performed in real time. Pacific Bell's Centrex Management Services (CMS) service option, for instance, allows the user system administrator to post up to 100 changes per day, with up to 10 changes posted on a priority basis (typically within two hours); the number of priority changes can be increased by special and prior arrangement.

On the other hand, Verizon's Customer Station Rearrangement (CSR) system features real-time and near real-time MAC support. Such capability is still limited; for example, the provisioning of a new Centrex line is not currently possible without human intervention and the issuance of a service order by the telco. The user, by the way, can place the service request and track the resulting service order electronically through systems such as Pac Bell's Service Manager system.

Support

As organizations depend increasingly on computerized communications systems and networks, support issues are paramount. System training, documentation, and technical support not only should be of high quality, but also should be readily accessible on a cost-effective basis.

Major PBX system manufacturers such as Avaya, Nortel Networks, and Siemens have made substantial commitments to providing high levels of support at both the technical and user levels. Clearly, however, the level of support provided to a specific company depends on the quality and experience of local-support personnel. Where the system is provided and maintained by a distributor rather than the manufacturer, users should carefully consider the level of support available and negotiate with the manufacturer for second-level support should the distributor fail to perform.

Aside from training and documentation, the effectiveness of PBX support is sensitive to the skill level and availability (number of qualified personnel and hours of availability) of technical support personnel, both remotely (dial-up) and locally (hands-on). Many large PBX systems are supported by internal technical staff who are trained and certified by the manufacturer. In these cases, the telecom manager should consider the availability of training offered by the manufacturer, including frequency, course level, and availability of training slots. While this approach offers the advantages of independence, the associated risks of in-house staff turnover must be recognized. Such risks can be mitigated by negotiating for backup support from the distributor and/or manufacturer, although they often suffer from employee turnover as well.

Support issues are minimal for users of conventional Centrex systems, since the telcos boast large, well-trained staffs. BellSouth is so confident of its support capabilities that it offers Centrex users a money-back guarantee within 90 days of cutover.

Support for client/server IP-based PBX and Centrex systems is viewed as an entirely different matter. Experienced technical support personnel generally are readily available in the mature domain of conventional PBXs and Centrex systems, and the associated costs of such personnel are relatively agreeable. Support for systems in the developing client/server IP-based domain is generally perceived as being quite another matter. The skills required in support of such systems are much more IT-related than they are telecom-related. As the demand for such skills has been so high during the high-tech boom of the past decade (the immediate slump notwithstanding), the associated costs of such support personnel generally is perceived as being much less agreeable.

Cost Management

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The effective and even real-time management of network usage costs has long been an advantage of PBX systems, with support from the appropriate telemanagement software. The call accounting capability of such software provides a wide range of reports on usage, allowing the virtually immediate correction of toll fraud and network abuse and misuse. Centrex, for the most part, does not provide such a high level of control, as bills and network usage reports (where available) are provided on a monthly basis. In order to achieve the same level of control, Centrex users typically must invest in expensive circuits to access that data, where the LEC provides such a capability.

There are exceptions, however. Verizon, in select areas, offers Centrex Call Management (CCM) and View@once software. In combination, these software systems allow Centrex customers to monitor outbound traffic through a variety of standard and customized reports, and in a variety of tabular and graphic formats. Also in select areas, Verizon offers access to call accounting information via dedicated lines between the customer premises and the Centrex CO, via dial-up modem access and via FTP download from its Web site.

System Enhancement

Because contemporary PBXs and Centrex COs are essentially highly specialized computer systems, they are software controlled. The software that drives these systems is extremely complex, and can be generally characterized as emphasizing reliability rather than flexibility. A CO switch, for example, involves millions of lines of carefully tested code, on top of which have been layered Centrex applications. ISDN and Signaling System #7 (SS7) software add significantly to the level of complexity, as all such system and network software is closely interrelated. While PBX software is somewhat less complex, it is by no means trivial in nature.

The point is that software is not perfect, even in mature, general-release systems. “Bugs” surface as the systems are placed under varying levels of stress in varying application environments. These bugs should be addressed quickly and completely since they can affect the performance of critical system responsibilities.

Additionally, software must keep pace with changes in the network environment. The changes in the NANP and the introduction of Universal International Freephone Numbers (UIFN) are fairly recent examples. Because the second-digit position in the Numbering Plan Administration (NPA), or area code scheme, opened on 1 January 1995, to allow the use of numbers other than 0/1, the switching systems, as well as the network, had to be capable of distinguishing between the new area codes and CO prefixes to properly route traffic. Since COs are part of the network, Centrex users had no real reason to be concerned; the telco ensured that the appropriate software changes were made. PBX users, on the other hand, were forced to pay for some combination of expensive software/firmware/hardware upgrades, assuming that the system was upgradable— many older PBX and key systems were not.

Developers of client/server IP-based systems suggest that such systems, whether PBX or Centrex in nature, are more easily upgradable. Their position is based on the fact that such systems have been developed with upgradability and flexibility in mind, much as is largely the case with any general-purpose computing platform written in a high-level language.

Security

System security against hackers, saboteurs, and toll-fraud artists is an increasingly critical concern, as evidenced by numerous, highly publicized cases. There is clearly limited defense against calling card toll fraud, to which Centrex and PBX users are equally susceptible.

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However, PBX users are especially vulnerable to fraud and sabotage through Direct Inward System Access (DISA) trunks, remote maintenance ports, and voice processing systems (i.e., voice mail and interactive voice response [IVR]). Although a number of active and passive means have been developed to limit unauthorized access and its consequences, the general level of vulnerability (and liability) is much greater for PBX users than for Centrex users. Centrex subscribers generally need to be less concerned about the likelihood of intrusion, abuse, and fraud because the security of the Centrex system is the telco's responsibility, and telcos tend to take those responsibilities seriously. If a security breach occurs, the responsibility usually rests somewhere between the LEC and the IEC, assuming that the Centrex user has taken reasonable precautions to prevent credit card abuse.

Points of Contact

When deciding between PBX and Centrex systems, customers should consider the number of contact points involved in the process of system acquisition, operation, and maintenance as a whole. The process no longer involves a single point of contact, as was the case prior to deregulation.

The conventional Centrex subscriber's options are somewhat limited because the switch, by definition, is provided by the LEC. The Centrex CO is also the single point of network access for voice networks of all descriptions (local exchange, intraLATA, interLATA, and leased line), although separate arrangements with all such network providers are the responsibilities of the user company. Terminal equipment and inside cable and wire systems will involve additional vendors, perhaps in the form of the telco's nonregulated subsidiary. The inside wire and cable facilities may involve not only an additional vendor, but also an additional owner.

PBX users can acquire switching equipment, terminal equipment, and cable and wire from the same vendor (the manufacturer or distributor) or may be involved with several vendors. Access to the local exchange and intraLATA networks still typically involves the telco, although access to providers of interLATA, leased line, packet data, and other networks may be provided either through the telco or on a "facilities bypass" basis. CLECs, for example, may be used to provide access to IECs. Of course, CLECs can do it all with minimal regulatory oversight, where they are in proximity to the customer premises.

Contingency Planning/Disaster Recovery

Network resiliency is a great concern to contemporary enterprises that depend heavily on communications systems and networks to support, and even drive, their core business. Voice, data, image, and video systems and networks are critical to the very survival of private and public sector organizations of all descriptions. Over the years, failures of domestic ILEC and IEC networks due to fires, power failures, cable cuts, and SS7 software failures repeatedly have underscored this point.

Centrex subscribers are particularly vulnerable in this regard. While the Centrex CO is highly redundant and constantly monitored, the Centrex subscriber totally depends on Centrex service for providing all features and functions, as well as access to a variety of networks. If the CO suffers a catastrophic failure, the subscriber will feel the impact in a most direct and significant way. This concern is more than conceptual. Some years ago, a fire in the Hinsdale, Illinois, CO left Centrex customers without dial tone for days and without full service for months. Similarly, earthquakes in San Francisco and Los Angeles left Centrex subscribers, including major hospitals, without dial tone for periods of up to five days. Notably, such failures affect not only incoming and outgoing calling from and to the wide area network (WAN), but also affect station-to-station calling, as all function and feature content reside in the centralized CO Centrex platform.

PBX systems are vulnerable to such failures as well. In fact, few PBXs are either as redundant or as well managed as COs. The risk of PBX failures can be limited, however, through diligent planning on the part

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of the telecom manager (budgets permitting). Recovery from such failures generally is less involved in the PBX domain. Therefore, catastrophic PBX failures are often of shorter duration than similar Centrex failures, although they may be more frequent.

The PBX user also has the advantage of diverse network access, although at additional cost. PBX access to the local exchange network still relies on the LEC, but the PBX can access multiple COs to mitigate the impact of a catastrophic CO failure. Further, multiple LECs, perhaps the ILEC and a CLEC, can be used. Additionally, PBXs can access IECs through the LEC CO by direct connection to the IEC POP, via a CLEC, or through some combination of the above. Access to data networks (e.g., frame relay) can be provided on a similar basis. Communications-intensive organizations increasingly are implementing some level of entrance, pair, cable, route, loop, CO, and carrier diversity for purposes of network survivability. Wireless technologies, both radio frequency (RF) and infrared (Ir), offer exceptional levels of redundancy at the local loop level, as a backup to wireline loops.

Relationship to the Network

Conventional Centrex systems are physical and logical partitions of the LEC CO. Therefore, and by definition, they are an integral part of the public switched telephone network (PSTN). PBX systems are separate and distinct from the public network, although they connect to it.

It is clear that certain public network-based services (e.g., Basic Rate Interface Integrated Services Digital Network [BRI ISDN]) will continue to be available to Centrex subscribers. ISDN offers a single point of access into an array of high-speed, fully digital networks and services. But as a circuit-switched technology, it does not offer the appropriate levels of flexibility and efficiency required for many contemporary data communications applications, perhaps most notably those that are IP-based. Broadband ISDN (B-ISDN) offers the bandwidth needed and will probably enjoy a more positive reception than did narrowband ISDN (N-ISDN). Advanced Intelligent Networks (AINs) offer advanced services, such as distributed ACD, on a network basis.

Major PBX manufacturers undoubtedly will continue to develop the necessary interfaces to such networks and services. The relationship between the network and CPE, however, will always be less than complete and transparent.

PBXs will continue to enjoy an advantage over conventional Centrex with respect to access to high-speed network technology and service offerings, including frame relay and ATM. Network options like these are generally accessed through high-speed, dedicated circuits to the LEC, IEC, or CLEC whether the user organization is centered on PBX or Centrex. The PBX user realizes additional flexibility, since multiplexers, switches, routers, concentrators, variously and routinely, can be the necessary physical interfaces and software to support such access. Further, value-added IP-based networks generally are more accessible via PBXs than Centrex.

Organizational Structure/Networking

An enterprise's organizational structure must be carefully considered during the PBX/Centrex decision cycle. A given enterprise can be characterized as a single-site or multisite in nature. Multisite enterprises can be further categorized as metropolitan, intraLATA, or interLATA.

Conventional Centrex is a clear and viable option to organizations that are highly centralized and served by a single Centrex CO, because all users have access to the same suite of features and functions accessed in the same manner. Multisite enterprises served by a single Centrex CO often find Centrex especially attractive because the technical and cost issues of connecting multiple PBXs or key systems are avoided. As such, multisite Centrex is the largest segment of the small-site Centrex market.

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Multisite enterprises served by multiple COs typically find Centrex to be less attractive, because the COs often are of different origin or generation, offer dissimilar capabilities, and/or are not easily networked. Conventional Centrex networks are not generally considered to be a viable option on an interLATA basis, since ILEC Centrex providers generally do not have the advantage of providing network service across LATA boundaries, at least not in most jurisdictions. Again, CLEC service providers are not so restricted.

In some cases, however, ISDN Centrex is available via dedicated Primary Rate Interface (PRI) facilities to provide wide area Centrex, also known as “virtual Centrex” or “city-wide Centrex.” In fact, these offerings increasingly provide multisite Centrex service from a single CO switch through geographically distributed remote line shelves. This is a significant improvement over the traditional approach of providing this service through interconnection of multiple switches in a Centrex tandem network.

Note that providers of IP-based Centrex, as they emerge and as their network service offerings develop, may not be nearly so restricted as either the ILEC or CLEC providers of conventional Centrex service. Rather, the full range of call control capabilities will be available across the Internet or other IP-based networks, at least theoretically.

PBX networks often and routinely are established on a multisite basis, whether metropolitan, intraLATA, or interLATA in scope. While the technical and cost issues can be significant where dedicated facilities (tie trunks) are involved, the advantages of a multisite PBX network, offering a consistent suite of features configured specifically to the requirements of the end-user population, are often clear and substantial. However, varying PBX software generics complicate the problem and solution set.

Network Integration: Convergence at the Protocol Level

There has been a good deal of talk over the past decade or so about network convergence. This loosely defined concept involves networks that are capable of supporting a variety of application types in a highly cost-effective manner, while supporting various levels of Quality of Service (QOS) or, at least, Grade of Service (GOS). The network technologies to be considered focus not so much on transmission (e.g., T-carrier, SONET, and DWDM), as they do on switching (i.e., circuit and packet switching).

Circuit switching certainly is capable of supporting any native information type and any application type, but not necessarily cost-effectively. Circuit switching commits network resources in the form of time slots to each connection, whether it is intended to support real-time, stream-oriented voice or video, or bursty data traffic. Circuit switching provides outstanding performance (i.e., QOS or GOS), but provides the same high level of performance for all connections, whether or not it is appropriate for the application type. In short, circuit switching is optimized for voice communications. Therefore, circuit switching is not considered to be cost-effective in a convergence scenario.

Packet switching involves the organization of data into packets, each of which travels independently through the network. During its travels, each packet associated with each call shares the resources of the network, including transmission links and switches or routers, with other packets associated with other calls. Depending on the specific nature of the network, the information type, and the application type, the network may support information transfer on either a connection-oriented or a connectionless basis. Further, various application types can be provided with differential levels of service. There are two candidate packet protocols for integrated networks: ATM and IP.

ATM

Asynchronous Transfer Mode (ATM) is a connection-oriented switching protocol that possesses the unique, inherent capability to provide guaranteed QOS at differing levels across multiple application types, simultaneously. For example:

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- Constant Bit Rate (CBR) service is guaranteed for uncompressed stream-oriented information such as voice, audio, and video.
- Real-Time Variable Bit Rate (rt-VBR) service is provided for real-time, compressed voice and video.
- Non-Real-Time Variable Bit Rate (nrt-VBR) service might support frame relay traffic or non-real-time, buffered voice and video.
- Available Bit Rate (ABR) and Unspecified Bit Rate (UBR) service levels might be exercised in support of LAN internetworking, Internet access, e-mail, file transfer, and other data application types tolerant of loss and delay.

ATM inherently can support all of these QOS levels simultaneously— a capability which is truly unique. ATM is positioned in the core, or backbone, of many carrier networks (especially data networks), where its capabilities can be fully utilized.

Increasingly, carriers also are deploying ATM at the edge of the network. In fact, a large percentage of DSLAMs (Digital Subscriber Line Access Multiplexers) run the ATM protocol in support of TCP/IP packet traffic for Internet access. This is due largely to the fact that the ILECs, currently the largest providers of DSL services, run ATM in the backbones of their data networks. Some large enterprises are accessing carrier networks over integrated local loops running the ATM protocol, with voice connecting from a PBX to an ATM premises-based switch, and data traffic connecting from a LAN hub, switch, or router. In fact, some PBXs now run the ATM protocol. To date however, there are no ATM-based Centrex offerings.

IP

The TCP/IP (Transmission Control Protocol/Internet Protocol) suite was developed for the packet-based ARPANET (Advanced Research Project Agency Network), which has evolved into the commercialized Internet, as we know it today. IP, the fundamental layer, is connectionless. TCP, which runs on top of IP, is connection-oriented. Application-layer extensions include User Datagram Protocol (UDP), FTP, Simple Network Management Protocol (SNMP), Simple Mail Transfer Protocol (SMTP), and Telnet. While the IP protocol suite was developed to support data applications that are tolerant of loss and delay, much work has been done to extend its application to information types such as real-time, stream-oriented, compressed voice and video. Various mechanisms, both standard and proprietary, are now available to provide differentiated Grades of Service, all on a *best effort* basis. The most notable of these GOS mechanisms currently is MPLS (MultiProtocol Label Switching), which has gained a very strong following in the service provider and domains.

Network Integration: Convergence at the Systems Level

During the past five years or so, there has been a great deal of developmental emphasis on systems that can integrate voice and data communications, and support a wide range of applications that benefit from such convergence. Conventional circuit-switched platforms clearly do not fill that bill, as they are far too rigid and far too inefficient in their support of data communications. They also have proved inefficient in support of voice communications, given the development of sophisticated voice compression algorithms that can reduce the bandwidth requirement for voice from 64 Kbps down to 32 Kbps and less with little or no loss in perceived quality. Early on, most of the developmental effort was focused on PBX systems, and a number of them have since made it to market. More recently, manufacturers from both the voice and data domains have announced the availability of next-generation Centrex systems, and a small number of service providers have deployed them.

IP PBXs

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The recent advent of the client/server PBX, also called the IP PBX, presents a threat to traditional PBXs. The client/server PBX is based on a client/server-computing model, with the server(s) being in the form of one or more industrial strength PCs positioned as applications servers. The clients run against the servers across a shared Ethernet LAN. A key advantage of IP PBXs is their inherent ability to share a single set of connectivity resources across both the voice and the data domains, as all communications share a common cable and wiring scheme, usually in the form of Cat 5 or Cat 5e cable.

In their simplest forms, the voice clients take the form of proprietary telephone sets. The data clients, of course, are desktop or laptop host computers. At the extreme, the clients are in the form of multimedia PC workstations which can serve both as general-purpose computer workstations and call controllers, and even as enhanced voice terminals. Positioned as a voice terminal, a workstation with the appropriate client software offers much enhanced call control capabilities, generally through a Windows graphic user interface (GUI). Thereby, an end user can accomplish such functions as conferencing and call transfer on a point-and-click basis. The advantage of open application programming interfaces (APIs) associated with such a client/server computing platform supports not only rapid development of feature content, but also enhanced user performance through a well-understood and highly intuitive user interface. Further, such PBX systems support a considerable level of configuration flexibility at the end-user level.

Several protocols are associated with such a client/server PBX. Fundamentally, they generally run over an Ethernet LAN. The TCP/IP protocol suite runs inside the Ethernet frames, as it almost always does in Ethernet LANs. ATM is used in some cases to interconnect the high-speed servers.

IP-PBX systems generally are available only in relatively small configurations, although several manufacturers have released systems of quite substantial size. Although issues of system security, reliability, and voice QOS continue to swirl around this emerging technology, the perception of the user community is increasingly positive. A number of manufacturers, including Avaya, Ericsson, and Nortel have developed IP-PBX products that support real-time compressed, packetized voice, as well as packet data at Ethernet LAN speeds including 10 Mbps, 100 Mbps, and 1 Gbps (Gigabit Ethernet).

IP Centrex

More recently, IP Centrex systems have been developed. Most such systems are in various phases of beta testing, although a few have been placed into commercial service, mostly by relatively new, small CLECs. IP Centrex serves as a multifunctional, carrier-class, IP-based call-processing platform. There are several approaches to IP Centrex.

One approach is that of a Class 5 CO switch equipped with an IP gateway, which supports connections to both the traditional circuit-switched PSTN, and the Internet or other IP-based network (i.e., LAN, WAN). This approach allows an established LEC with a circuit-switched network to phase in IP telephony. Users of traditional circuit-switched Centrex access the CO in the traditional manner, which generally is on the basis of one local loop per Centrex telephone number. IP Centrex users have several connectivity options.

The first option involves connecting legacy telephone sets and fax machines to a premises-based IP gateway in the form of a router, and the second involves an Ethernet LAN connected to a premises-based router. In the former configuration, the protocol conversion from circuit-switching to IP-based packet switching takes place in the gateway, with any necessary conversions from PCM (Pulse Code Modulation) to any of a number of compressed voice encoding algorithms also taking place in an embedded digital signal processor (DSP). Alternatively, a small number of legacy telephones (analog or ISDN) and fax machines may interface through an IP terminal adapter (TA), which performs much the same functions on a scaled-down basis.

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In the latter configuration, those conversions take place in the voice client, with the router simply serving to route off-premises calls to or from the IP-based voice network.

The voice clients in this latter configuration may be in the form of proprietary IP telephones, sometimes known as *hardphones*, or they may be in the form of *softphones* comprising telephony cards installed in host computer workstations equipped with microphones and speakers. The two configurations may be blended, as well, with the IP gateway serving the legacy station equipment connecting to a router, which also serves native IP-station equipment.

In any of these configurations, the connection from the premises-based gateway and/or router to the IP network-based IP gateway is over a broadband local loop, perhaps supporting 100Base-T Ethernet. The IP gateway at the edge of the service provider's network is collocated with the CO Centrex, and provides access to both the circuit-switched PSTN and the Internet or other IP-based network.

Another approach is much like the second option discussed above. In this configuration, users have voice clients in the form of either *hardphones* or *softphones*. Those phones connect over an Ethernet LAN to a premises-based IP gateway in the form of a router. A broadband local loop connects to an IP Centrex gateway at the edge of the service provider's IP network, or to an ATM network supporting IP traffic. The IP Centrex system is controlled by a centralized *softswitch* that provides all signaling and control functions to perhaps large numbers of such IP Centrex systems. Traffic destined for the circuit-switched PSTN is converted to PCM format, and traffic destined for the IP-based network is routed accordingly. The *softswitch*, or perhaps a separate signaling gateway, also accomplishes the signaling and control interface between the PSTN (e.g., SS7) and the IP network (e.g., H.323 or Session Initiation Protocol, or SIP).

IP Centrex has a number of advantages over and above those offered by conventional Centrex:

- **Voice Compression:** A variety of voice compression algorithms may be applied to the PCM voice samples, reducing bandwidth requirements considerably.
- **Convergence:** Voice and data traffic share the same network resources, including but not limited to broadband local loop access and core network switches and links. An intelligent gateway/router can dynamically allocate local loop bandwidth between data and compressed voice calls, thereby making highly effective use of available bandwidth, perhaps in consideration of QOS expectations.
- **Enterprise-Wide Service:** By virtue of the centralized *softswitch* signaling and control mechanism, multiple sites within the user enterprise can be served with the same features presented in the same manner.
- **MAC Activity:** Move, add, and change (MAC) activity can be accomplished automatically. IP voice clients can move around as freely as IP host computer clients, as the Ethernet LAN will automatically recognize the new location of the client when it is plugged into another jack. All features will be associated with the IP voice clients, moving right along with it. Technicians no longer need to be involved in making labor-intensive and expensive changes to the switch database.
- **Remote Access:** Telecommuters and mobile employees can connect to the virtual IP-based Centrex via the Internet, and on the basis of either a dial-up modem connection or, perhaps, a broadband asymmetric digital subscriber line (ADSL) connection.
- **Toll Charges:** Toll calls may be at no cost, as they may travel over the public Internet. This assumes, of course, that the service provider does not impose a usage-based pricing algorithm and that the current Internet pricing model does not change.

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On the negative side, IP Centrex suffers from many of the same issues as do all VoIP platforms and networks. Those issues include reliability and QOS. Further, IP Centrex systems currently support only a very limited set of the most basic voice features. However, it is important to consider that IP Centrex is very much in its infancy.

State of the Technology

During the past several years, IP has become the object of much attention, largely due to the popularity of the Internet and World Wide Web. While IP and its extensions currently do not offer the guaranteed QOS mechanisms of ATM, a great deal of effort is being spent to improve IP's performance in support of streaming voice and video, as well as the native data applications for which it was intended. At this point, it is important to note that IP-based WAN networking is not limited to the Internet. The very nature of the Internet as a public data communications network makes VoIP highly problematic, as the levels of congestion are highly variable and unpredictable. Therefore, the levels of latency and jitter can easily exceed acceptable tolerances for packet voice, even given the use of highly capable predictive voice compression algorithms.

Much less problematic are the special-purpose, IP-based networks being deployed by carriers such as Level 3. These networks make use of various GOS mechanisms such as MPLS running in exceptionally high-speed routers in order to route VoIP traffic over the most desirable network paths with minimal latency imposed at the router level.

They also make use of high-speed optical fiber transmission systems, variously running SONET/Synchronous Digital Hierarchy (SDH) and dense wave division multiplexer (DWDM). Some also make use of ATM in backbone switching applications. These technologies and protocols, among others and in various combinations, can be leveraged in order to support VoIP and other stream-oriented applications at a GOS level comparable to that experienced over the conventional PSTN. While such a GOS does not compare directly with the QOS guaranteed by ATM, it can come quite close, and undoubtedly will come closer into the future.

While it is unlikely that IP-based networks, much less the Internet, will soon replace the conventional PSTN, there is a strong possibility that such networks will, in effect, become secondary PSTNs, interconnected to the conventional as required. Further, they will be heavily used in enterprise networking and internetworking across a wide variety of information and application types. IP's flexibility, low cost, and high level of efficiency for many data communications applications make this outcome very likely.

These dramatic and revolutionary changes in the nature and structure of the PSTN will alter forever the relationship between the network and customer premises equipment (CPE). Many feel strongly that intelligence will migrate to the public networks and away from CPE. If that shift comes to pass, Centrex providers, both conventional and IP-based, may well have an advantage in terms of full, timely, and transparent access to a wide range of features and functions. Clearly, the carriers and service providers are highly interested in migrating business back to the network and away from CPE. Centrex is a key element in this continuing strategy.

Major Vendors and Designations

The North American PBX market is still dominated by Avaya, Nortel Networks, Siemens, and NEC America. Lucent and Nortel Networks dominate the U.S. market for conventional CO equipment, although some service providers have deployed Siemens and Ericsson CO switches on a limited basis.

Conventional Centrex service is generally offered by service providers on a regulated basis (some areas have been detariffed) to subscribers in their franchised servicing areas. Within the physical and logical

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limits of the CO platform, a Centrex feature set can be expanded through special tariffs for specific client applications. Some competitive carriers expanded their Centrex offerings as competition became a reality in the local exchange domain. Additionally with the advent of local competition, the IECs and CATV (cable TV) providers began to also offer Centrex services.

Competition took another giant step with the California PUC's decision to open the local market to competition beginning 1 January 1996. A number of major providers currently compete aggressively in this market, and over 30 other states have opened the local market to competition as well. California's aggressive move was overshadowed, of course, by the Telecommunications Act of 1996, which eventually promises to open both local exchange and interexchange markets to competition and virtually without restriction. While elements of the act have been challenged in the courts and some of those challenges may not be resolved fully for several years, it seems clear that the competition in the local exchange market will become increasingly competitive during the next decade, and Centrex will be a significant element of competing service offerings.

Conventional Centrex availability generally is limited to North America, with the U.S. being by far the largest Centrex market. Marketed aggressively by the RBOCs and large, independent telcos and service providers, Centrex goes by a variety of names including BellSouth Centrex (BellSouth), FasTrak Centrex ISDN (Pacific Bell), CentraNet (Verizon); and Centrex 21, Centrex Plus, and Centrex PRIME (Qwest).

The manufacturers of IP-based PBXs currently include traditional names such as 3Com, Alcatel, Avaya, Cisco, Siemens, and Nortel. But a number of more recently established and lesser known manufacturers have entered the IP-PBX market, as well, such as AltiGen, Shoreline, Vertical Networks, Interactive Intelligence, and Artisoft.

Wireless Centrex and PBX adjuncts are available through Ericsson and others, variously providing mobility through cordless, cellular, and personal communications services (PCS) technology. A number of ILECs (e.g., Southwestern Bell and Verizon) currently offer or support one or more of these wireless terminal equipment options, although availability varies widely.

Providers of IP-based Centrex fall into the generic category of Application Service Providers (ASPs). These network-based services are not yet widely available but certainly have the potential to be so.

Insight

Fit, Style, Legacy, Future

While the basic differences between PBX and Centrex, whether conventional or IP-based in nature, are relatively clear, the subtleties can be quite confusing. Therefore, the decision process can be difficult for many user organizations. Organizations that believe strongly in identifying their own needs, managing their own environments, and controlling their own destinies tend to favor PBX alternatives. Those enterprises that are highly seasonal, capital conservative, or minimally control-oriented, and are not especially demanding from a feature standpoint, tend to favor Centrex. Clearly, while such characterizations might seem overly simplified, the basic nature and culture of the enterprise can be as strong a force in the decision-making process as are technical and cost considerations.

More subtle issues abound. Fast-growing and dynamic companies that have high-priority, revenue-producing demands on limited capital resources often and clearly lean toward Centrex. Centrex offers the additional advantage of allowing these organizations to focus on their core business, without the distraction of managing a complicated technology resource; outsourcing telecommunications in the form of Centrex is most attractive in this kind of situation. Additionally, firms with trunk-intensive applications (i.e., large incoming call centers) may find that Centrex reduces the number of trunks or bandwidth (time

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slots) required to support such applications. A CO Centrex solution queues the traffic in the network, rather than at the premises. The advantages of client/server IP-based solutions in such an application generally point toward the PBX option at the moment, although IP-based Centrex systems are likely to soon offer substantial advantages, also.

Conventional PBX and Centrex systems increasingly will be deployed in tandem, and the same solution likely will emerge in the IP-based domain. That is to say that Centrex service will be used to supplement the capacity of a PBX during seasonal peaks of activity, to provide ISDN features to select workgroups, or to provide some level of redundancy if a PBX fails. The two alternatives, in fact, will often be considered complementary, rather than competitive. Pacific Bell has enjoyed considerable success with such an offering, which it markets as PBX Plus.

User organizations that need broadband services generally lean toward PBX solutions. Although Centrex providers will address these needs, their solutions are still some distance away.

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