BCR Best-In-Test— SME IP-PBX Systems

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Do good things come in small packages? Often they do, but not always when it comes to small IP-PBXs.

They say that good things come in small packages. But after six weeks of testing seven sub-1,000-station IP-PBXs, the results were uneven; some systems offer innovative and sophisticated features, others can't support even the most basic capabilities.

The same held true for performance. Some products have a long way to go before they offer a truly robust platform. In some instances, one-way latencies were well above 100 milliseconds, which greatly reduced voice quality. Only three of the products tested—those from Mitel, Siemens and Vertical—completed 100 percent of calls attempted during call-reliability testing, and most reliability scores came in well below the coveted "five-nines" (99.999 percent) rating.

Our testing took place during November and December 2002. We ran seven different systems through their paces in each of four criteria:

- **Basic features:** We asked each vendor to demonstrate 38 station features that are widely supported by TDM-based systems (see "The Basic Station Features").
- **Advanced features:** In this category, vendors were asked to demonstrate value-added, productivity-enhancing IP-based features that they felt differentiated their product from their competition. We also took each vendor's high-end IP-phone into consideration. In our view, this category not only represents the hunt for the elusive "killer application," it is an important barometer of development activity by the vendors.
- **Management:** Management interfaces were assessed in five sub-categories: Task Accomplishment/General Navigability; Reports; Real-Time Monitoring; Event, Alarm and Trap Management; and Diagnostics and Troubleshooting.
- **Performance:** Latency and voice quality were tested with each product's IP-phone, and call-completion rates under high load were also tested. High-availability capabilities claimed by vendors were also taken into consideration and tested where possible.

The vendors and systems tested were:

- **3Com** tested with release 4.1 of the SuperStack 3 NBX Networked Telephony Solution and its NBX Business Phone, also release 4.1.
- **Avaya** tested with beta version 1.3 of the IP Office 403 along with the Avaya 4612 IP-phone, ver. 1.6.
- **AltiGen Communications** submitted the AltiGen AltiServ Office, ver. 4.5. Its new phone, the Alti-IP600, was in beta when tested.
- **Mitel Networks** delivered its 3300 Integrated Communications Platform (ICP), version 3.2, and the phone was the 5140 IP Appliance, ver. 5.21.
- **Nortel Networks** was in beta with version 3.0 of the Business Communications Manager (BCM) when it was tested with version 0602B41 of the I2004 phone.

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TABLE 1 Best-in-Test Scoring

Category (Weighting)	3Com	Altigen	Avaya	Mitel	Nortel (BCR Best in Test)	Siemens	Vertical
Basic Features (20%)	70%	85%	80.%	90%	90%	90%	65%
Advanced Features (15%)	65%	80%	85%	90%	85%	75%	80%
Management (35%)	75%	80%	80%	75%	90%	80%	95%
Performance (30%)	80%	65%	70%	80%	85%	80%	80%
	74%	**77%**	**78%**	**82%**	**88%**	**81%**	**82%**

■ **Siemens** submitted version 3.0 of the HiPath 3700 and the OptiPoint 400 phone, ver. 3.5, which was in beta at testing.

■ **Vertical Networks** tested with the InstantOffice 6500 system, release 5.0; and the Polycom MGCP ver. 1.2 phone.

Cisco Systems was invited to submit its small-sized system, the Integrated Communications System (ICS) 7750. But as it did for the large enterprise system review published in the January 2003 issue of *BCR*, Cisco declined our invitation because timing issues conflicted with the release of new software.

Test Results Summary

The Nortel BCM handily took the *BCR* Best-In-Test (Table 1). Best-in-Test winners generally bat for average rather than hitting home runs, but the Nortel BCM did both: It showed consistently well in all categories, and received the highest ratings given in the Basic Features and Performance categories.

The Basic Station Features

The following is the list of 38 station features that, for purposes of testing, we deemed "basic." All tests were performed on IP-phone sets only.

While categorizing a capability as basic is subjective, these features have been supported by TDM-based systems for years. We used them as a barometer for how thoroughly IP based systems are replacing the station feature sets of their TDM-based predecessors. Where any feature was accessible via a PC application, but not from the phone, half credit was given.

■ **Automatic callback:** To an internal extension, based on busy or no answer. The same as camp on.

■ **Bridged call appearance:** The same phone number can appear and be answered on multiple phone sets.

■ **Call blocking:** Allows users to selectively block calls from user-defined origins (e.g. specific extensions, ANIs, off-net calls in general).

■ **Call conference:** Audio path for multiple parties on a single call, established just via user keystrokes, no outside intervention.

■ **Call drop:** Terminate a call without hanging up the receiver.

■ **Call forward all:** User can redirect all calls to another station or location.

■ **Call forward on busy:** User can redirect calls to another station or location when busy.

■ **Call forward on no answer:** User can redirect all calls to another station or location after specified number of rings.

■ **Call hold:** A button on phone set that places incoming call on hold, retrieves call.

■ **Call park/retrieve:** A user can put a call on "hold" (to a virtual extension) and then pick up from another phone in the system.

■ **Call pickup:** A user can answer a call ringing on another extension where both extensions are part of a pickup group. Note—if directed call pickup is available, users can pick up a specific extension.

■ **Call return:** Calls back the last incoming number.

■ **Call transfer:** Redirect an answered call to another user. This includes restrictions on trunk-to-trunk transfers, etc.

■ **Call waiting:** Stations currently connected receive an audible beep to identify that another call is pending. Note—display notification alone is not acceptable.

■ **Caller ID:** Displays the name and/or number of the calling party.

■ **Direct transfer to voicemail:** Automatically redirects all calls to voicemail with a single button push

■ **Distinctive ringing:** Ring with different characteristics, depending, for example, on whether a call is internal or external.

■ **Do Not Disturb:** Phones can be made to appear out of service.

■ **Follow me:** allows multiple, disparate phones to ring simultaneously when one extension is dialed.

■ **Free seating/hoteling:** A user can move from one location to another and access all his/her calls, features, button mappings, etc., without intervention from PBX administrator.

■ **Intercom—phone-to-multi-phone:** Allows voice paging through speakers of multiple system phones.

■ **Intercom—phone-to-phone:** A private, internal intercom capability for calling within a pre-defined group or department.

■ **Intrude:** Allows specified users to intrude on calls in progress.

■ **Last number redial:** Button causes last call to be re-dialed.

■ **Leave word calling:** Allows internal users to leave a short, pre-programmed message for another internal user.

■ **Message waiting light:** A visual indicator of a voicemail message (i.e., blinking lamp).

■ **Missed call indicator:** Lists missed calls.

■ **Multiple call appearance:** A single phone can have multiple, repeated instances of a single phone extension.

■ **Multiple ring styles:** Allows selection of available rings.

■ **Music on hold:** A caller hears music when placed on hold.

■ **Mute:** A mute button to disable the microphone.

■ **One-button send all calls:** Automatically redirects all calls to coverage with a single button push.

■ **One-button speed dial:** Programmable one-touch speed dial on a phone set.

■ **Personal call routing:** Users can define routing parameters, such as time of day, ANI, extension, etc. PC support of this feature is acceptable.

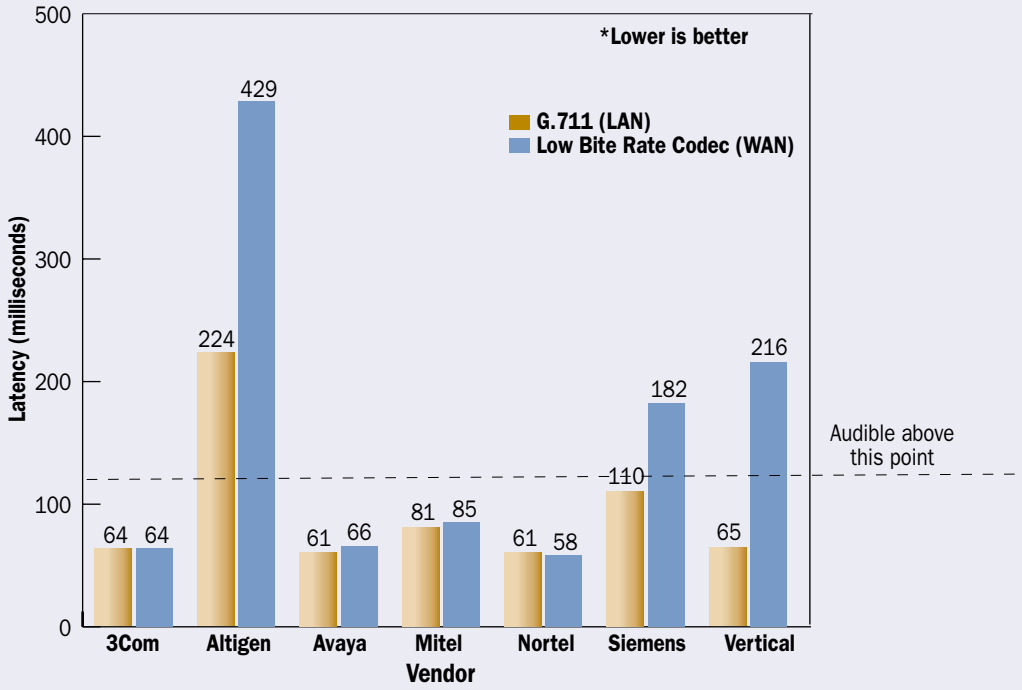
■ **Priority Ringing:** Distinct ring for calls from specified numbers.

■ **User directory:** Database of names, extensions, etc., accessible for look-up by any system endpoint.

■ **Volume control:** For speaker, handset, ringer.

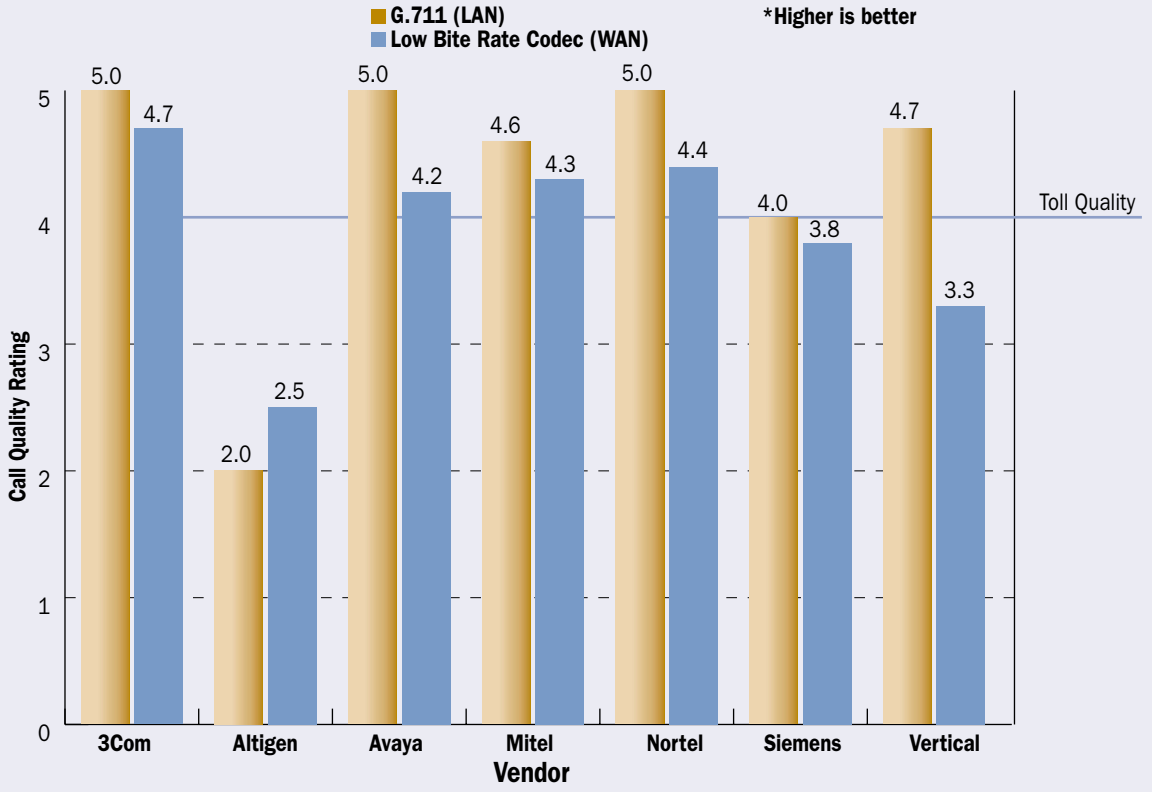
■ **Whisper page:** A user's admin assistant can bridge into a call, and only the local end will hear□

FIGURE 1 One-Way Latency



Note: One-way latency IP phone-to-IP phone using G.711 vocoder over a LAN, and a low bit-rate vocoder over a routed IP WAN. Avaya, Mitel, Nortel and Vertical used G.729a; 3Com tested with ADPCM; Altigen and Siemens used G.723.1.

FIGURE 2 Voice Quality Rating



Note: Three lab testers, in round-robin rotation, conduct real-time, 2-way conversations using phones on IP-PBX, over different connections. During each call the testers conduct the "countdown test" to assess the effects of latency; the "alphabet test" to assess any problems with bidirectionality; and note any echos, clipping, and/or other background noises. Rated on a 5-point scale – the same used in ITU MOS ratings. A rating of 4 or better can be considered “business quality.”

The 3Com system acquitted itself well with its basic feature support and performance. But its advanced feature presentation was unimpressive, it scored only 65, and its management interface was missing some important elements, such as adequate logging and SNMP support.

AltiGen rendered a consistent showing, scoring 80 percent in all categories except performance, where the AltiGen system showed very poorly overall (Figures 1 and 2).

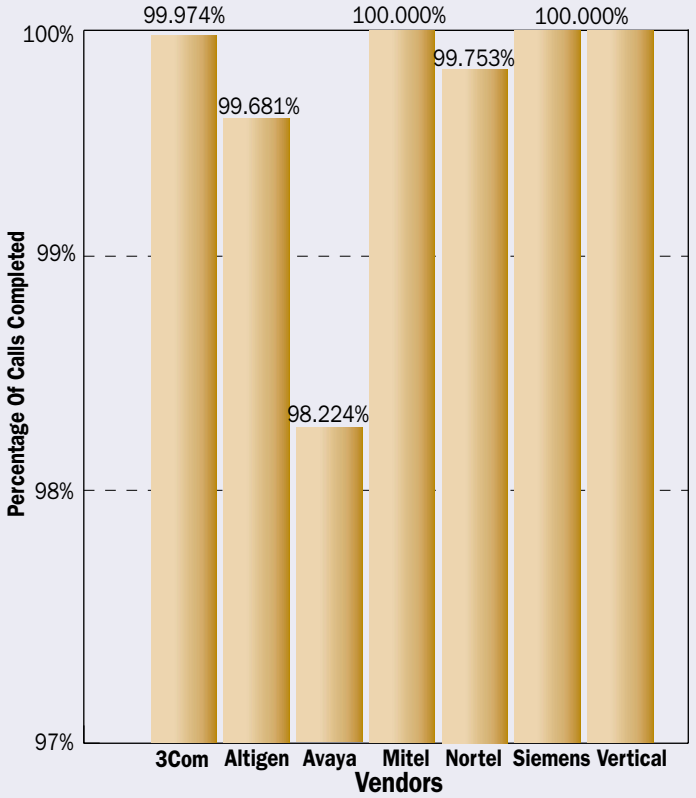
Avaya presented some compelling contact-center features (more on that later), and its management application was adequate. But its basic station feature support was surprisingly wanting, showing support for less than 80 percent of the basic features tested, and while voice-quality scores were excellent, reliability of the IP Office was cause for concern, as demonstrated by its showing in the Call Reliability test (Figure 3).

Mitel's was the only product within striking distance of the Nortel BCM. Its overall feature set was outstanding, with an overall score of 80 percent, and performance was good as well. The Mitel management system's poor reporting and lack of effective diagnostic functionality, however, proved to be a liability too large to overcome.

The Siemens system showed clear evidence of incremental progress in its HiPath 3700, which was the HiPath 3000 the last time we saw it (and it was called the Hicom 150H the time before that). Siemens' basic feature support was particularly strong, supporting 35 of 38 of the features rated. We felt, however, that the advanced features presented by Siemens were uninspired.

The Vertical InstantOffice is very much "the little box that could." Its management, in particular, is top-shelf (see "The Best of the Best-in-Test," p. 30). Especially notable is its exceptional troubleshooting and diagnostic utilities, and its overall ease of use. However, Vertical's poor showing in the basic features impaired its overall showing; InstantOffice supported only 22 of the 38 basic features we asked for.

FIGURE 3 Call Reliability



Note: Tests were all run continuously for at least 12 hours. A Hammer/Empirix call generator (a Load Blaster 500 system) delivers 3 calls per minute on each of twelve T1 trunk channels ingressing a PBX systems. The receiving PBX is configured to route the call via IP to a second PBX, then egress back to the Hammer tool on an outbound T1. Results are expressed as calls completed

Product Round-Up

To differentiate "big" systems from "little" systems for purposes of comparison, we chose a 1,000-station capacity as the cutoff point for two reasons. First, because it did the best job of grouping systems which—considering architecture, feature support, management complexity, as well as trunk and station capacity—really should be considered "birds of a feather." Second, because the conventional wisdom is that the "sweet spot" for value-added resellers—where the lion's share of the buying is done—is 300- to 1,000-stations.

This logic held for every product but one—the 3Com SuperStack NBX system capacity has doubled in each of the last three years, and it now supports up to 1,200 stations. Parenthetically, the Mitel 3300 ICP can support 1,536 endpoints overall, but only 700 can be IP-based. A discussion of each product tested follows. Products are summarized in Table 2, with detailed management and availability data In Tables 3 and 4.

3Com: Long known as a SME, LAN-based communications system, as noted above, the 3Com SuperStack NBX system now supports up to 1,200 stations (with a 4:1 station-to-trunk channel ratio). But if 3Com's station and trunk capacities narrowly qualify as a large enterprise system, it doesn't make sense to compare the NBX head on against big systems like Avaya's S8700 or a Nortel Succession. Indeed, the 3Com system demonstrated some significant shortcomings compared to other SME systems.

The SuperStack 3 NBX solution comprises two IP-connected, multi-slot chasses—the V5000 Chassis and the V5000 Call Processor. The former provides all PSTN trunking and analog interfaces, the latter logically terminates all VOIP stations, and provides call routing and control.

The SuperStack 3 NBX showed poorly in basic features, supporting only 27.5 of the 38 basic features required. (Note: Depending on the nature of the support, 1/2-point can be awarded).

For its advanced feature presentation, the 3Com team offered three applications. The first

was the NBX TAPI Dialer. A TAPI application, generally, is a PC or laptop application that routes signaling to the PBX via a data link, while voice is carried through whatever phone is at your disposal. With a TAPI application, you can use a PC or a laptop with a data path back to your company network to access PBX features like company directory, caller ID, call hold, call conferencing, etc., while using a POTS, wireless or any off-network phone to carry on voice conversations. The NBX TAPI Dialer can perform these functions, and it comes for free with the NBX system. Outlook contacts can be integrated to the NBX TAPI Dialer by installing another free application called the NBX TAPI Service Provider.

The second advanced feature was a softphone, the NBX PCXset. A softphone is exactly like a TAPI application, only now voice is transmitted and received through the PC or laptop via use of a microphone or—in most cases—a Universal Serial Bus (USB)-connected headset.

The third feature was Unified Messaging. NBX voicemail clients can receive their voicemail as .WAV file attachments on any IMAP 4-compliant messaging application, such as MS Outlook.

The 3Com NBX Business Phone is a fairly solid offering. It enables corporate directory access from the phone, a view of users' call logs, and it is the only phone in this test that successfully demonstrated full-duplex speakerphone functionality. On the minus side, it has no missed-call indicator and no call-duration monitor, and no plausible phone statistics are available for troubleshooting purposes.

While 3Com's advanced features do what they're supposed to do, in our view, they are hardly "advanced." This is reflected in its score—65—the poorest of any system in this category.

Though the SuperStack 3's station capacity has certainly expanded, the NBX NetSet management interface still reflects its small-office roots. The application is well conceived, and our engineers were particularly impressed by its ability to intuitively guide the installation process from a standing start. The problem is that it isn't very robust. You can extract some useful reports through a free standalone application called NBX Call Reports,

The Best Of The Best-In-Test

The downside to graded exercises is that all aspects of a given product—good, bad, or in between—get boiled down to a single, composite number. To address this, Miercom testers and the editors of *BCR* felt that credit should be given for those aspects of all systems reviewed that were particularly outstanding. This includes the large enterprise IP-PBX's reviewed in the January 2003 issue of *BCR* (see pp. 28–38) as well as the SME-class systems. Here's the best of what we saw in both tests.

■ **Best Management—Vertical Networks InstantOffice Remote Management System.** User experience is difficult to measure, but in the end, that is what gave Vertical the narrowest of nods over the Shoreline's ShoreWare Director. While each delivered similarly robust functionality, our testers thought that Vertical's application was slightly more intuitive and easy to use.

Honorable mention in this category goes to the Nortel BCM's Unified Manager with BCM Monitor. While not as intuitive to navigate, the BCM's management package was exceptionally robust.

■ **Best IP-phone—Mitel Networks 5140 IP Appliance.** The 5140 won the *BCR* IP-phone review published in September 2002 (pp. 36–41), and it still reigns. With its big, HTML-friendly display, text-messaging capability, highly useful Help utility and infrared port for PDA integration, the 5140 was the class of the field. The only other phone in both reviews that was particularly impressive was the Avaya 4620, whose large, WML-based display and PDA integration were noteworthy.

■ **Best Advanced Feature—Avaya S8700 Media Server with G600 Media Gateway.** Notice that we cited a PBX, and not a specific advanced feature. This is because the testers' short list of the top advanced features all came on Avaya's S8700, and they were in a hopeless stalemate over which was best.

First, Avaya's 4630 Web Phone represented an important milestone—the first color, touch-screen phone ever seen in our labs. Second, Avaya's IP Softphone for Pocket PC was cited not only for its ability to transform a PDA into a phone, but also for the ability to remotely manage a station phone. Media Encryption, the Avaya system's ability to encrypt station-to-station calls, also was a first—and an important one that other vendors would do well to emulate. And though not offered by Avaya as an advanced feature, Memory Mirroring—or the ability of a redundant S8700 Media Server to mirror the memory of a primary server in real time—is a noteworthy and exciting innovation.

Our testers also cited the Nortel i2050 Softphone for its remarkable voice quality.

■ **Best Availability—no award given.** While we would like to have given an award in this category, no product deserved one. Miercom's reviewers cited the Vertical InstantOffice 6500 for its 3N+1 redundant and hot-swappable power supplies, its dual power feeds and its relatively low susceptibility to DOS attacks. They also thought that the Siemens HiPath 3700 deserved mention for the redundancy of its modules. Though both products are solid overall, neither supports redundant call controllers.

Among the large enterprise systems, the Alcatel OmniPCX Enterprise was as stable as they come. They dropped no calls during call-load testing, and the modules on its media gateway were all hot swappable. The Alcatel system could not fail over to a remote controller, however, and its reboot time was on the slow side□

but events and alarms were unintelligible to anyone but the 3Com staff, monitoring capability is weak and there were no diagnostic tools or utilities available.

The SuperStack 3 scored excellent latency and voice-quality metrics of 64 msec for both conditions tested, and a 4.7 voice-quality score for its low bit-rate vocoder over a WAN to go with a perfect 5.0 for LAN-based G.711 calls. What cost 3Com in the performance category is its showing in the call-completion test. We used a Hammer LoadBlaster call generator tool to place three calls per minute on each of 12 T1 channels coming into a system. The receiving PBX is then configured to route the call via IP to a second PBX, then egress back to the Hammer tool on an outbound T1. The SuperStack3 completed a comparatively decent 99.974 percent of the calls attempted, but this was accomplished via Channel Associated Signaling (CAS) after multiple failed attempts to use PRI signaling.

■ **AltiGen:** Like 3Com, AltiGen offered one of the original LAN-based voice systems, and it is well known for its PC-based PBX. AltiGen is still relatively PC-based, although it runs on a Windows/Intel-powered server-class form factor these days. Station and trunk interfaces reside on 32-bit PCI risers, or daughterboards, that are inserted into the AltiGen system's motherboard.

The AltiGen system supported a solid 83 percent of the basic features tested (31.5 of 38). And our reviewers were impressed with AltiGen's support of sequential "follow-me," which enables users to define several extensions to ring in sequential order until the call "finds" the intended recipient. For instance, a rule can be defined whereby an incoming station call should bounce to another extension if not answered in two rings. If the second extension isn't answered in two rings, the call should be routed to a third extension, and if that one isn't answered, only then should the call be forward to voicemail.

AltiGen's presentation of its advanced features was highlighted by an application called Zoomerang. Upon accessing their voicemail, Zoomerang clients can hear messages, return a message and resume hearing voicemails without ever disconnecting from the voicemail server. Zoomerang also can be configured to notify clients of an existing voicemail message by placing a call to an off-net telephone.

AltiGen's AltiView is a call-center agent application with software hooks that enable such features as integration with contact management programs (like MS Outlook and GoldMine), MS NetMeeting for PC-based video conferencing and instant messaging. Call-center agents using AltiView also can get useful information, including the agent's own call-center statistics and queue information.

What hampered AltiGen's ability to score higher in this category is its new homegrown phone, the Alti-IP600. It is the only phone under review that did not support inline power. Moreover, from a security standpoint, passwords were viewable on the LCD in clear text when entered, and once a phone was logged into, anyone could change the configuration of the phone (e.g. button mappings) without a new password prompt.

Still, the Alti-IP600 has its benefits. The phone's "Who Am I?" functionality lets admins and users know who is logged into any given system phone. It also has "Feature In Use" indicators, which signal station clients coming back, for example, from vacation, that the "Forward All Calls" function is enabled on their phones. Also, the Alti-IP600 is the only phone under review that supports "hoteling," the practice of switching phone stations via login without requiring administrative intervention.

Managing the AltiGen system is a relatively pleasant experience. Screens are intuitive and easy to navigate. Reporting was adequate, and the Alti-Admin management application offered some useful IP and PSTN trunk monitoring. What's more, their MVIP Test Tool was particularly handy for troubleshooting system boards.

One glaring limitation, however, was that the AltiGen system lacks SNMP support, which means that a third-party, SNMP-based network management application or utility cannot "see" the non-compliant device. From a management standpoint, this basically isolates the device as a standalone network element. Logging and event management also were somewhat cryptic to the uninitiated.

AltiGen's poor showing in the performance category (with a score of only 65) can be explained largely by the fact that the AltiWare system switches all VOIP calls through its switching matrix. That means VOIP calls must be decoded before they can be switched, then re-encoded upon egress. The extra processing creates excessive latency. The AltiGen system posted latency and voice quality metrics that came well short of the standard for acceptable business-quality communications. (Miercom rates a score of 4.0 or higher as toll-quality and acceptable for most business communications.) Moreover, at 99.681 percent, only the Avaya system had a lower call-completion rate among the systems tested.

■ **Avaya:** The Avaya IP Office 403 is a single-chassis system that provides an all-in-one voice and data solution for small offices. In addition to a full-function PBX, it includes an integral router, firewall, DHCP, a RAS server and, on the system tested, an eight-port Ethernet hub. The IP Office 403 represents the low end of the systems tested, supporting a maximum of 98 stations (up to 90 of which can be IP) and one T1.

Surprisingly, the Avaya system supported only 30 of the 38 basic station features tested (79 percent). Our test engineers also complained about the IP Office's inability to manually set

Without SNMP support, a management app can't "see" the non-compliant device

codecs system-wide. Phones defaulted to G.729a with silence suppression, an oversight that Avaya reps already have taken measures to correct.

Avaya's rating in the advanced features category, however, was among the best of the products tested. Its advanced feature presentation was geared towards call centers, starting with voicemail Pro, a powerful IVR (Interactive Voice Response) management tool that guides users through the process of designing auto-attendant menus with a highly-intuitive, graphical, call-flow chart. The voicemail Pro package can include a Web-based software module called Campaign Manager, which leverages IVR to administer sales and marketing campaigns. Here's how it works: Let's say a mail recipient wishes to be removed from a mailing list. The person can call a phone number and convey his or her wish via a voice-prompted automated attendant system. With Campaign Manager, that request is queued and retrieved via the call center agent's Web-based interface and then, once acted upon, removed from the appropriate queue.

PC Wallboard is part of Avaya's Compact Contact Center (CCC) suite of contact center applications. It is a call center supervisor's tool that enables text-based communications with agents, with two primary functionalities.

TABLE 2 Product Overviews

	3Com Santa Clara, CA www.3com.com	**AltiGen Communications Fremont, CA www.altigen.com**	**Avaya Basking Ridge, NJ www.avaya.com**
System tested (version, release date)	3Com SuperStack 3 NBX (4.1; August 2002)	AltiServ Office (4.5, October 2002)	IP Office 403 (1.3, beta at time of test)
System Description	Two component system: V5000 Gateway Chassis for PSTN trunking and analog interfacing; V5000 Call Processor for all	Wintel server outfitted with PCI-based boards for station and trunk interfacing switching and VOIP functions	Single, closed chassis unit
System OS and processor	VxWorks, Intel	Windows 2000, Intel	Proprietary, Motorola
Station interfaces	Analog, IP	Analog, IP, wireless	Analog, digital, IP
Max overall station capacity†	1,200	272	98
Max capacity, IP stations only†	1,200	200	90
Max T1 trunks	30	8	1
Supports redundant call control?	No	No	No
How many systems can be networked under common management?	Up to 999, managed by 3Com Network Supervisor application	Up to 20, managed by DINA Manager application	Up to 16 can be networked, but not centrally managed.
Other network functions provided	Dedicated PBX only	Dedicated PBX only	Integral firewall, router, DHCP; 8-port hub module available
Codecs supported	G.711, ADPCM, G.723.1	G.711, G.723.1	G.711, G.723.1, G.729a
Is Voice Activity Detection supported?	Yes, for all codecs	Yes, for all codecs	Supported for all codecs
IP phone tested, (version, release date)	NBX Business Phone (4.1, August 2002)	Alti-IP600 (1012; beta at time of test)	IP 4612 IP Telephone (1.7; Oct. 2001)
Is power-over-Ethernet supported?	Yes	No	Yes
Percentage of 38 station features supported††	72% (27.5/38)	83% (31.5/38)	79% (30/38)
Cost per station†††	$677, with inline power	$627, with local phone power	$378, with local phone power

† Assumes 4-to-1 station-to-trunk channel ratio.

†† Half credit is given when the feature is supported, but only via a PC application.

††† Includes US List price for a system configured with 100 low-end IP phones, one T1 trunk, all hardware and software necessary to provide full VOIP support and basic PBX functionality; full management, licensing, and voicemail. In the case of Avaya and Nortel, systems were prices with 90 phones.

First, PC Wallboard allows agents to see "all points bulletins" in real time. Second, a supervisor can send a callback request to a specific agent's wallboard. Once completed, the agent can mark the callback as completed, and a notification is provided to the supervisor.

With a score of 80 in management, the Avaya system holds its own. The management interface, the IP Office Manager, is well-organized graphically. A particular strength is its real-time monitoring, offering granular visibility into the device for troubleshooting and monitoring utilization.

Also, Avaya's Line Monitor utility is a particularly effective T1 diagnostic tool. Our testers noted several weaknesses, however: The system offers no logging, alarm functionality or SNMP support, and reporting is available only by purchasing additional software.

Avaya's overall voice quality and latency metrics were excellent. And Avaya's IP Office, along with the Nortel BCM, was the only system that allowed for some level of re-homing phones when a primary call controller failed. But with completion of only 98.224 percent of calls attempted during the call-load test, the Avaya system registered the lowest metric of any system under review, which greatly accounts for its overall performance score of 70.

Mitel Networks Kanata, Ont., Canada www.mitel.com	**Nortel Networks Brampton, Ont., Canada www.nortelnetworks.com**	**Siemens Boca Raton, FL www.siemensenterprise.com**	**Vertical Networks Sunnyvale, CA www.vertical.com**
3300 Integrated Communications Platform (3.2, October 2002)	Business Communications Manager (3.0, beta at time of test)	HiPath 3700 (3.0, June 2002)	InstantOffice 6500 (5.0, October 2002)
Three component system: NSU for PSTN trunking, ASU for trunk and station analog interfacing Controller, serves call processing and management	Single, closed chassis unit	Multi-slot chassis populated with system controller and all interfaces	Multi-slot chassis populated with system controller, station and trunk interfaces
VxWorks, Motorola	VxWorks, Motorola	Proprietary, Motorola	Windows NT, Intel
Analog, digital, IP, wireless	Analog, digital, IP, wireless	Analog, digital, IP	Analog, digital, IP
1,536	250	500	192
700	90	500	192
16	3	5	4
No	No	No	No
Up to 80, managed by OPS Manager application	Up to 2,500, managed by Network Configuration Manager application	Yes, up to 16 with base management application	Up to 10,000, managed via Multisite Management application
Dedicated PBX only	Integrated VPN, router, DHCP, firewall, and RAS server	Dedicated PBX only	Cisco 1600 router and Ethernet switch hardware modules; VPN, firewall, DHCP, and RAS services also available
G.711, G.729a	G.711, G.723.1, G.729a	G.711, G.723.1	G.711, G.729a
No	Yes, for G.729 and G.723.1 only.	Yes; for G.723.1, but cannot be enabled system-wide, only at the phones	Yes, for both
5140 IP Appliance (5.21, October 2002)	i2004 (0602B41; Nov. 2002)	OptiPoint 400 (3.5, Nov. 2002)	Polycom SoundPoint IP 500 (1.2, Oct 2002)
Yes	Yes	Yes	Yes
91% (34.5/38)	88% (33.5/38)	92% (35/38)	58% (22/38)
$395, with local phone power	$619, with local phone power	$788, with local phone power	$670, with local phone power

Mitel was strong on features, weak on management

Mitel: The Mitel 3300 ICP system is composed of three closed-chassis modules: the NSU Network Service Unit), the ASU (Analog Service Unit) and the Controller. The NSU provides digital T1 trunking, the ASU provides all station and trunk analog interfaces and the Controller provides all switching intelligence and logical termination of VOIP connections. Unlike other multi-component architectures, the Mitel NSU and ASU chasses are not IP-networked—they are directly wired to the Controller.

The 3300 ICP's overall showing in the area of features was very strong—with a rating of 90 in both the basic and advanced features categories. The system supported 34.5 of the 38 basic features tested, and Mitel's phone—the 5140 IP Appliance—was easily the best phone we reviewed. Testers cited the 5140's ability to send and receive text messages to other Mitel system clients, its ability to display HTML pages and GIF images on its large, 320 × 240-pixel display and its infrared port for PDA integration.

Compared to the other systems tested, Mitel's array of advanced features was notably diverse. The 5700 Voice First Application combines a Mitel IP-phone, a 5750 Desktop Video Appliance and a desktop application to deliver video conferencing to the station. The IP Console 5550 is an application that effectively "morphs" a PC into an attendant console. The voice path is handled by a specialized attendant phone, which comes with an oversized keypad and a headset, but all call-handling tasks are dispensed via the application on the PC monitor.

Also demonstrated was the Symbol MiNet Wireless Phone, developed in partnership with Symbol Technologies. Using any wireless access point, a Mitel-branded Symbol Spectrum24 wireless phone can be used for IEEE 802.11(b)-based access to the Mitel PBX.

The weakest aspect of the Mitel system is its management. The frames-based Web interface is clean and well organized, but aside from some useful real-time statistics and relatively powerful MAC (moves, adds and changes) functionality, you can't do very much with it. No reports are available without purchasing additional software, events were decipherable only by Mitel personnel

TABLE 3 Management Assessment

Vendor/Product	3Com SuperStack 3 NBX AltiServ Office	AltiGen Communications	Avaya IP Office 403 3300 Integrated
Management Software Application(s)	NBX NetSet, rel. 4.1	AltiAdmin, ver. 4.5a	IP Office Manager, ver. 1.3
Application platform	Java-based Web interface served by EMWeb from the NBX Call Processor.	C++-based standalone Windows application	C++-based, standalone Windows application
Task Accomplishment, General Navigability	Good; tabs based navigation; reasonably easy after some quality time; easy to maneuver; could add phones easily by using auto discover.	Good; easy to navigate through; could set up T1; make changes to users easily	Good; frames-based with well grouped categories
Reports	Good; basic reports available with adjustable time fields; no user defined reports	Good; basic reports available with adjustable time fields; no user defined reports	Poor; no reports available without purchase of additional software.
Real-Time Monitoring	Fair; PSTN trunk information and station status	Good; IP and PSTN trunk information and station status	Very good; access to an extensive list of information
Event, Alarm, and Trap Logging	Poor; only decipherable by 3Com, no SNMP traps.	Poor; very cryptic logs, no SNMP traps	Poor; can only create logs of events witnessed in real-time, no SNMP traps.
Diagnostics and Troubleshooting	Fair; no diagnostics other than "online" status for T1s; system information is available	Fair; extensive diagnostic traces only deciphered by vendor; MVIP Test Tool for troubleshooting boards.	Fair; good diagnostics but no troubleshooting tools
Moves, Adds, And Changes			
Can users move phone instrument to new location without manual re-provisioning?	Yes; phones identified by Ethernet MAC address.	Yes; though login prompts occur on every reboot.	Yes; though achievable via static IP address to the phone.
Does logging in to a system phone transfer user "profile" to that phone (extension, button mappings, etc.)?	Not supported	Yes	No; Hotdesking feature allows only temporary login from a different phone.

and very little in the way of diagnostic and troubleshooting tools are offered.

The 3300 ICP performed well, registering metrics well within the realm of acceptable, business-quality communications. However, both the phones and the call controller proved to be highly susceptible to DoS attacks, and, at more than 12 minutes, the 3300 ICP's reboot time was by far the slowest of all systems under test to recover from a power outage.

Nortel: As opposed to a multi-slot chassis or a modular, multicomponent system, the Nortel BCM system is housed entirely by a single-box, closed-chassis form factor. In addition to functioning as a small office or branch office PBX solution, the BCM can also perform integrated VPN, router, firewall, DHCP and RAS server functions.

The BCM delivered 88 percent of the station features tested (33.5 of 38). The BCM also offered an impressive array of advanced features, and our engineers noted in particular the i2050 Softphone running on a PocketPC-based PDA. Nortel representatives claimed full support of all BCM station features on the i2050, and engineers noted anecdotally that voice quality through the PDA was surprisingly good.

Another advanced feature was a software application called Call Pilot, Nortel's unified messaging platform. Call Pilot allows BCM station clients to receive voicemails and faxes via popular IMAP-compliant client-messaging software, such as MS Outlook.

While unified messaging applications are common, our engineers felt that the fax-server integration of the Nortel implementation was noteworthy in several respects. First, BCM clients can be notified via voicemail that a fax is waiting for them in the queue. Second, a fax driver can be installed on BCM users' PC's that allows them to send faxes from their workstations. Third, the BCM fax server can function in a "fax overflow" mode, where the BCM back end will queue incoming faxes if the intended fax machine is in use, and will subsequently resubmit the faxes in queue to the fax machine when it is free.

A third feature, the Nortel Configuration Manager (NCM), allows centralized management of

Manageability of the Nortel BCM is exceptional

Mitel Networks 3300 Integrated Communications Platform	Nortel Networks Business Communications Manager	Siemens HiPath 3700	Vertical Networks InstantOffice 6500
3300 System Administrator, ver. 3.2	Unified Manager and BCM Monitor, ver 3.0	HiPath 3000 ManagerE, rev 3.15	InstantOffice Remote Management System, ver 5.0
Java-based Web interface served by GoAhead from the 3300 ICP	Java-based Web interface served by Apache from the BCM PBX	C++-based, standalone Windows application	Java-based Web interface served by IIS from the Instant Office 6500
Fair; frames-based with categories organized in a somewhat intuitive tree	Good; frames-based with categories organized in a somewhat intuitive tree	Fair; frames, tree and tabs management interface is organized; screen content requires training	Excellent; well-organized screens; graphical image of InstantOffice product particularly effective
Poor; no reports available without purchase of additional software	Good; basic reports available with adjustable time fields, but no user defined reports	Poor; no reports available without purchase of third party software	Good; basic reports available with adjustable time fields
Good; statistics available through CLI and manual refresh	Excellent; extensive list of elements and protocols	Good; station status is real-time, other statistics require manual refresh	Excellent; all aspects of call setup and trunk conditions
Fair; can be sorted but only deciphered by Mitel	Excellent; detailed information is available on events.	Good; events are legible and course of action sometimes provided.	Good; SNMP-based events manager well organized; some events are cryptic.
Poor; limited CLI accessible diagnostics	Excellent; diagnostics are available for all levels of administrator.	Good; can test down to the channel level through phone simulation application.	Excellent; provides detailed information and provides a very helpful T1 troubleshooting tool.
Yes; phones identified by Ethernet MAC address.	Yes; phones identified by Ethernet MAC address.	Yes; phones identified by Ethernet MAC address.	Yes; IP information resident in phone's memory.
Not supported	No; Hotdesking feature allows only temporary login from a different phone.	Not supported	Not supported

Siemens led the pack in basic-feature support

up to 2,000 BCM IP WAN distributed systems on a single interface, according to Nortel reps. While station configurations—like button-mappings—cannot be controlled remotely by the NCM, it can perform MACs, call-routing changes and can back up and restore system configurations. It even has a utility that will automatically compare configurations between multiple systems. What's more, the firewall, routing and DHCP functions of the remote BCMs also can be centrally managed using this powerful tool.

While not as intuitive to navigate as some systems (e.g., 3Com's or Vertical's), the manageability of the Nortel BCM is exceptional. Through a combination of its base management package, the Business Communications Manager and an additional standalone application called the BCM Monitor, the system delivers administrators highly granular real-time monitoring functionality, well-conceived and detailed events and alarms and useful, proactive diagnostic and troubleshooting tools. A handful of canned management reports, with definable time fields, adequately serve their purposes.

The BCM's latency and voice-quality metrics were stellar, with the lowest latencies and, with the exception of 3Com, the highest voice quality among all systems overall. What most hurt the BCM in this category was a 99.753 percent call-completion rate under load. Moreover, the Nortel BCM system overall is highly susceptible to DoS attacks. Still, with an overall rating of 85 for performance, the Nortel BCM achieved the highest score in this category.

Availability of the BCM is enhanced in two ways: First, phones can temporarily rehome to a second, pre-defined BCM system for temporary PSTN access upon failure of the primary call server. This is not to be confused with redundant call-control support—user accounts would have to be re-created if the primary call server can't be re-established. This does, however, provide an element of resilience. Second, the Nortel BCM not only re-routes outbound IP calls to the PSTN in the event of link failure, it can take a PSQM score—a voice-quality calculation—and reroute calls if the PSQM score falls below a pre-defined threshold. This unique and highly sophisticated feature factored into the BCM's score of 85 in performance.

Siemens: The classic, multi-slot chassis-based HiPath 3700 supported the highest number of station features tested of any system under review—35 of the 38 (or 92 percent), garnering it a 90 rating in this category.

However, its advanced feature set (rated a 75) wasn't as rich and, compared to most of its competitors, not as extensive. Advanced features included the HiPath ProCenter Office (HPCO), a small-office contact-center application. On the HPCO's management interface, testers cited easy access to important statistics, particularly agent states, wait times and calls in queue.

The HPCO application comes with two software modules of note. First is the Tray Phone CTI, which can be used either within or without the call center by administrators to monitor call states and provide inbound caller information for any HiPath

TABLE 4 Availability Matrix

Vendor/Product	3Com SuperStack 3 NBX	AltiGen Communications AltiServ Office	Avaya IP Office 403
Can outbound IP calls roll over to PSTN trunks if the IP link is down?	Yes	No	No
Is redundant VOIP call control supported?	No	No	No, but phones can temporarily re-home automatically to a second, pre-defined call server for PSTN access.
Other redundant/hot-swappable components	Power supplies, RAID 1 disks, media cards, Ethernet ports on controller	Power supplies and fans	None
Cold reboot time	4 min, 36 sec	3 min, 28 sec	5 min, 14 sec
Call reliability test results	99.9738%*	99.6812%	98.2236%
DOS Susceptibility—Call controller	Medium—reduced voice quality on calls but no reset	High—calls disrupted and controller reset	Medium—call setup process affected, but not calls in progress; no resets
DOS Susceptibility—IP phone	Medium—calls severely disrupted but no reset	High—calls disrupted and phone reset	High—calls disrupted and phone reset

* on re-test (only through CAS signaling)

phone client. Second is the HiPath ProCenter Communicator, a personal information manager not unlike MS Outlook, but designed specifically for the needs of contact agents. With Communicator, agents can answer emails, access contact information, receive voicemail and be notified of incoming calls—with caller information—from the same application.

Siemens' Client Assistant Web-based application is offered as part of its Xpressions unified messaging platform. Among other functions, it allows Siemens users to reroute faxes in queue to another fax machine, and to check voicemail messages from a standard Web browser.

The HiPath 3700 ManagerE—Siemens' management application—is organized, but understanding the contents of the screens requires practice. Reports aren't available without the purchase of additional software, but the HiPath ManagerE offers fairly robust monitoring, event logging and diagnostic functionality. Test engineers specifically cited Siemens' ManagerE's event viewer as informative, complete with recommended courses of action for certain events; and a phone simulation utility that allowed granular T1 troubleshooting abilities.

The Siemens system achieved the minimum acceptable rating for business-quality voice communications (4.0) for LAN-based G.711 calls, but a 3.8 voice quality metric for calls over the WAN using their G.723.1 codec. One-way latency on G.711 calls was 110 msecs; G.723.1 delays were a poor 182 msecs. Apart from those scores, the HiPath 3700 performed well. The HiPath 3000 aced the call-availability test, posted the fasted reboot time of any system under test and successfully demonstrated the ability to reroute outbound IP calls to the PSTN upon IP WAN link failure. The Siemens system proved highly susceptible to DoS attacks, however, which lowered its overall score in performance and availability.

Vertical Networks: Vertical's InstantOffice is well-known as an "infrastructure-in-a-box," small office solution. In addition to PBX functionality, its multi-slot chassis can be populated with any combination of WAN interface cards supporting DSL, frame relay or PPP; a Cisco 1600 router blade, an eight-port Ethernet switch module and more. InstantOffice also can provide data network services like VPN, DHCP and remote dial-up access.

In addition to its own line of digital phones, Vertical resells MGCP-based Polycom SoundPoint IP 400 and 500 phones. Without its own proprietary extensions to MGCP for enhanced feature support, it is not surprising that Vertical only demonstrated 22 of the 38 features tested (58 percent). Vertical representatives claim that the demand for IP-phones from their customers does not warrant more concern over their feature set, but the lack of support for basic features hurt Vertical's overall score.

However, in the advanced features category, Vertical scored an 80, on par with other products tested. Vertical's Call Management Suite, a call-center solution for smaller branch offices and retail stores, enables enhanced IVR capabilities and reporting without the need for an additional

Management remains Vertical's strong suit

Mitel Networks 3300 Integrated Communications Platform	Nortel Networks Business Communications Manager	Siemens HiPath 3700	Vertical Networks InstantOffice 6500
Yes	Yes; can also fail over on the basis of user-definable PSQM metrics over egressing link.	Yes	Yes
No	No, but phones can temporarily re-home automatically to a second, pre-defined call server for PSTN access.	No	No
None	Power supplies, fans, RAID1 disks	All non-CPU modules hot swappable; all except VOIP interface redundant	Dual power receptacles, 3N+1 power supplies, RAID1 disks
12 min, 30 sec	5 min, 25 sec	3 min, 6 sec	5 min
100%	99.753%	100%	100%
High—calls disrupted and controller reset	High—calls disrupted and phones reset; controller did not reset	High—calls disrupted and controller reset	Low—no disruption on calls no controller reset
High—calls disrupted and phone reset	High—calls disrupted and phone reset	High—calls disrupted and phone reset	Medium—calls disrupted but no phone reset

Security Issues And Solutions

Kenneth M. Percy and Randall E. Birdsall

IP-PBXs introduce vulnerabilities to telecom systems that are unique to IP-based networks. But the security vulnerabilities of VOIP networks can be mitigated by physically securing all network equipment and implementing a design that employs layers of security.

To illustrate, consider two types of attacks that we've analyzed during the course of IP-PBX testing: Packet-based eavesdropping and denial-of-service (DoS) attacks.

Analog or digital phones station lines on a TDM-based PBX system run all the way to the terminating PBX. This means eavesdroppers equipped with butt-sets can listen in, but only if they're physically located next to the pair of wires on which the conversation occurs. The best solution is fairly simple: Physically secure the PBX so unauthorized personnel cannot tamper with the system.

Packet-based eavesdropping poses another challenge, because in an IP-based network you don't have to be at an IP-PBX site to capture packets. Packet-based eavesdropping refers to the ability to perform a packet capture using packet-tracing software and to store whole conversations as electronic files and transfer them electronically.

You do, however, need access to the Ethernet switches where VOIP connections terminate. The equipment performing a packet trace must be part of the voice path or connected to a switch or hub through which the voice path traverses. So, if you can't get to the switches, packet captures can't be performed. Again, physically securing this equipment using buzzer systems, password-controlled locks, alarms and even cameras will help prevent this type of eavesdropping.

It's also important to screen employees who will be working in the IT center. Anyone with access to network equipment, including outside consultants and vendors, should be screened and closely supervised while on premises.

An effective network-based antidote to eavesdropping is a virtual private network (VPN). All data traversing a VPN link—including VOIP traffic—is encrypted, which protects it. VPNs can be used for PBX-to-remote-PBX communications, and for client-to-site VPNs for road warriors and home-office users.

We also assessed how well the IP-PBXs handled denial of service (DoS) attacks. DoS attacks generate a large amount of IP traffic directed at a weakness in the IP stack or a poorly designed network service. If carried out as intended, a DoS attack can cause complete loss of IP functionality and, in some cases, reset entire systems from the PBXs to the phones.

It's clear that DoS attacks are effective when levied against IP-PBX systems. We attacked the call controllers and the IP phones of all 12 systems tested in both the large enterprise PBX review and the SME systems. Among those, only two—the 3Com SuperStack 3 NBX and the Vertical InstantOffice 6500—showed acceptable overall resilience to our attacks.

The call controllers of five systems—the Alcatel OmniPCX Enterprise, the Avaya S8700 Media Server, the Avaya IP Office, 3Com's SuperStack 3 NBX and the Sphere Sphericall system—experienced either no susceptibility or some disruption in service. The rest were all highly susceptible to DoS attacks, meaning that either the controllers or the IP phones they serviced rebooted in order to reestablish service.

Interestingly, the Polycom IP-phones—which were tested as part of the Sphere, Vertical and Shoreline systems—were the most DoS-resilient IP-phones. Disruptions were observed, but the Polycom phones did not require reset to resume service under any condition tested. Among all other phones tested, only 3Com's were similarly resistant.

In most cases, a layered security strategy that includes an intrusion-detection system and a well-deployed firewall

management interface. It is managed via the InstantOffice's base management application.

For full-blown, robust call-center functionality, Vertical offers the InstantOffice Contact Center (IOCC) application. It delivers enhanced ACD functions, including skills-based routing and priority queuing, instant messenger-based "chatting," a supervisor console interface and a graphical IVR call flow design tool. Testers noted that the IOCC's reporting functionality provides a broad range of reports.

Multisite Management is a tool for managing up to 10,000 Vertical InstantOffice systems across an IP WAN, according to company representatives. While we had no way of testing this lofty claim, our engineers could attest to the ability of Vertical's GUI to group and organize that many nodes for purposes of coherent, centralized management. This application can perform upgrades across all systems under management. Though it cannot make global routing changes, Vertical's Multisite Management is a powerful tool for making scheduled backups of configurations, CDR databases, trunk statistics and reports.

Vertical's base management interface, the InstantOffice Remote Management System, has always been strong, helping Vertical achieve a score of 95 in management. Highly intuitive and rich with real-time statistics, Vertical's GUI has some of the best diagnostic tools ever seen in our labs. It offers a good handful of canned management reports, and its SNMP-based event viewer is well-organized.

The Vertical InstantOffice performed well. Uncompressed (G.711) VOIP calls exhibited low latency and excellent quality; no calls were dropped during our call-load testing, and the InstantOffice proved to be the system most resilient to DoS attacks under review. What kept the InstantOffice from receiving a higher score in this category was its high latency and poor

should prevent a DoS attack against the PBX systems' controllers. But an important consideration is that many DoS attacks occur *behind* the network firewall—i.e., they're "inside jobs." Therefore, deploying a dedicated, VOIP-enabled firewall for your PBX is a good idea where on-net security is a concern.

Of all the IP-PBX vendors we've tested, Avaya exhibited the highest level of commitment to secure VOIP communications. It is the only vendor that claims support for the ITU-T (International Telecommunications Union) H.235 protocol, which specifies the security requirements for H.323-based communications. H.235 addresses four specific security concerns: Authentication, which validates clients' identities; data integrity, which ensures data has not been altered; media encryption, or "scrambling" to prevent eavesdropping; and non-repudiation, which ensures that H.323 entities/nodes cannot "deny" having sent information.

As part of its advanced feature presentation for the S8700 Media Server described in last month's issue of BCR, Avaya demonstrated a proprietary implementation of media encryption between Avaya endpoints. When our testers performed a packet trace of a conversation between two endpoints, all they heard was white noise.

But clearly, IP-phones are the Achilles' heels. While firewalling the phones of key personnel is a good practice, doing so for every phone in a large installation is impractical. Although attacks to specific phones pose no danger to the PBX back-end itself, attacks directed at individual IP-phones are difficult to defend without some built-in resilience.

So where does the responsibility of the PBX vendor lie in all this? Some vendors take the view that it is the task of the surrounding network infrastructure to secure VOIP communications, just as it is to secure databases, messaging servers and other mission-critical applications. Indeed, it is unreasonable to cast all the burden of security upon the PBX. A firewall/VPN solution and an intrusion detection system are vital in the design of a stable VOIP network.

But when a voice network is brought to its knees by a DoS attack, the customer will undoubtedly call the PBX vendor, not the firewall vendor. So what can IP-PBX vendors do to effect better security? Here are our suggestions:

1. IP-PBX vendors are responsible for secure VOIP communications. Borrowing from the H.235 provisions mentioned above, IP-PBXs must address user authentication, data integrity, media encryption and non-repudiation. Also, data traffic specific to management and configuration of the system elements should be encrypted, especially passwords. Avaya has taken the lead in this area; more vendors should follow.

2. IP-PBX vendors are responsible for security vulnerabilities in the operating system they choose as their platform. Using a common, non-proprietary OS, like Windows or Linux, will increase the likelihood that crackers have had extensive experience interacting with it. While common OSs are an important upside to VOIP development, their security vulnerabilities must be thoroughly considered.

3. IP-PBX vendors are responsible for providing a well-designed IP stack. Not only should common services like FTP, Telnet, HTTP and NETBIOS be examined closely for vulnerabilities, designers also should develop these services to function under extreme stress. This is not as important for the phones as it is for the PBX itself, but both need attention. It's far preferable to have one caller experience problems placing calls than to put an entire office in a communications "black out."□

voice quality for G.729a-based calls over a WAN (216 msecs and 3.3, respectively).

State Of SME IP-PBXs

This test taught us a lot, including what categorizing an IP-PBX as "small," does *not* mean.

First, small does not mean the same, albeit scaled down, as a large system. Beyond the obvious, we discovered fundamental differences between these systems and those large enterprise systems described in last month's issue (see *BCR*, January 2003, pp. 28–38). The smaller systems don't offer as much user mobility from a moves, adds and changes standpoint, and they don't deliver the same level of performance or availability.

Second, small does not mean fewer options. This group of systems showed an astonishingly broad and powerful array of hardware and software-based advanced features, from wireless sets to PDA soft phones to video-to-the-desktop to highly sophisticated call-center platforms.

Third, small doesn't necessarily mean cheaper. While the prices cited in Table 2 are U.S. list and subject to discount, except for Avaya and Mitel, the per-station figures are above $600□

Companies Mentioned In This Article

Avaya (www.avaya.com)
AltiGen Communications (www.altigen.com)
Cisco (www.cisco.com)
Microsoft (www.microsoft.com)
Mitel Networks (www.mitel.com)
Nortel Networks (www.nortelnetworks.com)
Polycom (www.polycom.com)
Siemens (www.siemensenterprise.com)
Symbol Technologies (www.symbol.com)
Vertical Networks (www.vertical.com)

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