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VoIP is turning telephony into just another Internet application—and a cheap one at that

BY STEVEN CHERRY



ONCE UPON A TIME, NUCLEAR POWER WAS GOING TO MAKE ELECTRICITY “TOO CHEAP TO METER.” TODAY, THE INTERNET IS SUPPOSED TO DO THE SAME THING FOR TELEPHONE CALLS.

THIS TIME IT MAY BE TRUE.

Voice over Internet Protocol, or VoIP, is one of the fastest-growing, and most misunderstood, technologies in the world at the moment. Confusion, outdated beliefs, and urban mythology reign over such simple issues as how it works, the quality of the calls, and, of course, how much it costs—VoIP calls are not free now, and they never will be. As things are shaping up, though, they’re so cheap that carriers are letting customers make all the calls they want for a single monthly fee, typically US \$25 to \$35.

Simply put, VoIP means doing voice communications over the same networks that we rely on for data communications—the local networks that connect to our computers and the Internet that links them all together. If you’ve ever bought a prepaid phone card, especially one for international calling, you’ve probably already dialed into a VoIP system without knowing it. By crossing national borders as cheap Internet packets, instead of moving through an expensive switched circuit, an international VoIP call, while still billed per minute, costs pennies, not dimes or quarters.

In fact, those low costs, and the efficiencies for carriers of maintaining a single, unified telecommunications network, guarantee that all telephony will eventually be done over IP. Essentially everyone in the telecommunications industry agrees on that.

So, not surprisingly, there’s a cattle stampede of providers: in North America alone, some 400 VoIP services are now competing for residential customers, says William Cheek, an analyst at Parks Associates, in Dallas.

Even traditional local telephone companies are part of the herd. In the United States, Verizon Communications Inc., based in New York City, has been signing up subscribers since last July; rival Qwest Communications International Inc., in Denver, since August. SBC Communications Inc., in San Antonio, another regional giant, announced last fall that it would launch a VoIP service in early 2005. “The market is saturated with service providers already,” Cheek says. And many corporations, lured by the promise of cutting their telephony expenses by half or more, are turning to VoIP—at least for their internal communications.

The two largest call-anyone VoIP providers in the United States are each signing up about a thousand new customers a day—a rate

that compares favorably with other quickly adopted technologies, such as the CD player, satellite television, and high-speed Internet. One of these leaders is Vonage Holdings Corp., in Edison, N.J., a stand-alone VoIP company whose service runs over a household’s existing broadband line. The other is Cablevision Systems Corp., a Bethpage, N.Y., large regional cable TV provider, which began its VoIP service in November 2003.

Between them, as of January, Vonage and Cablevision had a little more than half of the 1 million U.S. households using VoIP. Of course, that’s just a tiny fraction of the total number of homes with telephone service in the United States—about 106 million (out of 109 million households in all).

Still, the momentum is clearly in favor of VoIP. According to the Telecommunications Industry Association, in Arlington, Va., at some point in 2006, more than half of all the new private branch exchanges being installed will be IP based. And the number of residential VoIP subscribers will rise 12-fold, to about 12 million, by 2009, industry analysts project. By that time, total U.S. revenue for business and residential VoIP products and services will be nearly \$21 billion, up from \$2.5 billion today, says Aaron Nutt, an analyst at Atlantic-ACM, a unit of Boston-based ACM Group Inc., which specializes in telecommunications consulting and market research.

VoIP services fall into two basic categories. The first are those from commercial providers, such as Vonage’s and Verizon’s, or AT&T’s CallVantage. Then there are the so-called free services, such as Skype, a relatively new but hugely popular system from Skype Technologies SA, in Luxembourg, founded by the makers of the equally popular, and free, Kazaa online music-sharing software.

The commercial systems connect into the traditional public switched telephone network, so you can use them to call anyone else with a telephone—whether or not they’re Internet-connected. Vonage is the oldest of these commercial call-anyone VoIP providers; yet it just celebrated its fourth birthday in January.

VoIP is, in some respects, further along elsewhere than in the United States. Businesses in South Korea, Ireland, and the United Kingdom are first, second, and third in the use of VoIP, according to the 2004 International Benchmarking Study, a survey of information technology usage that’s conducted annually by the UK’s Department of Trade and Industry.

The “free” VoIP services, as such, typically let you contact only other users of the service you’re on, and possibly users of some of the other free services. You generally can’t tie into the public

switched telephone network. Nor can you call into a free account from the regular phone network. So the free services realm is like a telephony archipelago, with limited ferry service between the islands and none to the mainland.

Much of the start-up ferment lately surrounds the free services, which don't charge for the calls but do require a broadband Internet connection and other resources (more on those later). Two of the most popular are Skype, mentioned earlier, and Free World Dialup in Melville, N.Y. Free World Dialup started as a 1995 experiment by serial entrepreneur Jeff Pulver, who was also involved in the start-up of Vonage and an earlier, pioneering VoIP venture, VocalTec Communications Ltd., in Herzliya, Israel. Formally launched in 2002, Free World Dialup is a labor of love more than a business, but it does a growing side business reselling Internet Protocol telephone equipment to those new to VoIP.

Skype, meanwhile, was launched in September 2003 by Niklas Zennström and Janus Friis. They had already become famous, or infamous (depending on your point of view), as the creators of Kazaa. In its first three months, Skype had over 2 million registered users worldwide. Probably many were just novelty seekers trying it out, but a little more than a year later, on 20 October 2004, VoIP hit a milestone when Skype first surpassed 1 million simultaneous users. If there is a specter haunting traditional telephony, Skype may be it.

The numbers are all the more impressive when you consider that VoIP as we know it today is barely a decade old. Before 1995, voice communication through a personal computer was virtually impossible. (As a technology, though, it goes back to the 1970s.) With personal computers lacking anything like a dial tone, there wasn't an established way for one computer to channel voice communication to another; nor could one signal to another that digitized voice data was being sent to it.

In 1995, VocalTec released an application, InternetPhone, which could handle those details, and VoIP was born. When the software was running on two computers, each created a buffer to receive audio data from the other. InternetPhone used an existing Internet chat system as a way for one computer to find another in cyberspace, relying on an add-on microphone and the computer's sound card to convert analog voice into digital packets and back to analog.

InternetPhone had plenty of limitations. Both computers had to be running the application at the time the call was placed; if your computer was off, or if it wasn't running the software, you simply missed the call. The early versions weren't fully duplex—you spoke and then waited for a reply, à la Citizen's Band radio. And many things we now expect from a telephone application, such as three-way calls, were basically impossible.

Still, by eliminating per-minute charges for simple, two-way telephony, InternetPhone foreshadowed a revolution in communications and earned its place in the technology pantheon. But there was still plenty of work to do to turn Internet voice communication into a mainstream

service. In 1999, the Internet Society, in Reston, Va., published a standard for Internet telephony, the Session Initiation Protocol. SIP is a general way for an application to make one computer user aware that another user is online and available for communication—it's the Internet's virtual dial tone. With SIP in place, the barriers to Internet telephony today have more to do with the financial issues of who, if anyone, gets paid for the call, rather than with the technical problem of getting an Internet-phone-enabled device to ring.

SIP went on to enable other Internet applications besides telephony; it's the protocol that lets a friend's name pop up in the buddy lists of instant messaging software. It's showing up in other applications, too, such as games. In fact, today, the easiest way to make a free Internet phone call is with a network-connected Xbox or by playing a multiplayer online video game. Headsets are pretty common in the game world these days, and with them, gamers talk to one another routinely, as teammates blasting away at virtual enemies in cyberspace.

MYTH 1 VOIP IS FREE.

Even the "free" VoIP services aren't really free. First of all, you need a broadband Internet connection (which many already have); it will set you back \$25 to \$60 a month, depending on where you live. In addition, you'll have to have some equipment. At a minimum, a special microphone, one with a built-in analog-to-digital converter and a USB or serial connector, is all that's needed to turn your computer's sound card and speakers into a phone. Most users spring for a \$30-to-\$50 headset that plugs directly into a USB port.

Alternatively, you could buy a phone designed for the task, which also plugs directly into your computer's Ethernet or USB port. Leading telecom manufacturers, like Avaya, Cisco, Lucent, and Nortel, make Internet Protocol telephone equipment, mainly for the corporate market but increasingly for small businesses and home broadband users as well.

Avaya's corporate equipment is particularly cost-effective, because the company, which was spun off from Lucent in 2000, specializes in upgrades to existing private branch exchange systems instead of to systems that require completely new hardware. For most businesses, though, the move to VoIP can still cost \$200 to \$400 per employee.

Lately, Skype has started blurring the line between free and for-pay services by offering its users the ability to call anyone, including people outside its service. In July, it introduced low international calling rates, generally 1.7 to 2.2 euro cents (2 to 3 US cents) per minute, covering most of the world. That's half, at most, of the rate of the cheapest prepaid calling cards.

Because most of a VoIP call, whether it's going 20 kilometers or 20 000, usually travels over the Internet, Skype's only real expense is for the last few kilometers, paying the local telephone company to ring the recipient's phone and complete the call. So the rate to call someone in, say, London, is the same whether you're calling from Beijing or the flat next door.



The commercial VoIP systems, which let you call anyone with a phone number, charge subscribers a monthly fee for unlimited nationwide calling. A large part of that cost goes toward the access charges that these companies pay the local phone companies for letting calls cross into and out of the public telephone network. For that privilege, the VoIP companies pay about 1 cent per minute at the wholesale level, according to Daniel Berninger, a technology analyst who was involved in the start-up of Vonage. Another VoIP service, Packet8, marketed by 8X8 Inc., in Santa Clara, Calif., has distinguished itself by including more and more calls to Europe in its fixed monthly price for North American subscribers.

By letting you make an unlimited number of calls, these commercial VoIP operators are basically making an actuarial wager on how much calling you're going to do. According to a Vonage spokesperson, the company makes money on every subscriber who uses its service for fewer than 400 outgoing minutes a month. The calculation must break down a bit for start-up RNK Telecom. In December, the Dedham, Mass., company rolled out a lifetime VoIP service for a one-time payment of \$999.



MYTH 2 THE ONLY DIFFERENCE BETWEEN VOIP AND REGULAR TELEPHONY IS THE PRICE.

Internet telephony and regular telephony are unlike one another in almost every possible way. Internet telephony depends on turning voices into packets of data and sending them through a relatively dumb network—the Internet. Those packets are sent to relatively smart devices: computers, PDAs, and IP phones.

The traditional phone companies do the exact opposite. They send voice as an analog signal through a system of wires and cables connected to incredibly smart central computers, called switches. At those switches, the voice signals are digitized and routed to other switches, which then ultimately route them to quite stupid devices, old-fashioned analog telephones.

Because of that setup, two other differences emerge. For a traditional phone network to roll out a new service, such as caller ID, those incredibly smart, complex switches need to be reprogrammed—no trivial task. A VoIP service can easily provide new programs for smart end-user devices, on the other hand, in much the same way that any software manufacturer comes out with a new feature. The VoIP companies, therefore, are continually offering new services that their switched-telephony world counterparts would find difficult or expensive to match.

To begin with, all the commercial VoIP services let you pick your area code and keep your number when you move, two things that are impossible with the geographically based traditional telephone system. In Europe, VoIP operators even let you choose which country your phone will be “local” to.

Then there are other benefits made possible by the end-to-end-digital nature of VoIP. For example, Vonage voice-mail messages are just digital audio files. You can play them on your computer after logging into the company's Web site, or you can even have them e-mailed to you, as attachments that can be stored on your local computer for as long as you like. Vonage also offers its customers an additional 800 phone number (that is, one that is toll-free to callers) for \$5 per month. AT&T lets CallVantage customers set up as many as five different phone numbers for a call to be forwarded to, and they can choose whether the phones should ring in sequence or all five at once.

VoIP systems don't differ just from traditional telephony; they differ from one another. Cable companies aren't known, for example, for their ability to deliver the “five 9s” reliability that tele-

phone companies like AT&T and Verizon traditionally aspire to. A 99.999 percent uptime means being down only 5 minutes per year. Cablevision, whose service area includes northern New Jersey, the traditional home of the old Bell Telephone network, doesn't even deliver three 9s, which would work out to 8 hours of downtime per year.

For one thing, sending voice as data packets willy-nilly through the Internet—the dumb network part of the VoIP equation—means that a VoIP call is at the mercy of the weakest link in what might be a very long chain. Packets must follow a path through various cables and wires and routers as they make their way from the caller to the people called and back again. Of course, that chain is much more robust than in the early days of Internet telephony. Indeed, in some ways, Internet service in the New York City metropolitan area withstood the 9/11 collapse of the World Trade Center complex better than the landline phone network. A key Verizon central office, located just north of the twin towers, was destroyed that day.

MYTH 3 QUALITY OF SERVICE ISN'T AN ISSUE NOWADAYS, BECAUSE THERE'S PLENTY OF BANDWIDTH IN THE NETWORK.

A traditional phone call sounds as good as it does because it commandeers a data channel that's 64 kilobits per second wide. The channel is completely devoted to the single call that occupies it. We call that system a switched network, because, originally, telephone operators flipped physical switches to open a dedicated electrical circuit between two phones. In addition, the phones that the parties use, and all the electronics in between, have always been optimized for the human voice and ear. All this means voice call quality is rather good, and consistently so. Cellular calls, by contrast, often get as little as 10 to 15 kb/s, and we all know how they sound.

For VoIP calls, especially ones made with the free services that depend on the Internet from end to end, a network designed for data is being used for voice. While the network may usually have



“Hello, China?” In 15 Minutes

SkypeOut, a commercial voice over Internet Protocol service from Skype Technologies SA, in Luxembourg, not only makes telephony

remarkably inexpensive—it’s hard to imagine VoIP being made much easier.

One cold January evening, on the way home from work, I stopped into a CompUSA store for a USB headset from Logitech International SA, a popular Swiss manufacturer of computer accessories based in Romanel-sur-Morges. It cost US \$34.99—about as much as a cheap phone. Once at home, I plugged the headset into my Macintosh and downloaded and installed the free software from Skype’s Web site (<http://www.skype.net>).

The Skype software—which for the Mac platform was, in January, still labeled a beta release—appears as a small window. You can add “contacts”—other Skype users—and if they’re online, they’ll show up on a contact list, just as they do in an instant messaging buddy list. You can highlight a contact and then press a large green “Call” button to dial—and it doesn’t cost anything at all.

With Skype and a growing group of other VoIP providers, you can also call anyone with a telephone, but, of course, those calls have to go through the traditional switched network, so they aren’t free. But they’re remarkably cheap—prices vary by country and range from 1.7 to 2.2 euro cents per minute. You need to give Skype money on account, in blocks of € 10 or € 25. It’s all remarkably hassle free, no matter where you live; you just fill out a simple e-commerce form with your credit card information and billing address.

I called my wife to try it out. She could hear me, but at first I couldn’t hear her through the headset. It turns out I hadn’t specified the headset as the selected device for sound in my Apple Macintosh’s Systems Preferences menu (as I could have learned from a quick glance at the accompanying Logitech instructions). A similar adjustment has to be made by Windows users. With the change made, I was ready to call China, specifically, my colleague Jean Kumagai, on assignment in the western city of Chengdu.

When I reached her on her hotel room phone, the sound quality was close to that of an ordinary landline call. The only difference was that each of us had a little trouble being sure the other was done talking. It wasn’t as bad as a satellite call, and there were no echoes or gaps in the conversation.

Oh, and one other difference: an 18-minute phone call was only 42 euro cents, about 54 U.S. cents. My regular long-distance company would have charged at least \$3.49, almost seven times as much as SkypeOut.

—S.C.

far more than 64 kb/s in available bandwidth to accommodate a new phone call, congestion can arise at any moment and cut the data rate to almost nothing—at least briefly. And the slightest hiccup in the connection, at any point, results in dropped packets and momentary gaps in the conversation.

The same hiccups mean nothing in e-mail, where a delay of several seconds is unnoticeable. Although telephony doesn’t involve large amounts of data, the time constraint makes it far more demanding than most other Internet applications.

There are three things to worry about in an Internet phone call. *Latency* occurs when data packets are delivered too slowly—usually because of network congestion. *Jitter* is a variation in the delays of packets—some arrive on time or only a bit late; others, sent just before or after, arrive much later. Finally, when packets are extremely late, the network drops them, resulting in *packet loss*. Latency and packet loss can create awkward momentary silences in a phone conversation or make it seem that one party is interrupting the other. These delays can cause echoes and other odd sound effects.

Hiccups generally don’t harm one-directional streaming audio and video, because those applications create data buffers several seconds long. When there’s a problem, data is drawn from the buffer. As long as the problems in the network are solved before the buffer is completely drawn down, the recipient never notices. An Internet phone call, with data flowing in real time and in both directions, can’t be buffered.

The situation is far from hopeless, though. In principle, a VoIP call can be given an arbitrarily large amount of bandwidth. That’s especially true within a corporate phone network, which often has optical fiber between buildings on a campus, and often between different campuses in a wide-area network. Voice packets are given special priority that ensures that the congestion preferentially affects applications other than VoIP calls.

Likewise, for commercial VoIP services like AT&T’s and Verizon’s, the core network has more bandwidth than it usually uses—the industry term for this is *overprovisioning*. So the main problem in making Internet phone calls has usually been the “last mile”—the connection between a household and the core network. But nowadays, home broadband more or less solves that problem: even an unimpressive 500-kb/s broadband connection has more than enough bandwidth for a high-quality phone call.

Nevertheless, because of the bursty nature of digital communications traffic, even the most overprovisioned network will have hiccups. Most networks exhibit a huge difference between their average and peak loads. Even the conventional U.S. telephone networks still have trouble keeping up with demand on Mother’s Day, their biggest day of the year.

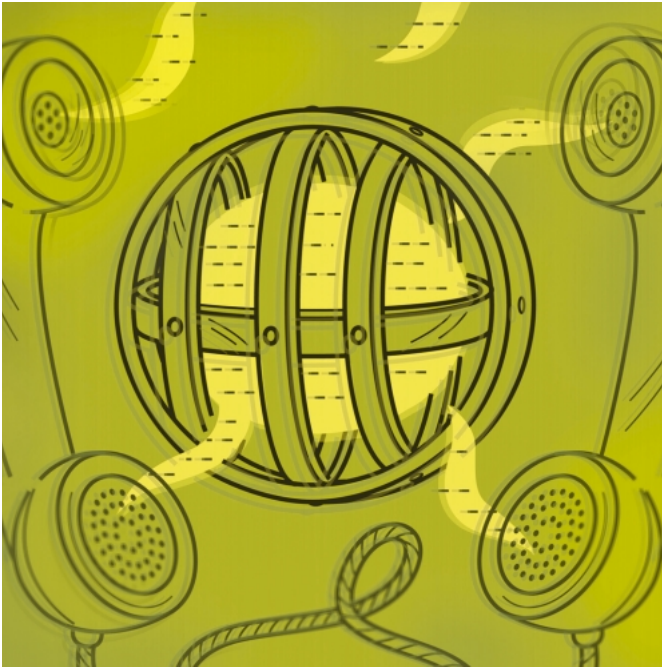
MYTH

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VOIP CAN’T REPLACE REGULAR TELEPHONY, BECAUSE IT STILL CAN’T GUARANTEE QUALITY OF SERVICE.

VoIP is a relatively new network application, so it should come as no surprise that its particular quality-of-service problems—latency, jitter, and packet loss—are still being worked out. But fundamentally, these are problems of network congestion, and network engineers have already devised some clever methods to guarantee a minimum bandwidth for a particular application. The latest scheme, Multiprotocol Label Switching, or MPLS, is still being refined by the Internet Engineering Task Force, an international volunteer organization sponsored by the Internet Society.

In an MPLS network, data packets are assigned labels by specialized routers, called MPLS routers, in the phone company’s net-



work. These labeled packets are forwarded not by the usual algorithms that best serve the Internet's overall traffic needs, but according to decisions that are tailored to the labels. Among the information these labels provide are the packet's origin and destination, its bandwidth needs, and its sensitivity to delays. The MPLS router then figures out a path for the labeled packet and sends it to the next router. The router can also store, and use, that path for all the other packets in the VoIP call.

The main point of these specialized paths is to route around congestion, although as a side benefit, routing by label is also faster than the usual methods, which require reading more of a packet's data. While MPLS is still a work in progress, a form of it is already being used in many VoIP networks.

MYTH 5

VOIP IS JUST ANOTHER DATA APPLICATION.

Oddly enough, most companies today assign the task of installing their VoIP networks to the in-house information technologies division, even though that group typically has little or no experience managing the firm's voice communications.

"Management says, 'You should be able to do this,' but there's a knowledge gap—IT doesn't understand phones," insists Todd Grafton, a telephony engineer at CDW Government Inc., a computer services and consulting company in Vernon Hills, Ill. "Almost always, the corporate phone system was run by an outside organization," Grafton adds. "It was contracted out. And the service requirements—five 9s and all that—are very different from what they are in many data centers."

Those service requirements include being able to dial police, fire, and ambulances in an emergency, which in the United States means dialing 911. That's not always easy to do. A school district has five or six buildings, says Grafton. "You can dial 911, but where are the paramedics going to show up?" Conventional phone networks have, by and large, solved the problem of forwarding a phone's location information to emergency personnel. But to do so in a VoIP network, corporations usually have to bring in consultants with experience in both traditional telephony and Internet Protocol networking to design and set up the system.

Then there's quality of service. "It's a myth that you can manage VoIP with the monitoring tools you already have," says Jim Su, a senior product marketing manager at Avaya Inc., in Basking Ridge, N.J. "You have to check each voice path—each end-to-end path—and troubleshoot it," says Su. "You need monitoring and management tools that are especially designed for that." Naturally, Avaya makes just such tools.

MYTH 6

VOIP ISN'T SECURE.

To the extent that VoIP is just another data application, it has no inherent protection against eavesdropping, but in practice VoIP is even more secure than old-style telephony. That wasn't always the case. "Going over an IP network, you could potentially intercept packets," says Su. "It was always possible to tap a phone call, but you had to tap into a physical line."

VoIP, on the other hand, is in cyberspace, in principle accessible from anywhere. But while that was true at one time, Su says, nowadays all IP telephony equipment, from the cheapest to the most expensive, uses encryption schemes that make it probabilistically impossible to listen in on an Internet phone call.

The typical encryption system uses public-key cryptography. Skype, for example, uses a method called the Advanced Encryption Standard, with encryption keys that are 256 bits long. Users log into the Skype application on their personal computer and are then recognized by a Skype server across the network. The server gives each party in a phone call a key to decrypt the packets sent by the other. The exchange of data between the end users and the Skype server is itself encrypted.

MYTH 7

A PHONE IS A PHONE IS A PHONE.

With IP telephony, calls aren't limited to traditional telephone devices. For example, when Avaya's Su leaves work, he reroutes his office extension to his home computer. With SIP in place, he says, "My colleagues can see that I'm available, even if they don't know what device I'm on, or if I'm at home. I can also just switch from voice to instant messaging or a videoconference. The telephony doesn't just reside in the computer—it's in the network." The industry even has a term for the way a software program, even the original VocalTec application, can turn a computing device into a phone—"softphone."

Those new phones and other devices, of course, have features and interfaces that most users won't bother to learn, just as we already ignore most of the features of our cellphones.

Bjarne Stroustrup, the redoubtable computer scientist who 20 years ago invented the C++ language while working at Bell Labs, once famously said, "I have always wished that my computer would be as easy to use as my telephone. My wish has come true. I no longer know how to use my telephone."

Bjarne, we have good news and bad news for you: it's going to get better—and worse. As phones become full-blown computers in their own right; as computers, PDAs, and other devices become phones; and as the boundless Internet becomes a phone network, we'll be surrounded by telephony choices that dazzle, delight, and befuddle us. Welcome to the world of VoIP.

TO PROBE FURTHER

Skype and Vonage are easily found on the Web at <http://www.skype.com> and <http://www.vonage.com>. The topic of quality of service was taken up in more detail in a September 2000 article in *IEEE Spectrum*, "The Cost of Quality in Internet-style Networks," by Amitava Dutta-Roy.