Compaq Computer Corporation

56 Kbps Analog Modems

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Executive Summary

With the ever-growing need for higher data communications throughput for applications such as web surfing or database access, the communications industry has been turning to new products and infrastructures to “feed” this growing appetite. Unfortunately, some of these new infrastructures, standards, and products have been slow to develop and have suffered from limitations that have made them less attractive than current analog modem technologies.

Recently, discoveries in the area of traditional analog modems have unearthed solutions that have removed the 33.6Kbps theoretical limit associated with analog modems and enabled up to 56 Kbps transfer rates through creative use of digital and analog technologies. This solution, however, does have its own limitations in that it can only operate when there is a single analog conversion in the entire transmission link. The remainder of the entire connection path must be fully digital. This paper will go into more detail on this limitation and why it exists, but essentially, single analog loop connections fall into 2 major categories:

1. Internet access via Internet Service Providers
2. Corporate network access via connections to Remote Access Servers

Fortunately, the majority of commercial modem connections fall into one of these two categories. Point-to-point dialing between two home owners will not work at 56 Kbps because the process involves two analog lines (i.e. from the user’s home to the central office and then back to another user’s home). In this case, the modems will transmit data at the highest analog standard common to both users’ modems, 33.6 Kbps, for example, at the highest end.

56Kbps solutions will be asymmetric. This means that 56Kbps throughput works in only one direction, downstream, from the Internet or corporate server to the user. Upstream rates, from the user to the Internet or corporate server will run at 33.6 Kbps. Benefits from this asymmetric design are application specific. That is, Internet surfers and remote access users who dial into their corporate server will find the high downstream rates great for retrieving large files. The bandwidth upstream, while smaller, will not be limiting because only a small amount of information is sent by the user (i.e. mouse clicks and key word searches). Employees accessing their corporate server, however, not to download files, but to work remotely with a program are sending large amounts of data both upstream and downstream. The smaller upstream rates, in this case, could prove limiting to program functionality.

Initial reaction to the announcements of 56 Kbps modems is very promising. Internet surfers, the primary market, will be able to access the Web at higher speeds downloading data twice as fast as the 28.8 Kbps users. As corporations upgrade their remote access equipment, employees in the field will also be able to connect at speeds up to 56Kbps.

Due to the high demand by end-users for this technology and the slow development of standards, pre-standards have been developed. Rockwell has partnered with Lucent Technologies to develop a compatible 56 Kbps solution, termed K56 Flex, while US Robotics, both a chip and modem manufacturer, has developed x2. An international standard from the ITU is not expected until 1998.

Section II: Recent History

The Beginning

On September 10, 1996, Rockwell Semiconductor Systems surprised the computer industry with its announcement of a new modem technology enabling transmission speeds of up to 56Kbps over standard phone lines. On September 11, US Robotics Corporation announced plans to pursue a 56 Kbps modem of their own. Lucent Technologies followed with a press announcement on October 16 with their plans to incorporate 56 Kbps technology into their modem products. These announcements were met with mixed reactions: computer and Internet enthusiasts cheered, ISDN evangelists groaned, and market analysts everywhere were left scrambling for answers.

Standards Committees

As with any new product, this technology will have the greatest value to users if it is standardized, so that products from different vendors can inter-operate. The process of standardizing new technologies, although complex, is important in that it ensures that products from different manufacturers are compatible. The two main standards bodies which will play an important role in the adoption of 56 Kbps modems are the TIA and ITU.

The TIA (Telecommunications Industry Association) is a North American standards body which reviews new technologies within Canada, Mexico, and the United States. In November 1996, the TIA founded a special ad hoc group (PN 3838) composed of North American industries, to develop an interim US standard for 56K modems. Headed by Intel, members also include Rockwell, Lucent, US Robotics, and Compaq, to name a few. This “standardization” process, begun in November of 1996, is expected to last from six to eight months.

The ITU (International Telecommunications Union), an agency of the United Nations, is a world-wide standards organization where both governments and industries cooperate to establish international standards for new technologies. The ITU sets the official standards that industries use today. (e.g. V.32, V.32bis, V.22) ITU conferences are held every six months throughout the world to review both new and current technologies. On average, it takes at least two years for a new technology to become standardized.

Section III: How does it work?

The following section provides a brief non-technical overview of what to expect with this new technology and how it works. For a more technical review, please refer to Section IV.

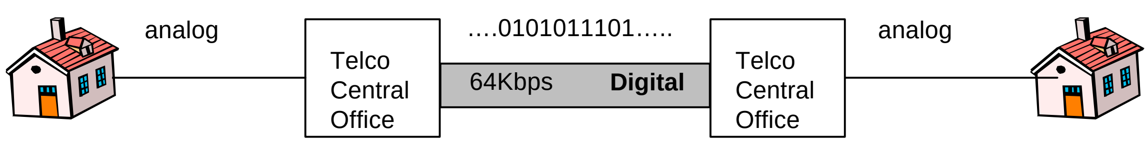
The Communication Path

Traditional Modems

Before discussing how 56Kbps modems function, it is important to review how current modem technologies (28.8 and 33.6Kbps) interact with the phone network. Specifically, what does the communication path look like and how do the modems send and receive data.

Let's first examine the "communication path" between two modems over conventional analog telephone lines using current 28.8Kbps and 33.6 Kbps technology. These are the standard modems in use today. With these modems, at least two analog portions in the communication path are analog. One portion, the link between central offices, is usually digital. Data transmitted from one house to the other is converted twice from analog to digital and digital to analog.

Conventional modem connection



Now let's focus in and look at the modems. The modems at each end of the connection do not realize that there is a digital link between them. Even though faster digital lines compose most of the path, because of their design, all they recognize is the analog portions of the communication path.

When these modems send and receive data to each other they have to do so through an underlying level of interference; what engineers call "noise". On average, analog lines inherently produce about 36dB (decibels) of noise or "static" when in use. (The noise level varies depending on the quality of the phone lines). The greater the amount of noise, the harder it is for the modems to receive information, and the slower they are able to operate.

One well-known theorem on modem speeds and line noise is the Hartley-Shannon Theorem or, as it is sometimes called, Shannon's Limit. Shannon's Limit states that the maximum theoretical speed for analog modems peaks at 33.6 Kbps. The reason is that because of the noise level present on analog lines (36dB), modems would never be able to negotiate through this interference fast enough to operate over 33.6Kbps.

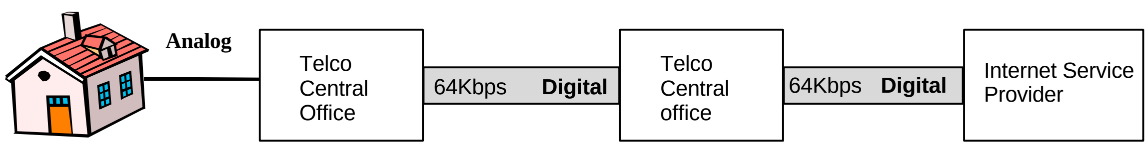
New 56Kbps Modems

Engineers, recognizing that a greater amount of "quieter" digital lines are in use, have taken advantage of these higher speeds and designed modems capable of receiving information at 56Kbps. That is, these modems will be able to receive information "downstream" from the Internet or a corporate server (which is linked digitally to the central office) at up to 56 Kbps, but will only be able to send data "upstream" at up to 33.6 Kbps.

Again, let us look at both the communication path and the modems for this new technology.

Notice that the communication path presented below now only has one analog line from the home to the central office. The rest of the path is digital and one of the homes has been substituted with a box labeled Internet Service Provider. These are important points, because for users to achieve speeds of up to 56 Kbps only one analog loop is permitted in the communication path (these new modems cannot "ignore" more than one analog/digital conversion) and the central office must connect ***digitally*** with whomever the user is calling.

56 Kbps modem connection



Because of these line conditions, point to point dialing from one home-owner to another would not work at 56 Kbps because two analog lines would be present in the communication path. This does not mean, though, that they would not be able to communicate. Rather, the modems would operate at 33.6 Kbps or whatever speed is common to both.

Now, let's look at the modems again. Unlike the 28.8 and 33.6 Kbps modems, which view the communication path as entirely analog, these new 56 Kbps modems recognize the path as entirely digital, that is, they "ignore" the one analog line. To do this, the modem in the home must synchronizes with the modem at the central office.

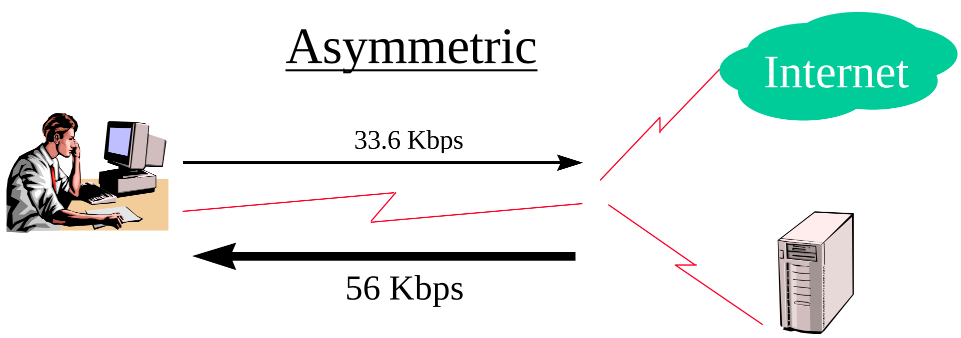
By synchronizing the user's modem with that of the central office, the signal becomes "cleaner". (i.e. less noise) With less noise interference, more data is successfully transferred, thus modem speeds increase. This increase in speed, however, does not mean that Shannon's Theorem was incorrect. Rather, the theory is still correct when modems are operating on an analog line with a signal to noise ratio (SNR) of

30dB. Synchronizing the modems helps to reduce this noise to achieve better throughput. This is not to say, however, that line noise will cease to be a problem. The noise levels will still vary with the age and condition of the telephone lines used - even with this new technology.

It is anticipated that these 56 Kbps modems will run at a true 56 Kbps ten percent of the time. That's about the same rate that 28.8 and 33.6 Kbps modems run at their top speeds. One advantage that this new technology has, though, over previous modem designs is the ability to operate at speeds slightly less than 56 Kbps. For example, if the modem was not able to reach 56 Kbps because of line noise, it could communicate at 46Kbps or 44Kbps or 42 Kbps, etc… Again, these speeds are dependent on the amount of interference encountered.

There is one other factor that could prohibit the modem from reaching 56 Kbps, compatibility. Because this is a new technology, universal design standards for the modem chips and the software have not yet been established. This means that some modems might not be able to communicate with each other at 56 Kbps because they are designed differently. For example, a modem using the Rockwell/Lucent design, K56 Flex, will not be able to communicate with a Internet Service Provider server which runs x2, the US Robotics 56 Kbps design. Likewise, x2 modems are not compatible with servers running K56flex. Nonetheless, as this technology requires a connection with a remote access server, compatibility issues could theoretically be avoided by providing both solutions on the server.

The diagram below shows how the current 56 Kbps technology sends data "downstream" from the internet or corporate server to the user at speeds up to 56 Kbps. "Upstream" speeds run at 33.6 Kbps.



Section IV: Detailed Description of 56K Technology Operation

Network Overview

To understand the operation of 56k modems, it's helpful to first review the basic structure of the telephone network. Over the past 20 years, the phone companies have migrated the telephone network from a predominantly analog structure to a digital medium. This move to a digital network has enabled the phone companies to offer new services (video, data, etc.), as well as match the increased demand for basic phone service. In most situations today, the only remaining analog portions of the network are located between the customer's premises and a central office(CO). Figure 1 illustrates the communication path for a typical connection between two residential locations. This path is applicable for both a conventional voice call as well as a data/fax modem connection.

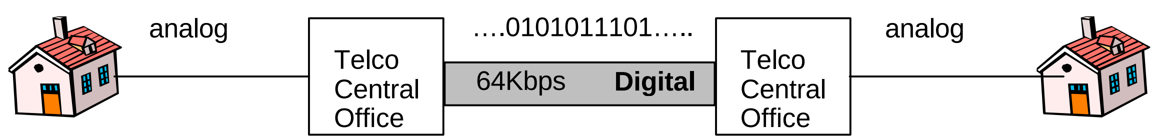


Figure 1: Residential to Residential connection over the PSTN

The analog portions of the communication path consist of twisted-pair copper wire between the central office and the customer premises. During a voice conversation, the analog signal represents the speech energy of each person speaking. During a data or fax connection, the analog waveform represents the modulated data in transit. In each CO, a codec (coder-decoder) provides both the analog-to-digital and digital-to-analog conversions. In one direction, the codec performs the A/D conversion by digitizing the analog signal into a 64000 bit/sec data stream[1]. The analog waveform is sampled 8000 times a second (8 kHz), and each sample is converted into an 8 bit value. Each eight bit sample corresponds to 256 possible quantization levels.

8000 samples/sec * 8 bits/sample = 64000 bits/sec

Each codec also performs the necessary D/A conversion by re-constructing a 64 Kbps data stream back into an analog waveform.

Figure 2 illustrates the most common communication path between a residential location and an Internet Service Provider(ISP) or central site remote access servers (RAS) at a

[1] Pulse coded modulation(PCM) refers to the process of digitizing an analog signal and transmitting it via a digital medium.

corporate office. The communication path in Figure 2 is applicable for a dial-up connection to the Internet. It is important to note that the modems operated by the ISP are digitally terminated to the phone network. In other words, the communication path between the PSTN and the ISP/RAS does not contain an analog-to-digital conversion.

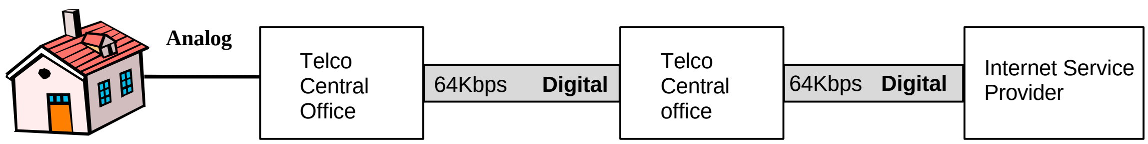


Figure 2: Residential to ISP/RAS connection over the PSTN

RAS/ISP's are digitally connected to the phone network via a T1 connection in the US or an E1 connection in Europe. A 1.544 Mbps T1 line contains 24 voice channels. Likewise, a 2.048 Mbps E1 connection contains 30 voice channels. Each voice channel is represented by a 64 Kbps data stream as described above. IRAS/ISP's maintain modem banks that terminate each 64 Kbps connection into a analog modem (V.34, V.32bis, etc.) For the ISP, a T1/E1 line provides a less expensive, more reliable connection to the PSTN than individual analog lines.

Network optimization for voice

It is important to understand that the phone network was designed and optimized for voice traffic. The network designers made tradeoffs between voice quality and network capacity, and these compromises have limited the maximum achievable data throughput to approximately 35 Kbps. The following network parameters translate into challenging impairments for analog modems.

Network parameter		Resulting analog impairment
• 8.0 kHz sampling rate	⇒	300-3500 Hz bandwidth
• 256 quantization levels	⇒	36 dB SNR[2]

Theoretically, the 8 kHz sampling rate limits the bandwidth of an analog signal to the range 0 - 4.0 kHz. In practice, the analog bandwidth is limited to the range 300-3500 Hz. During voice conversations, the limited bandwidth alters the sound of a person's voice, however, the resulting speech signal is still quite intelligible. In order to exactly reproduce the quality of a human speech, it would be necessary for the network to support a bandwidth of 200-10,000 Hz. While the actual bandwidth(300-3500 Hz) is an acceptable tradeoff for voice traffic, the limitation has a significant impact on data throughput.

Another factor limiting data throughput is line noise. The A/D conversion performed by each codec adds a small amount of random noise . This noise is caused by the codec when it samples each of the analog signal's 256 discrete quantization levels. The noise introduced by the A/D conversion is referred to as "quantization noise" . While this

[2] Signal to Noise Ratio

quantization noise is not audible during voice conversations, it does limit the maximum speed at which data can be transferred.

A measure of the amount of noise in a communication path is the signal-to-noise ratio(SNR). The SNR is computed by dividing the power of a signal, such as a modem waveform, by the power of the "noise floor." A lower noise floor translates into a "cleaner" communication path, and therefore a larger value for the SNR. For the phone network, the quantization noise limits the signal-to-noise ratio (SNR) to approximately 36 dB.

Shannon's Limit

The Hartley-Shannon Theorem (commonly referred to as "Shannon's Limit") states that the maximum data rate for a communication channel is governed by a channel's bandwidth and SNR. The Hartley-Shannon theorem can be summarized by the following equation.

Throughput = bandwidth * SNR

For the phone network, it has been generally accepted that "Shannon's limit" is approximately 35 Kbps, given a bandwidth of 3.5 kHz and a SNR of 36 dB. However, if the bandwidth or the SNR of a communication path can be increased, the maximum achievable throughput will be increased as well. For example, if the SNR of the phone network can be improved from 36 to 50 dB, the maximum achievable throughput would be approximately 60 Kbps.

V.34 operation over the PSTN

Existing analog modems (V.34, V.32bis, etc) view the PSTN as an analog system. In other words, analog modems have no indication that portions of the communication path are digital. This is true for all V.34 modems, including those that are digitally terminated to the phone network.

During a modem connection, each modem (answering and originating) characterizes the communication path in terms of analog impairments. Each modem measures parameters such as bandwidth, SNR, and round trip-delay and then selects the highest possible data rate based on the measured impairments. Under the network impairments of limited bandwidth(300-3500 Hz) and limited SNR (36 dB), the maximum rate for the V.34 modulation standard is 33.6 Kbps.

56K operation over the PSTN

A fundamental principle of PCM modems is the strategy of leveraging the digital portions of the phone network. Unlike V.34 modems, 56K modems are based on the assumption that one modem, either answering or originating, will be digitally terminated to the network. Fortunately, this assumption is valid when dialing into an ISP as depicted in figure 2.

With one modem digitally terminated, both modems are capable of synchronizing to the phone network. By synchronizing to the network, specifically the codec in the CO, 56K modems are able to reduce the quantization noise introduced by the codec itself. A lower noise floor is equivalent to a "cleaner" communication path, and therefore enables a higher speed data rate. The quantization noise is no longer treated as a random noise source, but a deterministic impairment that can be compensated for.

So, how do 56k modems synchronize to the codec and therefore the network? Let's look at the down stream data channel(ISP to customer) and examine how data is transferred.

Bytes of data travels digitally across the network and are converted into specific quantization levels(voltage) by the codec in the CO. Since, different values of data arrive continuously, the output of the codec(the analog voltage) changes over time. Figure 3 illustrates a simple case of a voltage waveform generated by a codec with 4 quantization levels, instead of the actual 256. The dotted line represents the analog voltage resulting from the ISP modem transmitting the data sequence

0, 1, 2, 3, 2, 1

The time intervals(t=0, t=1, t=2, etc) represent the exact instant in time the codec is converting a new sample value. The spacing of the time intervals is controlled by the 8 kHz network clock. The challenge for the user's modem would be to determine which of the 4 possible quantizations levels was generated by the D/A converter, and to repeat the process 8000 times a second.

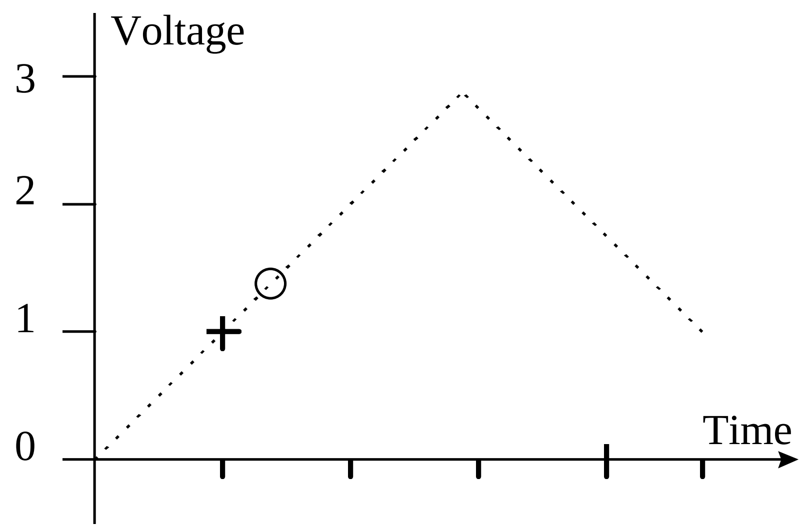


Figure 3: Output of 4 level A/D Converter

The user's modem must be able to synchronize to the network in order to examine the analog voltage(the dotted line) at the exact points in time(t=0, t=1, t=2, etc.) corresponding to a new sample value[3]. For example, if the user's modem can examine the waveform exactly at time t=0, then the modem can determine that the voltage(marked by a '+') corresponds to a value of '1'. If the user's modem inadvertently examines the waveform sometime between t=0 and t=1, then the modem will detect a different voltage(marked by 'o') and be unable to determine if a value of '1' or '2' was transmitted.

If 56k modems could discriminate between all 256 levels, then the achievable data rate would match the network rate of 64 Kbps. In practice, it's only possible to utilize a maximum of 128 levels, resulting in 7 bits of data per sample. With 7 bits/sample and 8000 samples/sec the data rate is

8000 samples/sec * 7 bits/sample = 56000 bits/sec

[3] The ability for a modem to synchronize to the network clock is referred to as "timing recovery" or "clock recovery."

If a 56k modem cannot discriminate between 128 quantization levels, then the modem will fall back to a slower data rate by choosing a fewer number of levels to utilize. Table 1 summarizes the data rates for varying numbers of quantization levels.

Number of quantization levels per sample	Bits per sample	Data Rate (bits/sec)
2	1	8000
4	2	16000
8	3	24000
16	4	32000
32	5	40000
64	6	48000
128	7	56000
256	8	64000

In principle, it's possible to apply the same method in the other direction, and achieve similar data rates in the up stream channel(customer to ISP). However, due to additional complexities in the up stream direction, first generation 56k modems are likely to limit the up stream data rate to 40 Kbps.

Summary

In order for a 56Kbps enabled modem to function at 56Kbps speeds, three criteria must be met.

1. Only one analog to digital conversion can occur in the entire communication path.
2. One end of the connection must terminate at a digital circuit.
3. Hardware at both ends of the connection must support the same 56K pre-standard.

Section V: Questions and Answers

When can 56K modems be used?

The way that 56K modems work puts some unique requirements on the modem connection. Specifically:

- Modems on both ends must implement the same version of 56 Kbps
- Modems must be digitally connected to the telephone network. That is, there is a T1/E1 or ISDN digital channel directly between the modem and the digital backbone of the telephone network. This is becoming increasingly common for Internet Service Providers and large corporate remote access servers.
- No more than one analog link in the complete connection path: the end-user's wire to his central office
- No conversions of the digital signal anywhere in the network (this is almost never an issue except over transoceanic connections)

The user does not have to know all this in advance. During initiation of the data connection, the two modems determine whether they both implement the same protocol, and whether the specific connection will support 56K transmission. If not, they will set up a conventional V.34 modem connection instead.

How do 56K modems achieve higher data rates? I thought 33.6kbps was the theoretical limit for analog modems.

Refer to Section III and IV for a detailed description of how 56K modems operate. The process of digitizing the analog signal is called "quantization" and introduces "quantization noise" onto the pure analog signal. The amount of noise is small for voice calls, but for very high speed modems, it imposes a theoretical limit on data transmission using analog techniques to about 35kbps. This is aside from any noise on the telephone wire itself, which generally lowers the modem throughput even further.

56K modems get around this problem through their requirement that at most one of the modems (the end-user's) can be connected to the telephone network via an analog local loop. The Internet Service Provider (ISP) or corporate remote access modem pool must be connected digitally to the telephone network. As a result, a 56K modem is able to treat the whole connection as a single <u>digital</u> channel, with an impairment, namely the analog link. It uses a completely different form of encoding the data, as a series of bits which the end-user's central office converts to voltage pulses on the line. With a single analog link in the connection, both modems are able to synchronize exactly with the generation of each voltage pulse by the central office, allowing the end-user's modem to detect the pulse levels accurately. If there were two analog connections in the link, the lack of coordination between the timing of the two separate analog to digital conversions would destroy the digital channel and introduce excessive quantization noise.

What is the current market situation for 56K modems?

Today, all major modem technology vendors have announced that their new modems will be "56K upgradeable" which means they are capable of being upgraded to 56K at some time. Each modem vendor's implementation of 56K technology is currently proprietary and unique to that vendor although Lucent and Rockwell have agreed to make their chipsets fully inter-operable . Vendors are also claiming that their modems will be upgradeable to the final standard when one is approved.

As for standards, there is currently no industry standard for 56K modems. It is expected that the TIA (Telecommunications Industries Association) will fairly quickly (mid-1997) adopt an interim standard which will be widely adopted in North America. The ITU (International Telecommunications Union) sets standards for the whole world, including North America, but is expected to take much longer (up to two years) to set a 56K standard. If a server could be created such that Internet Service Providers and corporate MIS managers are able to support multiple standards on their servers, this would help to alleviate the compatibility concerns.

In the meantime, the real value of 56K for end-users is determined by whether they can connect to the Internet at 56K. In order to do this, Internet service providers must install 56K capable modems in their modem pools which are compatible with their customers' 56K modems. With multiple 56K implementations available, each modem vendor's goal is to convince as many ISPs as possible to adopt its implementation.
Corporate users are generally expected to wait until at least an interim standard is available before deploying 56K modems in their modem pools.

Is this a new modem standard for higher speed data access?

This higher speed data access technology is only in the pre-standard stage as a new method for remote access at speeds up to 56Kbps. It has not yet been standardized by either the TIA or ITU.

Who will provide this new higher speed data protocol?

At this time, Lucent, Motorola, Rockwell, and US Robotics have all announced plans to deploy this new higher-speed analog modem technology in their company's modem chips. In the case of Lucent and Rockwell, this means that modem vendors who use their chipsets will include the higher-speed protocol in their new modem designs. US Robotics writes its own modem code and manufacturers its own modems and has announced that they will include this new protocol in their own modems.

At the same time, it is not enough to have a new modem in your PC in order to be able to surf the Internet at 56Kbps. The ability to utilize this higher speed requires that the modems at the central sites upgrade as well. While a maker of customer modems may have a large number of installed modems in consumer PCs, the central site modems at the ISPs and in Remote Access Servers must also be upgraded with the SAME protocols. The market for central site modem banks at ISPs is split quite differently from the end user market.

When will this technology be available to the consumer?

It is expected that modem vendors and ISPs will begin rolling out this new technology in 1Q97 with support becoming more widely available as the year progresses. Based upon the deployment of 33.6Kbps over 28.8Kbps, widespread support by ISPs will not likely occur until the Fall of 1997. While 33.6Kbps technology exists today, there are still a number of ISPs who have not officially announced and advertised support for this protocol.

Do I have to buy a new modem in order to get the faster speeds?

Yes and No. Some vendors modems will be software-upgradeable to support this new protocol. The safe answer is that you probably WILL need to purchase a new modem in order to benefit from this new technology.

How are Internet Service Providers (ISPs) and corporate remote access managers reacting to this new technology?

There has been much reaction and speculation by the ISPs and remote access managers surrounding the announcement of this new technology. ISPs with the foresight that 56 Kbps will provide a significant competitive advantage are aggressively planning the implementation of this new technology. Implementation of the new technology will, however, be strongly dependent upon the success of field trials which several ISPs, America Online foremost among them, are beginning at this time. Corporate remote access managers are also planning their own field trials and will likely be upgrading their infrastructure soon thereafter.

When will a standard for 56Kbps data transfer be implemented?

The earliest possible time by which a standard will be ratified by the International Telecommunications Union (ITU), which covers this new data speed, would be January of 1998. That is the MOST optimistic time. It should be stated, however, that this is probably unlikely to become a standard by that time. The reason for this is due to the competition among chipset vendors to convince the ITU to make their implementation become the industry standard. Based upon experience with other standards, it is not expect to become an industry standard until the third quarter of 1998.

Can I send files to another PC at 56Kbps?

No. Unless there is only one analog path in the connection with a fully digital path at the opposite end, you will not be able to connect at 56Kbps. Unless your friend or co-worker's PC is connected to the telephone infrastructure via a digital pipe (T1, for example), this method will not work.

Can I connect at 56Kbps regardless of where I am calling to if the other end is 56K-enabled?

No. If there is even one additional analog conversion in the connection somewhere, this higher speed will not work. This is because the technology requires a very accurate synchronization of one codec to the other in the receiving equipment. Additional digital to analog and analog to digital conversions in the connection will force the connection to default to a slower speed.

What percentage of the time will I be able to connect at 56Kbps?

Some users may never reach 56 Kbps due to "dirty" lines just as in 28.8 and 33.6 Kbps modem speeds. While it is expected that 10% or less of the population will be able to connect at 56 Kbps, slower fallback speeds are being built into the protocol.

Section VIII: Related Information on the Web

Modem Manufacturers & ISPs

http://www.ascend.com/pressrel/press83.html

http://www.ascend.com/pressrel/press91.html

http://www.bocaresearch.com/press/091196a.htm

http://www.diamondmm.com/whats-new/press-releases/files/56ksupport.html

http://hosted-www.ftel.com/press_rels/prcyclone56k.htm

http://www.hayes.com/56kpres.htm

http://www.microcom.com/modems/prmod56.htm

http://www.netcomm.com.au/press_releases/56k.htm

http://www.zoomtel.com/news/56kmodem.html

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