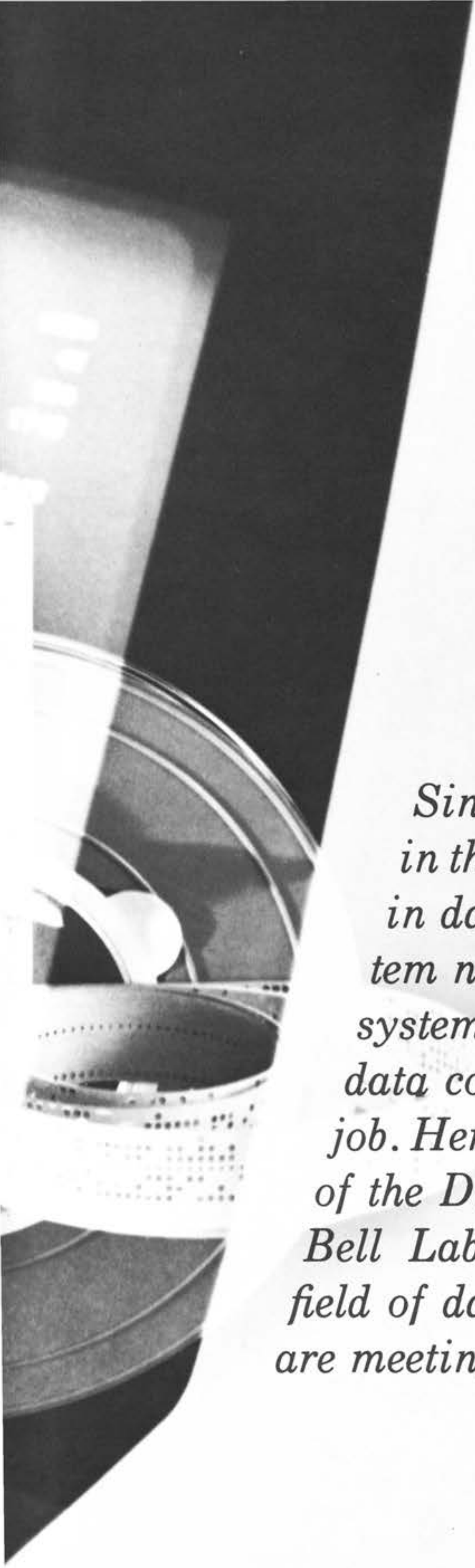

DATA·phone
START
AUTO
TEST
CLEAR TALK
DATA



Data Communications In the Bell System

An Interview with V. M. Wolontis

Since the upsurge of computers that began in the 1950's, there has been a rapid growth in data communications over the Bell System network. Designing the equipment and systems to handle still larger quantities of data communications in the 1970's is a big job. Here, V. M. Wolontis, Executive Director of the Data Systems Engineering Division at Bell Laboratories, reviews the growth in the field of data communications and tells how we are meeting the challenges posed by this growth.

Q: *Mr. Wolontis, the field of data communications is taking on more and more importance. Since you have specialized in this field for some time, perhaps you can give us a little background as to the nature of data communications and how it has grown in recent years.*

A: Literally, data communications, or more specifically the electrical transmission of data, is actually older than the electrical transmission of voice: The Morse telegraph, which sends binary digits over wires, predates the telephone by some thirty years. And of course the telegraph evolved into the teletypewriter, which also represents a form of data communications. But the real beginning of data communications, as we know it today, comes with the upsurge in computers in the late 1950's.

Q: *Is there a simple definition that we can use for data communications?*

A: A precise definition is very hard to formulate, but from a practical standpoint, data communications covers anything that isn't either voice or video. I'm including in this category both analog and digital information, and the latter case covers both numerical and alphabetic data. This includes the output from a teletypewriter, or the information one computer or business machine might send to another, but it also includes such things as a human "talking" to a machine using TOUCH-TONE® keying, or the transmission of an electrocardiogram. In this case, a doctor at a patient's home can send an electrocardiogram in real time over an ordinary telephone connection to a central point where a specialist can read it and give him a diagnosis over the telephone. Another example of analog data could be facsimile, which can be used to send graphic or printed material. But except for such relatively minor cases, the bulk of the data we're talking about involves communication with computers or other business machines.

Q: *Your definition excluded video. In particular, then, PICTUREPHONE® service is not data communication?*

A: That's right, we view Picturephone and other video signals as a separate category. So you might say there are three major categories of communication—voice, data, and video.

Q: *Yet aren't there plans to transmit the Picturephone signal over long distances in digital form?*

A: Yes, and that brings out an important distinction between digital transmission and data transmission. The nature of the original source signal determines if data communication is involved. A customer who wants to send his voice or a picture of his face to the other end of the line is not sending data. A series of numbers or digits sent from one machine to another, however, is data. Now, we might send either one of these signals in digital form over the line. And in this case, a voice or video signal would be indistinguishable from a similar bit stream conveying numerical data until the signal is received at the other end. Nevertheless, one is data communication; the other is not.

Q: *What means do we use to send data over the telephone network?*

A: The bulk of our data communication services are handled over ordinary switched or private-line

We see an evolution toward an ultimately all-digital switched network—at least between central offices—to provide a wide spectrum of customer services including Picturephone and higher-speed data services.

voiceband telephone circuits with the aid of so-called data sets. These data sets translate the customers' signals into a form suitable for transmission over voiceband channels. The input to the data set is likely to be a binary stream (i.e., a sequence of "bits"), or it could be a sequence of electrical contact closures, or in some cases an analog signal such as facsimile. Typically, these signals are sent out on the line as tones in the frequency range of 300 to 3000 Hz. But the point is that we take whatever the original signal is and translate or modulate it, send it over the voiceband channel, then demodulate it at the other end, and deliver it to the customer looking very much like what it was at the starting point. In the case of data on the switched network, we refer to this form of communication as DATA-PHONE® service.

Q: *At what speeds can digital data be sent over voiceband channels?*

A: The Bell System currently offers a line of data sets that span a range of speed and cost. If the customer's need is to get the largest possible quantity of data per second over the connection, the latest high-speed data sets will send it at rates of up to 3600 or 4800 bits per second over the DDD network and at rates as high as 7200 bits per second or more over private-line voice channels. But these are sophisticated sets and accordingly cost more. On the other hand, if the customer has a simpler application or makes less use of the service per day, we have simpler data sets that can send data at 2000 or 1200 bits per second. One of these sets may do his job for him at a substantially lower cost. And, of course, for teletypewriter speeds there are sets that are still more economical.

Q: *Has there been much pressure to increase the speeds at which customers can send data?*

A: Yes, a number of data customers are definitely interested in increasing the speed at which they can send data over voice channels. And for these customers who need more than the maximum speed that is possible on voiceband channels, we've developed equipment for transmitting data over wideband facilities, such as a groupband channel, which is the equivalent of 12 voiceband channels. Currently, on a groupband channel we are able to send data at speeds up to 50,000 bits per second. And we have a new data set in development that can send data at a rate of at least 72 and in some cases 108 kilobits per second.

Now if you want still higher speeds you can use a supergroup (equivalent to 60 voiceband channels) and so on up in bandwidth. But such wideband services are provided over private lines, and the customer must have a need to transmit data in sufficient quantities to justify the cost of a fulltime channel.

We've recently introduced switched common-user wideband service. DATA-PHONE® 50 is the first example in this category. With this service a customer can dial a call and send data at speeds up to 50 kilobits per second.

There is, incidentally, another way of sending high-speed data that is kind of exciting, and also brings back the subject of digital versus data transmission. That is, if you know that you have a digital transmission facility in the telephone plant to begin with (for example, T-1 carrier*, which is already in widespread use), you can put digital data directly into that bit stream and send it at rates approaching 1½ million bits per second without going through the process of modulation onto an analog facility.

We've seen some examples already that illustrate the advantages of such a system. For instance, a technical trial using T-1 lines was conducted a little over a year ago to show how newspaper copy could be sent from a centralized composing room to strategically located suburban printing plants. Using high-quality facsimile, a full page of newsprint was sent in 6 minutes at a resolution of approximately 600 lines per inch. The data rate was 460.8 kilobits per second. And with data rates in the megabit range it's possible to send a page in less than 3 minutes.

Incidentally, when a T-1 system is used for ordinary voice communication, each voiceband channel requires 64,000 bits per second of transmission capacity. If such a channel is used for data, you can see that the bit rate available greatly exceeds what can be done with a voice bandwidth analog channel. This illustrates the advantages for data communications as digital transmission facilities become more widespread.

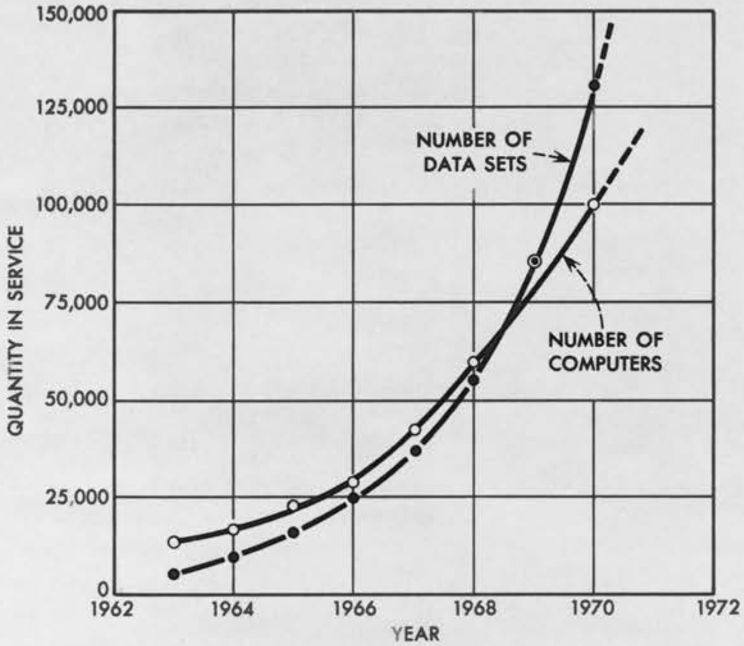
Q: *From what you have just said, I take it the predominant means for sending data up until now has been over analog lines?*

A: Yes, that has been true in the 60's.

Q: *Will there be any change during the 70's?*

A: Yes, indeed. We see an evolution toward an ultimately all-digital switched network—at least between central offices—to provide a wide spectrum of customer services including Picturephone

*See *Digital Communication*, RECORD, *February 1967*.



The rapid growth of data communications has been primarily influenced by the increasing need to move information to and from computers. And modern time-shared computers can communicate with many data stations simultaneously. Thus, the number of data sets is growing more rapidly than the number of computers.

and higher-speed data services. With such a network, the benefits to the high-speed data user are substantial. For example, we can provide a low-cost "megabit Dataphone" service useful to customers with high-speed facsimile needs or with computers or magnetic tape terminals operating in the megabit-per-second range.

This capability will mean a major step forward in the area of switched digital communication. The obvious advantage of common-user switching, of course, is that the customer can use the facility only when he needs it, which might be 10 minutes a day, instead of using a private line that is assigned to him 24 hours a day. Such data service can be made available at speeds an order of magnitude higher than that of Data-Phone 50 service.

Q: *It's easy to see the kind of impact that computers "talking" to each other have had in creating a demand for higher data speeds. But when humans want to "talk" to computers, don't they do it at much lower speeds?*

A: Yes, and that area is one we see in a sense as "exploding" right now in terms of numbers of customers and numbers of applications. If computers are talking to one another you would typically have one data set at each computer and a connection between them. Even if all the computers in the country were engaged in this form of communication, the number of data sets required would be in the vicinity of one or two hundred thousand. On the other hand, a time-shared computer "conversing" with humans can handle 50 or more customers simultaneously. And each of these people needs some form of data set (although some of these could be simple TOUCH-TONE® telephones). At the computer end, in any event, a computer port and an associated data set are required. Thus, this multiple use of the computer is likely to result in tremendous growth in data set demand, which is one measure of the size of the data communications business.

Q: *You mentioned that people might use a Touch-Tone telephone to gain access to the computer. What other devices are in use?*

A: Of course the Touch-Tone telephone has the great advantage that it is widely available and is very inexpensive. It is most useful for simple applications, where the twelve keys provide sufficient input capability and where voice answerback from the computer is acceptable. In particular, it may be the key to providing computer access for residential users in the future.

Where more elaborate input and output capabilities are required, the two most widely used instruments for communicating with a computer are the teletypewriter and the cathode-ray tube terminal. In both cases, the input to the computer is by a keyboard, which provides both alphabetic and numeric characters plus some special characters. The teletypewriter supplies an output in printed form; the cathode-ray tube provides a visual display.

One terminal in the cathode-ray tube category that may gain wide-spread use in the future is the Picturephone station set. If a customer is subscribing to Picturephone service for face-to-face communication, he can get computer access as a bonus by merely ordering a special data set that will translate the output from his computer into a format suitable for display on the Picturephone tube. Touch-Tone input capability is associated with the standard Picturephone station; if an alphanumeric keyboard is required, it can be provided through acoustic coupling.

Q: *Do human-to-computer communication systems pose any special problems?*

A: Yes, there are two major problem areas: One is communication cost to the customer; the other stems from the special traffic characteristics that these kinds of applications exhibit.

The cost problem arises in part because the customer has many more data terminals and ports per computer than he would in computer-to-computer communication, hence communication costs represent a much larger fraction of his total expense than previously. Secondly, the utilization of the communication channels may be very inefficient in that the user may key a few characters into the computer, receive a reply, and then stop for some time to consider his next action—for example, if he is "debugging" a computer program—meanwhile, holding the line. Ideally, the customer would like to be charged only for the characters transmitted rather than for holding time.

While some data customers have use patterns much like those of the ordinary telephone user, others have different traffic-related problems. These are of two types: One, occurring in the case of inquiry-response traffic is that very short holding times—and hence, for well-loaded computer ports, high calling rates—put a greater burden on the common-control equipment in the switching machine than voice traffic would; the other, typical of the programming application, is that extremely long holding times—in some cases, several hours—put requirements on the switching network beyond what is required for normal telephone traffic.

Q: *That sounds like a real challenge. Just how do you devise an economical communications system that takes into account the operating habits of data customers?*

A: The simplest thing we can do, which in fact we have already done, is to provide concentration. Specifically, the users of many time-shared systems tend to be located in geographic clusters of a few miles in radius. For example, you may have fifty or more users on a college campus or in an industrial complex who want to talk predominantly to one computer. The high cost of computer ports makes it desirable to provide the minimum number necessary to handle the traffic. Now if we take advantage of the geographic clustering of the users and put a concentrator either at the computer location or somewhere in the middle of the cluster, we can hold down the costs. We do this by running the lines from the users to the concentrator, and then running a smaller number of trunks between the concentrator and the computer. Thus, we have concentrated the traffic to the computer to permit efficient use of computer ports.

With this arrangement, because of the limited distance between the stations and the computer, the low-speed terminals can be connected by a low-cost dc data set through the concentrator to another dc data set at the computer, thus yielding additional economies. No dialing is required. The user goes off-hook at his terminal by simply pressing a button. If a trunk is available, his line is cut through directly to the computer. If all the trunks are busy, he receives a signal which acknowledges his bid for service and connects him as trunks become available.

Q: *I gather then that concentration can be used to handle computer traffic with a variety of terminals, and the number of trunks can be engineered to meet a particular community's needs?*

A: Yes, that's quite right. We determine the number of trunks that would be required from measurements of calling rates and holding times of the customer. But this doesn't get to the nature of the customer's traffic while he is holding. A concentrator of this type simply sets up a full-time channel between the customer and the computer for as

We're looking into better approaches to maintenance . . . using a computer to check the performance of data sets faster and more accurately . . .

long as he needs it. If you want to take advantage of the pauses in his communication, then you need to do some digital interleaving, or multiplexing, but this is harder to prove in on an economic basis.

Q: *You said earlier that you have already used concentration. Is this a regular Bell System service offering?*

A: Yes, this new service concept, labeled DATREX®, service was introduced by the Bell System commercially in the spring of 1970. We tested the service in a field trial at Dartmouth University in 1969. In this case, there were 30 stations located in or near Hanover, New Hampshire, with access to a central computer. The reaction to this trial was very favorable and the equipment worked well. Incidentally, additional features such as access from stations outside the cluster and access to other computers were also included in the trial and will become available shortly.

Q: *I'm getting a picture that data communication systems are more difficult to engineer than voice systems.*

A: I would readily agree with you. In part, that may be true simply because we have a much better understanding of the voice customer, and his needs are less variable.

Q: *Carrying that point one step further, are there any special problems involved in handling higher-speed data communications over the* DDD *network?*

A: Yes, let me mention a couple: Set-up time, and error performance. Depending on how many offices you go through, the distance, and the level of traffic, a typical telephone call takes perhaps 10 to 15 seconds to be set up in the DDD network. Now, for many data applications this is perfectly adequate, but there are others, and some of them very critical ones, where it is not. An example would be an airline reservation system. One way or another we have to handle such applications by means other than the conventional Data-Phone approach.

The specific case of airline reservations was handled by what we call a high-speed selective-calling line. This is simply a "party line" operating at 2400 bits per second through all the required airport locations—sort of a loop around the country—and connected to the ticket agents' consoles at each airport. With this system, the ticket agent can key in a few bits, and within a total elapsed time of three seconds, the information goes to New York, where it is processed in a computer, and a return answer is displayed on the console.

One of the things I think we will undoubtedly see in the future are more requirements of this kind, where we have to do things in addition to what we can do with the Data-Phone approach.

Q: *I imagine that this problem will become more critical as computers become more complex and a greater variety of communication takes place between machines?*

A: Oh yes. And, in fact, computers can be quite sophisticated in the way they interface with the telephone network. One of many examples of this is the whole area of error control. I'm sure you're aware that any data connection will occasionally have an error introduced in it. Whether you are sending 2,000 or 10,000 bits per second, maybe all your bits get through correctly or maybe some of them don't.

We can provide schemes of error detection and correction if the customer wants them. Alternatively, computers or specialized data terminals can do similar things. What they do is to add bits (to provide redundancy) to the bit stream. That is, you send more bits than the actual message requires so that you can check on what has already been received. For example, the simplest system is called "parity," where you simply add up the binary digits in a portion of your message. If the sum is odd, you add a 0; if it's even, you add a 1, or vice versa. At the other end you detect an error by finding out whether the check bit is correct or not. There are many more sophisticated schemes of that kind that can also be implemented.

Q: *Are error-correcting schemes offered as a part of Data-Phone service?*

A: In certain cases, yes. Our most sophisticated Data-Phone data set, which I referred to earlier, will include the option of error detection and correction.

Q: *Does this mean that with error detection and correction the entire message would be received without an error?*

A: No, you can never guarantee the detection or correction of all errors, but by using sufficiently sophisticated schemes you can reduce the error probability to any specified level. There is a sacrifice, however. You pay the price of introducing a speed reduction due to the redundancy. For example, in a typical code, 1/6 of the total bits in a message might be devoted to redundancy. If a message comes through correctly without retransmission of any blocks, it will be at 5/6 the channel rate. In such a case, the error rate is likely to improve by a factor of 100 or more.

Q: *Mr. Wolontis, an article appearing in the April issue of the* RECORD *described a system to read utility meters over the telephone network. Using your earlier definition, would this be another form of data communication?*

A: That is correct. It's a very specialized form of data communication, in that what we are trying to do, in cooperation with the electric, gas, and water companies and the meter manufacturers, is to read the meters in the customers' homes by electric means, thereby avoiding the problems of the manual method of meter reading.

One serious obstacle to introducing automatic meter reading is that when the meter reader goes down the street from one house to the next, only spending a short time per house, the cost of doing that is rather modest. Typically, it may cost a quarter to read a meter, and many of the utilities read their meters only six times a year. So, even with some overhead savings added, the total cost that you have to work with, if you are trying to do the job automatically, is something like two dollars a year. And if you start thinking about charges for any kind of equipment to be installed in a house and maintained in good order, you realize that $2 a year is very modest indeed.

We are currently participating in field trials to establish the technical feasibility of a meter reading system. The purpose is to determine that, once installed, the equipment will function properly and that the interface between our equipment and that of the other utilities has been thought through properly. The economics are still very much an open question.

Q: *With all the new kinds of data services we've been talking about and the tremendous growth of data communications, it sounds as if there will be many different kinds of data equipment in use. What about maintenance? Are there any provisions for testing this equipment?*

. . . we have both the people, the technology, and the commitment to assure a bright future in data communications.

A: I'm glad you brought up that subject. By the mid 1970's, we expect there will be well over a million data sets in service. We've already begun to look into a better approach to maintenance. Currently, Data-Phone stations are tested largely by manual means. For example, a man at the Data-Phone data set calls up a man at the testboard in a central office and they go through a sequence of routines to check the performance of the data set.

We have plans under way to bring the computer to the aid of these people. First of all, a computer can go through the steps faster and more accurately, and it will leave an automatic record of what took place. Second, tests can in many cases be performed without sending a man to the customer's location. We're currently making plans to test these concepts in an operating environment.

Q: *From what you have said, data communications is evolving rapidly, and we are continually learning how to deal with new problems.*

A: Yes, that's certainly true. It might be interesting to note that a part of this learning process is a large-scale field survey that was recently completed. In this case, we went out into the field with data sets and transmission measuring equipment. We went to a number of different central offices around the country placing calls between these offices and other offices chosen on a sampling basis to represent the whole Bell System. We measured both the data transmission performance of the data sets and the traditional transmission characteristics of the connections during the test calls. This provides us with information on error performance during data transmission and permits us to correlate it with the transmission parameters of the network at the time that errors occur. Such information is useful in designing data sets for the future. It also helps us formulate transmission and maintenance objectives.

Q: *It sounds as if this information would also be useful to the operating companies in maintaining their lines.*

A: That's a valuable byproduct. It gives them additional information on what their customers are experiencing. And it is of value to the customer to know what he can expect in the way of error performance on the network. Typically, for the great majority of switching offices, Data-Phone service gives you less than one error in 100,000 bits on about 90 percent of the connections dialed. When the survey results have been analyzed in detail, we plan to publish information of this type, as we have done following previous surveys.

Q: *Looking into the future, do you think the field of data communications is going to continue much the same as it appears to be moving today?*

A: The basic trend of rapid growth in all speed ranges, and in private line as well as Data-Phone service, will certainly continue as far ahead as we can see. But in addition, there are several new aspects that will have an important influence on the nature of data communications in the future. One of these, which I already alluded to briefly, is the emergence of a nationwide all-digital communication network. With such a network, we can easily and economically derive channels for data transmission at any desired array of speeds, and our data customers can benefit from the very low error rates inherent in regenerative all-digital transmission systems. As required, we may also provide such channels on a common-user switched basis, and with set-up times considerably shorter than those possible with Data-Phone service.

Q: *There are many people today involved in the design of data communications equipment. How do you view our position in this field?*

A: That question brings out another factor that will have an important influence in the future, namely the recent filings and decisions that make it permissible for our customers to use their own modulation and demodulation equipments (or "modems") on the switched network, provided specified precautions are taken to safeguard the service of others. How many customers will provide their own modems (some integral with the business machine) is obviously a matter of conjecture, and depends in part on how well—technically and economically—we meet our customers' requirements. My own guess is that the majority of customers will continue to use our data sets. After all, we are a recognized leader in the field of data set design, and our data sets enjoy an excellent reputation, particularly with respect to error performance and reliability.

The important question, though, is not whose modem is used but whether the overall service satisfies the customer's needs. To meet this challenge, we have both the people, the technology, and the commitment to assure a bright future in data communications.