the Availability Digest

www.availabilitydigest.com
@availabilitydig

Modem Memories

Dr. Bill Highleyman
Managing Editor, Availability Digest
November 2015

Data communication has come a long way since AT&T (American Telephone and Telegraph) first introduced it in the late 1950s. I was recently taken on a nostalgic trip back to those early days while touring the Computer History Museum in Mountain View, California. You see, at Bell Telephone Laboratories, I supervised the development group that designed one of the very first modems (modulator/demodulator) for the transmission of data over telephone lines – the DataPhone 103. I was amazed to see a DataPhone 103 in a display case in the Museum, and the memories returned.

Could Data Be Sent Over Telephone Lines?

When I first joined Bell Labs in 1958, shortly after receiving my Master's Degree in Electrical Engineering from MIT, the Labs was just finishing up a year-long trial to determine if, in fact, it was possible to send data over the telephone network. They had sent a van to travel the country with equipment designed to send data back to the Labs' facilities in Murray Hill, New Jersey, over the telephone network. The result was sadly negative – data could not be reliably transmitted over the telephone network as it currently existed. The problem? Echo suppressors.

Each telephone line segment has a certain "impedance" that is a function of its length and the type of cable used. A line segment's impedance is a measure of the opposition that the line segment gives to a signal flowing through it. The longer the line, the greater its impedance. When two lines join, the impedance mismatch between the two lines causes a small amount of the signal traveling over the line to be reflected back to the speaking person. The result is an echo that is audible and disconcerting to the person speaking. (Have you ever tried to speak into an echo chamber? You rapidly lose the capability to speak clearly.)

To correct the echo problem, most long-distance trunk circuits were fitted with echo suppressors. These devices blocked the return circuit to kill the echo when someone was speaking. Yes, two people could not talk at the same time – only one would get through. I can remember trying to interrupt my other party by speaking swiftly, hoping to get a word in edgewise so I could get the line.

The problem this posed for data communication was that full-duplex communication, in which data was traveling in both directions simultaneously, would not be possible. Even for half-duplex communication, in which only one side transmitted at a time, a station that had been receiving could not begin transmitting until it had sent a tone for a period of time to reverse the echo suppressors in the connection. This was time-consuming and dramatically impacted the ability to transmit data at (what were then) high speeds.

AT&T desperately wanted to introduce data communication, so at this point two decisions were made. One was to fix the telephone network. The other was to begin the development of data communication equipment that businesses could lease to send data.

Fixing the Telephone Network

The fix to the telephone network was conceptually simple but massive in scope. A standard impedance for the trunk circuits was specified, and specialized devices were added to each end of each trunk circuit to make its impedance match the standard.

This effort took several years (four or five) to complete, but in the end echo suppressors were retired. The telephone network could now be used for data transmission.

DataPhone Development

Simultaneous with the telephone network upgrade, the development of data communication equipment began. There were several groups working on the development of this equipment, as there were various models with different capabilities that had been specified. All of these different devices were called "DataPhones" by AT&T.

DataPhone 101

The DataPhone 101 was already in service, having been introduced in 1958. It provided a communication rate of 110 bits/second meant to service the new Model 33 and Model 35 ASCII teletypewriters. Since these typewriters were only half duplex (i.e., they could not send and receive at the same time), and since the speeds were so low, echo suppressors were not a problem.

Bits vs Baud

I just said that the DataPhone 101 had a speed of 110 bits per second. This is not really true. "Bits" is a measure of information. A teletype character is actually 11 bits in length – a start bit, eight data bits (in ASCII), and two stop bits. Thus, the DataPhone 101 could transmit ten characters per second. Each character included eight bits of data. So the information rate of the DataPhone 101 was actually 80 bits per second.

The DataPhone 101 accomplished this by sending a sequence of 110 "ones" and "zeros" per second. This speed is properly referred to as the "baud" rate. Thus, the correct statement is that the DataPhone 101 transmitted at a speed of 110 baud. I will use the term "baud" in what follows to characterize the speeds of the various DataPhones.

DataPhone 103

There was no DataPhone 102. The next in line was the DataPhone 103, which was my baby. The DataPhone 103 was designed to provide full-duplex communication at a rate of 300 baud in each direction via frequency-shift keying. The originating station sent a signal shifting between 1270 hertz for a mark (a "one") and 1070 hertz for a space (a "zero"). The answering station shifted between 2225 hertz for a mark and 2025 hertz for a space. At 300 baud, it would have taken seven hours to transmit a standard, one megabyte JPEG photo!

The DataPhone 103 was introduced by AT&T in 1962.

DataPhone 202

The other DataPhones that were developed at the same time were the DataPhone 201 and the DataPhone 202. The DataPhone 202 was a higher speed, half-duplex version of the DataPhone 103. It communicated at 1200 baud using frequency-shift signaling, transmitting a mark at 1200 hertz and a space at 2200 hertz.

DataPhone 201

The DataPhone 201 was a half-duplex DataPhone operating at the “blazing” speed of 2,400 bits per second (not baud). It used four separate frequency bands, each simultaneously sending two bits of an eight-bit character using phase-shift keying. Each channel transmitted its corresponding bits at a rate of 300 bits per second. Since there were no start/stop bits, this speed of 8 x 300 = 2,400 bits per seconds was truly the information rate.

As Time Went By

As the years passed, DataPhone speeds over the telephone network increased to 4,800 baud, then to 9,600 baud, and finally to 19,200 baud by using ever more sophisticated techniques. Next came 3G, 4G LTE, and the Internet, providing data-communication speeds orders of magnitude greater than what could be sent over the telephone network. The age of the DataPhone had come to an end.

The AT&T Stranglehold

From the onset, AT&T refused to let any other manufacturer develop its own data-communication equipment and attach it to the AT&T network. At that time, AT&T had a monopoly on the communication network – there were no Verizons or Sprints. AT&T’s argument was that equipment that was not properly designed could damage its network.

Several companies that were in the data-communications business sued AT&T to gain access to its telephone network for data communications using their devices. In a landmark case, Judge Learned Hand forced AT&T to open its network to other data-communication providers.

In 1982, the U.S.’s Reagan Administration used the Sherman Act to break AT&T into one long-distance company and seven regional “Baby Bells,” arguing that competition should replace monopoly for the benefit of consumers and the economy as a whole. Bell Labs was spun off from AT&T and became jointly owned by the Baby Bells as their development arm. However, competition between the Baby Bells led each to form their own development arms; and Bell Labs disappeared into history.

Summary

It took only about four decades for data-communication speeds to progress from a thousand bits per second to multimillion bits per second. Today’s Internet would not be very useful at DataPhone speeds, though I can remember having to live with such speeds to get my email in the late 1990s.

In fact, the DataPhone 103 technology lives on. DataPhone 103 modulation is still in use today in shortwave radio, amateur radio, and some commercial applications. Its low signaling speed and use of audio frequencies makes it suitable for noisy or unreliable narrowband links.

Every technology must have a beginning, and I am excited to have been part of that beginning.