Bits and Bauds

Here's an excerpt from The Modem Reference, written by Michael A. Banks and recommended by Jerry Pournelle in Byte, The Smithsonian Magazine, et al. The right to reproduce this article is granted on the condition that all text, including this notice and the notice at the end of the article, remain unchanged, and that no text is added to the body of the article. Thanks! --MB

BITS, BAUD RATE, AND BPS
Taking the Mystery Out of Modem Speeds
by Michael A. Banks

Modem transmission speed is the source of a lot of confusion, even among otherwise informed computer and modem users. The root of the problem is the fact that the terms "baud" and "bits per second" are used interchangeably and indiscriminately. I strongly suspect this is a result of the fact that it's easier to say "baud" than "bits per second," though misinformation has a hand in it, too.

If you've ever found yourself confused by the relationship between bits and baud rate, or if you think that a modem's baud rate is the same as the number of bits or characters it transmits per second, please read this article carefully; I guarantee to clear up the confusion and disabuse you of any false concepts ...

Bits per second (bps)

Bits per second is a measure of the number of data bits (digital 0's and 1's) transmitted each second in a communications channel. This is sometimes referred to as "bit rate." Individual characters (letters, numbers, etc.), also referred to as bytes, are composed of several bits. While a modem's bit rate is tied to its baud rate, the two are not the same, as explained below.

Baud rate

Baud rate is a measure of the number of times per second a signal in a communications channel varies, or makes a transition between states (states being frequencies, voltage levels, or phase angles). One baud is one such change. Thus, a 300-baud modem's

signal changes state 300 times each second, while a 600- baud modem's signal changes state 600 times per second. This does not necessarily mean that a 300-baud and a 600-baud modem transmit 300 and 600 bits per second, as you'll learn in a few lines.

Determining bits per second

Depending on the modulation technique used, a modem can transmit one bit--or more or less than one bit--with each baud, or change in state. Or, to put it another way, one change of state can transmit one bit--or more or less than one bit.

As I mentioned earlier, the number of bits a modem transmits per second is directly related to the number of bauds that occur each second, but the numbers are not necessarily the same.

To illustrate this, first consider a modem with a baud rate of 300, using a transmission technique called FSK (Frequency Shift Keying, in which four different frequencies are turned on and off to represent digital 0 and 1 signals from both modems). When FSK is used, each baud (which is, a gain, a change in state) transmits one bit; only one change in state is required to send a bit. Thus, the modem's bps rate is also 300:

300 bauds per second X 1 bit per baud = 300 bps

Similarly, if a modem operating at 1200 baud were to use one change in state to send each bit, that modem's bps rate would be 1200. (There are no1200 baud modems, by the way; remember that. This is only a demonstrative and hypothetical example.)

Now, consider a hypothetical 300-baud modem using a modulation technique that requires two changes in state to send one bit, which can also be viewed as1/2 bit per baud. Such a modem's bps rate would be 150 bps:

300 bauds per second X 1/2 baud per bit = 150 bps

To look at it another way, bits per second can also be obtained by dividing the modem's baud rate by the number of changes in state, or bauds, required to send one bit:

$$\frac{\text{300 baud}}{\text{2 bauds per bit}} = \text{150 bps}$$

Now let's move away from the hypothetical and into reality, as it exists in the world of modulation. First, lest you be misled into thinking that "any 1200 baud modem" should be able to operate at 2400 bps with a two-bits-per- baud modulation technique; remember that I said there are no 1200 baud modems. Medium- and high-speed modems use baud rates that are lower than their bps rates. Along with this, however, they use multiple-state modulation to send more than one bit per baud.

For example, 1200 bps modems that conform to the Bell 212A standard (which includes most 1200 bps modems used in the U.S.) operate at 300 baud and use a modulation technique called phase modulation that transmits four bits per baud. Such modems are capable of 1200 bps operation, but not 2400 bps because they are not1200 baud modems; they use a baud rate of 300. So:

300 baud X 4 bits per baud = 1200 bps

or

$$\frac{\text{300 baud}}{\text{1/4 baud per bit}} = \text{1200 bps}$$

Similarly, 2400 bps modems that conform to the CCITT V.22 recommendation (virtually all of them) actually use a baud rate of 600 when they operate at 2400 bps. However, they also use a modulation technique that transmits four bits per baud:

600 baud X 4 bits per baud = 2400 bps

or

$$\frac{\text{600 baud}}{\text{1/4 baud per bit}} = \text{2400 bps}$$

Thus, a 1200-bps modem is not a 1200-baud modem, nor is a 2400-bps modem a 2400-baud modem.

Now let's take a look at 9600-bps modems. Most of these operate at 2400 baud, but (again) use a modulation technique that yields four bits per baud. Thus:

2400 baud X 4 bits per baud = 9600 bps

or

$$\frac{\text{2400 baud}}{\text{1/4 baud per bit}} = \text{9600 bps}$$

Characters per second (cps)

Characters per second is the number of characters (letters, numbers, spaces and symbols) transmitted over a communications channel in one second. Cps is often the bottom line in rating data transmission speed, and a more convenient way of thinking about data transfer than baud- or bit-rate.

Determining the number of characters transmitted per second is easy: simply divide the bps rate by the number of bits per character. You must of course take into account the fact that more than just the bits that make up the binary digit representing a character are transmitted when a character is sent from one system to another. In fact, up to 10 bits may be transmitted for each character during ASCII transfer, whether 7 or 8 data bits are used. This is because what are called start- and stop-bits are added to characters by a sending system to enable the receiving system to determine which groups of bits make up a character. In addition, a system usually adds a parity bit during 7-bit ASCII transmission. (The computer's serial port handles the addition of the extra bits, and all extra bits are stripped out at the receiving end.)

So, in asynchronous data communication, the number of bits per character is usually 10 (either 7 data bits, plus a parity bit, plus a start bit and a stop bit, or 8 data bits plus a start bit and a stop bit). Thus:

$$\frac{\text{300 bps}}{\text{10 bits per character}} = \text{30 characters per second}$$

$$\frac{\text{1200 bps}}{\text{10 bits per character}} = \text{120 characters per second}$$

$$\frac{\text{2400 bps}}{\text{10 bits per character}} = \text{240 characters per second}$$

Common speeds

The most commonly-used communications rates for dial-up systems (BBSs and online services like CompuServe, DELPHI, and GEnie) are 300, 1200, and 2400 bps. A few older systems-- especially Telex systems--

communicate at 110 bps, but these are gradually going the way of the dinosaur. 4800 and 9600 bps modems are generally available, but few online services or BBSs accommodate them. This will be changing in the near future,

however, with the cost of high-speed modem technology decreasing as the demand for it increases.

Modems with even higher bps rates are manufactured (19,200 and up) but these are not used with dial-up systems; the upper limit on asynchronous data transmission via voice-grade telephone lines appears to be 9600 bps. The use of higher transmission rates requires special dedicated lines that are "conditioned" (i.e., shielded from outside interference) as well as expensive modulation and transmission equipment. #

If you found this article useful, you may want to pick up a copy of the book from which it was excerpted:

THE MODEM REFERENCE
by Michael A. Banks
Published by Brady Books/Simon & Schuster
ISBN # 0-13-586646-4 $19.95

In addition to explaining the technical aspects of modem operation, communications software, data links, and other elements of computer communications, the book provides detailed, illustrated "tours" of major online services such as UNISON, CompuServe, DELPHI, BIX, Dow Jones News/Retrieval, MCI Mail, and others. It also contains information on using packet switching networks and BBSs, as well as dial-up numbers for various networks and BBSs.

You'll also find hands-on guides to buying, setting up, using, and troubleshooting computer communications hardware and software. (And the book "supports" all major microcomputer brands.) For more information, contact:

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