cable. As computer systems became faster, application software emerged that used networks more frequently and therefore required higher bandwidth. **Local area networks** (LANs) also became more popular and had to be more reliable and easier to maintain.

In the past 10 years, more and more local area networks have been realized with twisted-pair cables. The primary advantages of twisted-pair cable compared with other wiring technologies are the low price and the wide availability. Using twisted pair, computers are no longer connected to a shared cable, but rather, to an Ethernet hub. There are several types of hubs: passive hubs, intelligent hubs, and switching hubs. Passive hubs serve simply as a conduit for the data, enabling it to flow from one computer to the other. Intelligent hubs contain additional hardware for monitoring the network traffic going through, helping the administrator to find errors inside the network more quickly. Switching hubs actually read the destination address of a network packet and forward them directly to the correct target. Twisted pair is becoming more and more popular and is, together with optical fiber, likely to become the main wiring technology to be used in LANs.

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—*Gerald Friedland*

Two's Complement

Numbers are represented in the **binary system** using strings of binary digits (**bits**). Digital computers operating with binary numbers can perform all necessary arithmetical operations. However, the question arises of how best to represent signed numbers in computers. One method would be to use two extra symbols (+ or −) to mark the positive and negative numbers. This would, however, require a bit of storage in memory. Computer architects realized early that there is a more efficient way of dealing with binary signed numbers: the two's-complement representation.

There are two ways of thinking about the two's-complement representation. When using it, a maximum number of bits for the numbers is defined in advance. Since computer memories work with, for example, 16-, 32-, and 64-bit words, this is a straightforward requirement. Assume for example that numbers will be processed using only eight bits. A two's-complement representation can be thought of as assigning weights 1, 2, 4, 8,16, 32, 64, and −128 to the eight successive bits from right to left. Notice that the last weight is negative. Using these weights, any decimal number between −128 and +127 can be represented. The number −128, for example, is just the binary string 10000000. The number −1 corresponds to the string 11111111 (eight ones). The reader can check that the weights of the bits, multiplied by the corresponding bit, lead to these numbers. Notice also that since the weight −128 is larger than the sum of all other positive weights, any number with a one in the most significant bit is negative, whereas any number with a zero is positive. We know immediately that the number 11110000 is negative, without having to perform any calculations.

The second way of thinking about two's-complement numbers is related to the way in which a positive binary number is transformed into the corresponding negative number. To transform the number 00000011 (a decimal 3) into −3, we do the following: Complement all eight bits of the original number and add a 1 to the result. In our case, the complement of the binary number 00000011 is 11111100 (every 1 is transformed into 0, and vice versa) . Adding a 1 yields 11111101, which is the two's-complement representation of −3, as the reader can check using the weights mentioned above.

When the binary representation uses more than 8 bits, the same approach is used, but only the most significant bit gets assigned a negative weight. All other weights, which are potencies of 2, are positive.

The main benefit of using the two's-complement representation is that subtraction of binary numbers can be reduced to addition. To subtract the number A from the number B, just complement A, add a 1, and add the result to B. The result is then B+(−A), that is, B−A, as desired. The arithmetical logical units of today's computers work in this way.

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