FIBRE CHANNEL (FC) - 1

FC-1: 8b/10b encoding, ordered sets and link control protocol

FC-1 defines how data is encoded before it is transmitted via a Fibre Channel cable (8b/10b encoding). FC-1 also describes certain transmission words (ordered sets) that are required for the administration of a Fibre Channel connection (link control protocol).

8b/10b Encoding

In all digital transmission techniques, transmitter and receiver must synchronise their clock-pulse rates. In parallel buses the clock rate is transmitted via an additional data line. By contrast, in the serial transmission used in Fibre Channel only one data line is available through which the data is transmitted. This means that the receiver must regenerate the clock rate from the data stream.

The receiver can only synchronise the rate at the points where there is a signal change in the medium. In simple binary encoding (Figure 3.11) this is only the case if the signal changes from ‘0’ to ‘1’ or from ‘1’ to ‘0’. In Manchester encoding there is a signal change for every bit transmitted. Manchester encoding therefore creates two physical signals for each bit transmitted. It therefore requires a transfer rate that is twice as high as that for binary encoding. Therefore, Fibre Channel – like many other transmission techniques – uses binary encoding, because at a given rate of signal changes more bits can be transmitted than is the case for Manchester encoding.

The problem with this approach is that the signal steps that arrive at the receiver are not always the same length (jitter). This means that the signal at the receiver is sometimes a little longer and sometimes a little shorter (Figure 3.12). In the escalator analogy this means that the escalator bucks. Jitter can lead to the receiver losing synchronisation with the received signal. If, for example, the transmitter sends a sequence of ten zeros, the receiver cannot decide whether it is a sequence of nine, ten or eleven zeros.

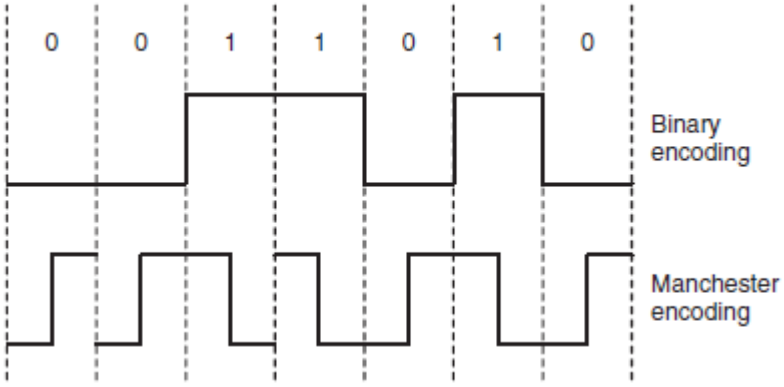

Figure 4.11 In Manchester encoding at least one signal change takes place for every bit transmitted.

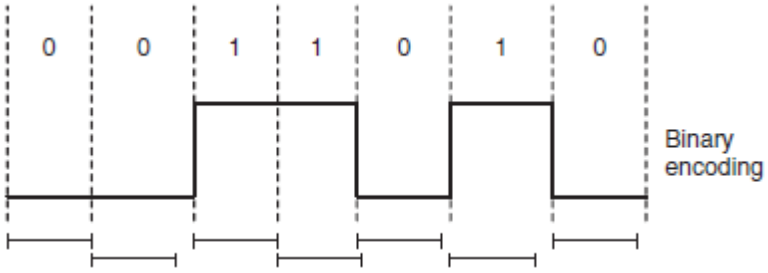

Figure 4.12 Due to physical properties the signals are not always the same length at the receiver (jitter).

If we nevertheless wish to use binary encoding, then we have to ensure that the data stream generates a signal change frequently enough that jitter cannot strike. The so-called 8b/10b encoding represents a good compromise. 8b/10b encoding converts an 8-bit byte to be transmitted into a 10-bit character, which is sent via the medium instead of the 8-bit byte. For Fibre Channel this means, for example, that a useful transfer rate of 100 MByte/s requires a raw transmission rate of 1 Gbit/s instead of 800 Mbit/s. Incidentally, 8b/10b encoding is also used for the Enterprise System Connection Architecture (ESCON), SSA, Gigabit Ethernet and InfiniBand. Finally, it should be noted that 1 Gigabyte Fibre Channel uses the 64b/66b encoding variant for certain cable types.

Expanding the 8-bit data bytes to 10-bit transmission character gives rise to the following advantages:

• In 8b/10b encoding, of all available 10-bit characters, only those that generate a bit sequence that contains a maximum of five zeros one after the other or five ones oneafter the other for any desired combination of the 10-bit character are selected. Therefore, a signal change takes place at the latest after five signal steps, so that the clock synchronisation of the receiver is guaranteed.

• A bit sequence generated using 8b/10b encoding has a uniform distribution of zeros and ones. This has the advantage that only small direct currents flow in the hardware that processes the 8b/10b encoded bit sequence. This makes the realisation of Fibre Channel hardware components simpler and cheaper.

• Further 10-bit characters are available that do not represent 8-bit data bytes. These additional characters can be used for the administration of a Fibre Channel link.

Ordered sets

Fibre Channel aggregates four 10-bit transmission characters to form a 40-bit transmission word. The Fibre Channel standard differentiates between two types of transmission word: data words and ordered sets. Data words represent a sequence of four 8-bit data bytes. Data words may only stand between a Start-of-Frame (SOF) delimiter and an End-of-Frame (EOF) delimiter.

Ordered sets may only stand between an EOF delimiter and a SOF delimiter, with SOFs and EOFs themselves being ordered sets. All ordered sets have in common that they begin with a certain transmission character, the so-called K28.5 character. The K28.5 character includes a special bit sequence that does not occur elsewhere in the data stream. The input channel of a Fibre Channel port can therefore use the K28.5 character to divide the continuous incoming bit stream into 40-bit transmission words when initialising a Fibre Channel link or after the loss of synchronisation on a link.

Link control protocol

With the aid of ordered sets, FC-1 defines various link level protocols for the initialization and administration of a link. The initialisation of a link is the prerequisite for data exchange by means of frames. Examples of link level protocols are the initialisation and arbitration of an arbitrated loop.