transmit a frame successfully, an average N_r transmission attempts will be required. We can modify the expression for link utilization, therefore, to give:

$$U = \frac{T_{ix}}{N_r T_{ix} + 2N_r T_p} = \frac{1}{N_r\left(1 + \frac{2T_p}{T_{ix}}\right)}$$

We can derive the value of N_r from a knowledge of the BER, P, of the link. If P is the probability that a bit will be corrupted then, if we assume random errors, the probability that a frame of length N_i bits is received without errors is given by:

$$P_f = 1 - (1 - P)^{N_i}$$

Hence the probability that a frame is received with errors is given by:

$$P_f = 1 - (1 - P)^{N_i}$$
$$\simeq N_i P \text{ if } N_i P \ll 1$$

For example, a BER of 10^{-4} means that, on average, 1 bit in 10^4 will be corrupted. Hence for, say, 1000-bit frames:

$$P_f = 1 - (1 - 10^{-4})^{1000} = 0.095$$

or

$$P_f = 10^3 \times 10^{-4} = 0.1$$

Now, if P_f is the probability that a frame is corrupted, then $(1 - P_f)$ is the probability that an uncorrupted frame will be received. Hence:

$$N_r = \frac{1}{1 - P_f}$$

For example, if $P_f = 0.5$, $N_r = 2$, that is, if on average 50% of the frames are corrupted, then each frame will have to be transmitted twice. This is so since 50% of the retransmitted frames will also be corrupted, assuming ACK-frames are not corrupted. Because of their short length relative to I-frames, this is a reasonable assumption. In practice, therefore, all the link efficiency values must be divided by N_r. That is:

$$U = \frac{1 - P_f}{1 + 2a}$$

The major advantage of the idle RQ scheme is that it requires a minimum of buffer storage for its implementation, since both P and S need contain sufficient storage for only one frame. In addition, S must retain only a record of the identifier of the last correctly received frame to enable it to detect duplicates. In general, the various retransmission schemes trade buffer storage requirements for transmission efficiency. Because of its low storage requirements, however, idle RQ is used extensively in applications that involve a relatively simple device (such as a terminal or personal computer) at one end of the link.