Overcoming Difficulties

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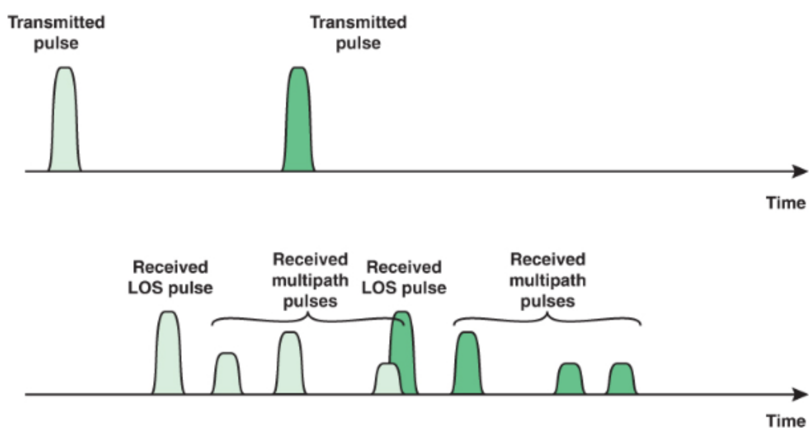
Contents

Now that some radio technologies have been presented in this Introduction to 5G, it will be easier to understand how those radio technologies overcome the difficulties of mobile radio presented in an earlier section.

Channel Correction

The difficulties of mobile radio listed in a preceding section are addressed here. Recall that radio signals can take multiple paths from transmitter to receiver, and that the resulting signal is greatly complicated by this multi-path transmission.

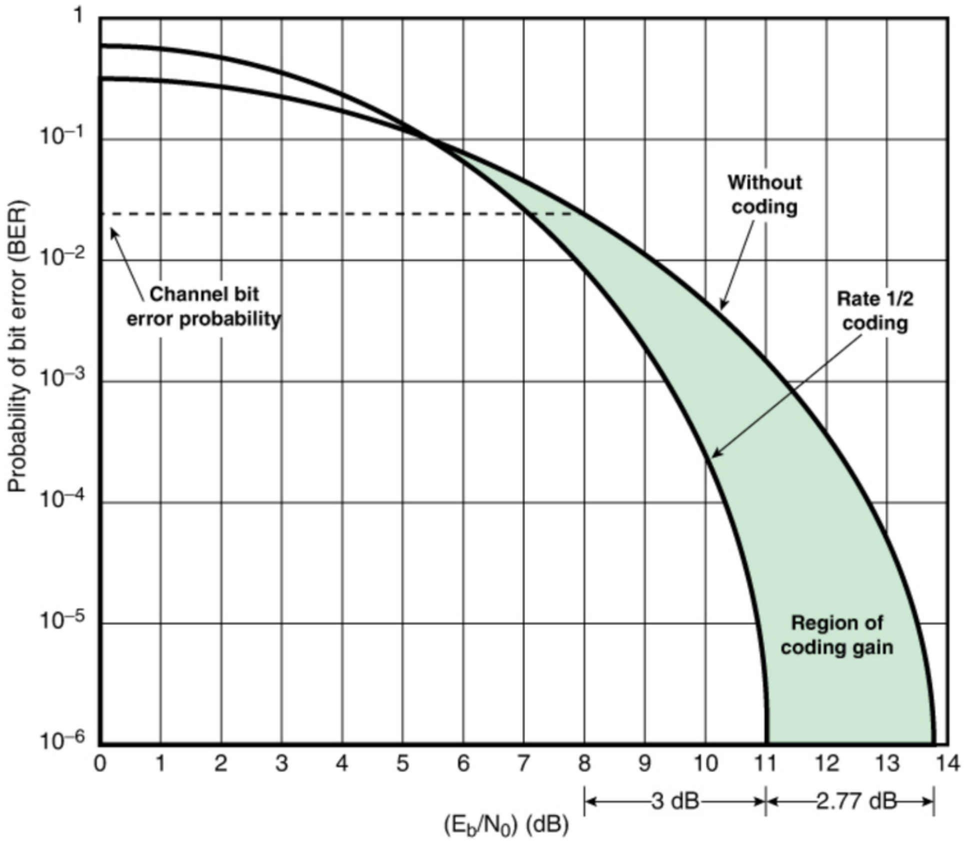


Adaptive Modulating and Coding

Modern systems measure the rate of received errors and communicate that information between transmitters and receivers. This allows rapid changing of modulating and coding schemes. For example, a radio bearer might be using 64-QAM and getting a high error rate, so it drops to 16-QAM. Changes like this can take place very rapidly, even hundreds of times per second. This can help the system deal with fast fading.

Forward Error Correction

Error correction techniques like check digits and Hamming coding are applied in digital radio transmission systems. The term “forward” indicates that the error correction is done at the receiver end using only received data. (There is no retransmission request.) To do this, more bits must be sent than the number of data bits. In mobile radio the ratio of total bits sent to data bits sent is 2 to 3. This is high, but as stated previously, mobile radio must overcome substantial difficulties. The diagram below shows that, above a threshold, a lower E_b/N_0 is required to achieve the same error rate if that ratio is 2. This is despite the fact there are twice as many opportunities for errors since twice as many bits are sent. This is why below a certain E_b/N_0 the error rate is actually higher with error correction. This is among the reasons that adaptive coding is needed.



There are two forward error correction (FEC) schemes presented in 3GPP specification for 5G:

- low density parity check (LDPC)
- polar code

These FEC schemes are too technical for this Introduction to 5G.

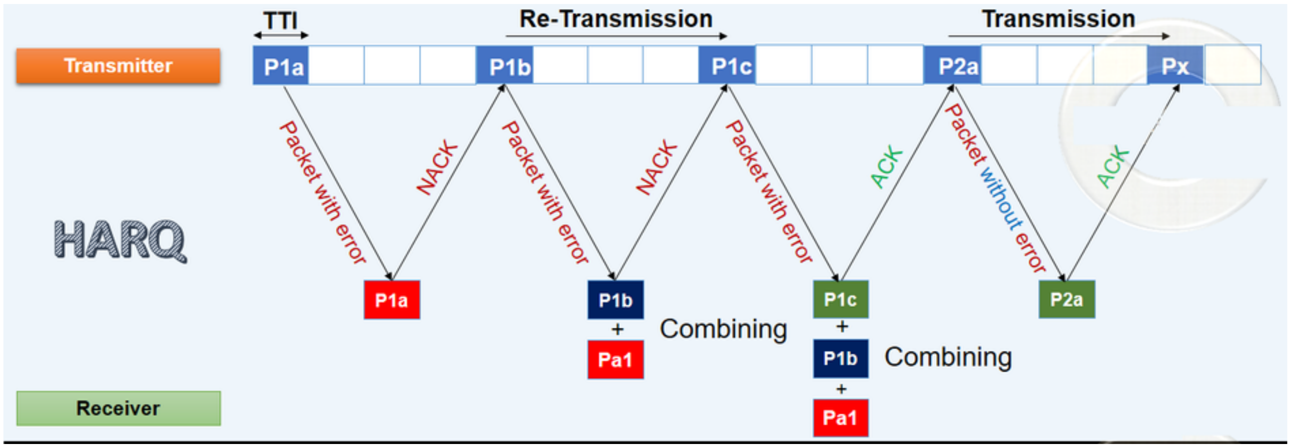
HARQ

Use of a FEC might be less than enough, or more than enough to deal with the bit error rate of transmission, and that status might rapidly change.

When a forward error correcting scheme is unable to correct a detected error, the retransmission is requested. This combination Automatic Repeat reQuests (ARQ) and FEC is called hybrid-ARQ (HARQ).

There are often add ons to HARQ, like retaining the packet that could not be corrected and comparing it with it's retransmission, assigning probabilities of various correction possibilities, etc. There is even a mechanism to detect and utilize when the FEC is more than necessarily for the current signal to noise ratio channel quality information (CQI) can signal that it is safe to reduce the transmission bit rate by deleting bits that the system is certain the FEC can correct. This scheme is called puncturing.

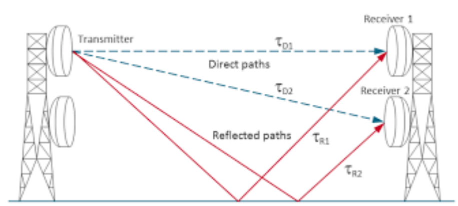
In the image below, packet 1 (P1) has too many errors to be corrected in its first two transmissions (P1a, P1b). So, for each of these the receive sends back a "not acknowledged" message (NACK). However, on the third transmission of the packet (P1c) there may still be errors, perhaps too many errors for the FEC to correct. However, the system compares and combines P1a, P1b, and P1c, and with the information from this comparison is able to correct P1. An acknowledgment message for P1 is then sent back, and the transmitter sends the next packet, P2.



Since waiting for acknowledgement can be time consuming, parallel HARQ mechanisms are often set up in a scheme called N-channel stop and wait.

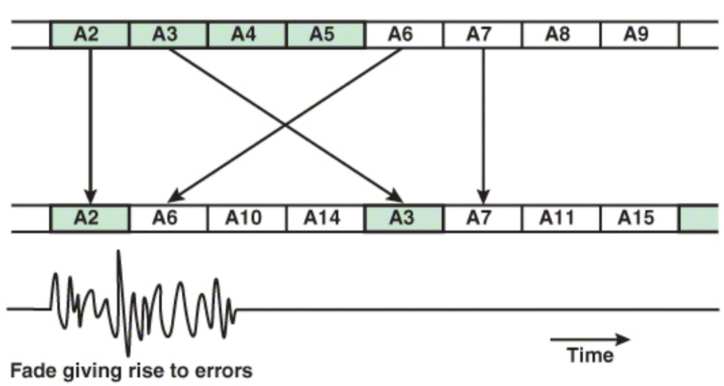
Space Diversity

Consider several receiving antennas that are spatially separated. The multi-path effects to each antenna are different, if the antennas are sufficiently far apart. The transmitted signal can then be recovered by analyzing what received signal from the multiple antennas have in common.



Time Diversity

If temporary noise, or temporary fading due to slow fading reduces the signal to noise ratio for a time, then the information transmitted in that time will have a high error rate. If too many of the bits transmitted in a time interval are in error then error correcting codes can not correct the errors. So, in anticipation of such temporary moments, consecutive bits of data are shuffled so that they are no longer consecutive before transmission. Thus, the when the bits are received and put back in their original order, it is not consecutive bits, but rather spread out bits, that are corrupted. This allows error correcting codes to deal with the errors from the temporary problem. Of course, this shuffling causes delay.



Frequency Diversity

OFDM takes a single stream of bits and splits it up into streams on and different frequencies. Those frequencies are called subcarriers. This spreading out over frequencies reduces the required bit rate for each stream; each subcarrier carries a trickle of information. This greatly reduces the difficulty of extracting digital signal from radio signal.

Also, DFT-S-OFDM spreads the subcarriers over a greater frequency range with silent subcarrier frequencies in between. This also reduces the difficulty of extracting digital signal. This is an example of a class of techniques called “spread spectrum” that dates back to 2G systems.

Key Enablers

The following are listed as key enablers for 5G radio technology.

- scalable numerology
    - six combinations of subcarrier spacings and TTIs (compared to on e option in 4G) each with options for number of symbols per slot
    - adjustment of which subcarrier frequencies are in use via DFT-S-OFDM
- ultra lean design
    - reduced always on transmission
        - to reduce overall energy use
        - support for low powered IoT devices
    - beam-forming centric in for both control and user plane communication to
        - reduce energy use
        - reduce interference
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    -
- support for low latency
    - with mini-slots
- spectrum expansion
- forward compatibility