The Essential Merit of Bit-Swapping

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Abstract

Bit-swapping is the essential adaptive hand-shaking mechanism used by DMT modems to adapt to line changes. This document shows that:

1. the bit-swap protocol in ADSL standards is resilient to errors, even if entire acknowledgement commands are lost.
2. Bit-swap is essential to viable operation of so-called "lite" DSL modems as well as "heavy" DSL modems.

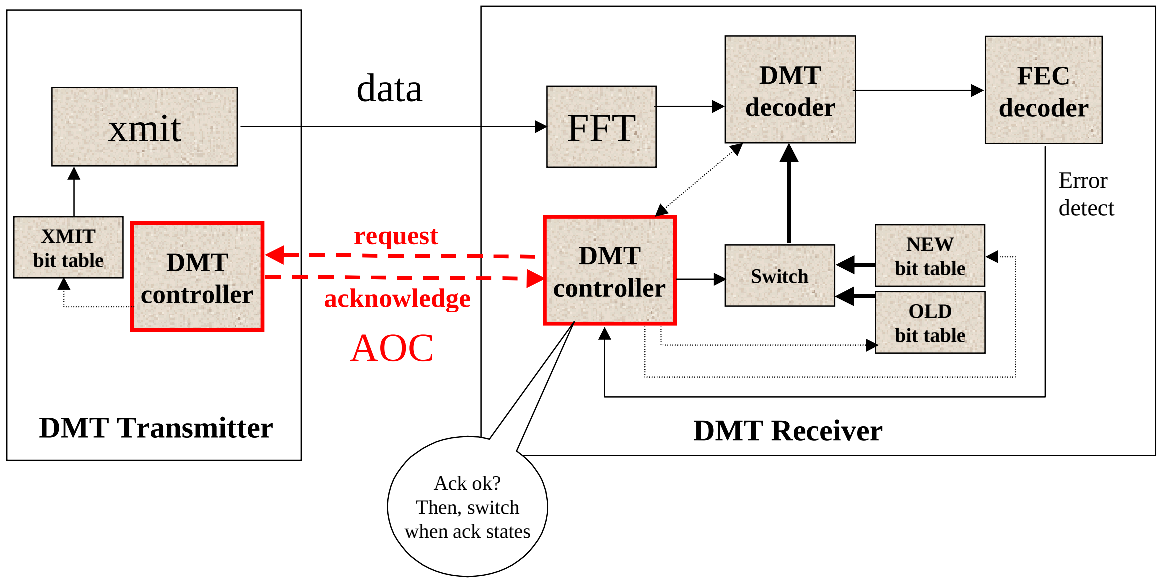
1. Resiliency

The bit-swap protocol is resilient to loss of hand-shake commands. A situation recently suggested as a "flaw" in bit-swap suggests that bit errors caused by large impulses can cause a bit-swap acknowledgement to be ignored. This is not true in the implementation of Figure 1:

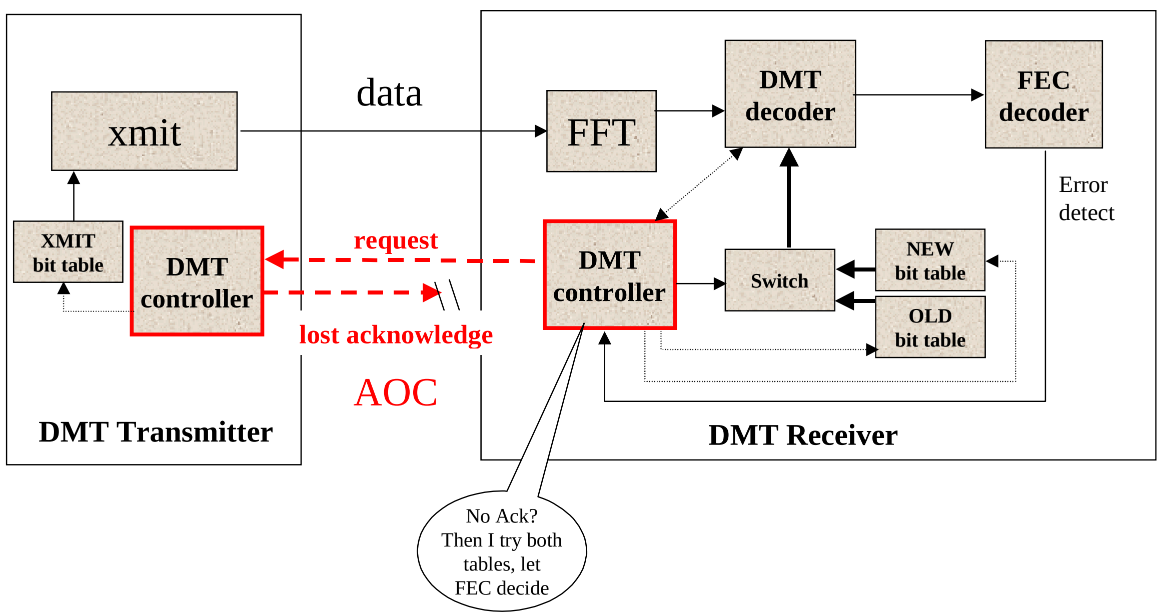
In this implementation, the receiver initiates a swap of a bit from tone *m* to tone *n* through the AOC DMT-control channel shown (this channel is actually embedded in the data channel, but shown separately for illustration in Figure 1. A bit-swap "request" command is sent from the receiver to the transmitter through a heavily protected reverse "AOC" channel.[1] The transmitting modem then "acknowledges" the request through the forward "AOC" channel and specifies a time for the new bit table to be implemented. If either command is not received for any reason, the receiver can simply monitor the incoming signal using two bit tables (this can be implemented simply in several fashions), OLD and NEW. The FEC corrected/detected error flag (syndrome) can be monitor which of the tables, OLD or NEW, is correct. The receiver then knows whether the swap was implemented by the transmitter or not, even if one or both of the AOC commands could not properly traverse the channel.

Bit swap implementations can thus be fully resistant to AOC channel errors.

[1] The AOC channel uses a triple match (out of 5 tries) protocol with 16 bit header, which even when the channel bit rate is a coin/flip probability of ½ leads to a probability of false command receipt of once in billion years if the phone in splitterless DSL rang every minute for those billions of years. (False commands do not occur in practice – the only possibility is a missed command.)



a). Bit swap with AOC functioning properly – Receiver DMT controller switches to new bit table at time specified by AOC acknowledgement.



b). Bit swap with lost AOC acknowledgement – Receiver DMT controller tries both switch settings using the FEC decoder correct/errors detect to arbitrate.

Figure 1 – Illustration of for functional and disfunctional AOC.

2. Necessity of bit swap

Bit-swap is an essential feature of a DMT DSL modem. A simple situation is illustrated in the figures below for a 4.25 km 26-gauge twisted pair. One bit distribution corresponds to the DSL being the first one deployed/used in a cable. The second distribution corresponds to the new bit distribution that is best when one crosstalking DSL is used. This crosstalker is an HDSL, but one could readily produce similar results for other types of crosstalkers and/or noises. The 1.5 Mbps data rate is readily achieved with the HDSL crosstalker both when the bit distribution is properly optimized for 0 crosstalkers (34 dB margin) or for 1 crosstalker (19.3 dB margin).

However, if the original crosstalk-free bit distribution were to be maintained after the single HDSL crosstalker turned on, then the margin is **NEGATIVE 6dB,** (-6 dB). This results in unnecessary retraining of the modem and loss of service. The performance loss is over 25 dB if bit-swap is not used (19.3 dB – (-6 dB)= 25.3 dB). Bit-swapping by contrast allows the first modem to vary its bit distribution to the new optimum bit distribution, allowing a full 19.3 dB of margin to be achieved. This process is seamless, almost always without errors and always without service interruption for retraining. There are many other types of crosstalk and other noise examples that lead to bit-swapped correction of the DMT distribution. This realistic example simple shows one case in which bit-swap is necessary for restoration of margin and continued flawless operation of the DMT modem. There are many other similar cases that could be produced.

Clearly, Bit-swap is essential for DMT-based DSLs.

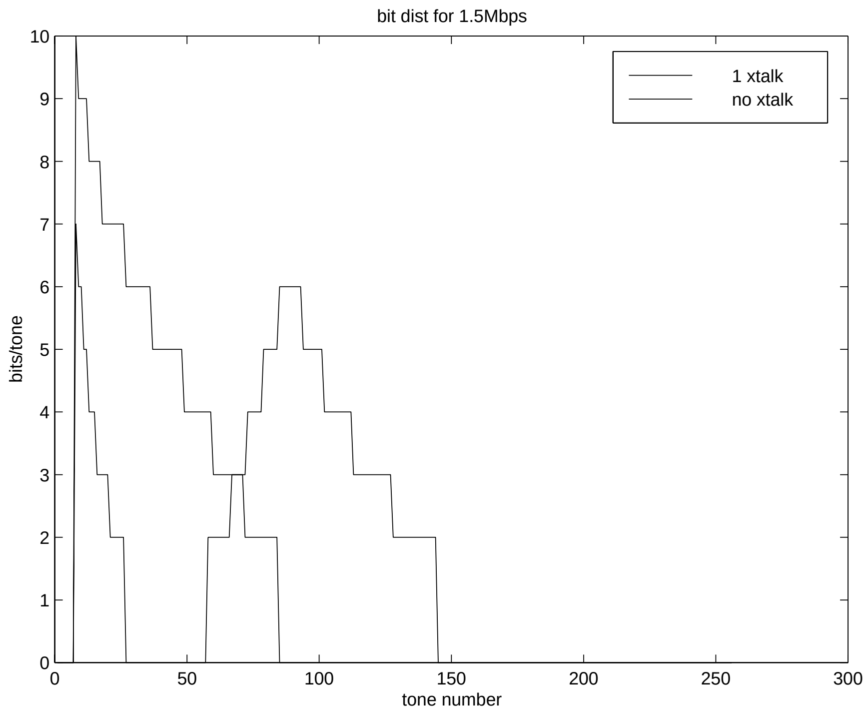


Figure 2 – Optimized bit distributions for 0 crosstalkers and 1 crosstalker on 4.25 km 26-gauge twisted pair (xtalk is HDSL, background noise is –140 dBm/Hz).

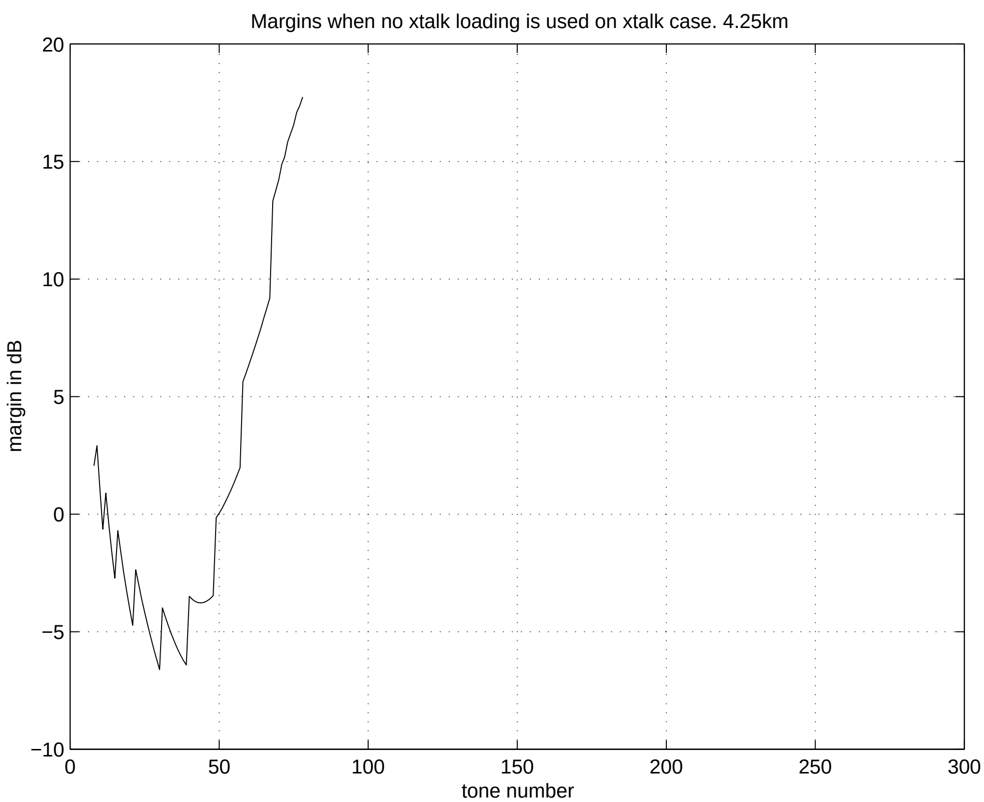


Figure 3 – Margin for NO SWAPPING when the crosstalker is turned on.