# *-ZyXEL White Paper-*

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## xDSL Dynamic Adaptation to varying noise conditions on the loop

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## 1. Introduction

This ZyXEL White Paper provides the reader with a brief introduction to the on-line reconfiguration (OLR) techniques employed by xDSL COE and CPE equipment to cope with varying noise conditions on the local loop.

## 2. Noise Types in the Loop Environment

The noise environment on a local loop can be split into a static, and a transient part.

### 2.1. Static noise

The static part is taken into consideration at the initialization of the link, and no dynamic adaptation is necessary for this type of noise. Examples of static noise:

- Crosstalk from adjacent pairs in the cable binder.
- Background or cosmic noise (this noise type comprises the noise floor defined in ITU to be -140 dBm/Hz used for performance measurements).
- Internal noise from the device itself (Typically noise from on-board SMPS)
- Quantization noise in the ADC (analogue-to-digital converter).

### 2.2. Transient noise

The second part of the noise is the transient noise. Since transient noise is dynamic by nature, this noise cannot be taken into consideration when initializing the link[1], but have to be taken care of on-the-fly using OLR techniques. Examples of transient noise are:

- The noise that a defect refrigerator emits whenever the compressor starts.
- Lightening transients (not direct strike – That would certainly cause more problems than a mere retrain of the link…)
- Another user turns on equipment connected to an adjacent pair in the cable binder, causing the crosstalk noise level to increase.
- Micro-interruptions (very short-duration breaks in the loop – usually due to temperature variations or mechanical vibrations).

## 3. Overview of OLR methods

On-Line Reconfiguration (OLR) can be defined as an umbrella of methods used to change certain parameters on an ADSL link without causing a retrain of the link.

OLR is really an ADSL2 term – in ITU-T G992.1 (traditional ADSL) the term On-Line Adaptation was used, but since the functionality is the same I choose to use the term OLR for both ADSL and ADSL2 throughout this document.

### 3.1. Bit Swapping

Bit swapping enables an ADSL system to change the numbers of bits assigned to a sub carrier, or to change the energy transmitted by a sub carrier without interrupting the data flow. Bit swapping is the only OLR method supported by ADSL. Bit swapping reallocates the bits between sub carriers (see Figure 1) so in effect a bit swap will never affect the overall bit rate of the link.

Bit swapping procedures for up- and downstream directions are independent, and may occur simultaneously. Support for bit swapping is a mandatory functionality for ADSL2(+) devices, as well as VDSL2 devices, but optional for ADSL devices.

[1] Actually one could say that the target SNR margin (usually 6 dB) to some extent takes dynamic noise phenomena into consideration, however this is not really the case for narrow spectrum noise, which can completely destroy the margin on a single sub carrier without significantly affecting the average SNR margin.

The benefit of bit swapping is that the link can adapt to varying noise conditions on the loop by reallocating bits from sub carriers with degraded SNR margin to sub carriers with excess SNR margin. The process of performing a bit swap involves some communication and synchronization between receiver and transmitter, which can take some hundreds milliseconds, which means that if the noise transition is faster than this, some CRC errors can occur before the link has been adapted to the new noise scenario.

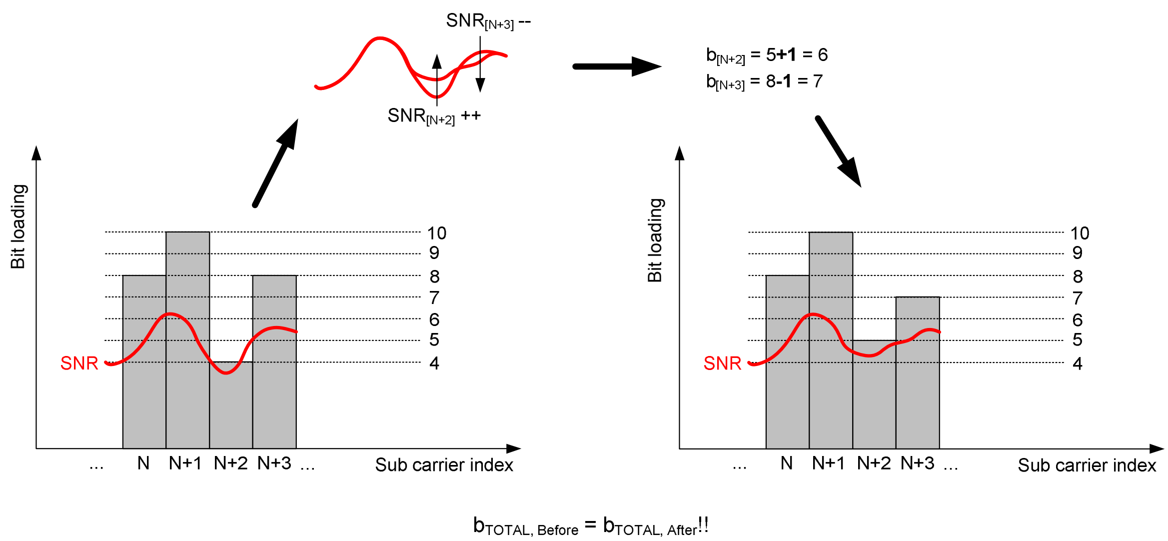


**Figure 1: Example of a bit swap. Noise on sub carrier N+2 decreases, while noise on sub carrier N+3 increases. This result in one bit being reallocated from sub carrier N+3 to sub carrier N+2.**

Bit swapping is always initiated by the receiving end, i.e. for downstream the CPE initiates bit swapping, and for upstream the COE initiates bit swapping. Support for bit swap is mandated by the ITU standards, and the procedure for requesting a bit swap as well as the needed synchronization is also described here. The exact algorithm used in the receiver to decide whether a bit swap is needed or not is vendor discretionary, which accounts for some differences in behavior between different chipsets.

Since bit swapping is an autonomous functionality, there are no higher-layer management primitives defined to control the functionality.

## 3.2. Dynamic Rate Repartioning

When a line is configured to use multiple latency paths, DRR (Dynamic Rate Repartitioning) can be used to change the data rate allocation between the latency paths without interrupting the data flow. Increasing the data rate on one latency path means decreasing the data rate on another latency path, and hence DRR does not affect the total bit rate of the link.

DRR is optional for ADSL2(+), and for VDSL2 the functionality is ‘for further study’. DRR is not supported by ADSL. Since DRR is used in response to higher-layer commands, the chipsets support the underlying functionality but it is up to the system integrator to implement the needed management features to control the functionality. Support for DRR is communicated between CPE and COE during the initialization phase.

Besides reallocation of data rate between latency paths, DRR also support changes to bit allocation and fine gain between sub carriers, i.e. bit swapping.

Assuming that a service provider use multiple latency paths to separate different types of traffic, e.g. IPTV from 'normal internet', an application of DRR could be used to dynamically reallocate data rate from the IPTV service to the internet service when the subscriber is not watching TV. The opposite direction could also be used where the link rate is 'under-provisioned', e.g. a service of 4 Mbps internet + IPTV where the IPTV service require 20 Mbps, but the link can only sustain a 22 Mbps bit rate. Here DRR can be used to allocate bit rate from the internet service when the subscriber watches TV.

## 3.3. Seamless Rate Adaptation

Seamless Rate Adaptation (SRA) is used to reconfigure the total data rate of a line by modifying framing parameters as well as bit loading and fine gains on sub carriers.

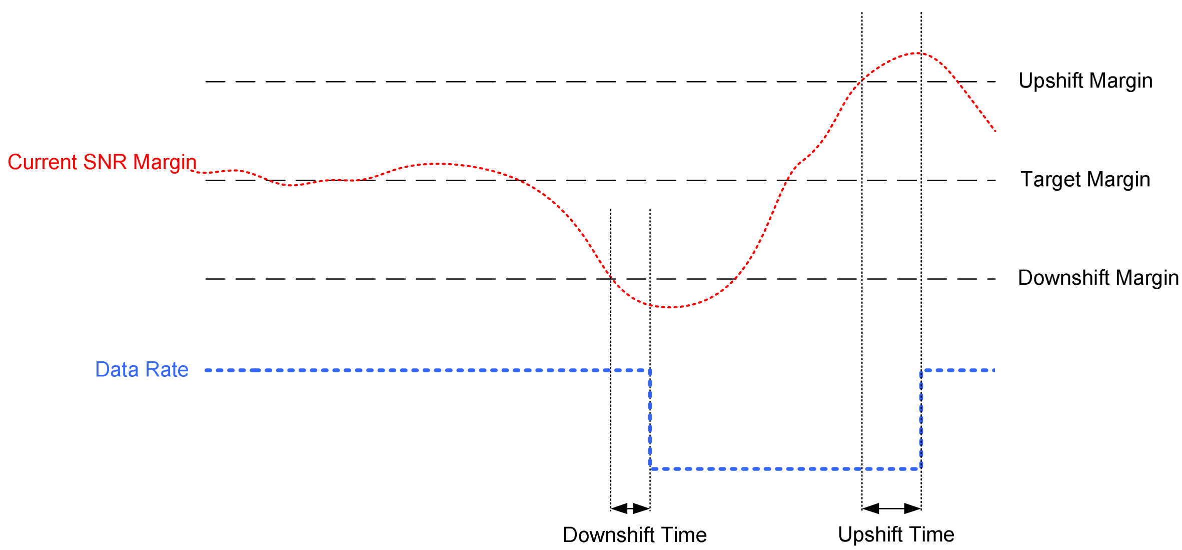


**Figure 2: SRA functionality described. The overall data rate is decreased and increased autonomously in order to keep the current margin close to the target margin.**

Four management parameters are defined for SRA:

- Upshift Margin: Threshold for increasing the data rate.
- Upshift Time: Minimum time for which Current SNR > Upshift Margin.
- Downshift Margin: Threshold for decreasing the data rate.
- Downshift Time: Minimum time for which Current SNR < Downshift Margin.

If the current SNR margin drops below the defined threshold (downshift margin) for a predefined time (downshift time) the data rate is reduced in order to increase the margin. Similarly if the margin increases above "Upshift Margin" for at least "Upshift Time" the data rate is increased.

Using this functionality the link can be trained to the maximum acheivable data rate, and the link will in SHOWTIME automatically adapt to changing line conditions without interrupting the data flow.

Furthermore SRA is used in relation with the Fast Retrain algorithm defined for ADSL2, where the training time (the time it takes the link to enter SHOWTIME) is kept very short. This type of initialisation saves time by making faster (and less accurate) loop and noise estimation. Therefore

SRA is used, after the link has entered SHOWTIME, to ‘fine-tune’ the link parameters to ensure a long-term stable link.
SRA is supported by ADSL2(+) and for further study for VDSL2. ADSL does not support SRA, but a similar functionality was indeed specified by ITU in G.992.1, called DRA (Dynamic Rate Adaptation). This functionality however was never really widely used, so few chipsets supported this, and the interoperability between chipsets was poor.

Some ADSL deployments used a quasi-static rate adaptation scheme where the same four parameters (up/down shift time/margin) was used, but a change in data rate involved a retrain of the link.