OFDM (DMT) Bit and Power Loading for Unequal Error Protection

Werner Henkel and Khaled Hassan

School of Engineering and Science International Universities Bremen (IUB)

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- The different error sensitivities of different communication devices, e.g.,
- Matching the channel variations to enhance performance and

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- \Diamond Matching the channel variations to enhance performance and throughput.

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Advantages of UEP Physical Transport

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Advantages of UEP Physical Transport

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Advantages of UEP Physical Transport

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Advantages of UEP Physical Transport

Why UEP physical transport?

- Reduce effort and complexity
- Arbitrary performance steps

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Bit-Loading Algorithms

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Bit-Loading solutions:

- Optimum: add bits to the locations of minimum incremental power, e.g.: Hughes-Hartogs and Campello
- Sub-optimum: based on Shannon capacity (Chow et. al.) or Lagrange-optimization (Fischer-Huber and Yu-Willson)

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Bit-Loading by Chow et. al.:
\n
$$
b_k = \log_2\left(1 + \frac{\text{SNR}_k}{\gamma}\right)
$$

Bit-Rate Maximization Problem:

$$
\max_{b \in \mathbb{Z}} \left\{ B_{\text{tot}} = \sum_{k=0}^{N-1} b_k \right\}
$$

subject to
$$
\sum_{k=0}^{N-1} P_k(b_k) < P_T,
$$

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Quantization Error:

$$
\hat{b}_k = \lfloor b_k + 0.5 \rfloor_0^{b_{\text{max}}}
$$

$$
\Delta b_k = b_k - \hat{b}_k
$$

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UEP: Bit-Loading Proposed UEP Bit-Rate Maximization

Modifications to Bit-Loading by Chow et. al.

Problem definitions

- *N_g* levels of protections with noise margins γ*j*
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- Target-rates T_j for each class
- \bullet Over all target bit-rate B_T

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SNR-sorting

- SNRs have to be allocated to *Ng* levels.
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SNR-sorting

- SNRs have to be allocated to N_g levels.
- Allocate important data to weaker subcarriers to protect them against non-stationary noise.

- **C** Compute b_{ki} using γ_i
-
- \bullet
- \bullet
- \bullet

Input: $\mathsf{SNR}_{k,j}$ in k^{th} subcarrier of j^{th} class, *N*, *Ng*, *BT* , *Tj* , and ∆γ **Output:** γ*j* , average probability of error \mathscr{P}_{ej} , and bit-loading

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- **•** Compute b_{ki} using γ_i $(γ_i = γ₀ - j \cdot Δγ)$.
-
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Input: SNR $_{k,j}$ in k^{th} subcarrier of j^{th} class, *N*, *Ng*, *BT* , *Tj* , and ∆γ **Output:** γ*j* , average probability of error \mathscr{P}_{ej} , and bit-loading

- **Compute** b_{ki} using γ_i (γ*^j* = γ⁰ −*j*·∆γ).
- Adjust *M_j* iteratively, if $∑_{k,j} b_{k,j} < T_j$
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- If $B_{tot} \neq B_T$, $\gamma_{0,new} = \gamma_{0,old} \cdot 2^{\frac{B_{tot}-B_T}{N}}$
- \bullet
- The power is allocated according

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ADSL2*plus* with 512 subcarriers is considered for this channel.

- A wireline cable of diameter 0.4
- \bullet A combination of T1 + HDSL
- \bullet

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- ADSL2*plus* with 512 subcarriers
- A wireline cable of diameter 0.4 mm and 2 km length is assumed.
- \bullet A combination of T1 + HDSL
- **•** Additionally, real measured

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- ADSL2*plus* with 512 subcarriers
- A wireline cable of diameter 0.4
- A combination of T1 + HDSL NEXT and −130 dBm/Hz AWGN is used for the bit-loading.
- **•** Additionally, real measured

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- \bullet
- A wireline cable of diameter 0.4
- \bullet A combination of T1 + HDSL
- Additionally, real measured impulse noise is introduced after bit allocation.

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Simulation Results UEP Performance: SER Analysis

SER for Stationary and Non-stationary Noise

SER for stationary noise SER for non-stationary noise

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UEP bit-loading and power-allocation:

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SNR-Sorting Scheme Inverse SNR-Sorting Scheme

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Conclusions

- We described an UEP bit-allocation scheme as an extension of the algorithm by Chow et al..
- **Allows arbitrary margin**
- SNR-sorting will ensure that the

Modified bit-loading:

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- **Allows arbitrary margin** definitions and bit-rates according to the priorities.
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10 non-UEP (2304 bits) 10^1 y, (1408 bits) 10^{\degree} V₀ (128 bits) £ 10 γ. (768 bits) 10^1 non-UEP Chow-Cinff **IFP SNR-sorting** UEP inver. SNR-sorting 10 10 15 20 25 SNR [dB]

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2304 bits/DMT frame - T_n = 128, T₁ = 768, T_n = 1408

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- SNR-sorting will ensure that the high-priority class will still be well protected even under non-stationary noise.

$\overline{10}$ 10^{-1} 1_n $\frac{\alpha}{22}$ 10 $-\bullet - \gamma_0$ SNR-sorting **B** y, SNR-sorting $-\theta - y_2$ SNR-sorting \leftarrow - γ_0 inver. SNR-sorting + - y, inver. SNR-sorting -*- - y., inver. SNR-sorting = = pure Chow-Ciof 16 18 20 22 24 26 28 SNR

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SER with impulse noise

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Open points:

Possible mixed allocation and hierarchical modulation.

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Thank you!

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