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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Outline





Why Unequal Error Protection (UEP)?

- Why UEP Physical Transport?
- 2 UEP: Bit-Loading
 - Previous Work
 - Proposed UEP Bit-Rate Maximization
- 3 Channel Model
 - Noise Environment
- 4 Simulation Results
 - UEP Performance: SER Analysis
 - Bit and Power Loading

5 Conclusions

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Realizing UEP



- Source encoders of some applications deliver data of different importance.
- ♦ The different error sensitivities of different communication devices, e.g., PDAs, laptops, ···.
- Matching the channel variations to enhance performance and throughput.

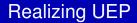
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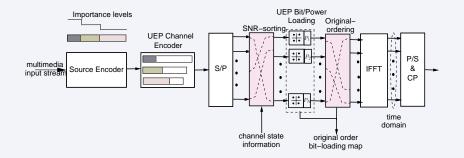
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Motivations W

Why UEP Physical Transport?

Advantages of UEP Physical Transport





Why UEP physical transport?

- Reduce effort and complexity
- Arbitrary performance steps

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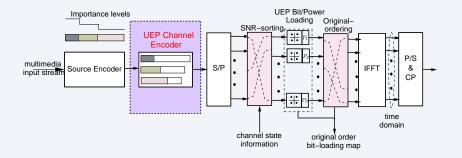
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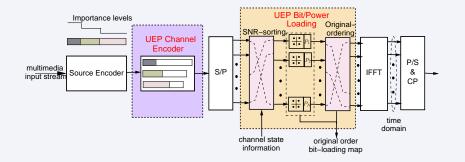
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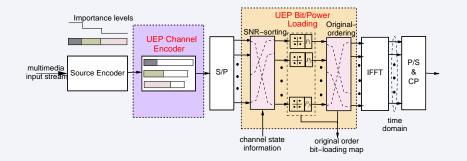
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Bit-Loading Algorithms



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.:
$$b_k = \log_2\left(1 + \frac{\mathsf{SNR}_k}{\gamma}\right)$$

Bit-Rate Maximization Problem:

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

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

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Quantization Error:

$$egin{array}{rcl} \hat{b}_k &=& \lfloor b_k \!+\! 0.5
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Proposed UEP Bit-Rate Maximization

Modifications to Bit-Loading by Chow et. al.



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Problem definitions

- N_g levels of protections with noise margins γ_j
- Noise margin step size $\Delta \gamma_i$
- Target-rates T_j for each class
- Over all target bit-rate B_T

$$\begin{array}{lll} b_{k,j} &=& \log_2\left(1+\frac{\mathrm{SNR}_{k,j}}{\gamma_j}\right) \\ \hat{b}_{k,j} &=& \lfloor b_{k,j}+0.5 \rfloor_0^{b_{\max}} \\ \Delta b_{k,j} &=& b_{k,j}-\hat{b}_{k,j} \end{array}$$



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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 points.

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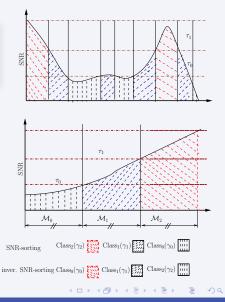
SNR-sorting

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Input: SNR_{*k,j*} in *k*th subcarrier of *j*th class, *N*, *N_g*, *B_T*, *T_j*, and $\Delta \gamma$ **Output:** γ_j , average probability of error $\overline{\mathscr{P}}_{ej}$, and bit-loading

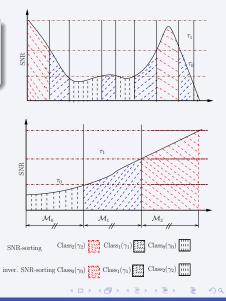
- Compute b_{kj} using γ_j $(\gamma_j = \gamma_0 - j \cdot \Delta \gamma)$.
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- If B_{tot} ≠ B_T again, add or subtract bits according to Δb_k.
- The power is allocated according to \$\overline{\mathcal{P}_{ej}}\$





Input: SNR_{k,i} in k^{th} subcarrier of j^{th} class, N, N_g , B_T , T_j , and $\Delta \gamma$ **Output:** γ_i , average probability of error $\overline{\mathcal{P}_{e_i}}$, and bit-loading

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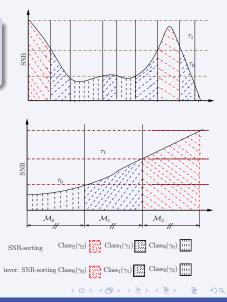


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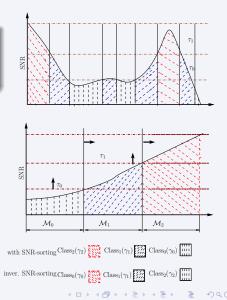
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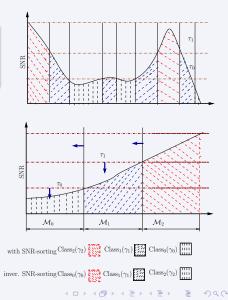
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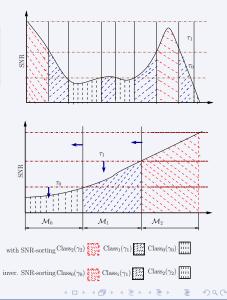
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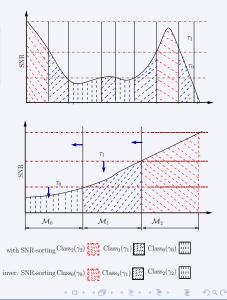
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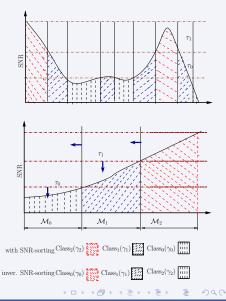


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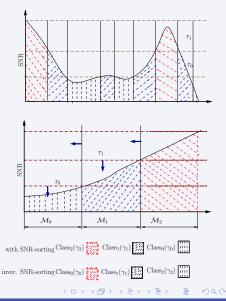


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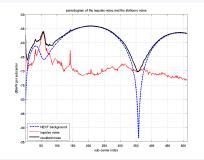
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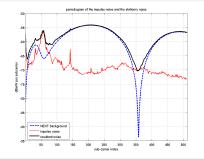


 ADSL2plus with 512 subcarriers is considered for this channel.

- A wireline cable of diameter 0.4 mm and 2 km length is assumed.
- A combination of T1 + HDSL NEXT and -130 dBm/Hz AWGN is used for the bit-loading.
- Additionally, real measured impulse noise is introduced after bit allocation.

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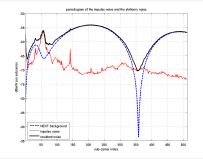
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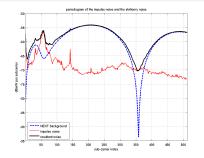
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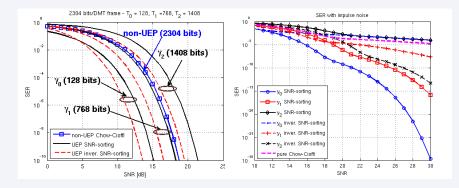
Simulation Results UEP Performance: SER Analysis

SER for Stationary and Non-stationary Noise



SER for stationary noise

SER for non-stationary noise

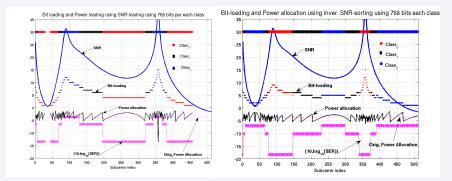


UEP bit-loading and power-allocation:



SNR-Sorting Scheme

Inverse SNR-Sorting Scheme



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- We described an UEP bit-allocation scheme as an extension of the algorithm by Chow et al..
- Allows arbitrary margin definitions and bit-rates according to the priorities.
- SNR-sorting will ensure that the high-priority class will still be well protected even under non-stationary noise.

Open points:

Possible mixed allocation and hierarchical modulation.

Modified bit-loading:

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2304 bits/DMT frame - To = 128, T, =768, To = 1408 10 non-UEP (2304 bits) 10-2 γ. (1408 bits) 10 y, (128 bits ŝ .6 10 γ. (768 bits 10 non-LIEP IEP SNR-sorting EP inver, SNR-sorting 10 10 15 20 25 SNR [dB]

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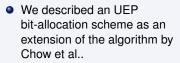
SER with impulse noise 10 10 10.1 ti 10 🖸 y, SNR-sorting -v. SNR-sorting v., inver. SNR-sorting -x - y, inver. SNR-sorting pure Chow-Ciof 18 20 24 26 28 SND

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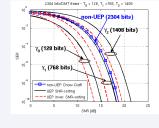
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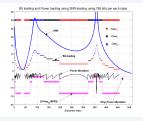
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