

# Adaptive Bit Loading

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Author/ Email: Hesham ElBakoury

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# GOAL

**The goal of the presentation is to identify areas for further Task Force study in order to support Adaptive Bit Loading in EPoC.**

# AGENDA

- **Adaptive Bit loading definition and advantages.**
- **Requirements of Adaptive Bit Loading.**
- **Adaptive Bit Loading Algorithms**
  - Example.
- **Unicast Bit Loading for US and DS.**
- **Areas of Study for the EPoC Task Force.**
- **References**

# Adaptive Bit Loading

- In adaptive Bit-loading the number of bits that can be transmitted in each subcarrier is determined by the SNR on the subcarrier.
  - According to Shannon's theorem we should be able to get more bps/Hz using subcarriers that have higher SNR.
  - SNR varies from user to user on the same subcarrier and also varies over time.
  - Channel utilization and data rate can be significantly improved by using adaptive bit loading.

# Downstream SNR Distribution of Cable Modems

- Comcast ran an experiment where downstream SNR is measured by 20 million cable modems.
- 2.4% of cable modems have SNR 40 dB or better
- 97.6% of cable modems report SNR less than 40 dB
- Since a small percentage of modems have SNR below 33 dB and a small percentage of modems have SNR above 40 dB, a single modulation and coding scheme will either lose many modems or under utilize many modems.

# Variation of SNR below 25MHz

Frequency Range	SNR
5-10 MHz	15 dB
10-15 MHz	25 dB
15-20 MHz	25 dB
20-25MHz	30 dB

- ❑ Average SNR is 22.5 dB.
- ❑ We need to support variable bit loading for spectrum below 25Mhz.

# Requirements of Adaptive Bit Loading

- Support for Multiple Modulation Order: The transmitter and receiver should be able to support multiple modulation orders.
- Real-time Channel Knowledge: We must have instantaneous channel knowledge to implement adaptive bit loading. This can be obtained by transmitting a “pilot” signal at regular intervals.
- Communication of Bit Loading info: CLT should be able to communicate bit loading info to transmitter using OAM, signaling symbols, ....
  - Bit loading info includes which subcarriers that are ON and the corresponding bit loading.

# Adaptive Bit Loading Algorithms

- There are mainly two classes of adaptive bit loading algorithms, namely:
  - [Rate-adaptive algorithms.](#)
  - [Margin-adaptive algorithms.](#)
- Rate-adaptive (RA) algorithms strive to maximize the data rate subject to power and BER constraints (see next slide for an example).
- Margin-adaptive (MA) algorithms strive to minimize the transmitted power subject to data rate and BER constraints.
- The last slide provides references to Adaptive Bit loading algorithms.



# Adaptive Bit Loading Algorithm [3]

- The bit loading algorithm in this example aims to solve the following rate-adaptive problem given a target mean BER  $P_T$  and a fixed energy distribution across all the subcarriers:

$$\text{Maximize } \sum_{i=1}^N b_i \text{ subject to } \bar{P} = \frac{\sum_{i=1}^N b_i P_i}{\sum_{i=1}^N b_i} \leq P_T$$

where  $b_i$  and  $P_i$  are the number of bits and BER of the  $i$ th subcarrier respectively.  $N$  and  $\bar{P}$  are the number of used subcarriers and their mean BER respectively.

- The Goal is to maximize throughput subject to power and BER constraints.

# Unicast Bit Loading Table

UNICAST DS/US

	SC 1	SC 2	SC 3	SC 4
CNU1.1	8	10	10	10
CNU1.2	10	8	10	12
CNU1.3	12	8	12	12
CNU2.1	8	12	8	10
CNU2.2	8	12	8	8
CNU3.1	12	12	12	10
CNU3.2	12	10	12	12
CNU3.3	10	8	12	12

Bit-loading table

UNICAST DS/US Using Sub-carrier groups.

	SG 1	SG 2	SG 3	SG 4
CNU1.1	12	8	10	10
CNU1.2	10	10	10	8
CNU1.3	12	8	10	12
CNU2.1	8	12	8	12
CNU2.2	8	12	10	8
CNU3.1	12	12	10	10
CNU3.2	12	8	12	12
CNU3.3	10	10	8	12

Bit-loading table

- ❑ The memory used to store the bit loading table will be much less when bit loading is used per **subcarrier group**. If for example, the group contains 12 subcarriers the table size is reduced by a factor of 12
- ❑ Bit loading of the group depends on the SNR of each subcarrier within the group.

# Possible Areas of Study for EPoC TF

- The variation over time of SNR for subcarriers and users.
- How often bit loading should be adapted to channel conditions ?
- We have to study the efficiency gain of adaptive bit loading vs the complexity required to achieve it.
- How to communicate bit loading info: OAM, Signaling Symbols, ... etc ?
- Should we support Margin-adaptive (MA) algorithms ?

# References

- [1] "A Practical Discrete Multitone Transceiver Loading Algorithm for Data Transmission Over Spectrally Shaped Channels," *PS Chow, JM Cioffi, JAC Bingham - IEEE Transactions on Communications, 1995*
- [2] "Discrete Bit Loading for Multicarrier Modulation Systems," *J Campello - Information Theory IEEE Proceedings, 1998 .*
- [3] "Low Complexity Discrete Bit-Loading for OFDM Systems with Application in Power Line Communications", Khalifa S. Al-Mawali, Amin Z. Sadik, Zahir M. Hussain, June 2011.

# Thank you

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