29. Treffen der VDE/ITG-Fachgruppe 5.2.4

Admission Control in OFDMA Networks

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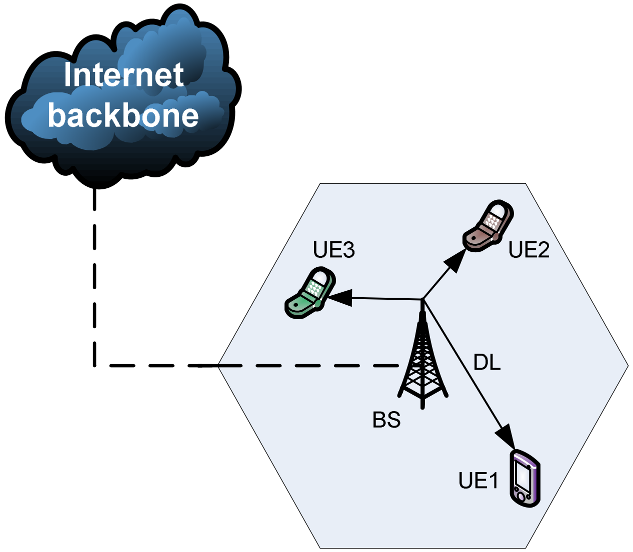
FACHGRUPPE INFORMATIK

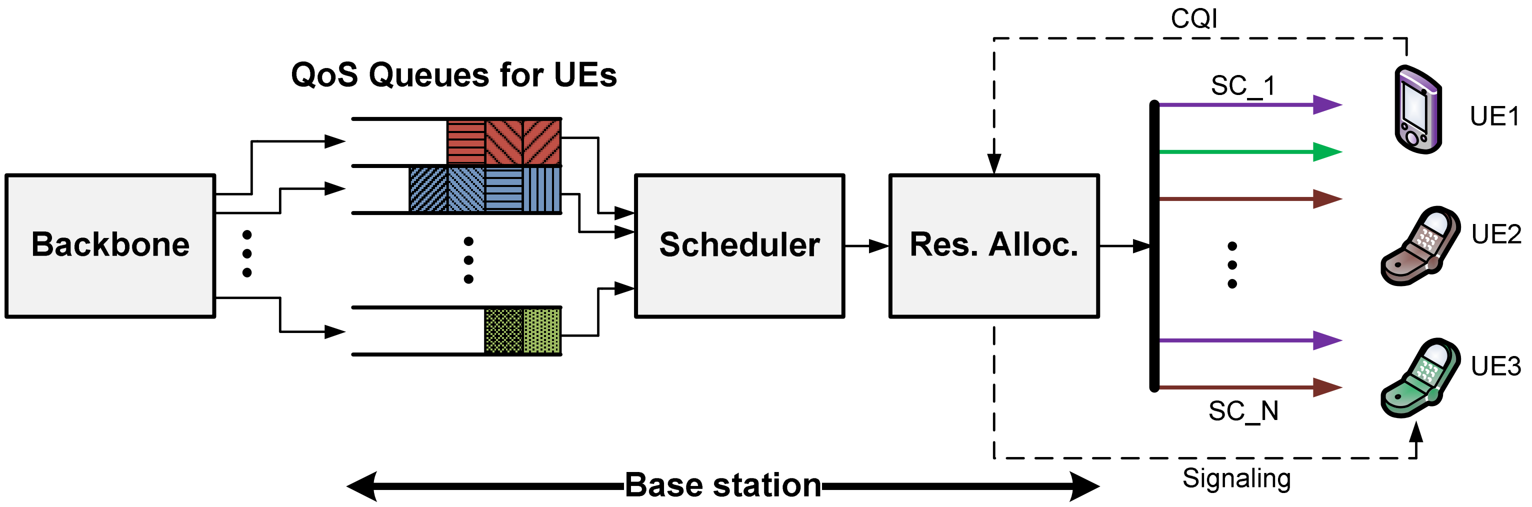
Outline

- Introduction
- Mathematical modeling
- Problem statement
- OFDMA channel transformations
- Application to admission control
- Some results
- Conclusions

Introduction I

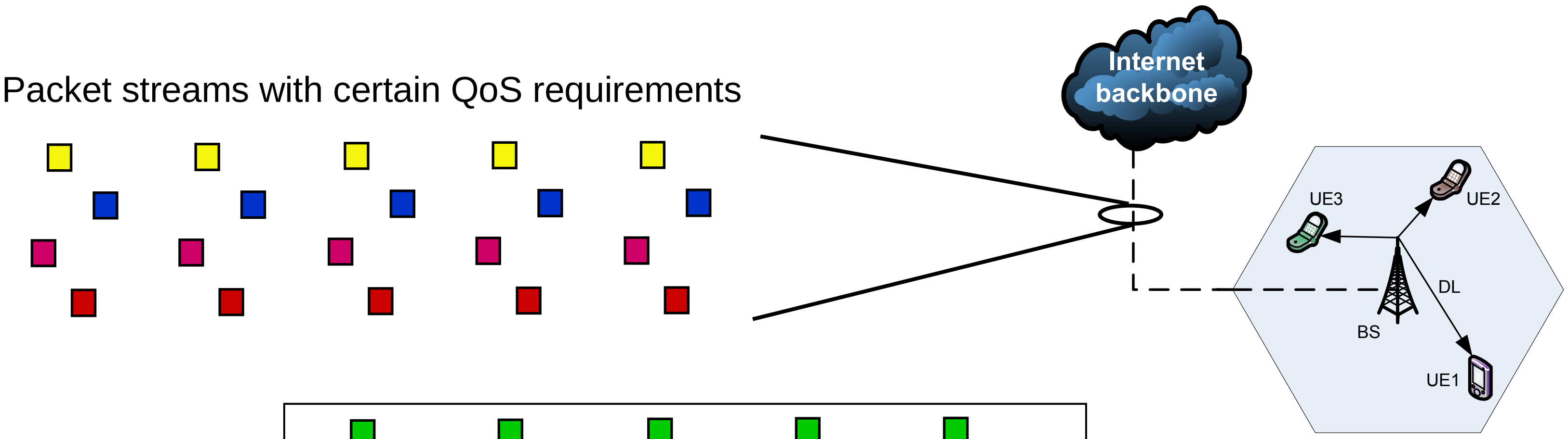
- OFDM-based centralized system (e.g. LTE, WiMAX)
- Various traffic types with different QoS requirements transmitted
- Down-link is bottle neck
- Channel state dependent resource assignments





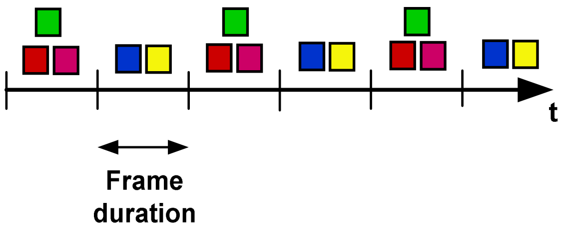
Introduction II

Packet streams with certain QoS requirements



Now assume a new stream requests admission to the cell. Can the cell serve this stream? Where to preallocate resources from?

Will the scheduler be able to complete transmissions according to preallocations?



Admission control unit pre-allocates transmission resources according to QoS requirements.

Mathematical Model

- **Let us focus on a single frame:**
  - Scheduler passes J packets (one from each flow served in this frame) of size σ_j to the resource assignment unit.
  - N subcarriers/subchannels are available for this
  - Down-link phase features S symbols per subcarrier

- **Assume the following:**
  - Each subcarrier receives equal share of transmit power p_n
  - Discrete set of modulation types are available
  - Target BER (from target PER) determines switching points, function $F()$ matches SNR to rate per symbol

- **How are subcarriers assigned?**

Mathematical Model

- **Maximize the minimum rate per terminal per frame**
  - Referred to as rate-adaptive problem

$$
\begin{aligned}
\max \quad & \epsilon \\
\text{s. t.} \quad & \sum_j x_{j,n} \leq 1 \quad \forall\, n \\
& S \cdot \sum_n F\left(\frac{p_n \cdot g_{j,n}}{\sigma^2}\right) \cdot x_{j,n} \geq \alpha_j \cdot \epsilon \quad \forall\, j
\end{aligned}
$$

- $\frac{p_n \cdot g_{j,n}}{\sigma^2}$ **: Signal to noise ratio (SNR)**
- $x_{j,n}$ **: Assignment variable (binary)**
- α_j **: Weighting factor (different packet sizes)**

Problem Statement

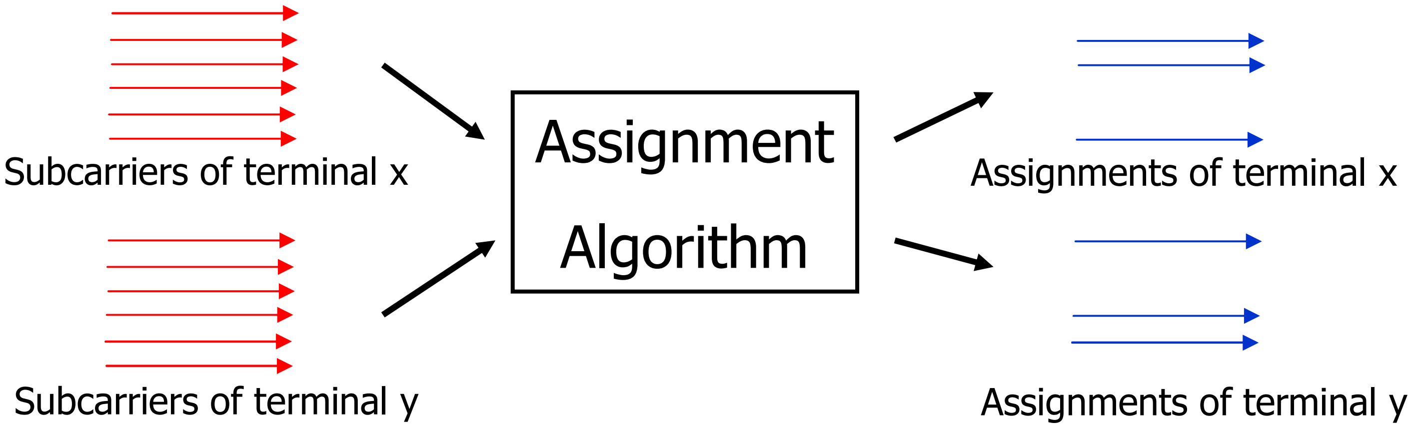
- **How does the scheduler know how many packets J can be served in one down-link frame?**
  - i.e. such that $\sigma_j \geq \epsilon \quad \forall j \in J$?
  - Not based on a particular channel gain matrix!

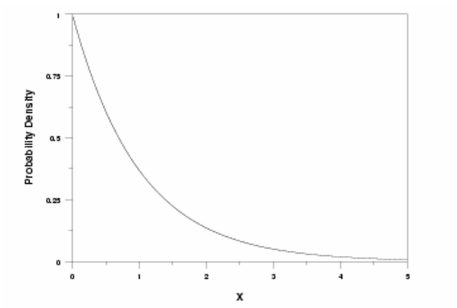
- **What happens if we schedule instead $J + 1$ packets?**

- **Problem: Adaptive resource allocation per frame!**
  - As channel gains are random, assigned capacity is random too!
  - We never know how many packets can be served, there is always an outage probability associated with scheduling J packets!
  - Admit as many flows to a frame as outage probability is inline with QoS requirements of the flows!
  - How can this be done?

OFDMA Channel Transformation I

- **Need an estimate of ϵ (better: a PDF)**
- **ϵ relies on channel gain statistics**
  - Common model: basic channel gains are exponentially distributed





?

OFDMA Channel Transformations II

- **Derivation of exact statistics is difficult (impossible?):**
  - Optimally: exhaustive search (NP hard)

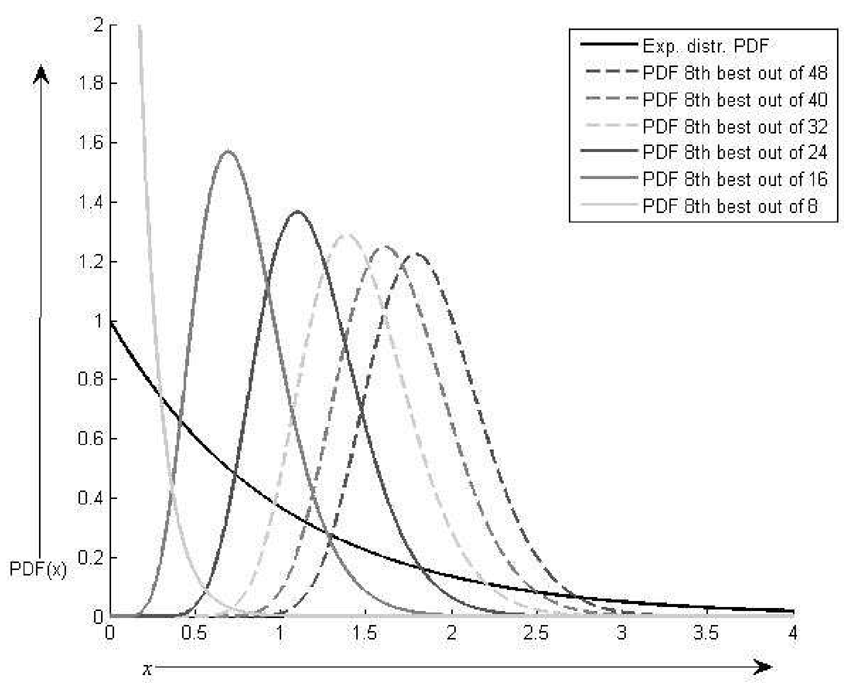
- **Analyze a suboptimal algorithm ➔ yields lower bound**

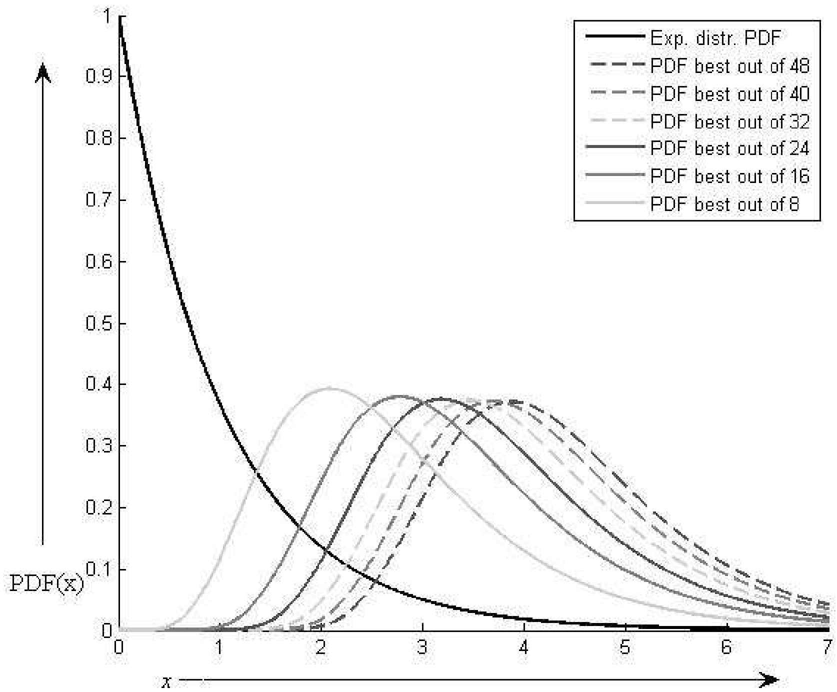
- **Choice of suboptimal algorithm: Two-step approach**
  - Allocation: How many subcarriers does each terminal receive for next frame?
  - Assignment: Which subcarriers does each terminal get?

- **We can obtain the channel gain statistics for each assigned subcarrier by applying order statistics!**

OFDMA Channel Transformations III

- **Channel gain PDF for the k-th worst subcarrier chosen out of a set of A_j subcarriers**





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Probabilistic Rate Guarantees

- Derive directly the rate PMF for each chosen subcarrier
- Total rate per frame per terminal is the sum of the (random) individual rates:

$$Z_j = \sum_{i=1}^{l_j} z_{j,(i)}$$

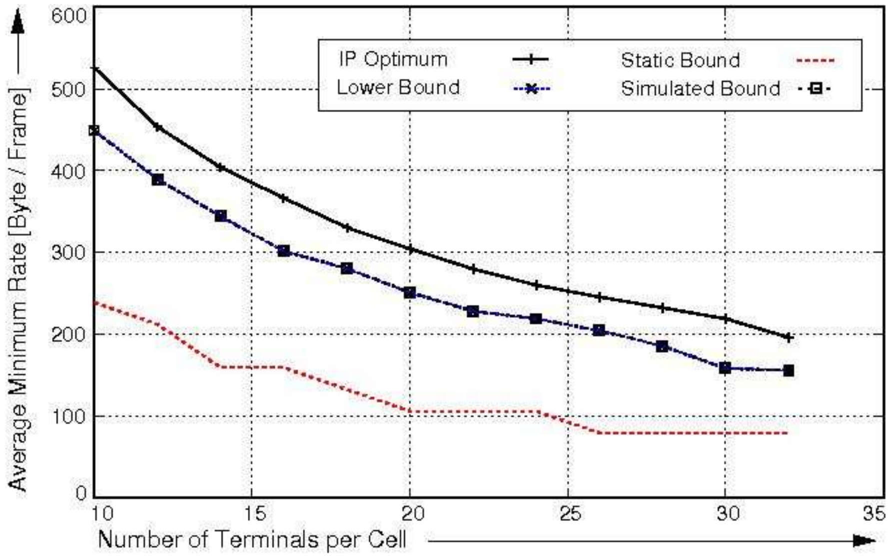
- Total rate PMF is obtained by convolution:

$$p\left(Z_j\right) = \bigodot_{i=1}^{l_j} p\left(z_{j,(i)}\right)$$

- Note: <u>This is only true if random variables are independent</u>. This is not the case (order statistics !), we still apply this as approximation and compare the obtained bound with simulations!

Example Numerical Investigation

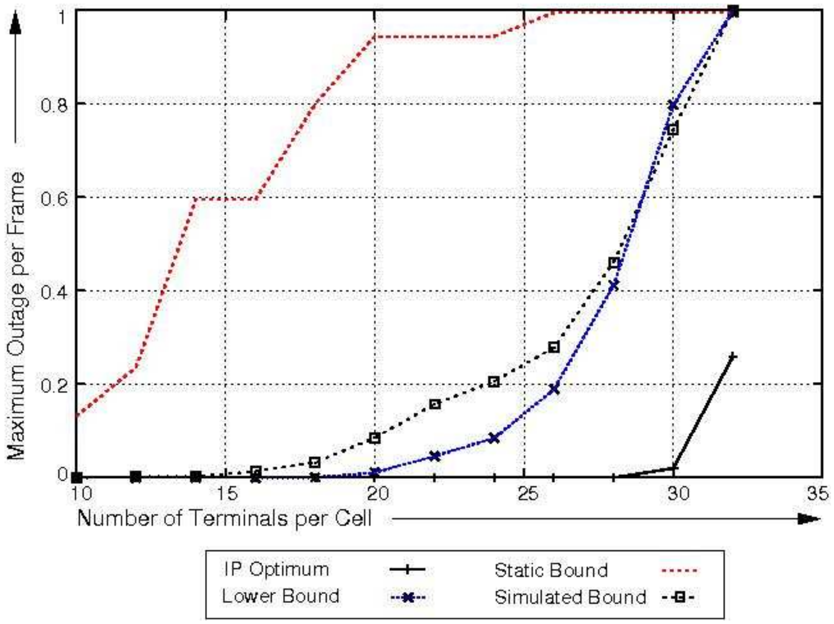
- **Average minimum rate for an increasing number of flows**



Parameters:
- **10 MHz bandwidth**
- **96 subchannels**
- **4 modulation types (BPSK, QPSK, 16 QAM 64 QAM)**
- **5 ms frame length**
- **S = 24 symbols**
- **Circular position of terminals**
- **10 dB average channel SNR**
- **Indep. Rayleigh fading**
- **Convolutional coding rate ¾**
- **Required BER: 0.0052**

Example Numerical Investigation II

- **Outage analysis for increasing number of flows**
  - How often can a packet not be transmitted during one frame?



Parameters:
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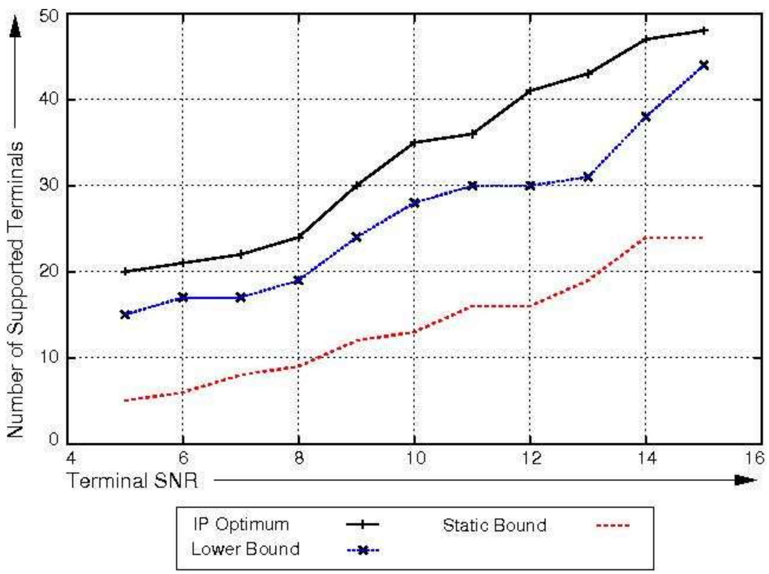
- Circular position of terminals
- 10 dB average channel SNR
- Indep. Rayleigh fading
- Convolutional coding rate ¾
- Required BER: 0.0052
- G.711 VoIP streams
- MAC packet size: 170 Byte

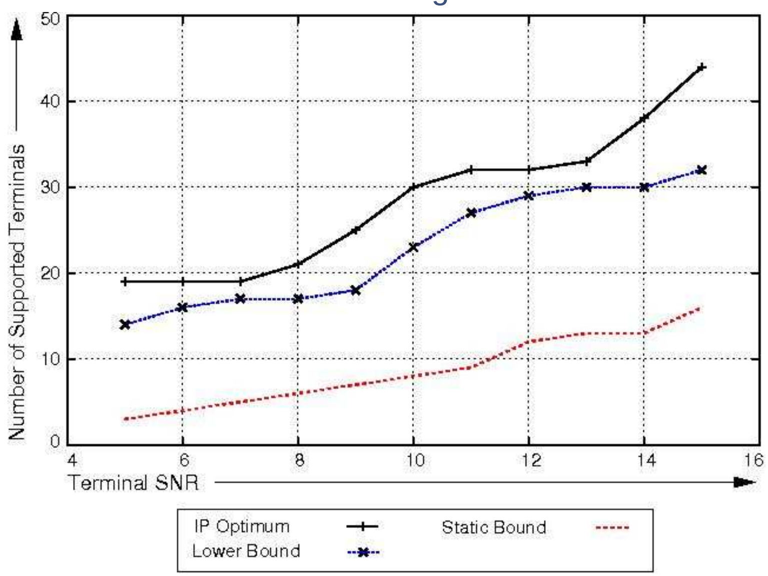
Example Numerical Investigation III

- **Admission of G.711 VoIP streams:**
  - How many streams can be served in a single down-link frame?
- **Criteria:**
  - Average rate: All admitted streams must be served with 68 kBit/s
  - Outage criteria: All streams should have less than 5% packet outage

Average Rate



Outage



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Conclusions

- **Order statistics provide a powerful tool for analyzing QoS in OFDMA networks**
  - Analytical description of transformed channel gain PDF
  - Still, not an exact performance predictor due to dependencies in the order statistics

- **Significant improvement in QoS prediction compared to related work**

- **Some extensions possible …**

Some Facts

- **Rate adaptive optimization problem is NP hard**
  - Partition reduces (in polynomial time) to the corresponding recognition problem
- **Related optimization problem: minimize the transmit power for a set of rate requirements**
  - Referred to as margin adaptive problem
  - This is also NP-hard, margin adaptive problem has the same recognition version! (applies only to discrete power steps)
- **So, how can we solve these problems?**
  - Linear relaxation with some rounding strategy
  - Heuristics (matching)
  - Ask Prof. Schmeink and Prof. Mathar for more

Assignment algorithm

- **Assuming a given allocation $\{l_j\}$:**

Given: Set of gains $\{g_{j,n}\}$ and allocations $\{l_j\}$

Initialize: $\forall j \in J : X_j = \emptyset, \mathcal{N} = \{1, \cdots, N\}$

for $(j \in J)$ **do**

  while $(l_j > |X_j|)$ **do**

    $\tilde{n} = \text{argmax}_{n \in \mathcal{N}} \{g_{j,n}\}$

    $X_j = X_j \cup \tilde{n}$

    $\mathcal{N} = \mathcal{N} \setminus \tilde{n}$

  end

  return X_j

end

$$f_{\tilde{X}_{(k/N)}}(x) = k \cdot \binom{N}{k} P(X \leq x)^{k-1} \cdot P(X > x)^{N-k} \cdot f_X(x)$$