Hierarchic and Dynamic Spectrum Reallocation using Double Auctions

Dennis Burgkhardt

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Universität Karlsruhe (TH)
Forschungsuniversität · gegründet 1825

Institut für Nachrichtentechnik
Prof. Dr.rer.nat. Friedrich K. Jondral

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Motivation

- Spectral Resources for Mobile Communications are limited

“Scarcity” ⟺ Measurements

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Flexible Allocation

Motivation

- Spectral efficiency needs more flexible usage of resources
- Overlay and underlay systems
  - Additional systems
  - No changes in existing regulation and systems
- Free Access
  - Basic regulation only
  - Competitive access (ISM bands)
- Make licenses more flexible
  - Renting
  - Trading ⟵

Auctions

- Auctions as a means for (re)allocating goods
- Bids determine prices *and* allocation at once
- Classification
  - Open – Sealed-bid
  - One good – Combinatorial
  - Single – Double
- Examples
  - Spectral Licenses
  - Internet Platforms
  - Stock Exchanges

Auctions for Spectral Resources

- Auctions and Spectral Resources
  - Timescale
  - Who trades
  - Reliability – flexibility

- Long-term (years)
- Regulator – Operators (Operators – Operators)
- Reliable
- Static
- Global

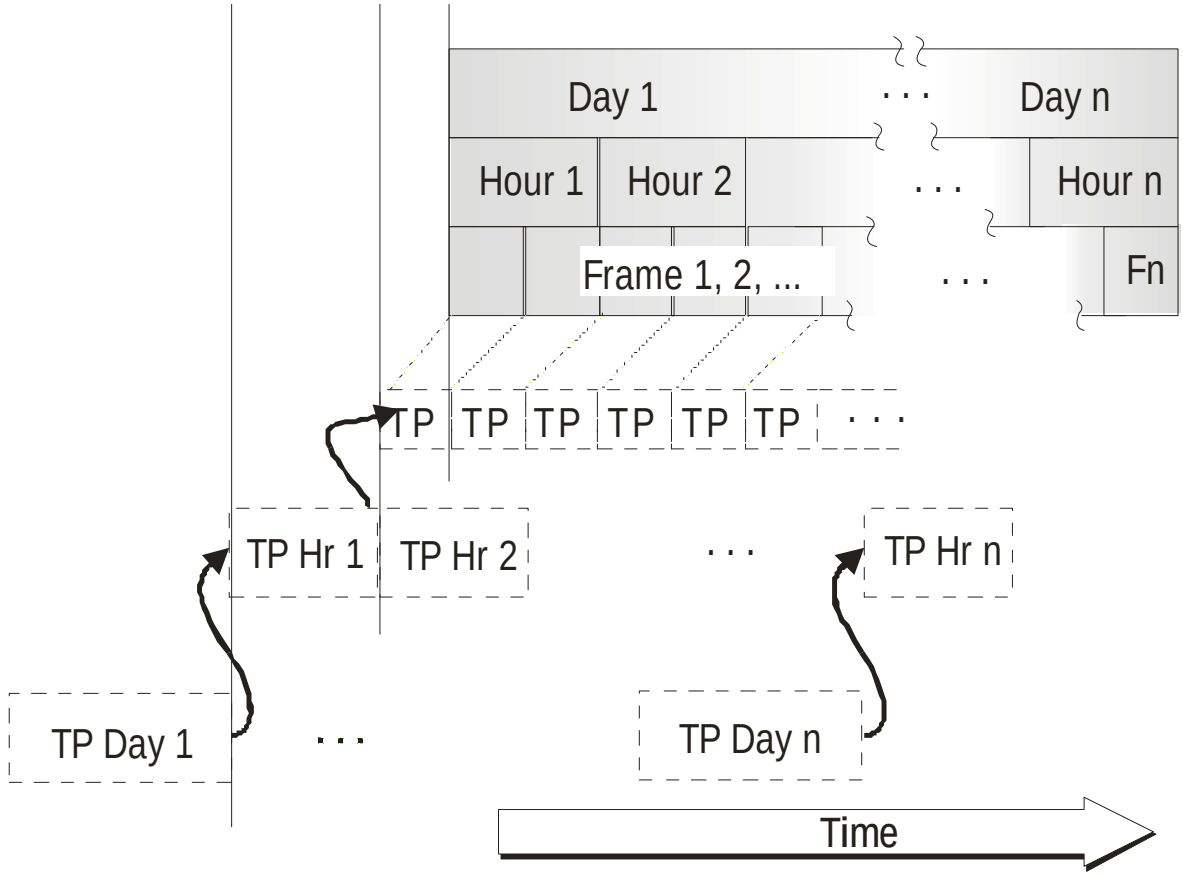
- Short-term (minutes/frames)
- Operators – Operators (Operators – Users)
- Fast changing situations
- Highly flexible
- Local

Hierarchic Resource Trading

- Compromise: resource auctions between operators in mobile radio system
- Trading goods can be frequency channels for certain times in a FDMA system
  - Abstracted, interchangeable goods
- Hierarchic adaptation of allocation to current demand situation
  - Long-term, regional: coarse demand estimation
  - Short-term, local: more precise demand prediction
- Starting from allocation given by regulation

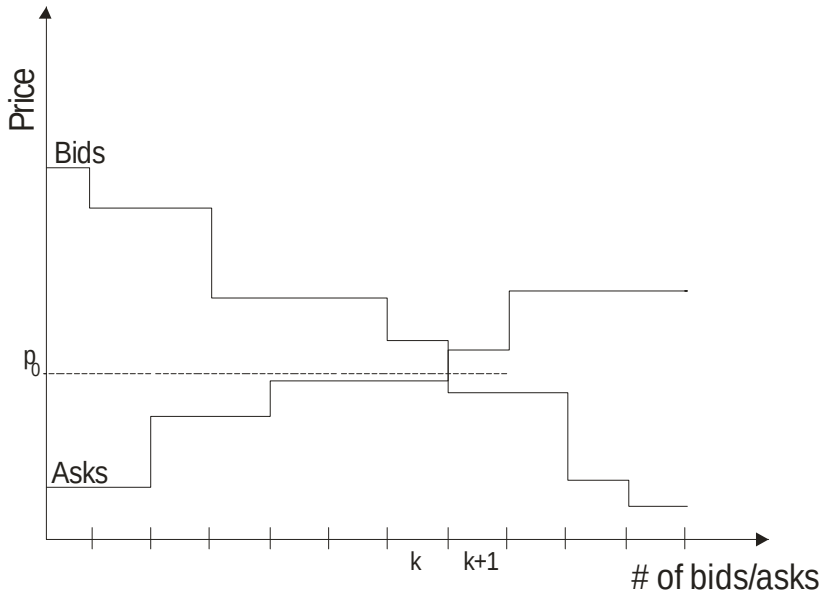
Hierarchic Resource Trading

- Example of trading hierarchy in time direction



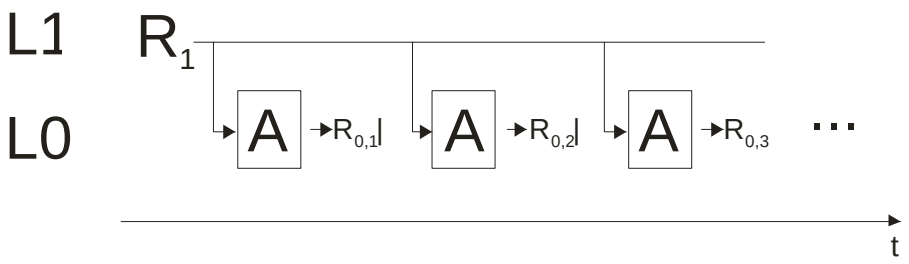
Double Auctions

- Operators trade resources with each other on different levels of granularity
  - Dependant on situation: buyer or seller
  - Double auctions according to McAfee
  - Comparable to stock exchanges



Scenario

- At any time instant, all the B resources are allocated to one of the N operators
- The allocation to each operator as a number of resources is denoted as R
- Resources enter the next, more granular level
- Operators compare their current demand to actual allocation
- Reallocation based on auction result. Physical allocation on lowest level only



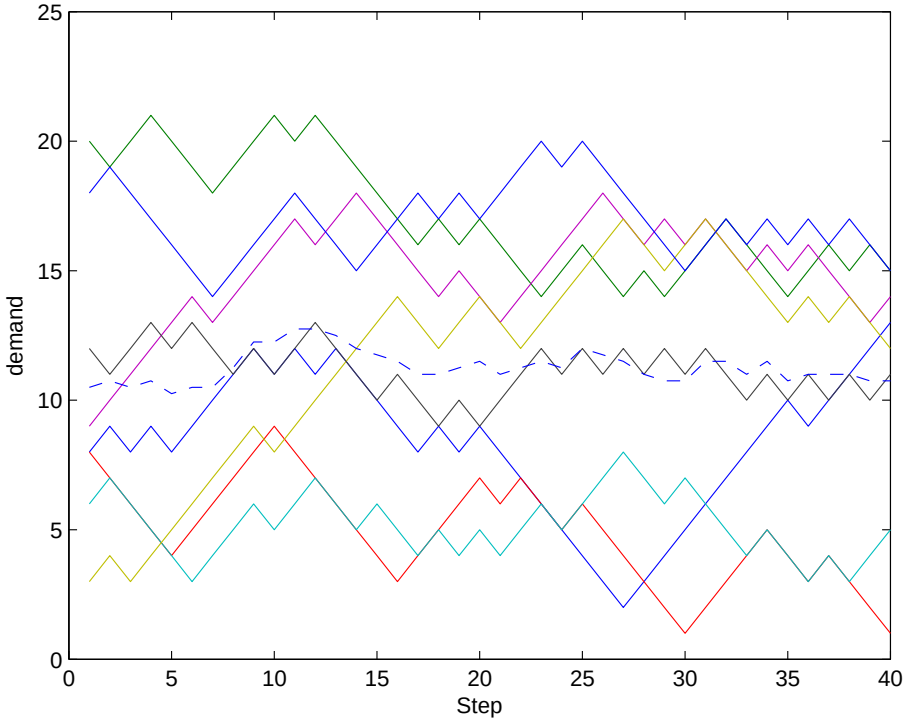
- Double auction:
  - All bids/asks from each operator are collected by broker
  - Outcome is number of resources to be reallocated

Traffic Model

- A generic traffic model is assumed
  - To model the mean demand, i.e. coarsely estimated, demand, a starting value is drawn from a normal distribution
  - For several steps, representing the short-term variations, demand is adapted following a random walk process
- The statistical parameters are identical for all operators
- Demands D_j of each operator are independent

- The mean sum demand is later used as simulation parameter

Random Walk



- Random walk: Adaption of demand by +1 or -1 in each step
- Constant mean: Starting point may be seen as “coarse estimation” of demand
- Variance increases with time

Figures of Merit

- Usage: Fraction of resources used over time
  - Network view

- Overload: Demand cannot be served with available resources
  - Operators‘ view

Case discrimination

- Case 1: Static allocation without trading
  - The current allocation method: no dynamical refinements

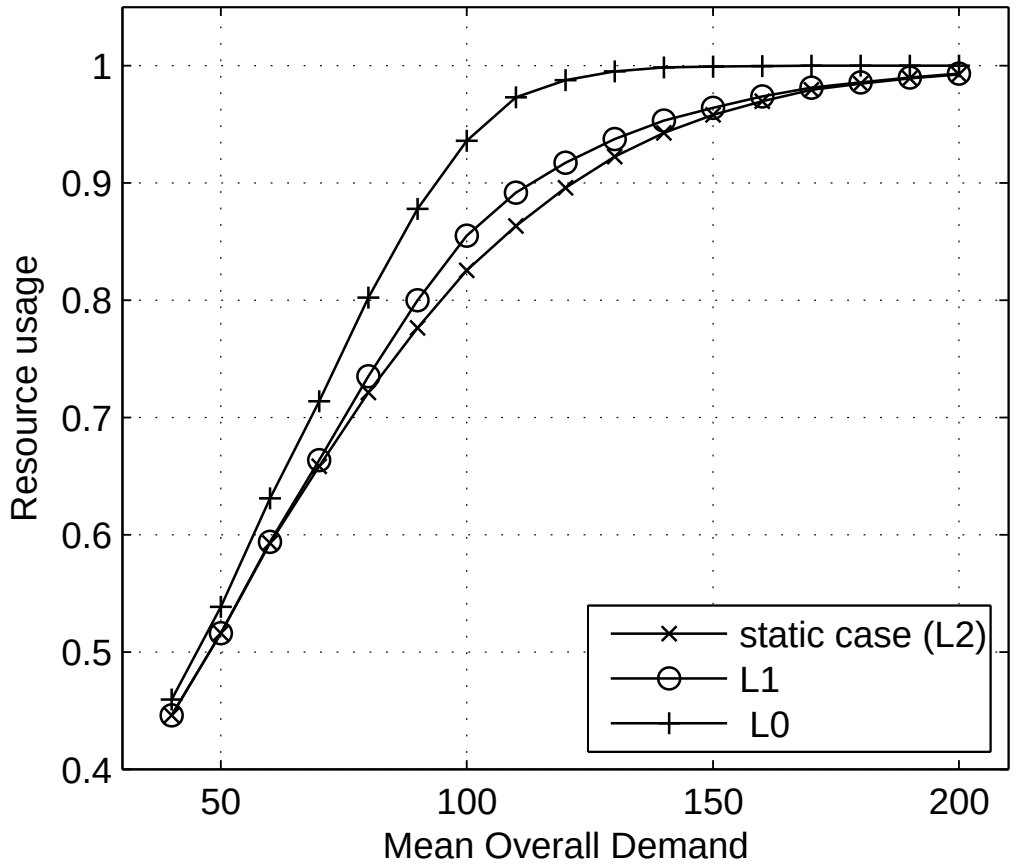
- Case 2: Ideal Reallocation
  - Trading case, dynamical refinement
  - Here: disregarding valuations, equiv. same valuations for resources
  - Serving as an optimal case that all possible transactions are conducted

Example Parameters for Results

- N = 8 operators
- B = 100 resources
- Initial allocation: 12/13 Resources per operator
- 40 time frames / auctions on most granular level

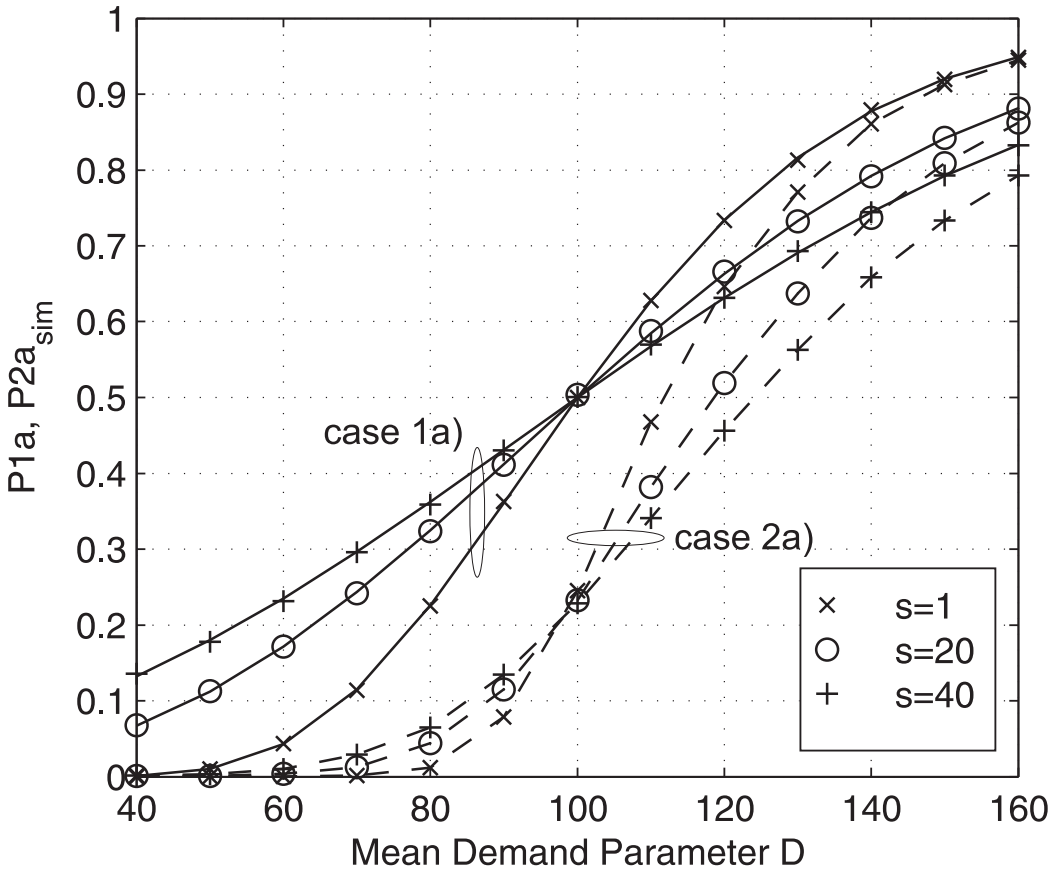
Resource usage

- Overall fraction of resources used



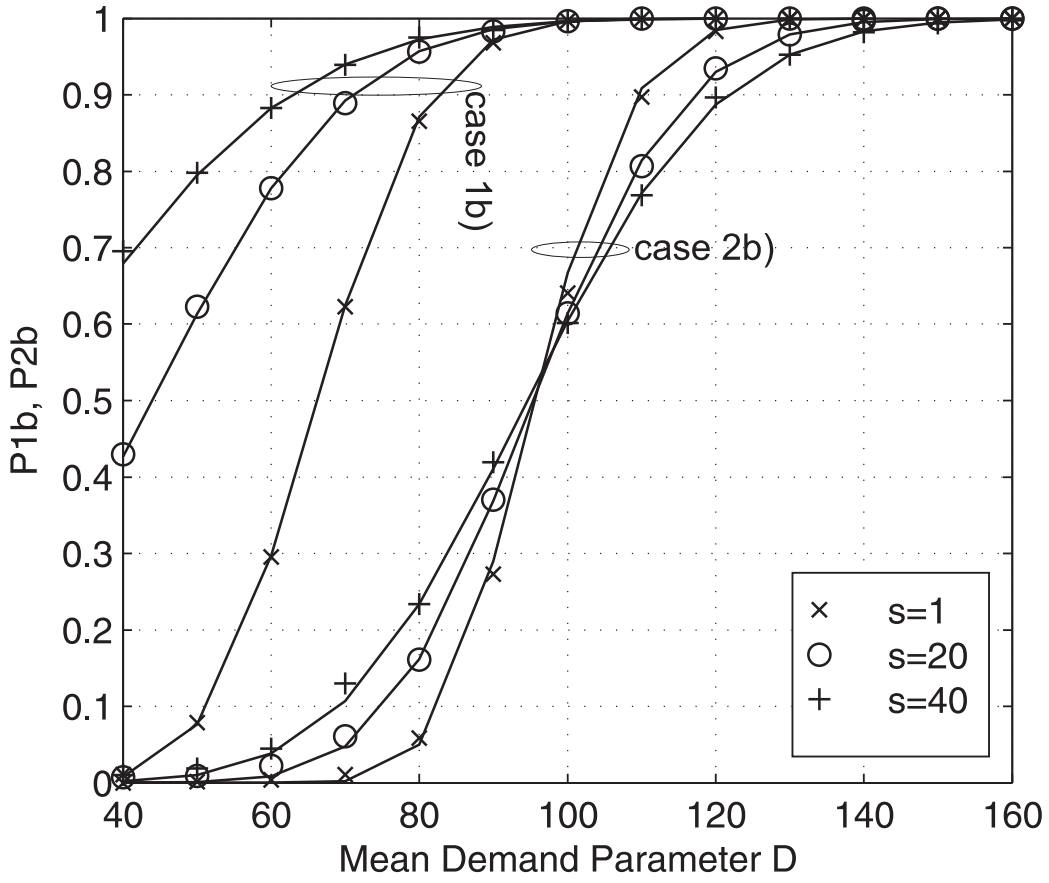
Outage

- Per-operator overload probabilities



Outage

- System overload probabilities



Summary

- Trading spectral resources between mobile operators
- Compromise between reliable allocation and short-term adaptation
- Resource usage could be improved
- Network as well as per-operator and system overload probabilities could significantly be reduced

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Thank you for your attention!