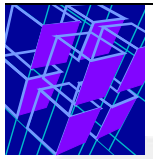

Multi-Period Resource Allocation at System Edges
Capacity Management in a Multi-Provider Multi-Service Internet

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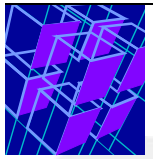

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Outline

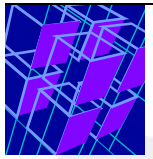
Motivation

MPRASE - The Framework

Examples

- **A: The Single Provider Problem (SPP)**
- **B: The Multi Provider Problem (MPP)**
- **Further Examples and Application Examples**

Conclusions and Outlook



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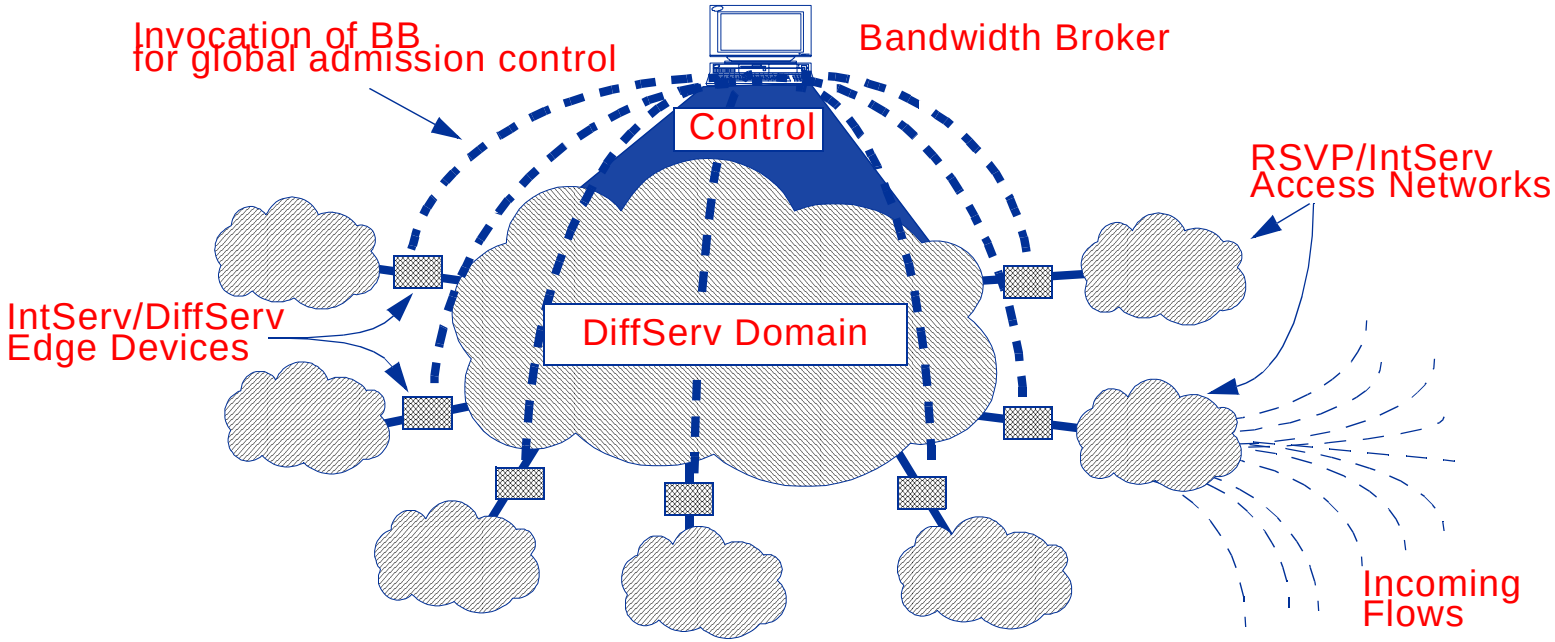
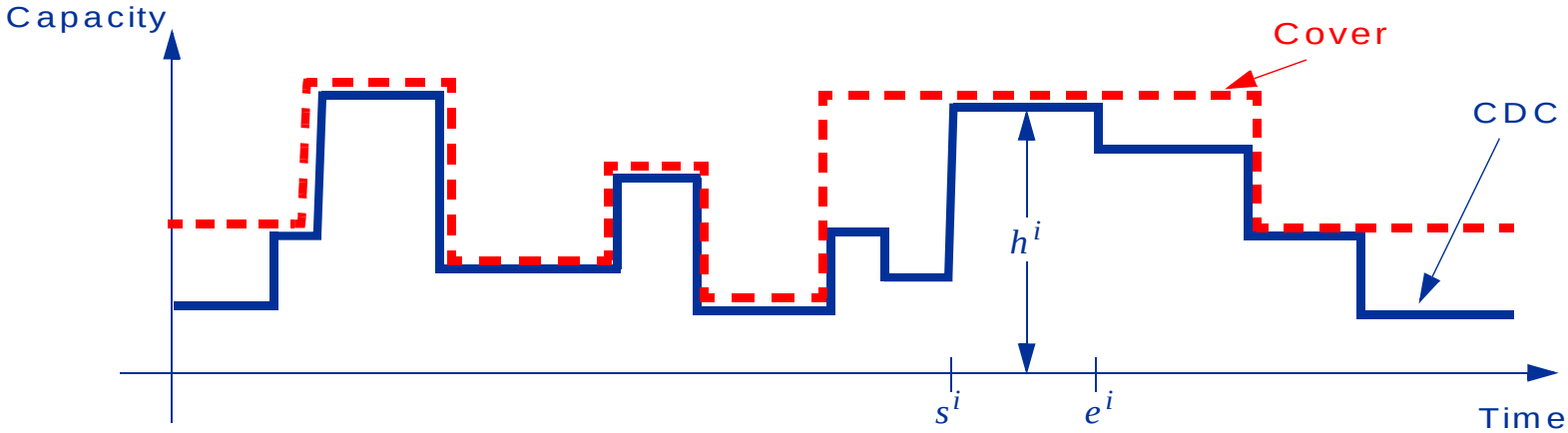
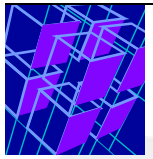
Motivating Example: Decoupling different Timescales

Example: RSVP/IntServ over DiffServ/Bandwidth-Broker



Smooth Capacity Demand Curve (CDC) of a faster time scale system





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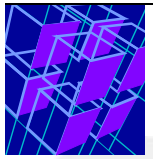
Motivation

CAN WE FIND A GENERAL MATHEMATICAL FRAMEWORK THAT DESCRIBES THESE KIND OF PROBLEMS AT A SYSTEM'S EDGE?

⇒ **MPRASE (Multi-Period Resource Allocation at System Edges)**



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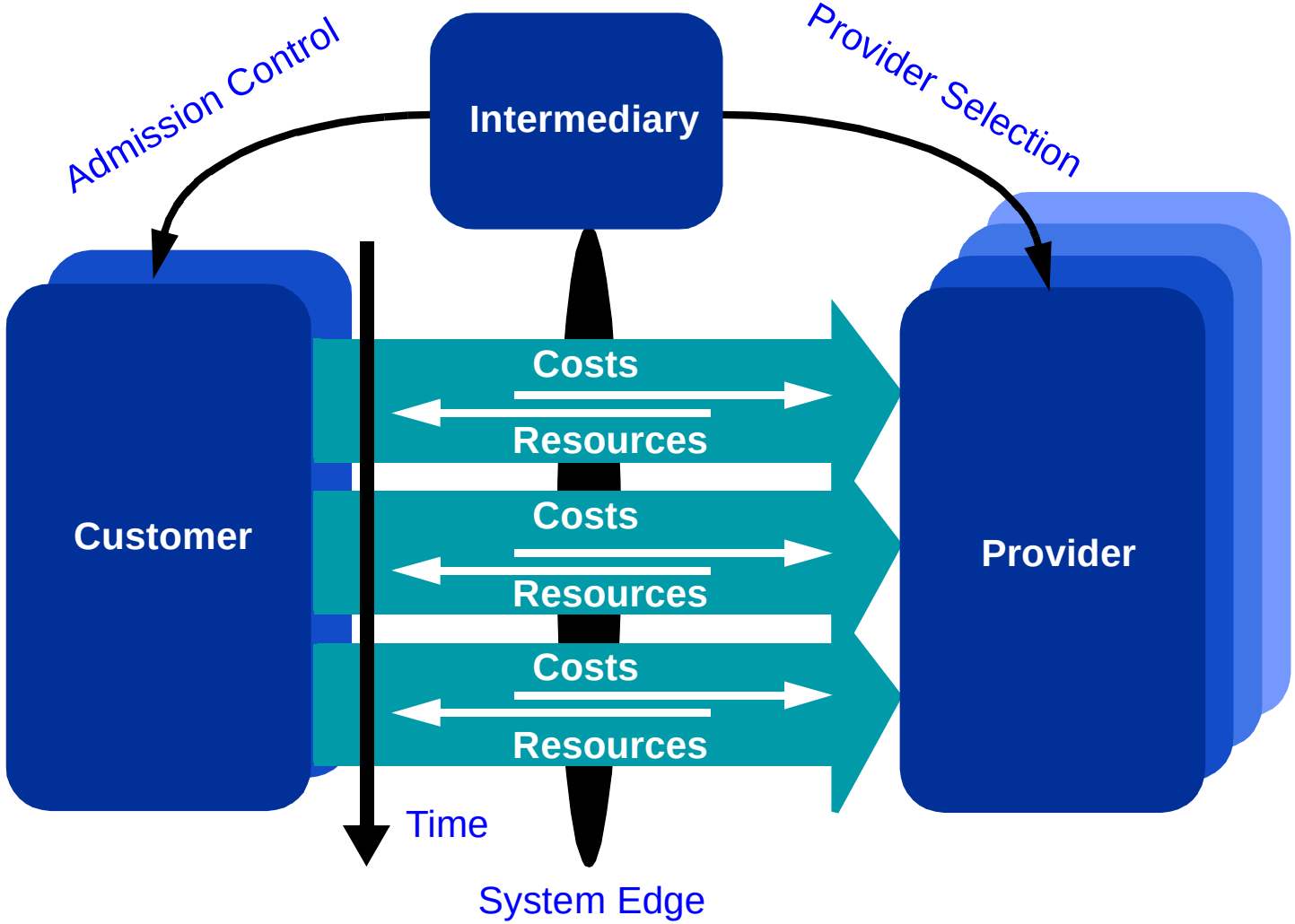
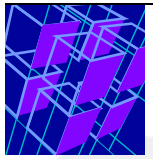
The MPRASE Framework

- **Multiple periods**
- **Resources are allocated between provider(s) and customer(s)**





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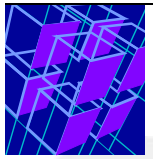
Customer and Provider Models

Customer Model

- **Single or multiple customers**
- **Flexibility of demand**
  - inflexible
  - degraded quality
  - dissatisfied

Provider Model

- **Single or multiple providers**
- **Limited vs.unlimited capacity**



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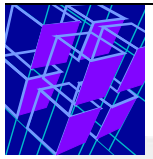
Cost and Resource Models

Cost Model

- **Fixed transactional cost per allocation/reservation**
- **Variable costs for resource allocation**
- **Linear vs. non-linear costs**

Resource Model

- **One-dimensional vs. multi-dimensional**
- **Deterministic vs. statistical**



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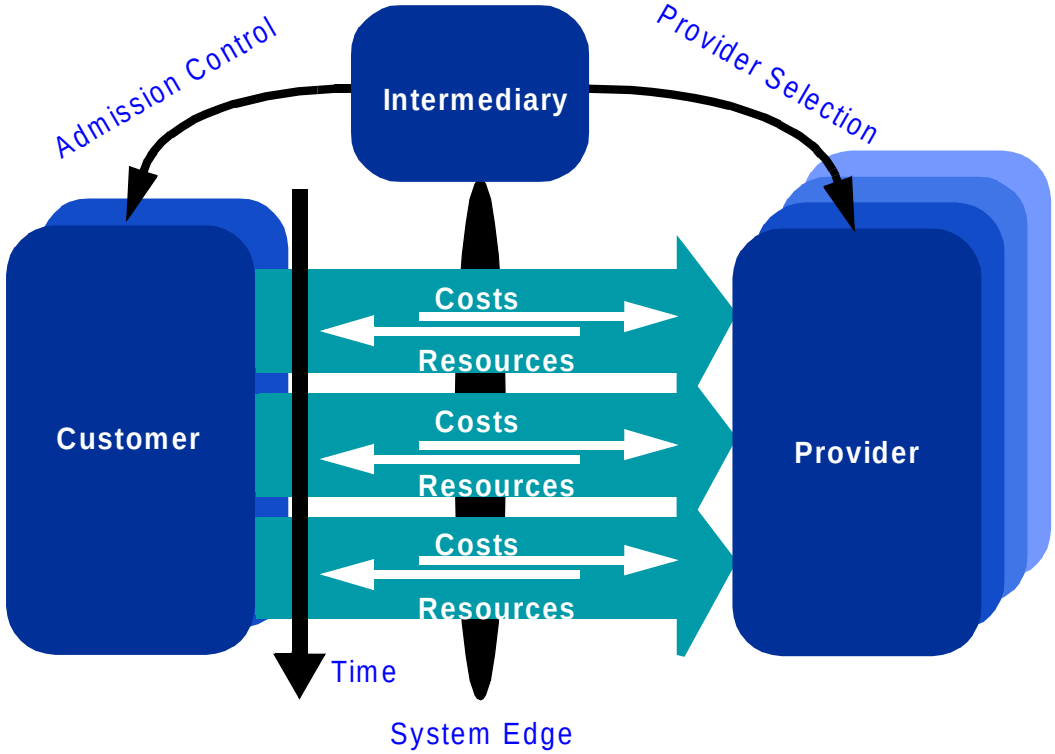
Edge and Intermediary Models

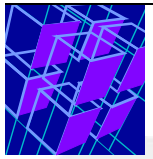
Edge Model

- **Deterministic vs. statistical or completely uncertain future demand**

Intermediary Model

- **Instance that solves the problem**
- **Can also be part of the customer or provider (see MPP)**





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Problem Incarnation A: The Single Provider Problem (SPP)

Description:

- **Customer Model**
  - One customer
  - Demand b_t must be fully satisfied for all T periods
- **Provider Model**
  - One provider
  - Unlimited capacity
- **Resource Model**
  - One-dimensional Resource (e.g. Bandwidth)
- **Cost Model**
  - Fixed costs per allocation/reservation
  - Variable costs per allocated/reserved bandwidth per period
  - Linear costs
- **Edge Model**
  - Deterministic (complete knowledge)
- **Intermediary**
  - Minimize costs of the customer

Mathematical Model for the SPP

Given:

b_t demand (in period t)

f_t, c_t fixed and variable costs (in period t)

Wanted:

x_t resource allocation (in period t)

z_t 1 if resources are reallocated in period t and 0 otherwise

$$\text{Minimize} \quad \sum_{t=1}^{T} f_t z_t + \sum_{t=1}^{T} c_t x_t \qquad (1)$$

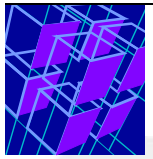
subject to

$$x_t \geq b_t \qquad \forall t = 1, ..., T \qquad (2)$$

$$x_t - x_{t-1} \leq M \cdot z_t \qquad \forall t = 1, ..., T \qquad (3)$$

$$x_{t-1} - x_t \leq M \cdot z_t \qquad \forall t = 1, ..., T \qquad (4)$$

$$z_t \in \{0, 1\} \qquad \forall t = 1, ..., T \qquad (5)$$



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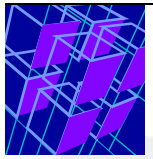
Algorithms and Performance

T = 50

Algorithm	Time (sec)
Branch and Bound	1920,7
Dyn. Programming	0,0026

T = 1000

Algorithm	Time (msec)	Deviation from Optimum
Dyn. Programming	9000	0 %
Peak Heuristic	< 1	123.81 %
Merge Heuristic	2	4.79 %
Split Heuristic	10	25.93 %
LP Heuristic	452	22.34 %
Merge and Split	5	3.85 %
LP + Merge and Split	452	1.77 %



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Incarnation Example B: The Multiprovider Problem (MPP)

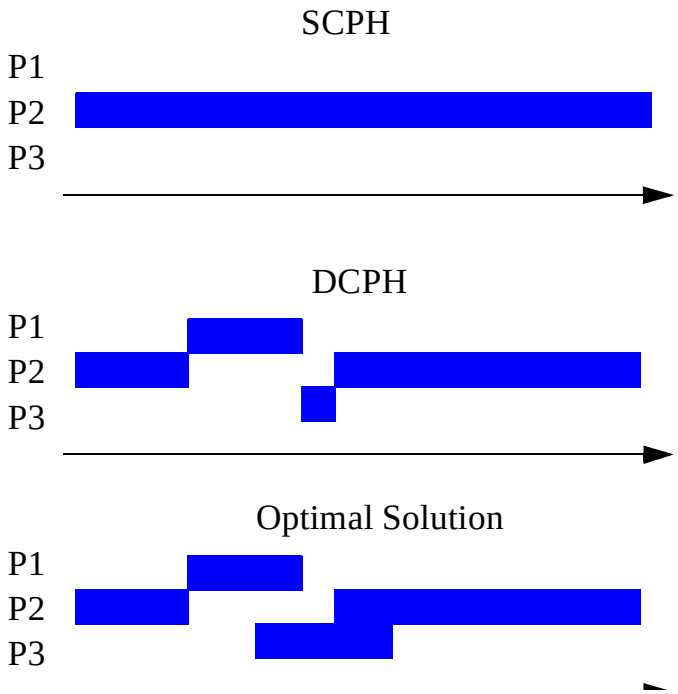
Similar to the SPP but with the following provider model:

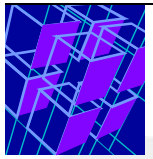
- **Multiple providers**
- **Optional: limited capacity**

⇒ **This results in a much higher complexity compared to the SPP**

Reusability of the SPP algorithms:

- **LP, Merge and Split**
- **Static Cheapest Provider Heuristic**
- **Dynamic Cheapest Provider Heuristic**





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Other Problem Incarnations in the Framework

Flexibility on the demand side

- **Multiple customers, customer selection (admission control problem)**
- **Degraded quality**

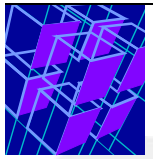
Uncertainty

- **Various kinds of uncertainty about future demand**

Resource Model

- **Token-bucket allocation**

...



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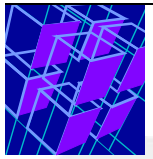
Applicability of the Framework

Networking Context

- **Intserv/RSVP over Diffserv/BB**
- **Admission Control**
- **Reservation in Advance**
- **Renegotiation for VBR Streams**
- **Cost minimal token bucket reservations**
- **...**

Other Context

- **?**



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Conclusions and Outlook

MPRASE (Multi-Period Resource Allocation At System Edges)

- General class of optimization problems at system edges
- Broad applicability in networking
- Mathematical description
- Reusability of algorithms

Further information

- Technical Report KOM, TU Darmstadt 05/2000
  ftp://ftp.kom.e-technik.tu-darmstadt.de/pub/TR/TR-KOM-2000-05.pdf
- Schmitt, Heckmann, Steinmetz: Decoupling Different Time Scales of Network QoS Systems (presented at SPECTS 2001)
- Jens Burkhard Schmitt: Heterogeneous Network Quality of Service Systems (2001)