Autonomous Units for Communication-based Dynamic Scheduling

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Overview

- Autonomy in logistics
- Planning package transportation
- Transport networks
- Autonomous graph transformation units
- Sample negotiation
- Conclusion

Autonomy in Logistics

- Dynamics in logistics needs a paradigm shift
- Autonomy instead of centralized control:
  Passing control capabilities to the logistic objects
- Formal framework for modelling autonomous behaviour:
  Autonomous graph transformation units
- Communication-based approach

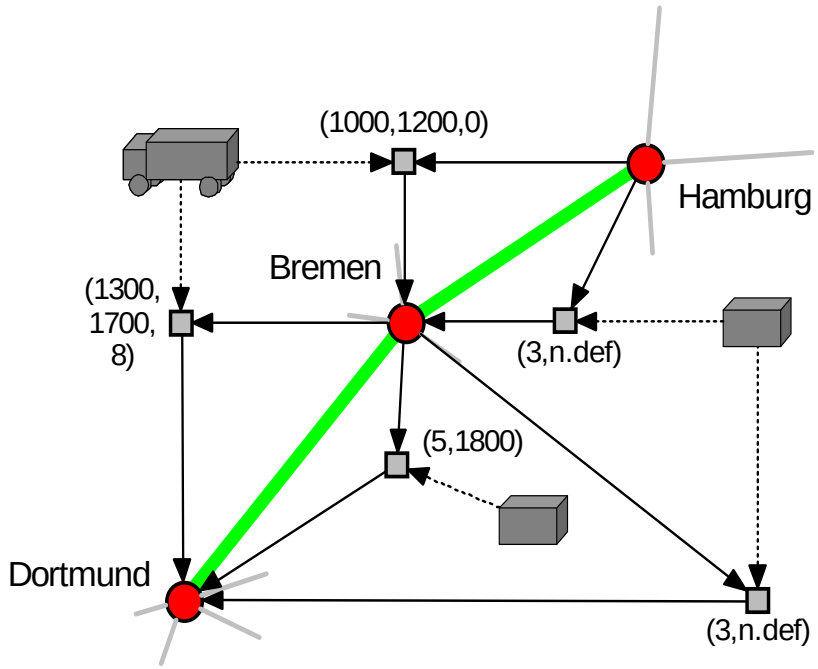
Planning Package Transportation

- Packages have to be transported from one consolidation point to another
- Trucks with fixed routes and timetables
- Routes of packages have been planned according to truck timetables
- Which of the waiting packages are actually transported should be scheduled according to their own constraints

$\Rightarrow$ Market-based approach: Negotiation between packages and truck based on payment of transport rates

Transport Networks

- Road map modelled as a graph
- Trucks and packages are so called autonomous units represented as nodes
- Tour nodes represent tour sections
- Graph transformation rules for offers and replies



Autonomous Graph Transformation Units

Graph transformation

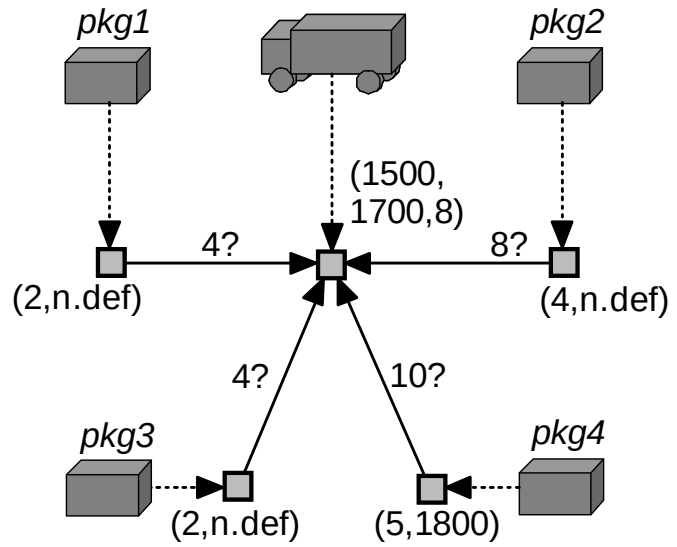
- A graph represents an environment
- Rule application on a graph realizes changes in environment
- Yielding a formal operational semantics including parallelism, concurrency and an inductive proof principle

Autonomous transformation unit

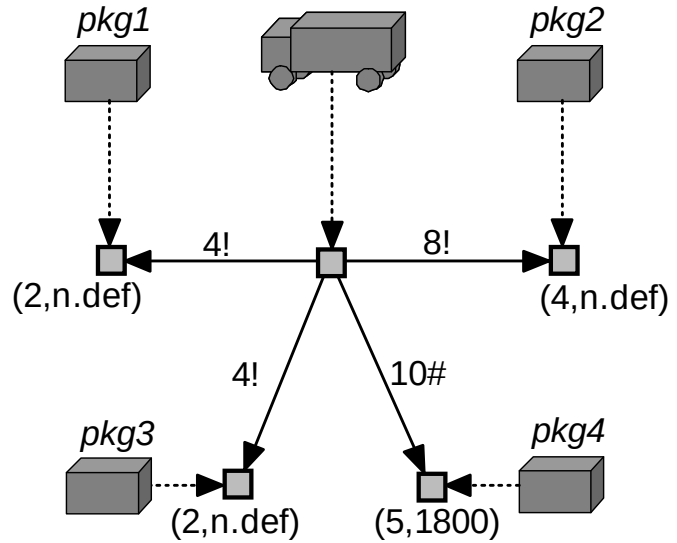
- Rule-based instantiation of the idea of an agent in a multi-agent system
- Autonomy: Next action is based on nondeterministic selection of a rule locally within each unit (rather than on control from outside the unit)

Sample Negotiation (1)

- Packages arriving at consolidation points are queued according to their arrival time
- Each package makes an offer for transportation to the desired truck
  Transport rate:
  weight of package $*$ transport time



- Truck scans the offers respecting the queue order, accepts as many offers as its capacity allows and rejects the rest

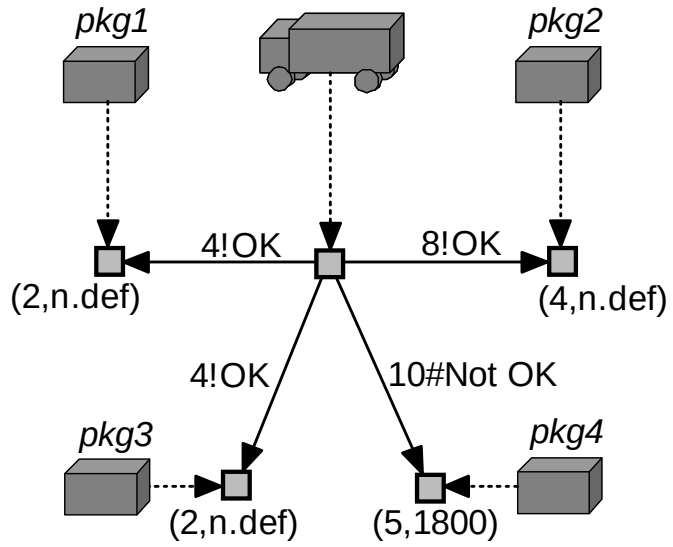


Sample Negotiation (2)

- Each package answers to acceptance/rejection of offer
- If all packages accept decision by truck

  $\Downarrow$

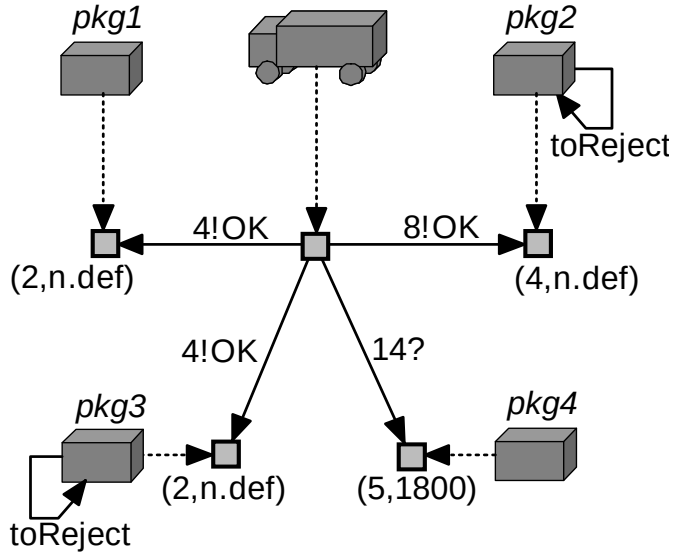
  Transport schedule can be fixed



- If a package rejects decision

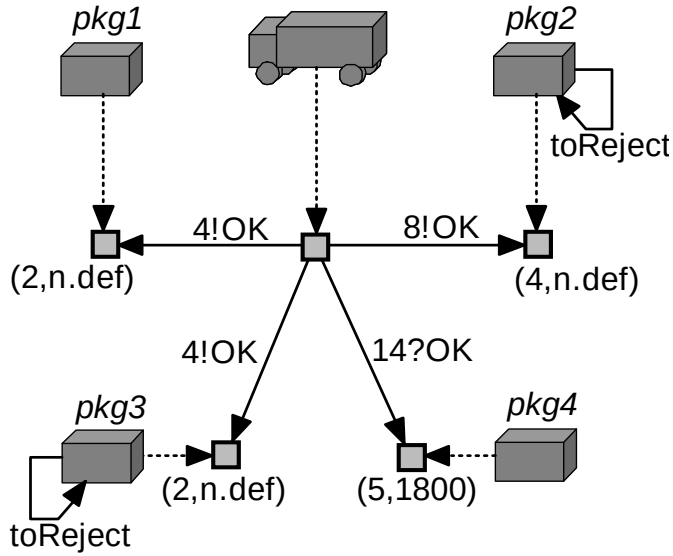
  $\Downarrow$

  Truck calculates new transport rate for this package:
  Missing amount compared to full truckload + 1 for every previously accepted and now rejected package



Sample Negotiation (3)

- If the respective packages accept the new transport rates



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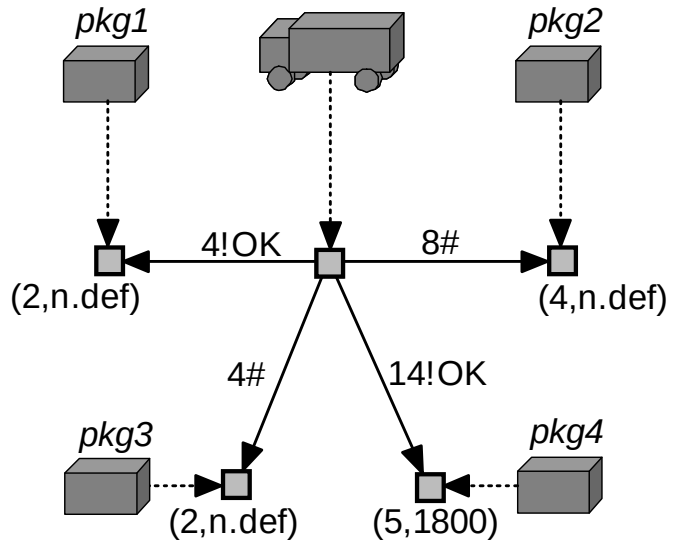
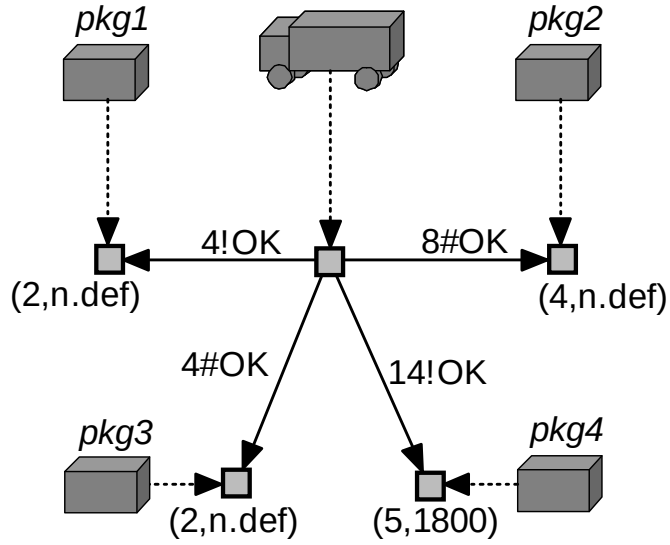
- Truck issues new transport decision



Sample Negotiation (4)

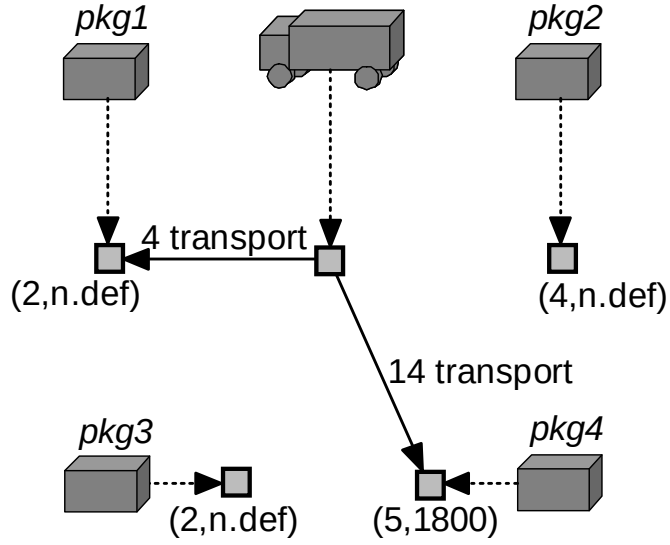
- The now rejected packages answer to the new decision



- If the now rejected packages accept the new situation

  $\Downarrow$

  Transport schedule can be fixed



Sample Negotiation (5)

- If a now rejected package disagrees with new situation a further negotiation starts
- From now on the new transport rate is calculated as before $+ 1$ for every round of negotiations
- No endless negotiation
  - Package has only a fixed amount at its disposal
  - Alternatively restrict the number of rounds of negotiations

Conclusion

Results

- Communicating autonomous units can model alternatives for transport scheduling
- Formal framework allows to prove properties of the modelled system

Future work

- Additional factors for negotiation process
  - customer retention
  - transhipment costs
  - competition between logistic companies
- Simulate and compare various negotiation concepts

Thank you for your attention!