Transporting people with reduced mobility through the airport

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My background

- M.Sc. Mathematics, Eindhoven University of Technology
- Ph.D. Scheduling, Eindhoven University of Technology
- Engineer in Informatics Division, National Aerospace Center NLR: Air Traffic Management, simulation, optimization
- Lecturer/Researcher, Department of Information and Computing Sciences, Utrecht University: advanced planning algortihms, simulation, software- and gameprojects.

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The problem

- People with reduced mobility (PRM) require assistance when travelling through the airport
- Airport with different terminals
- Within terminal:
  - Employees transporting up to two PRMs, depending on their disability.
  - Outside lounges PRMs have to be assisted/supervised by employee (not left alone)
  - Supervised lounges
- Special inter-terminal busses
- Special platform busses to access aircraft at a remote stand
- Busses transport at most 12 PRM's

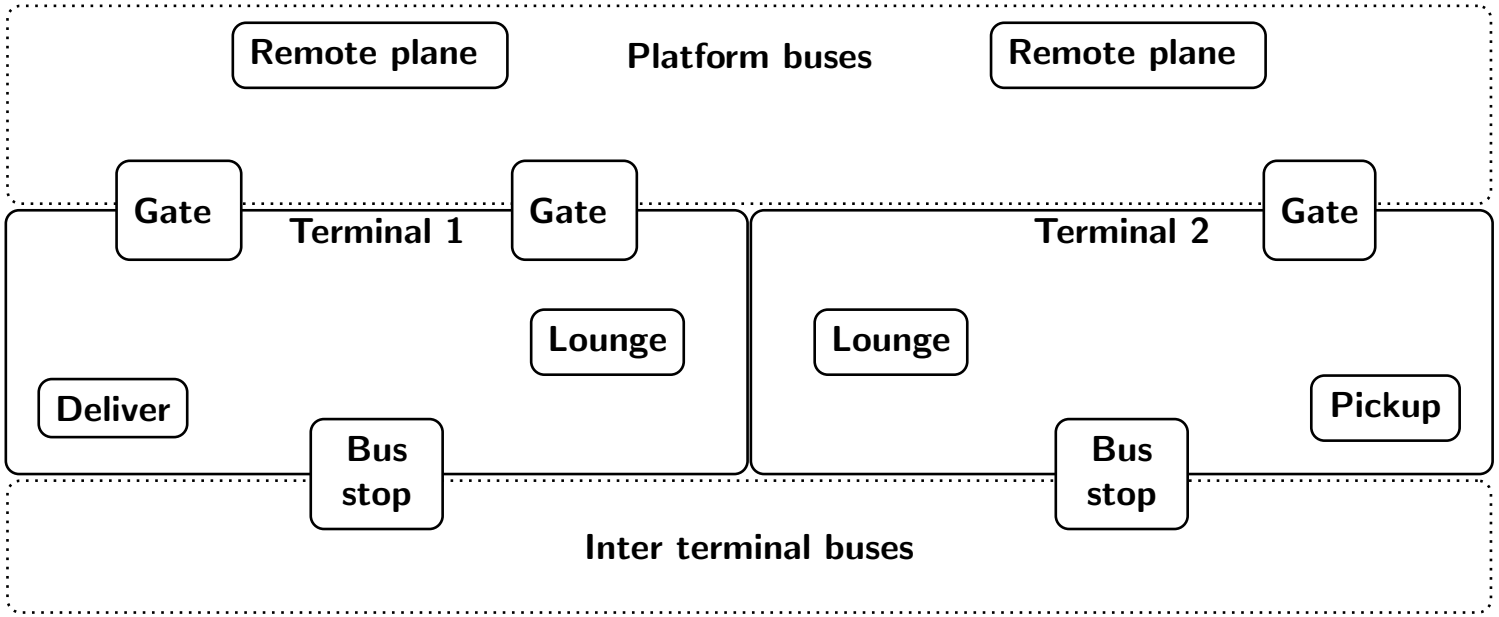
The problem(2)

We want to find a schedule for the airport employees and busses.

We received instance data from an airport transporting 300 to 500 PRM's daily, which we used for our experiments.

Journeys of PRMs

- Arrival journey.
- Departure journey.
- Transfer journey.



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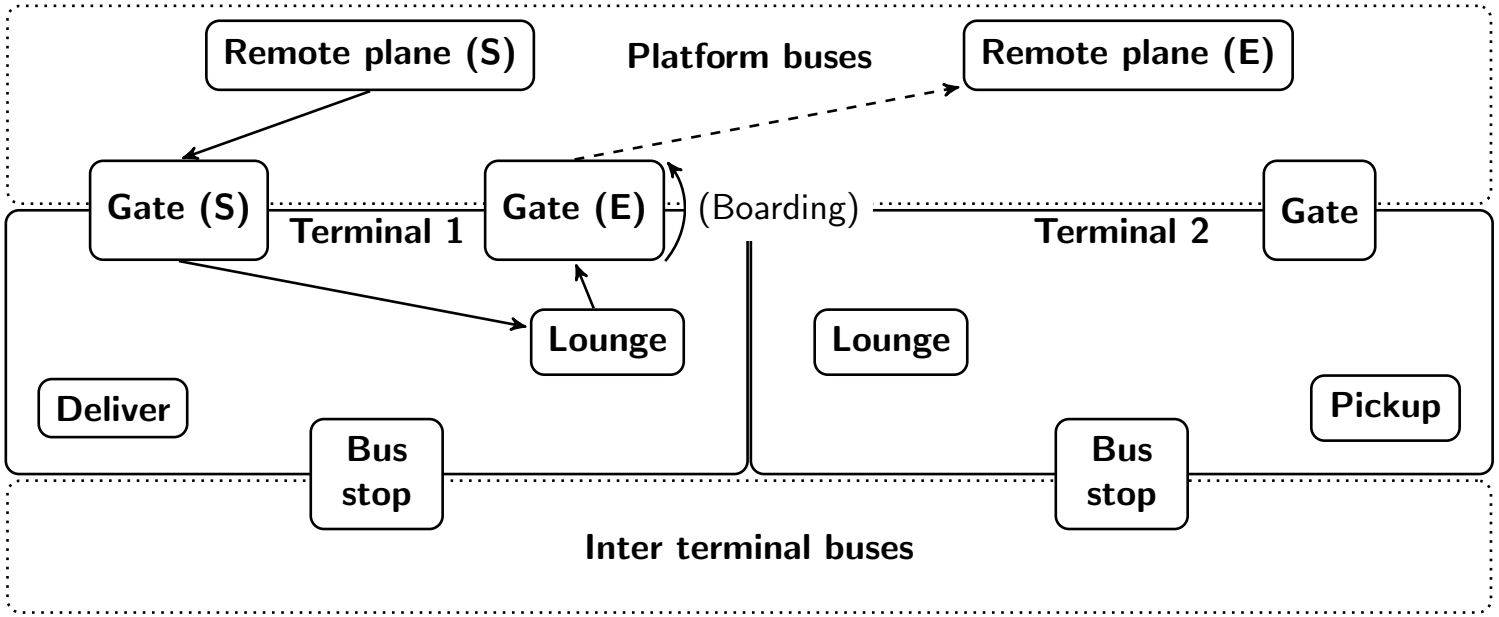

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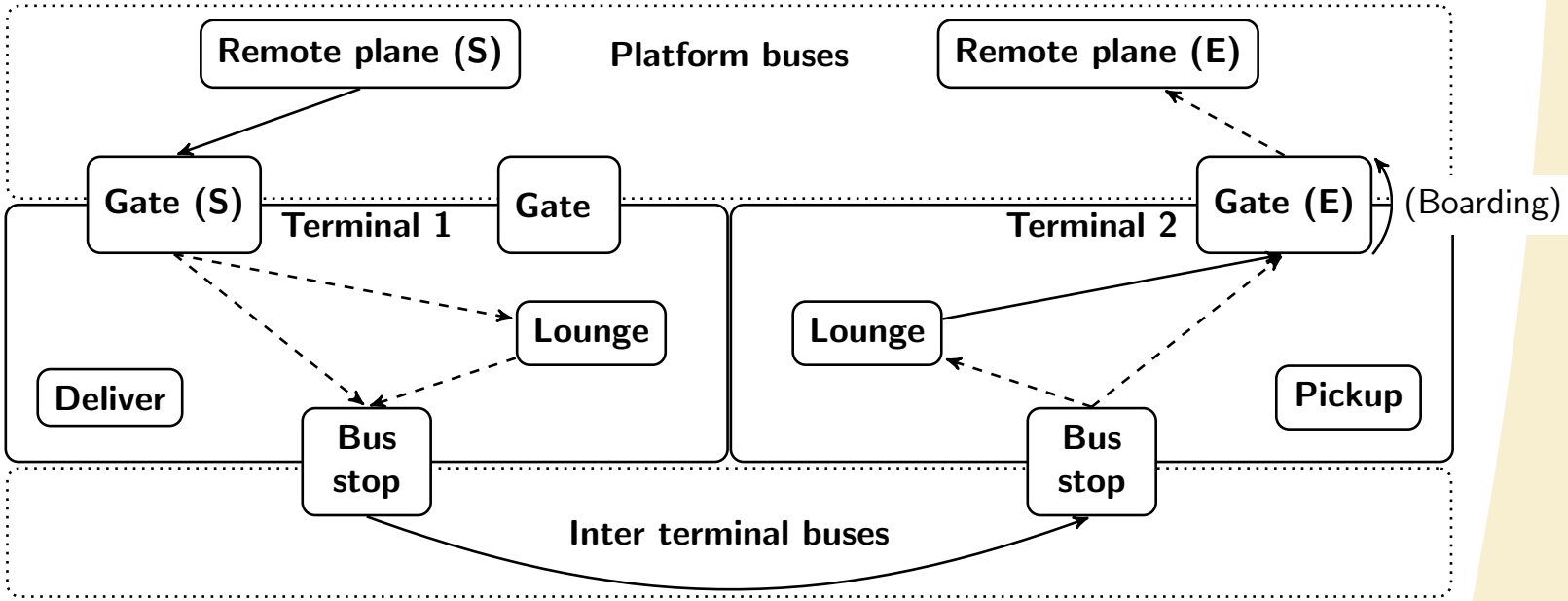

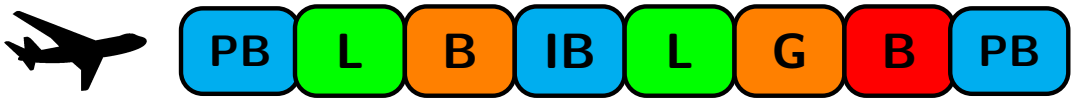

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Waiting

Waiting in the lounge:

A PRM obtains uncomfortable waiting by:

- Waiting at handover
- Detour

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Objective (2)

Find a schedule of employees and busses such that:

- We minimize the number of declined PRMs where we prioritize PRMs who booked ahead.
- Minimize the uncomfortable waiting time

The schedule must be found within 2 minutes of computation time.

$\mathcal{N}P$-hard optimization problem.

Approach Reinhardt et al

- List insertion heuristic
- Simulated annealing to find good order of list
- Found good schedules some 0 PRMs declined.
- Schedules contain uncomfortable waiting time

Additions

Add robustness to the optimization objectives.

Synchronization

- Segment groups
  - Fixed start times for segment groups involving boarding/disembarking
  - Use the lounges to split journeys.
- Improve schedule by focus on one or more PRMs sharing a trip.

Strictly avoid uncomfortable waiting time: fixed at 0

In a deterministic setting

Robustness

A connection is robust when there is slack time between subsequent segments on an employee or bus.

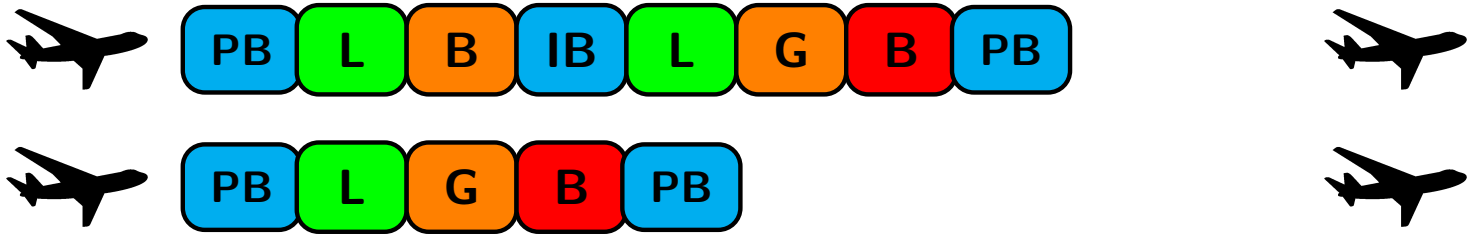
The slack s_{r_1,r_2} of 2 subsequent segments r_1 and r_2 on employee e is equal to the start time of r_2 minus the end time of r_1 minus the travel time:

$$rp(r_1, r_2) = \left\{ \begin{array}{ll} 0 & \text{if } r_1 \text{ and } r_2 \text{ concern the same PRM} \\ (20 - min(s_{r_1,r_2}, 20))^2 & \text{otherwise} \end{array} \right\}$$

We use lexicographical ordering to include robustness in our objective function.

Synchronization: segment groups

Transfer:



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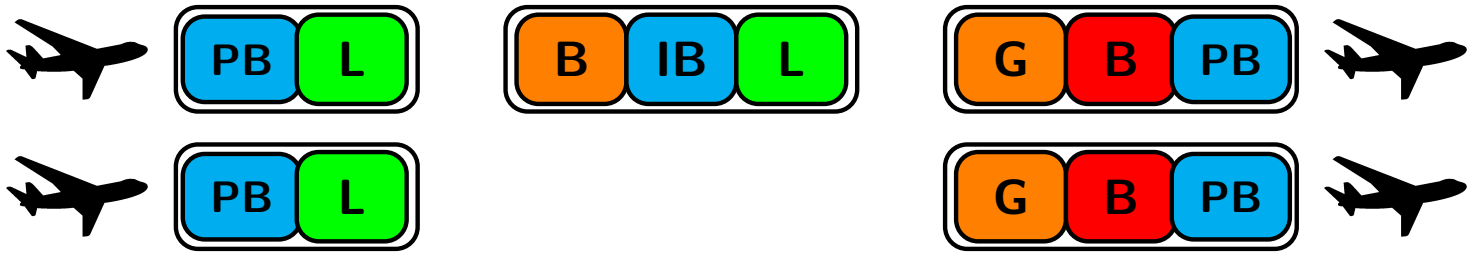
Synchronization: segment groups

Segment Groups:

Transfer:



- Fixed start times for segment groups involving boarding/disembarking of aircraft.

Strictly avoid uncomfortable waiting time: fixed at 0

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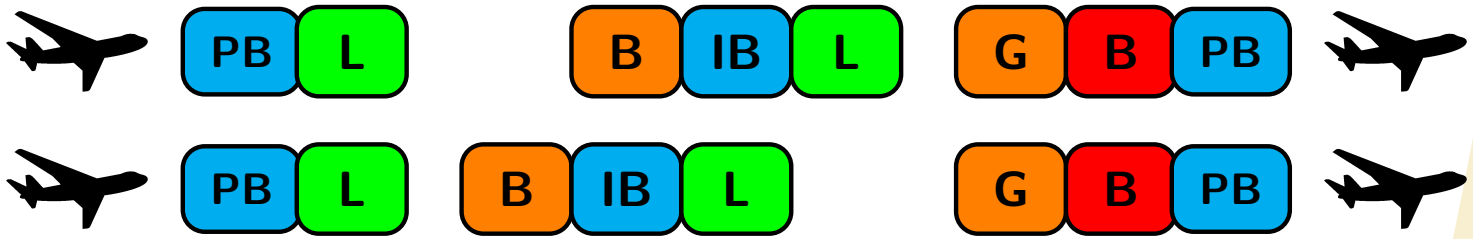
Synchronization: Sharing segments

Segments between 2 PRMs can be shared with one employee/bus:

- Arrive with the same flight.
- Depart with the same flight.
- Travel between the same terminals.

Transfer journeys of 2 PRMs:



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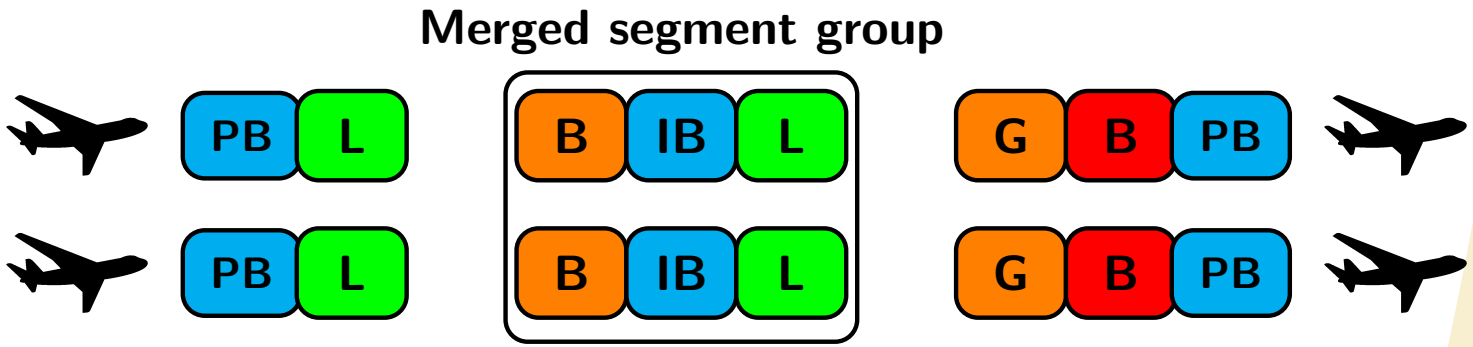

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Decomposition Model

In our approach to this problem we want to make use of a decomposition model:

Master-level: Determine feasible start times for the segments.

- Local Search, i.e. iterative search heuristic.

Sub-level, i.e. in each step of Local Search: assign the tasks to the employees

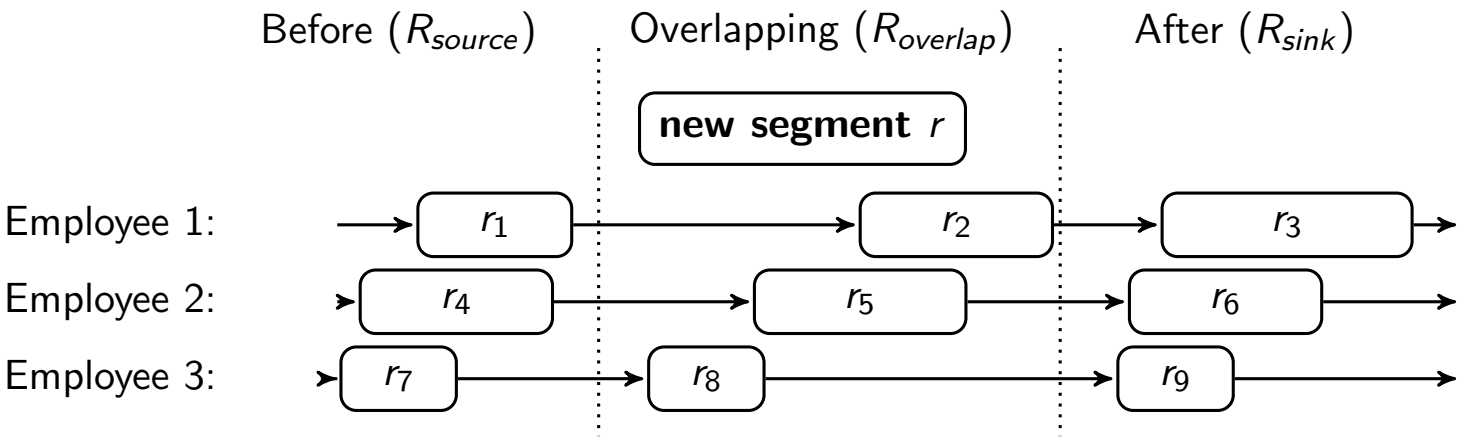
- Matching

Local search

- Simulated annealing.
- Assign feasible start times for segments.
- Accepts or declines PRMs.
- Starts with empty solution.
- Mutations:
  - Plan PRM
  - Decline PRM
  - Merge segment group
  - Move segment group
  - Split merged segment group.
- Objective function: lexicographical ordering.

Local matching

- Uses old solution prior mutation.
- Represents the schedule as graph $G = \{V, E\}$.
- Matches mutated segments along with competing segments.



- Part of the schedule change.
- Exchange sequences of tasks.

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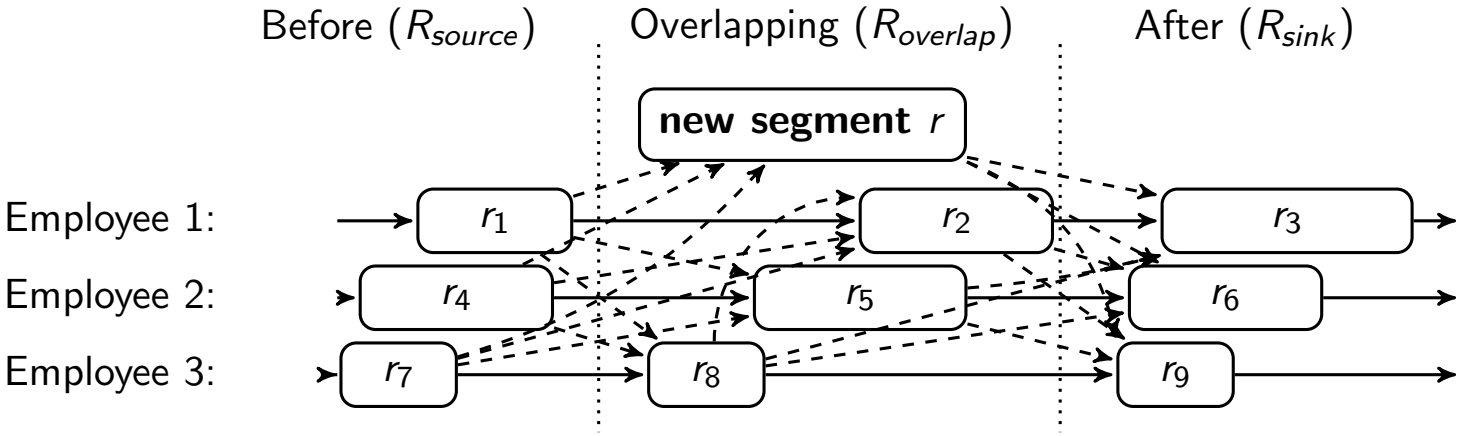

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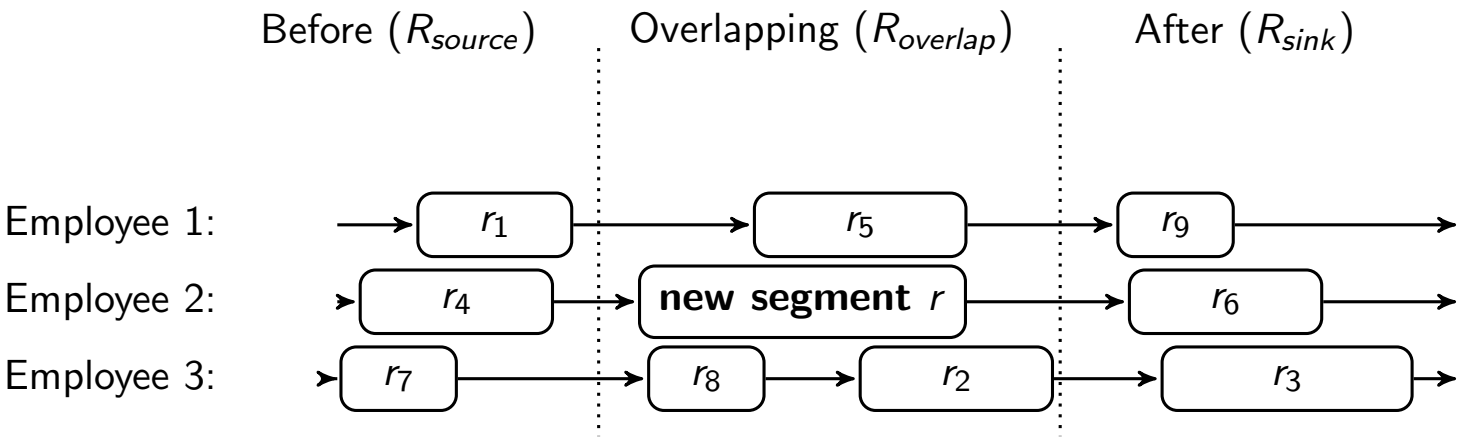

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Results Local matching

instance	time(s)	iterations	Best		Average	
			declined	robust	declined	robust
1	1,8	11143	0	0	0,0	0,0
2	70,7	500000	1	0	1,4	183,2
3	43,4	289371	0	0	0,0	0,0
4	17,7	115761	0	0	0,0	0,0
5	51,9	243457	0	0	0,0	0,0
6	47,0	160797	0	0	0,0	0,0
7	10,4	69227	0	0	0,0	0,0
8	14,5	82530	0	0	0,0	0,0
9	9,5	58167	0	0	0,0	0,0
10	52,4	257654	0	0	0,0	0,0
11	51,2	174627	0	0	0,0	0,0

- Optimum solutions except instance 2. (broken instance)
- Robust
- Fast

Simulation

- Robust vs no robust.
- Disturbances:
  - Additional PRMs. (100)
  - Flight delays.
  - Walking time differs.
- Start with initial schedule.
- Same instances, seed, flight delays and PRMs.

Simulation results

statistic	robust mean	robust var.	no robust mean	no robust var.	p score
declined booked	$1,15$	$1,49$	$1,08$	$1,49$	$0,52$
declined immediate	$2,4$	$3,89$	$2,37$	$3,88$	$0,56$
wait time	$87,35$	$2024,87$	$170,6$	$8212,02$	$1,10E^{-15}$
full reschedules	$11,4$	$20,50$	$11,15$	$21,12$	$0,37$

- Less wait time.
- Same amount of rescheduling.

Conclusion

- Found schedules 0 PRMs declined
- Realized 0 uncomfortable waiting time.
- Robustness cost function helps to improve schedule
- Identical shifts makes problem easier.
- If 0 uncomfortable waiting time turns out to be infeasible, algorithm can be extended with splitting of segment groups.