Modeling Demand Responsive Transport using SARL and MATSim

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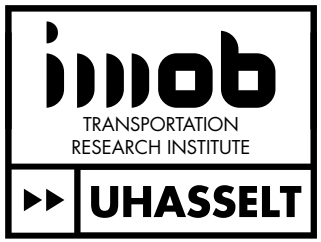

Overview

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Introduction: *Problem Context*

1. Public Transport widely used
2. Flanders, Belgium
3. Basic Mobility
   - Distinction between areas
   - Amplitude and frequency
   - Distance homes and bus stops
   - $\rightarrow$ expensive! (Thin Flows)
4. Basic Accessibility
   - PT should be complemented with other transport
   - train + bus {kernel, additional (feeder), specific (local, DRT)}
5. Aim:
   - Can DRT substitute certain PT lines?
   - Under which subsidy condition can DRT survive?

Overview

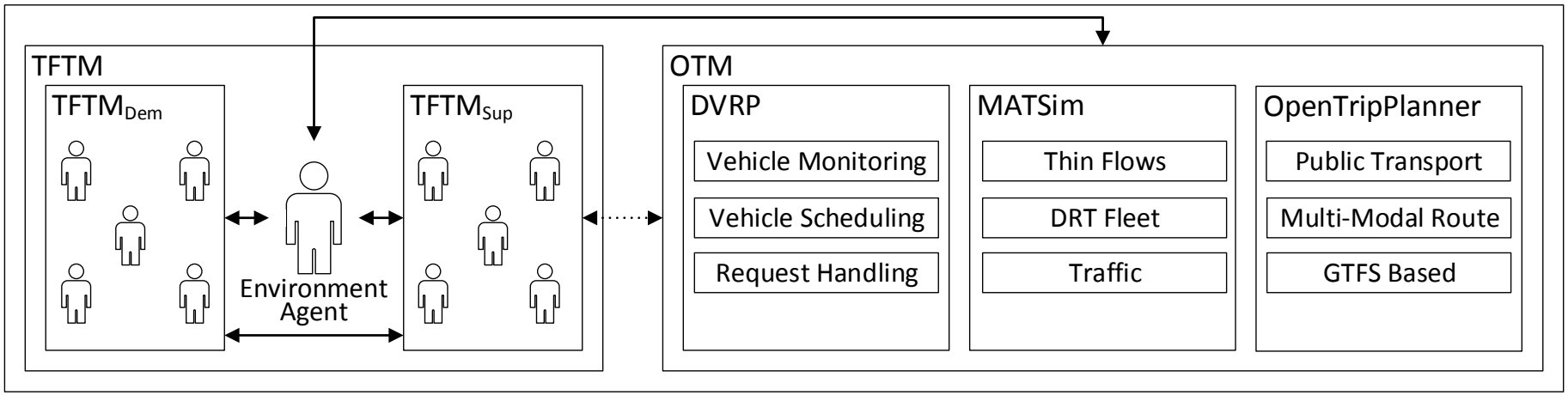
Modeling DRT: *Simulation*

1. Micro-simulation
2. Aggregation methods inappropriate
   - Averaging demand ignores effects of distribution
     - temporal dimensions
     - spatial dimensions
   - Spatial and temporal variability $\rightarrow$ influence outcome
3. Negotiation about trips
   - Timings
   - Transfers
   - Labels (mobility impairment, subsidies)
4. `SARL`

Modeling DRT: *Software Overview*

- Simulation over a long term period
- Demand: need trips
- Supply: provide trips
- Two parts:
  - Thin Flows Travel Model (`TFTM`):
    - negotiation between agents (demand - supply)
    - `SARL`
  - Operational Travel Model `OTM`:
    - External API
    - efficient scheduling trips
    - DRT $\rightarrow$ `MATSim`
    - PT $\rightarrow$ OpenTripPlanner

Modeling DRT: *Software Overview*



Modeling DRT: *Thin Flows Travel Demand Model*

1. TFTM_{Dem}
2. Customers in thin flows executing schedules
3. Travel decisions: trip sequence feasibility
   - mode choice, service selection
   - accessibility
     1. by own means (walk, bike, car, . . .)
     2. using collective and/or public transport
   - determines potential feasible solutions (based on estimated timing)
4. Customer can
   - ask for $N \geq 1$ different proposals for multi-leg trips
   - wait for $M \in [1, N]$ proposals before deciding which option to choose,
   - require sequences of chronologically non-contiguous trips (atomic),
   - refuse some proposals

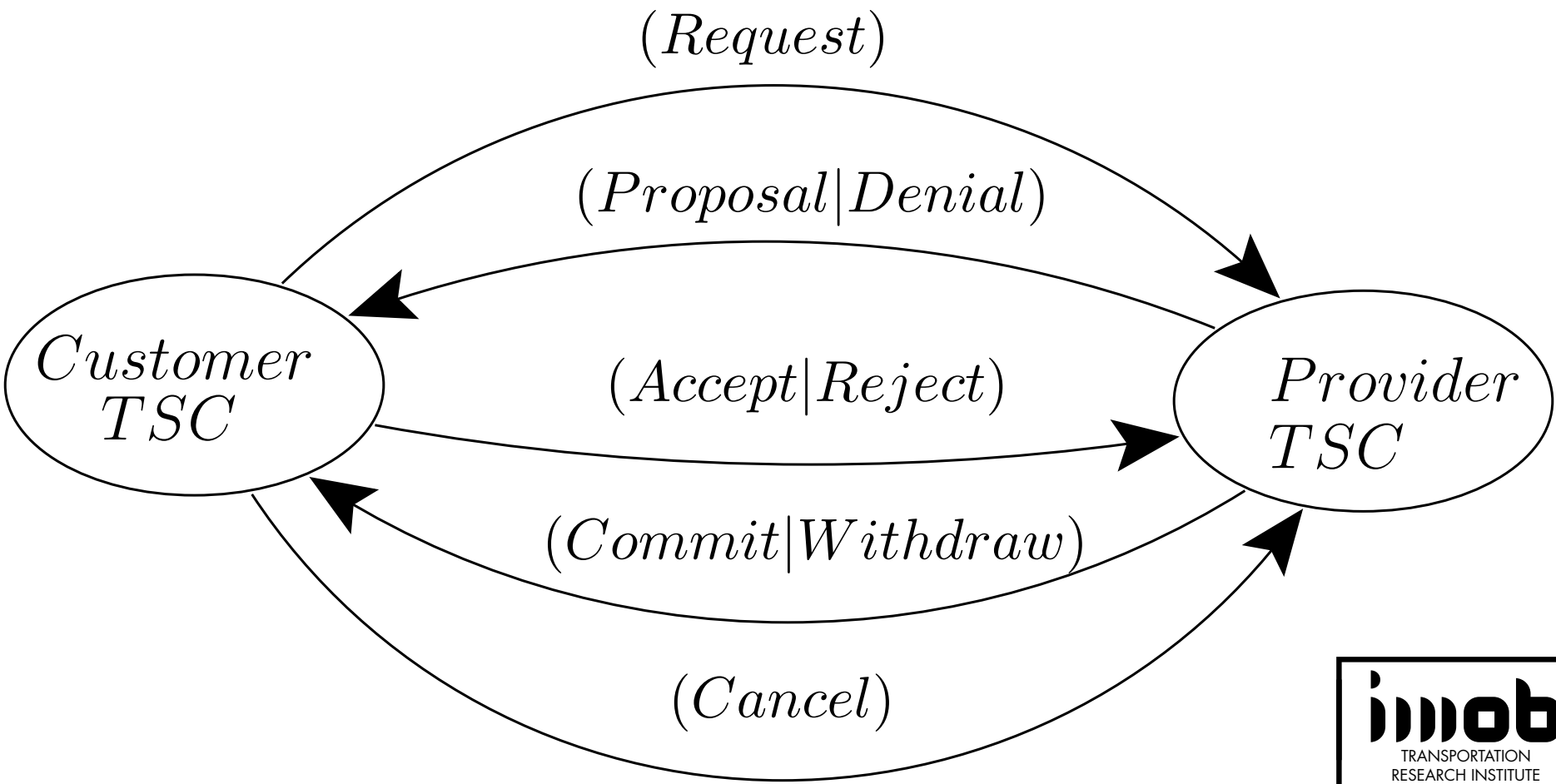
Modeling DRT: *Thin Flows Travel Supply Model*

1. TFTM_{Sup}
2. Companies providing transport (public, private)
3. Can use OTM (`MATSim`, OpenTripPlanner)
4. Requests to `OTM` are preprocessed in TFTM_{Sup}
   - reduce time consuming `OTM` operations
   - `TFTM` model $\rightarrow$ legal, functional constraints
     1. physical accessibility (labels)
     2. user qualification rules
   - `OTM` model $\rightarrow$ operational constraints
     1. on fleet operations (VRP, feasibility)

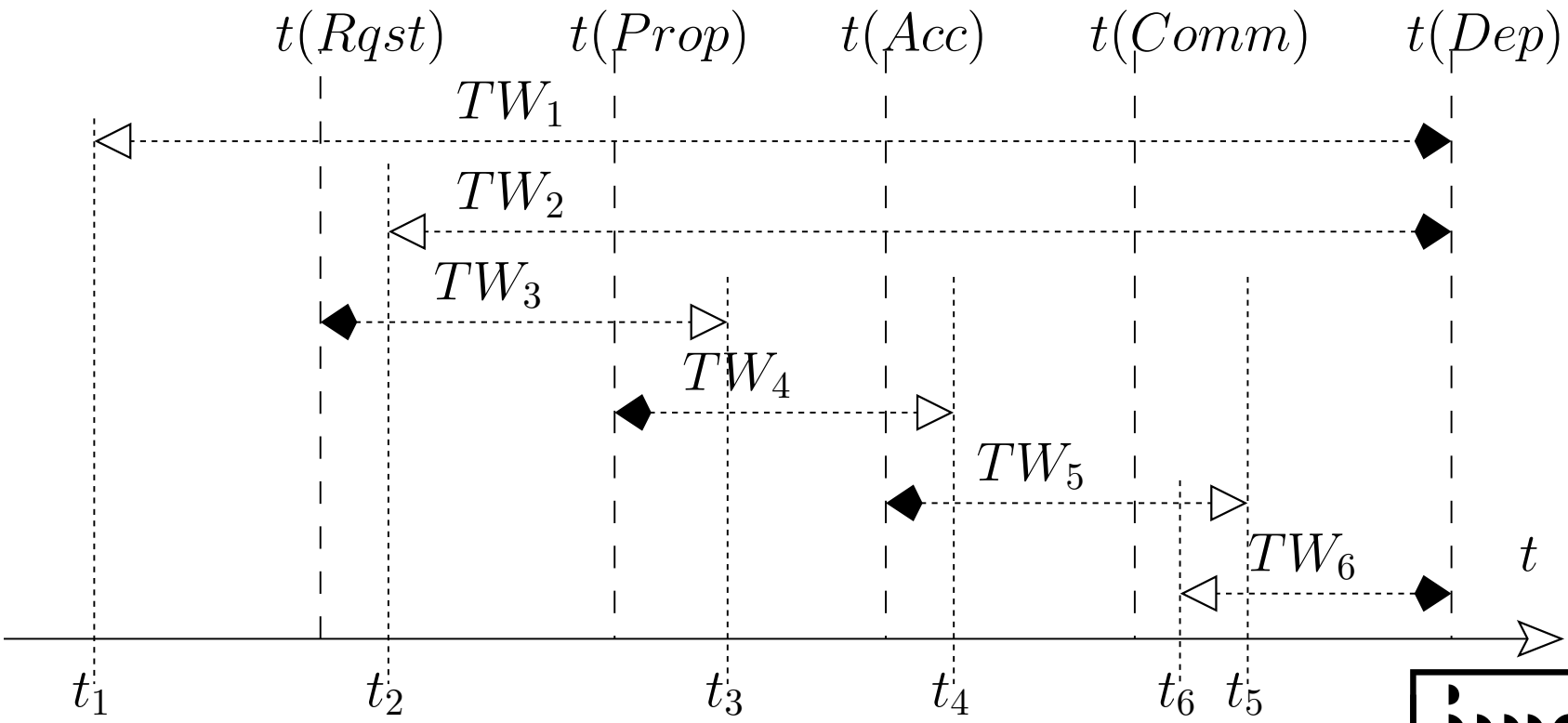
Modeling DRT: *Operational Travel Model* (OTM)

1. Two goals:
   - Microscopic simulation including thin flows, DRT fleet, traffic etc. (MATSim)
   - Dynamic vehicle routing (monitor and schedule vehicles, and handle incoming requests) (MATSim's DVRP).
2. DynAgents
   - Plans can be changed at any moment
3. Supply and demand are dynamic and stochastic
4. Requests from TFTM to OTM are translated into taxi requests for MATSim's DVRP

Modeling DRT: *Negotiation Messages*



Modeling DRT: *Negotiation Time Windows*



Overview

Co-Simulation Protocol: *Synchronization*

1. SARL → no notion of simulated time
2. Implemented conservative synchronization (*Cich, 2017, PAAMS*)
   - Single "Environment agent"
     - Manages time
     - Manages synchronization between `TFTM` and OTM
     - No agent needs to explicitly time-sync → simulated time proceeds to moment in which at least one agent needs to do something
   - Time is incremented using a constant period
   - Non-monotonic time evolution mechanism is under construction
   - Messages sent in period $p_i = [t_i, t_{i+1})$ → received in p_{i+1}

Co-Simulation Protocol: *Simulation*

1. Agent generates trip request ($A \rightarrow B$)
2. Requests are collected
3. At the end of time period
   - Requests transformed into JSON
   - Sent to OTM
4. OTM processes JSON objects
5. OTM simulates one time period after each synchronization point
6. OTM sends JSON object back to `TFTM`
   1. replies to requests
   2. unsolicited OTM events (e.g. passenger arrivals)
7. Sockets provide the JSON exchange

Overview

Conclusion:

1. Framework to combine micro-simulators
2. SARL simulation is coordinator
3. `MATSim` and OpenTripPlanner called when needed
4. Advantage: combine existing simulators
5. Proof-of-concept simulation is operational, no production results yet

Questions?

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