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Dynamic Train Demand Estimation and Passenger Assignment

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Agenda

- Background
- Research Problem
- Data
- Challenges
- Methodology
- Case Study
- Conclusion

Background

- Rapidly increasing public transport travel demand due to population explosion
  - London has suffered a 70% increase in public transport patronage over the last 20 years
  - Sydney train network has reached 377.1 M patronage in 2019, 17.7% increase since 2013
- Understanding passenger flow in the train network is significant
  - Situation awareness
  - Response to service disruptions
  - Transport planning

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Research Problem

- Our research problem is to estimate passenger flow in the train network
- It can be divided into two sub-problems
  - Estimate time-dependent Origin Destination (OD) matrix
    - Where are the passengers from?
    - Where are the passengers to?
    - When?
  - Passenger assignment – assign passengers to specific trains
    - What are the paths that the passengers travel from origins to destinations?

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Data

Network layout data

Train stations

Connections between stations

Station platforms

Timetable data

Departure times

Arrival times

Stations

Station Patronage data

Number of passengers tapping-on

Number of passengers tapping-off

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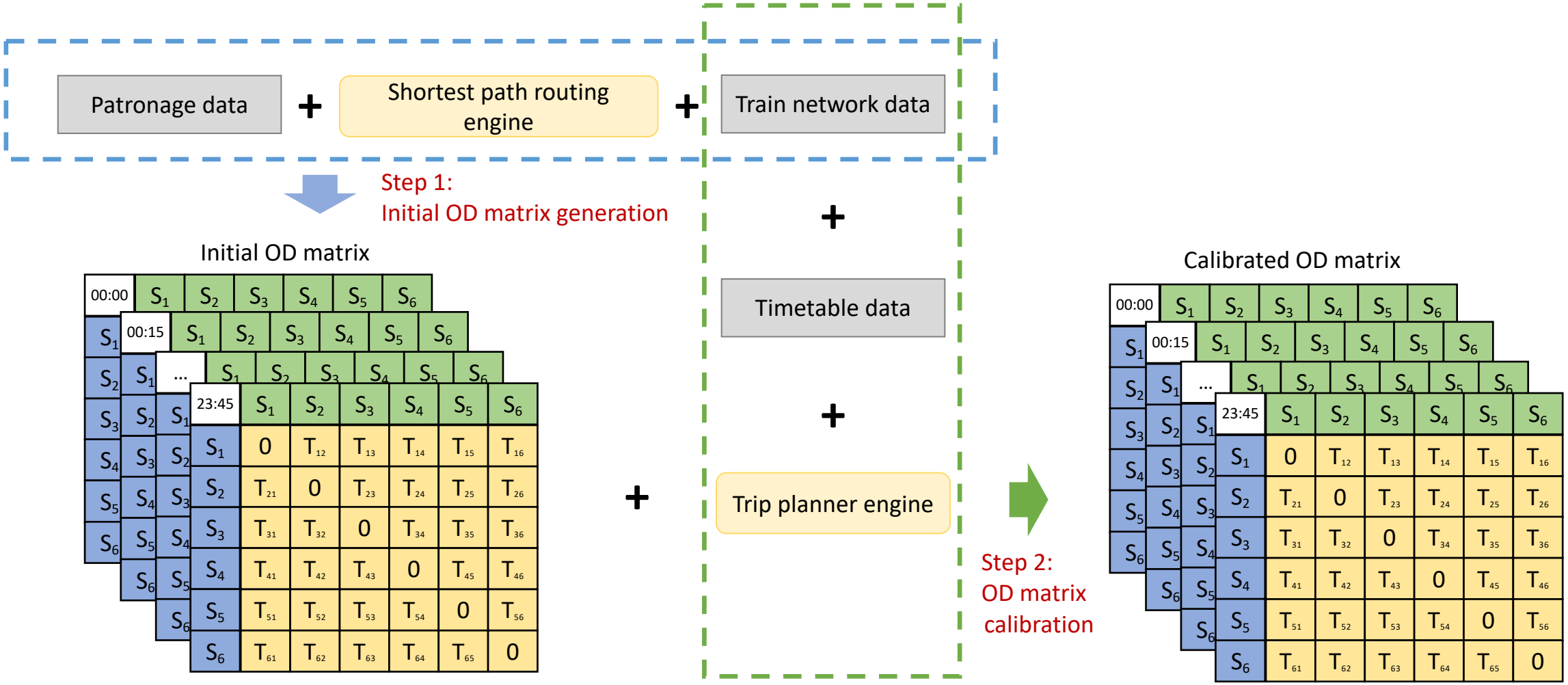
Challenges

- Patronage data is aggregated for every 15-minute time interval
- It is unknown which tap-on and which tap-off belong to a same passenger
- It is unknown which train a specific passenger boarded once he/she entered a station
- In-station transfer: passengers could take various transfer options from a same origin to a same destination

Method to Estimate Time-Dependent OD Matrix



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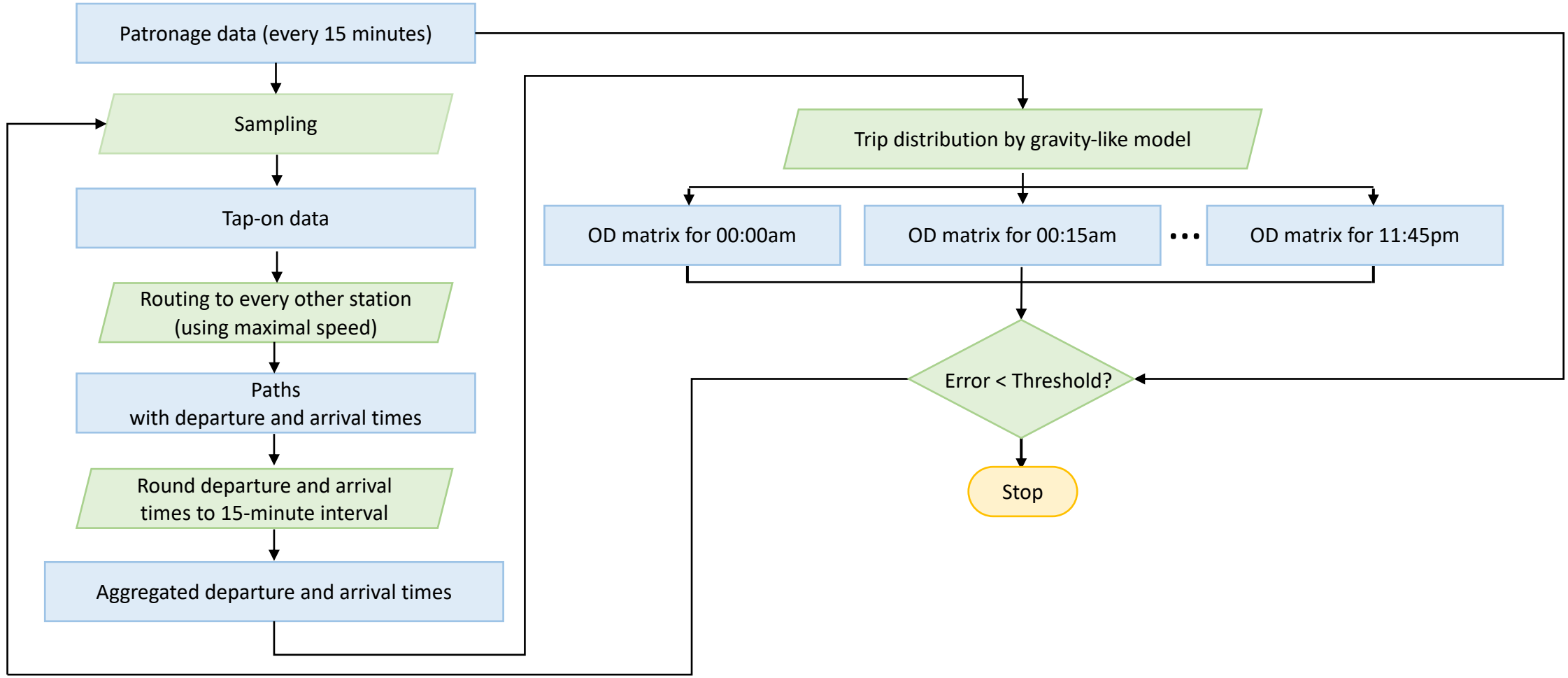
Initial OD Matrix Estimation



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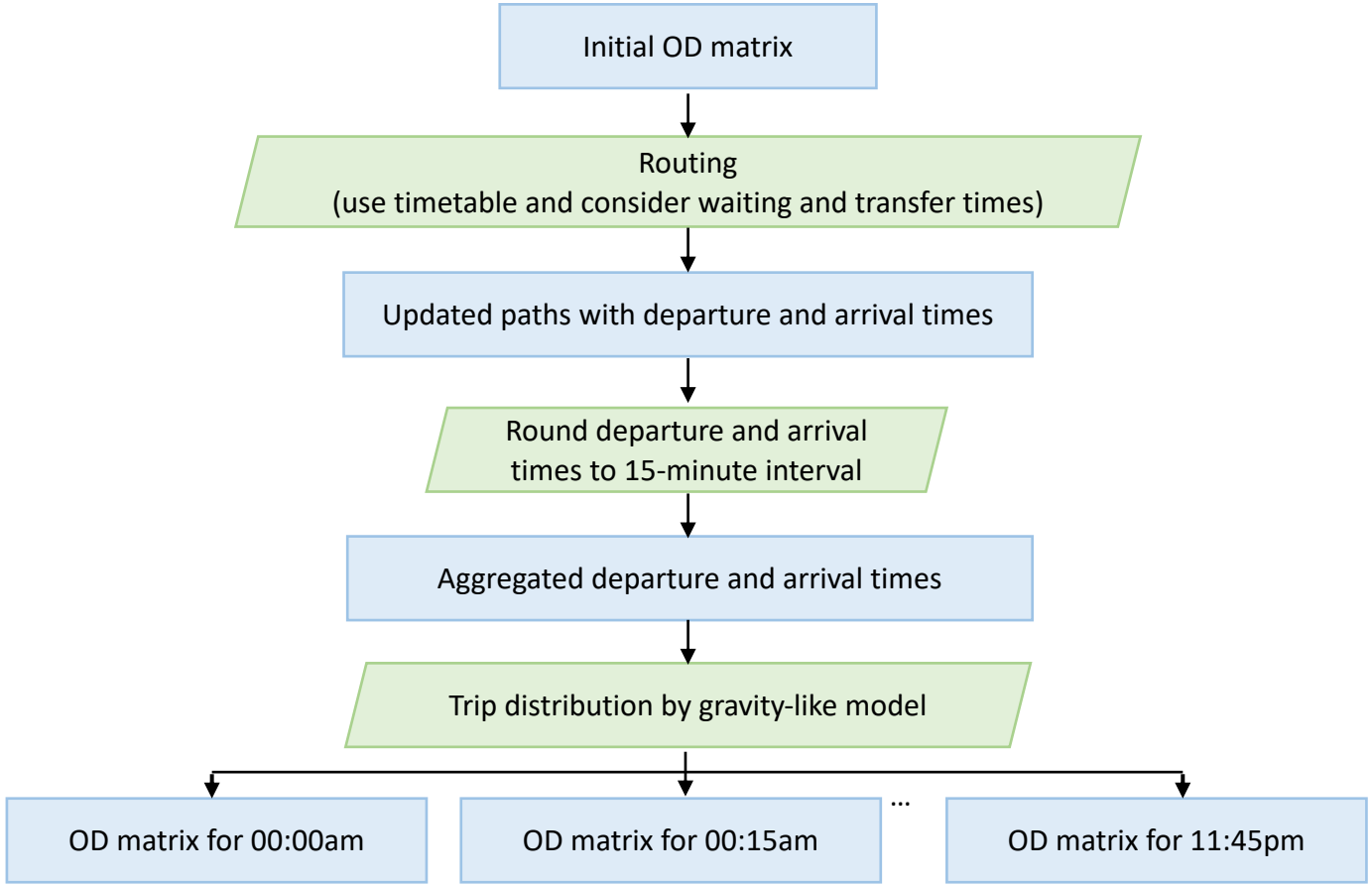
OD Matrix Calibration



	S_1	S_2	S_3	S_4	S_5	S_6
S_1	0	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}
S_2	T_{21}	0	T_{23}	T_{24}	T_{25}	T_{26}
S_3	T_{31}	T_{32}	0	T_{34}	T_{35}	T_{36}
S_4	T_{41}	T_{42}	T_{43}	0	T_{45}	T_{46}
S_5	T_{51}	T_{52}	T_{53}	T_{54}	0	T_{56}
S_6	T_{61}	T_{62}	T_{63}	T_{64}	T_{65}	0

$T_{ij} = (t_{ij}, ((p^1_{ij}, w^1_{ij}), (p^2_{ij}, w^2_{ij}), \ldots, (p^k_{ij}, w^k_{ij}))$

t_{ij}: total number of trips from S_i to S_j

p^k_{ij} : path k from S_i to S_j

w^k_{ij} : weight of path k from S_i to S_j

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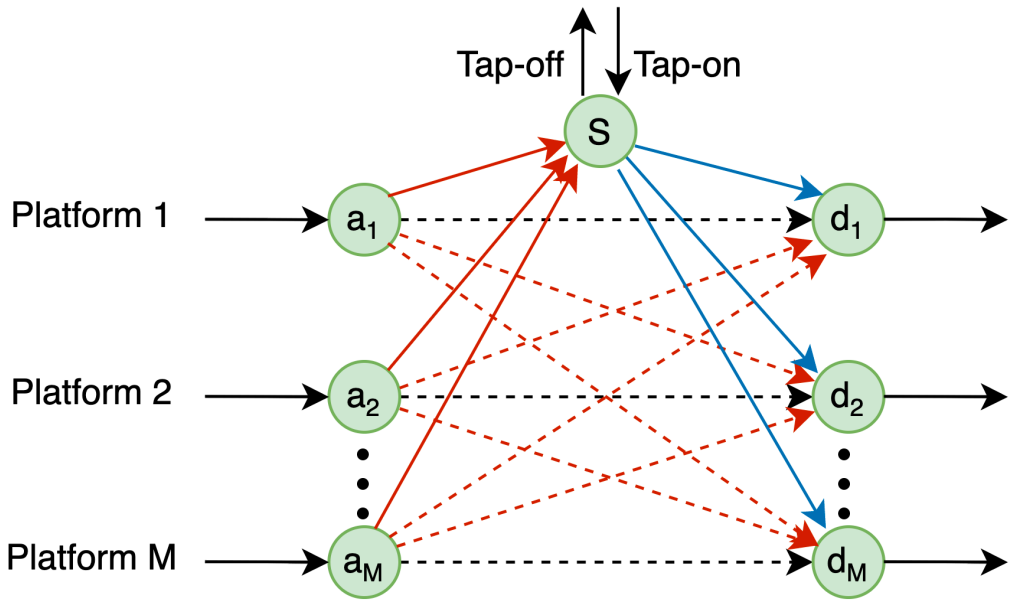
Passenger Assignment



a_m arrival at platform m

d_m departure from platform m

S at station entry/exit

platform to station exit

Transfer between platforms

remain in train

station entry to platform

Number of passengers remaining in the same train at a platform

$$Np_{a_m}^{remain}(T_r) = \sum_{t_{a_m}^i \in T_r} (Np_{a_m}(t_{a_m}^i) \times Pr_{t_{a_m}^i t_{d_m}^i}(d_m|a_m))$$

Number of passengers exiting from a platform

$$Np_{a_m}^{exit}(T_r) = \sum_{t_{a_m}^i \in T_r} (Np_{a_m}(t_{a_m}^i) \times Pr_{t_{a_m}^i}(S|a_m))$$

Number of passengers transferring from a platform

$$Np_{a_m}^{transfer}(T_r) = \sum_{t_{a_m}^i \in T_r, t_{a_m}^i < t_{d_n}^j} (Np_{a_m}(t_{a_m}^i) \times \sum_{n=1, n\neq m}^{M} Pr_{t_{a_m}^i t_{d_n}^j}(d_n|a_m))$$

Number of passengers entering to a platform

$$Np_{d_m}^{enter}(T_r) = \sum_{t_{d_m}^i \in T_r, t_{d_m}^i > t_{a_n}^j} (Np_{d_m}(t_{d_m}^i) - \sum_{t_{a_n}^j \in T_r} (Np_{a_n}(t_{a_n}^j) \times Pr_{t_{a_n}^j t_{d_m}^i}(d_m|a_n)))$$

Number of passengers transferring to a platform

$$Np_{d_m}^{transfer}(T_r) = \sum_{t_{d_m}^j \in T_r, t_{d_m}^j > t_{a_n}^i} \sum_{n=1, n\neq m}^{M} (Np_{a_n}(t_{a_n}^i) \times Pr_{t_{a_n}^i t_{d_m}^j}(d_m|a_n))$$

Number of passengers in a station

$$Np^{total}(T_r) = Np^{total}(T_{r-1}) + \sum_{t_{a_m}^i \in T_r} \sum_{m=1}^{M} Np_{a_m}(t_{a_m}^i) + Np_{T_{on}}(T_r) - \sum_{t_{d_m}^i \in T_r} \sum_{m=1}^{M} Np_{d_m}(t_{d_m}^i) - Np_{T_{off}}(T_r)$$

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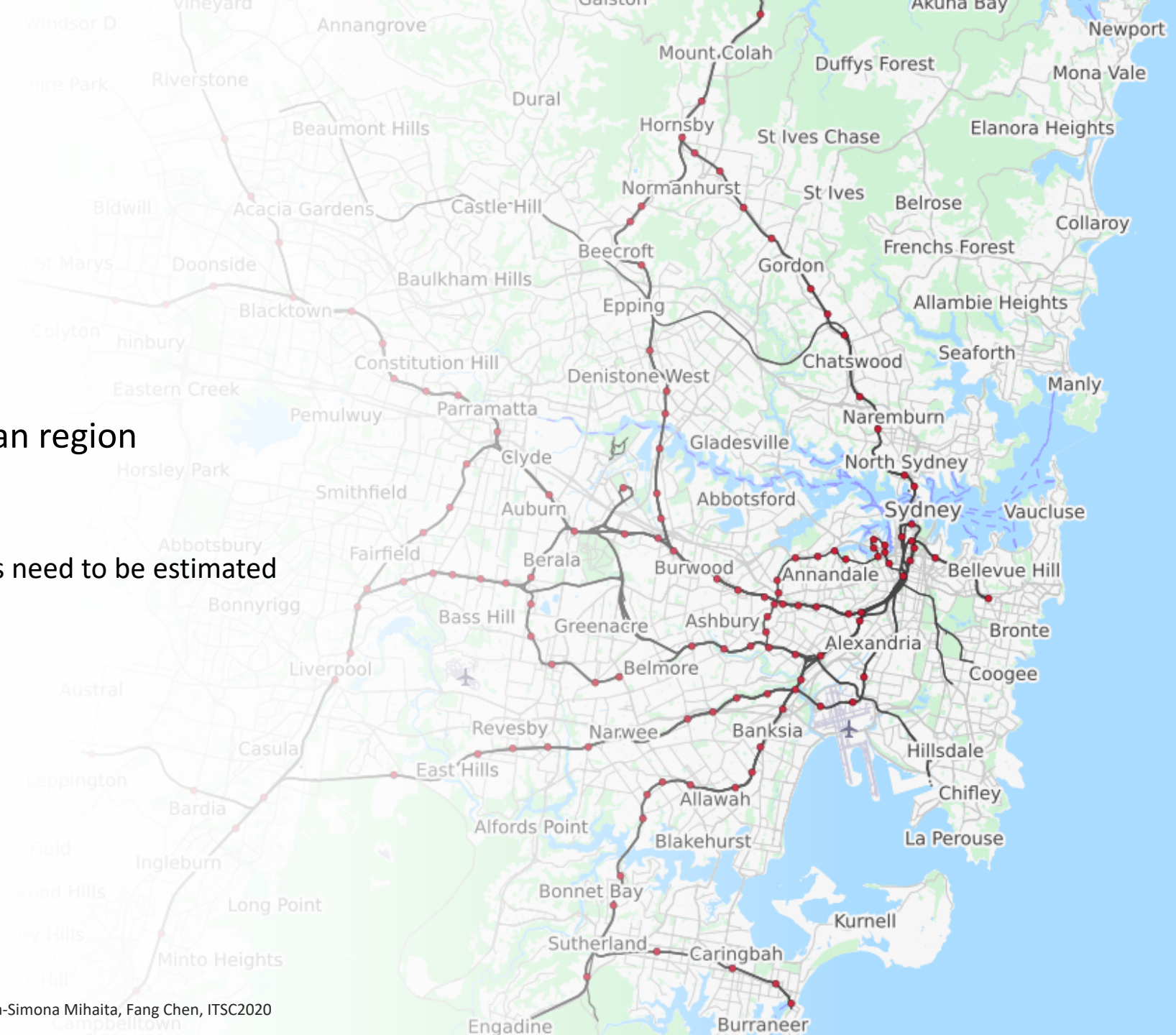
Case Study

Sydney train network in metropolitan region

- 175 train stations
- 506 platforms
- 2.9 million time-dependent OD pairs need to be estimated



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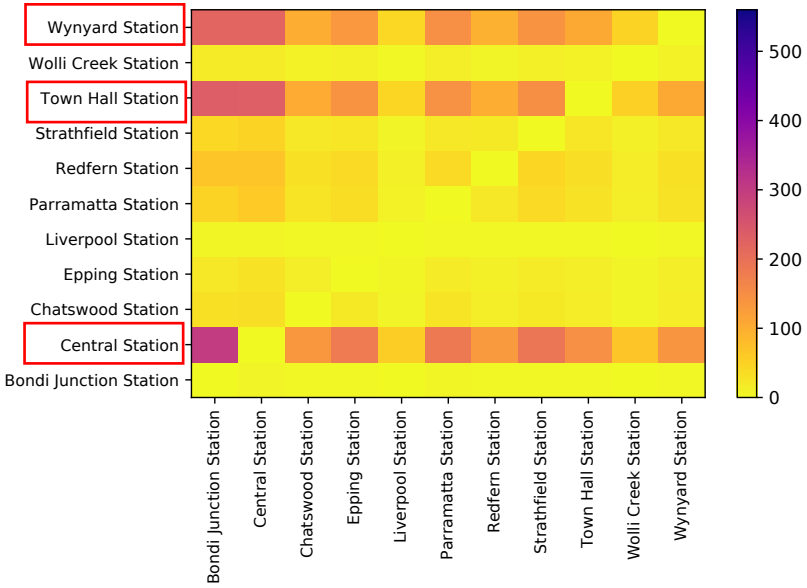
Results: Time-Dependent OD Matrixes

OD matrix heat maps for 11 selected stations

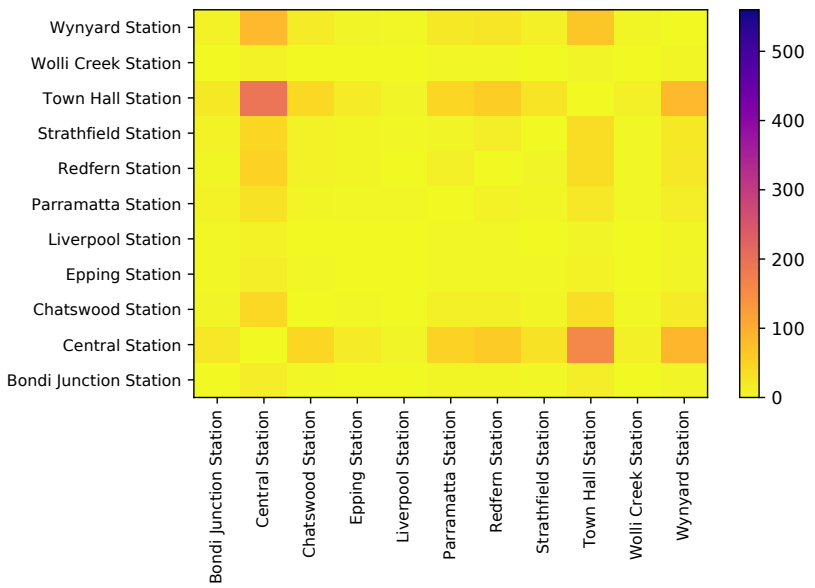
- 3 major stations in CBD (Central, Town Hall, Wynyard)
- 8 interchange stations outside CBD (Redfern, Strathfield, Parramatta, Liverpool, Chatswood, Epping, Bondi Junction, Wolli Creek)

Observations

- More passengers are travelling to the 3 CBD stations in the morning peak hours
- More passengers are travelling from the 3 CBD stations in the afternoon peak hours



08:00AM



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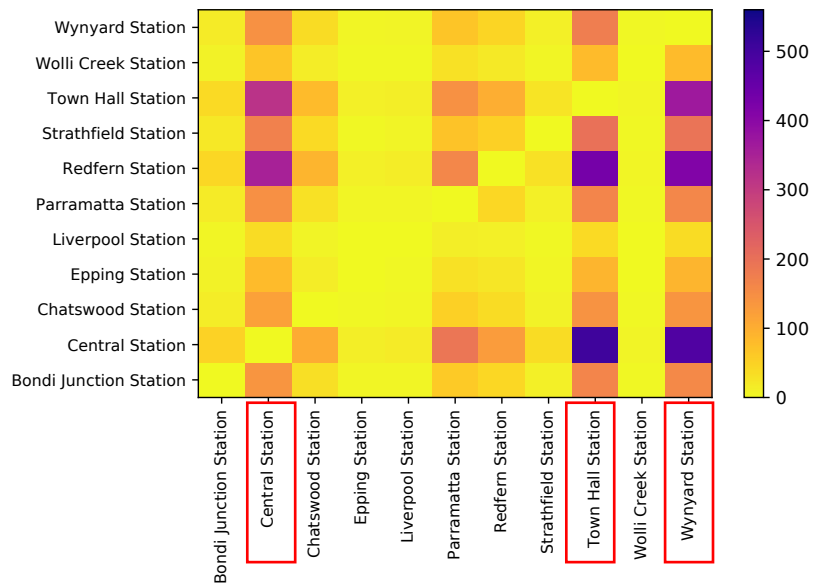

17:00PM

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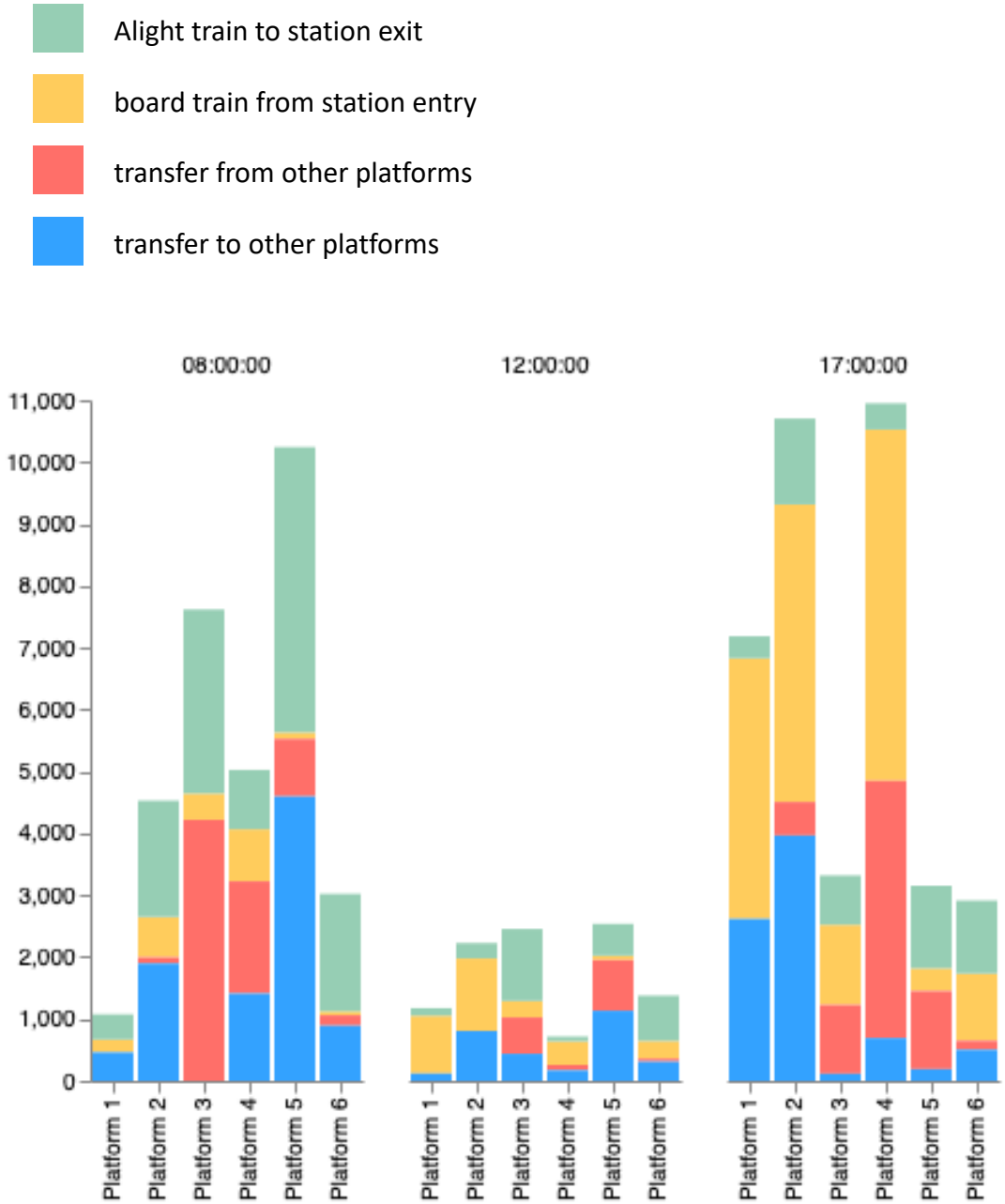
Results:
Passenger Assignment

An example of passenger flow in Town Hall Station on 8:00AM, 12:00PM and 17:00PM

Observations

- In morning peak hours:
  - Large number of passengers alighting trains and exiting station
  - Large number of passengers transferring from platform 5
  - Large number of passengers transferring to platform 3
- In afternoon peak hours:
  - Large number of passengers entering station and boarding trains
  - Large number of passengers transferring from platform 2
  - Large number of passengers transferring to platform 4



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Conclusion

Main contributions of this work

- A method for estimating time-dependent OD matrix consisting of two steps:
  - Initial OD matrix generation
  - OD matrix calibration
- A method for passenger assignment which can quantify passenger flow at platform level of granularity
- A case study on Sydney train network
  - 175 train stations and 506 platforms
  - 2.9 million time-dependent OD pairs generated

Thank you!