Modern Approaches For Real-time Rescheduling In Metro And Mainline Railway Systems

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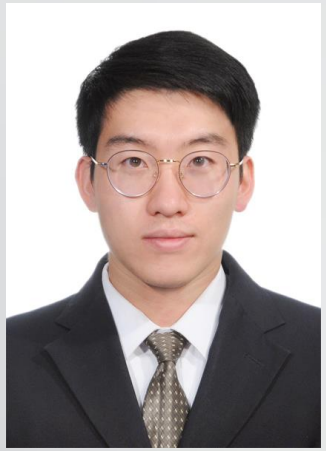
About Myself



2010-2014	**Harbin Institute of Technology, China**	**B. Eng**
2014-2015	**University of Birmingham, UK**	**M. Eng**
2015-2020	**University of Birmingham, UK**	**Ph.D**

Ph.D. thesis: '*A Multi-Agent-Based Approach for Resolving Real-Time Train Rescheduling Problems of Large- Scale Railway Networks*'

From May 2020	**Newcastle University, UK**	**Research Associate**

My research interests

- Algorithm development
- Multi-agent system
- Railway condition monitoring
- Automatic train operation (ATO)
- Railway control command and signalling
- Decentralised optimisation
- Freight logistics
- Railway decision support system
- Railway traffic modelling
- Railway RAMS and security

Contents

- Metro and mainline railway traffic
- Rescheduling in metro system
- Rescheduling in mainline railway
- A solution for testing novel applications for railway traffic management systems (OPTIMA, Shift2Rail)

Metro and Mainline Railway Traffic

- Their differences between metro and mainline rail

	Metro	Mainline
Features	• Running in inner urban area/ short distance • Separate tracks (underground/ elevated) • Simple environment • High frequency • Up to 100km/h	• Intercity/ long distance • Separate tracks, may share with metro • Complex network with variable disturbances • Operated restrict to timetable • Usually above 120km/h
Service type	• Passenger central	• Service central
Service objectives	• Deliver passengers to their destinations • Minimise energy consumption	• On-time • Minimise energy consumption
Rescheduling methods	• Readjust headway • Passenger management	• Readjust junction passing sequence • Readjust arrival and departure time

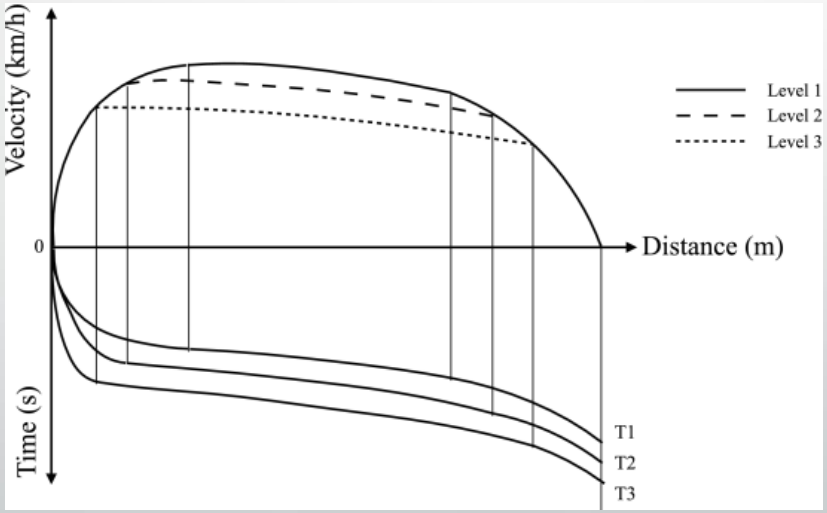
Rescheduling in Metro System

An approach to minimising energy consumption and average passenger waiting time

- **Motivations & Challenges**
  - Minimizing train delay and minimizing energy consumption are inherently conflict control targets;
  - Passenger flow is hard to predict in practice;
  - Train speed profile is usually generated offline and not changeable.

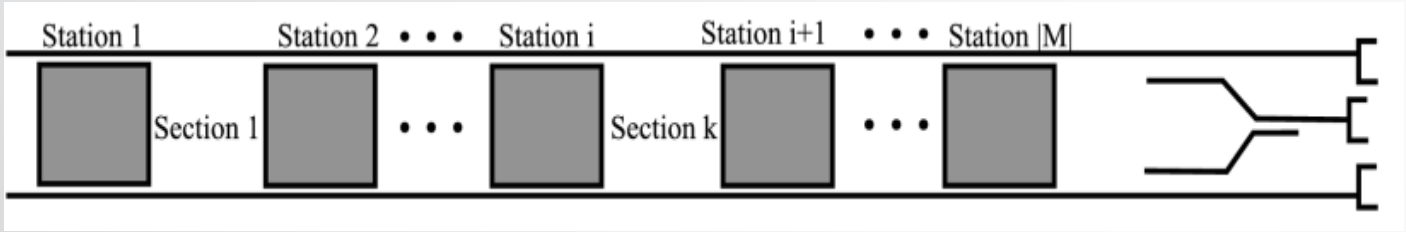
Rescheduling Approach for Metro System

- Modelling Approaches [1]
  - Passenger flow information is supported by origin-destination (OD) matrices;
  - Three driving modes are defined and used to generate lower and upper bounds of running time;
  - Timetable rescheduling problem is modelled by mixed integer programming (MIP).

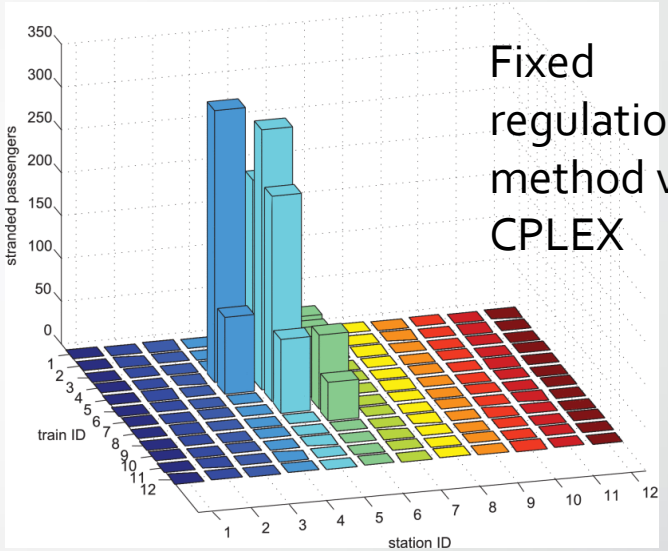


[1] Z. Hou, H. Dong, S. Gao, G. Nicholson, L. Chen, and C. Roberts, "Energy-Saving Metro Train Timetable Rescheduling Model Considering ATO Profiles and Dynamic Passenger Flow," *IEEE Trans. Intell. Transp. Syst.*, 2019

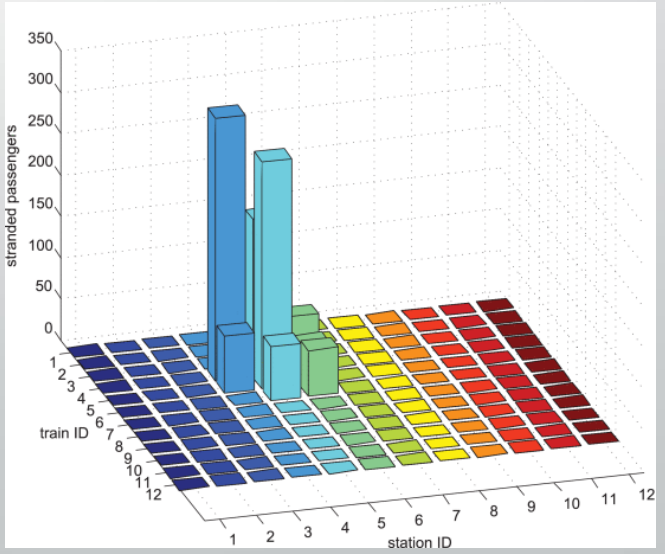
Rescheduling Approach for Metro System



- A single line metro system is used to test the proposed approach;
- CPLEX is used to resolve the rescheduling problem;
- Proposed method can generate a solution in 8s;
- Mean value of passenger waiting time and number of stranded passenger are reduced significant.



Fixed regulation method vs CPLEX



Rescheduling in Mainline Railway System

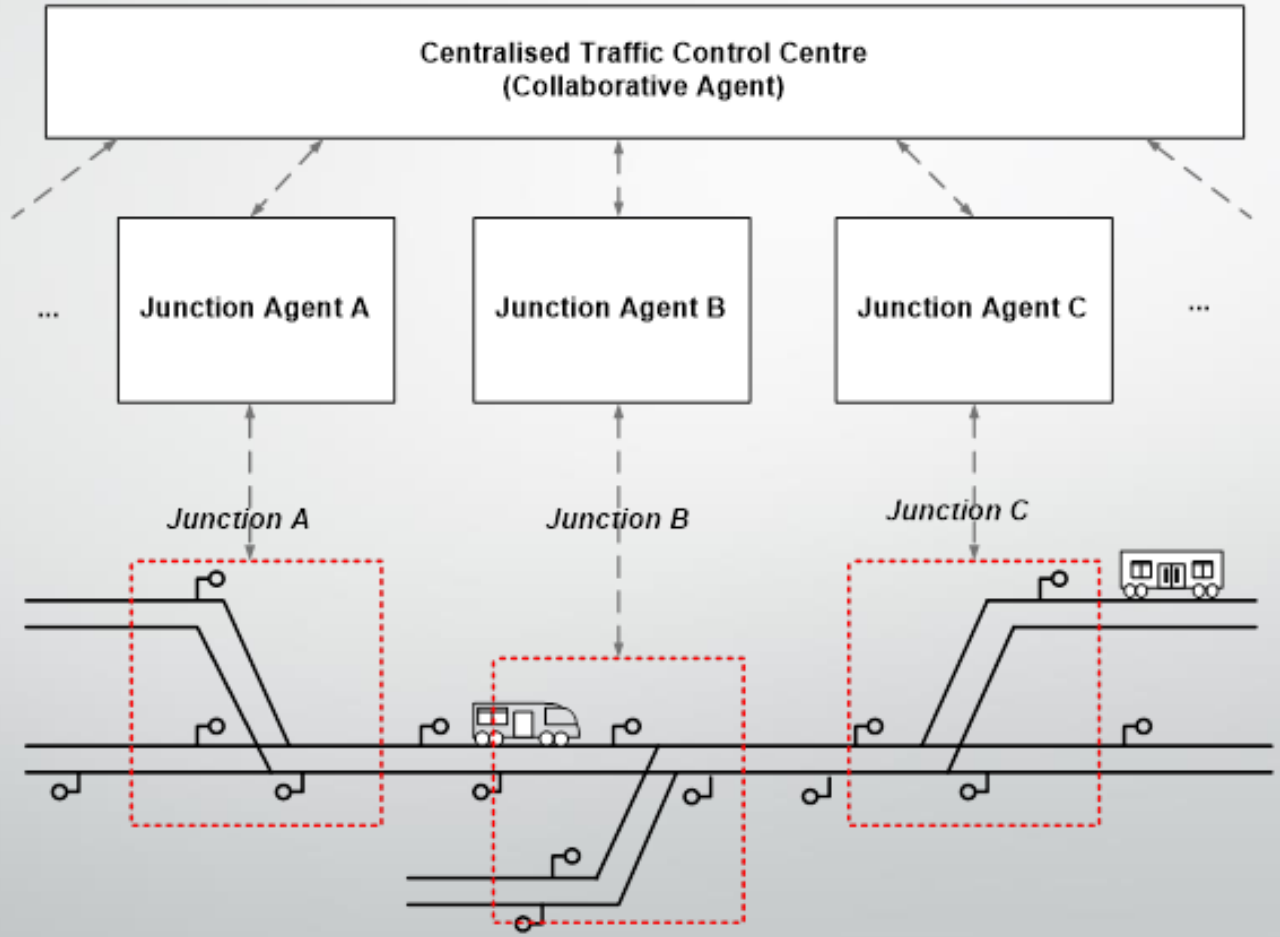
A multi-agent system for rescheduling problems in mainline railway

- **Motivations & challenges :**
  - Resolving rescheduling problem for large scale railway network is challenging due to large searching space.
  - Rescheduling decisions made in each local traffic centre but railway timetable is strong linked.
  - A single tuning of train timetable may lead to domino effects across whole network.
  - A decision making system for large scale network is critical and essential in future.

[2] J. Liu, L. Chen, C. Roberts, G. Nicholson, and B. Ai, "Algorithm and peer-to-peer negotiation strategies for train dispatching problems in railway bottleneck sections," *IET Intell. Transp. Syst.*, vol. 13, no. 11, pp. 1717 – 1725, 2019
[3] J. Liu, L. Chen, C. Roberts, Z. Li, and T. Wen, "A Multi-agent Based Approach for Railway Traffic Management Problems," in 2018 International Conference on Intelligent Rail Transportation, ICIRT 2018, 2019.

A multi-agent System for Rescheduling Problems in Mainline Railways

- System architecture[4]



[4] J. Liu, "A Multi-agent-based Approach for Resolving Real-time Train Rescheduling Problems of Large- scale Railway Networks," Ph.D. thesis, University of Birmingham, 2020.

A multi-agent System for Rescheduling Problems in Mainline Railways

- Train rescheduling problem is modelled as MILP;
- Genetic algorithm is applied to solve local rescheduling problem;
- Peer-to-peer negotiation strategies and Condorcet voting are applied to trade-off between local optimization and global optimization;
- UK infrastructures are used to test the proposed approaches, which shows an improvement up to 34.11% against First Come First Served.

Shift2Rail(S2R) Joint Undertaking (JU) IP2

- To deliver, through railway research and innovation, the capabilities to bring about the most sustainable, cost-efficient, high-performing, time driven, digital and competitive customer-centred transport mode for Europe.
- Shift2Rail contribute to:
  - Cutting the life-cycle cost of railway transports by as much as 50%
  - Doubling railway capacity
  - Increasing reliability and punctuality by as much as 50%
- Innovation Programme 2 (IP2) focuses on the development of Advanced Traffic Management and Control Systems for railways including positioning systems; Traffic Management Evolution; Automation; Moving block and train integrity; Smart procurement and testing; Virtual coupling and Cyber security.

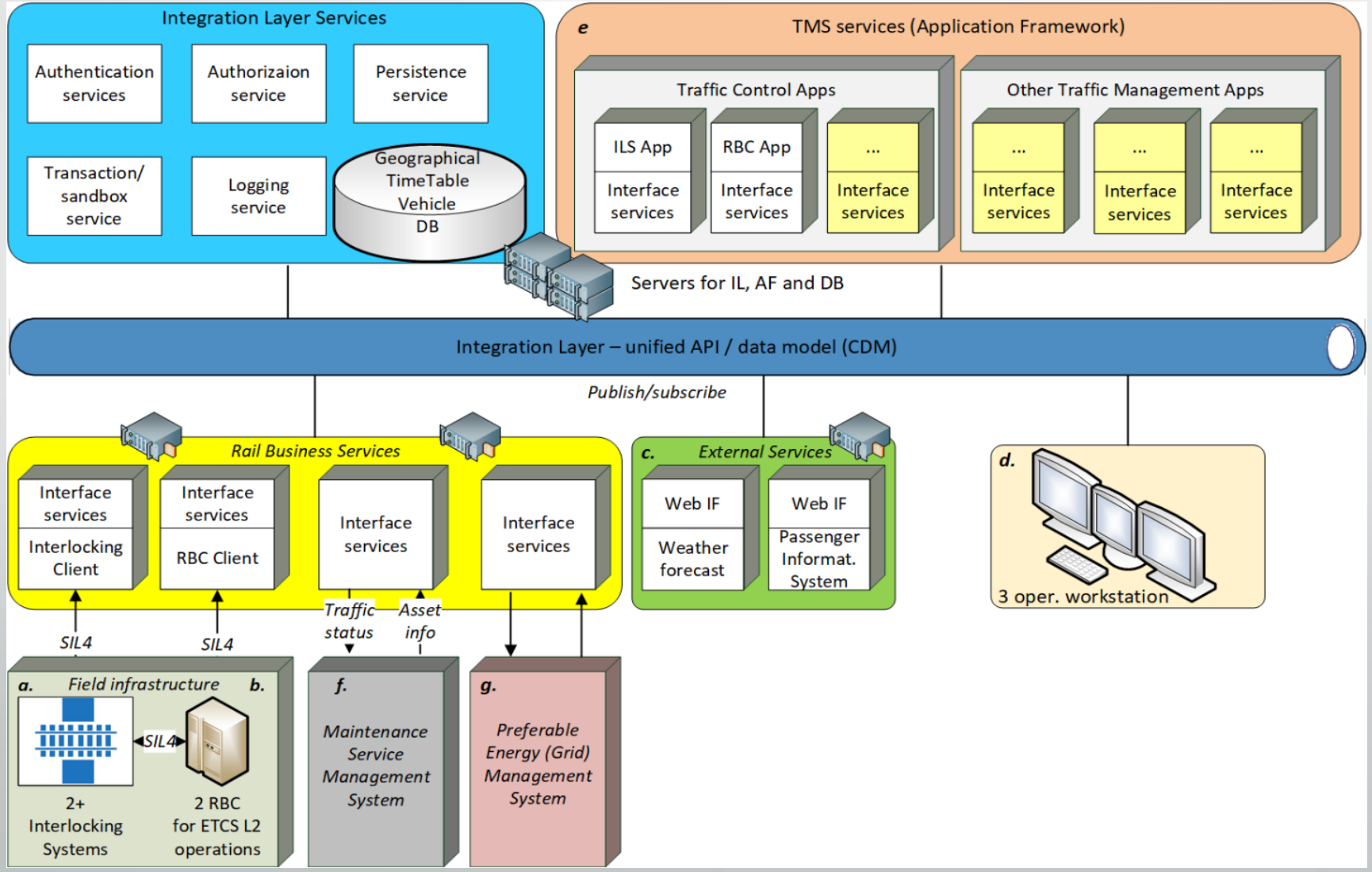
European Rail Traffic Management System (ERTMS)

- ERTMS is a major industrial project developed by eight UNIFE members - Alstom Transport, AZD Praha, Bombardier Transportation, CAF, Hitachi Rail STS, Mermec, Siemens Mobility and Thales;
- ERTMS provides the European Union with a unique opportunity to create a seamless railway system, which ensures interoperability for EU trains;
- Increasing railway capacity, minimizing primary and secondary delay are critical objectives for developing ERTMS.

cOmmunication Platform for TraffIc ManAgement demonstrator (OPTIMA)

- Motivations
  - TMS across EU countries are developed with different data structure, interface, and etc.
  - Verification and validation of TM solutions is challenging in practice, which has concerns on expense and safety.
- Technical objectives
  - Develop a middleware of Integration Layer;
  - Standardize data structure of TMS;
  - Design a communication platform to manage the connection between several services/clients and the TMS;
  - Develop a virtual environment for testing candidate modules developed by the relevant S2R members from railway industry.

General architecture of the OPTIMA



Thank you!

- Any questions, please do not hesitate to contact with me
- Email: Jin.Liu@Newcastle.ac.uk