Agent-Based Computational Approach to Airline Competition and Airport Congestion Problems

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Agent-Based Approach

- The traditional approach to analyze transportation problems has been the "***Top-down approach***"

- The ***individual*** parts (passengers, airlines, airports, and Air Transportation authorities) have great ***autonomy*** to make decisions, communicate and to interact with one another

Agents

Objectives of Agents

- Airline : Maximize Profit
- Passenger : Decrease Travel time and Cost
- Airport : Minimize Congestion

Agent Behavior

- Relatively ***minor*** change in agents' behavior can cause ***significant*** change in whole system

- Complex collective behavior can be ***emerged*** from simple actions of individual agents - passengers, airlines, airports and aviation authorities

Simulate Agent Behavior

- ***Congestion*** in air transportation could be viewed as ***emergent phenomena*** that is sometimes difficult to predict and that is even sometimes counterintuitive

- A promising way for analyzing congestion in air transportation is the development of the simulation models that can ***simulate behavior of every agent***

Agent-Based Model in Air Transportation

- Our Agent-based model considers that each part act based on its local knowledge and ***competes*** and/or ***cooperates*** with other parts

- Model developed allows agents that represent airports to increase the capacity, or to significantly ***change landing fee policy***, while the agents that represent airlines learn all the time, ***change their markets, fares structure, flight frequencies, and schedules***

Congestion Pricing

The basic idea of ***congestion pricing*** in air transportation is to introduce peak-period pricing and other possible strategies as a powerful tool that will be capable to ***modify*** airlines' use of existing airways and airports and to ***change*** passengers' behavior

Congestion Pricing (Continued)

- ***Vickrey***: "Charges should reflect as closely as possible the marginal social cost of each trip in terms of the impacts on others. There is no excuse for charges below marginal social cost."

- Airlines (and passengers) should pay a ***price equivalent to the delay cost they impose on others***

Non-Cooperative Evolutionary Game between Agents

To explore ***evolved unplanned coordination*** under the different landing pricing strategies produce similar results like the planned global coordination with the "***central planner***" whose main objective is the ***minimization of the total air traffic congestion***

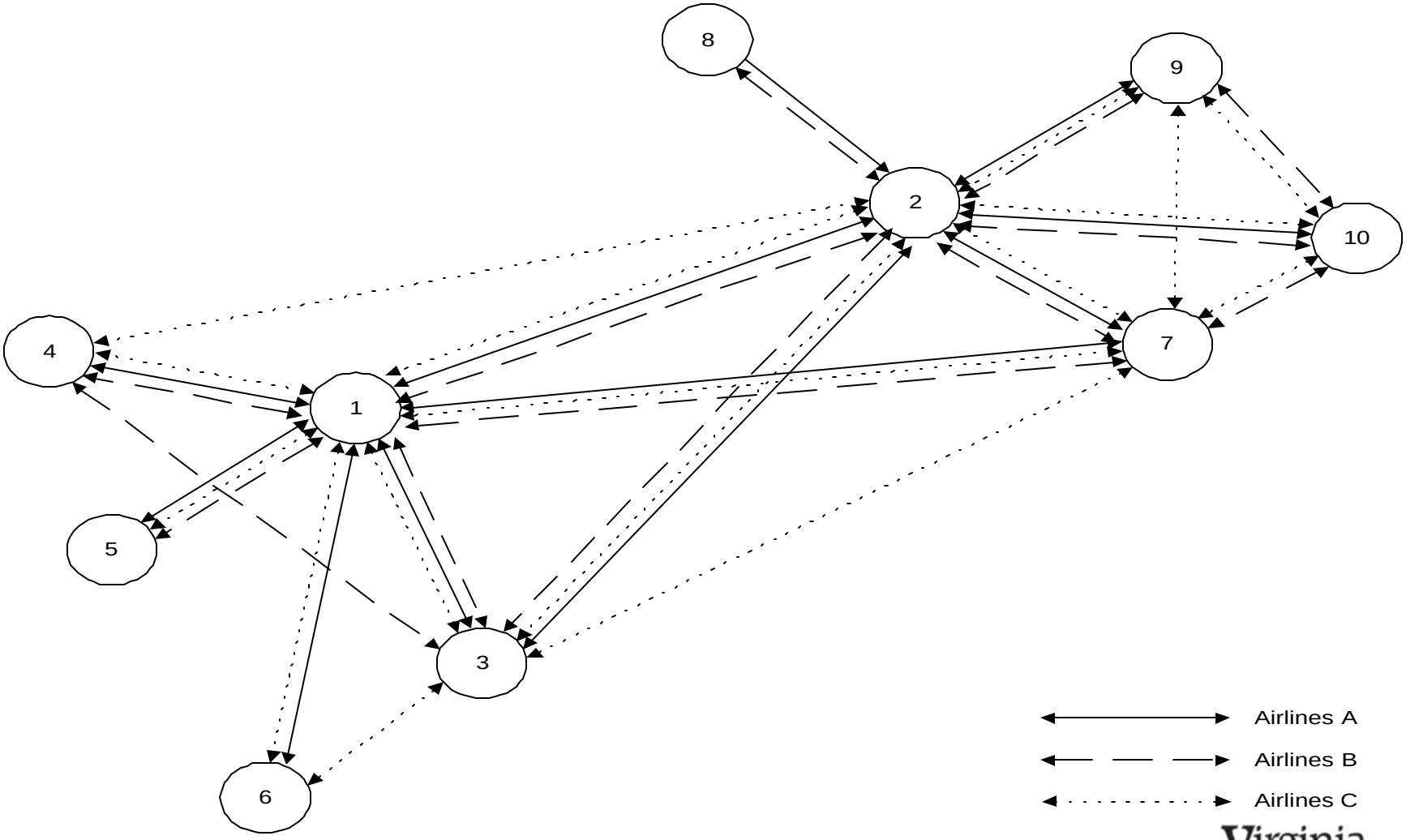
Airlines Behavior

For every airline that operates in the network determine:

- ***Set of routes*** that airline flies, ***aircraft types*** on these routes, ***flight frequencies and departure times***

- ***Under the time dependent airport landing fees***

Airlines Competition



Strategy of Airlines

The strategy of airline *j* related to the *i*-th market during *G*-th iteration：

$$S_{ij}^{G} = \{P_{ij}^{G}, N_{ij}^{G}, A_{ij}^{G}, D_{ij}^{G}\}, \quad i = 1,2,...,K \qquad j = 1,2,...,M$$

Payoff of Airlines

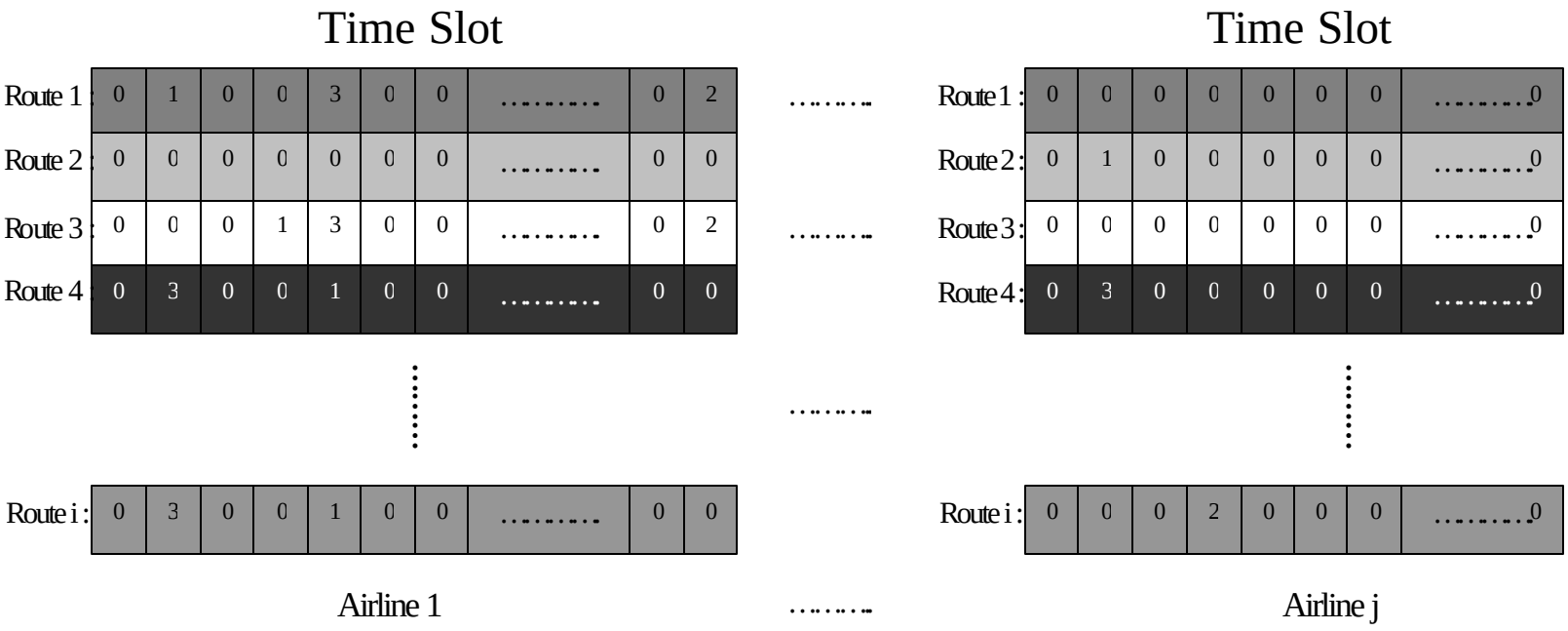
The total payoff of airline j at generation G :

$$TP_j^G = \sum_i^M P(S_{ij}^G)$$

Payoff of Airlines (Continued)

- Iteration (generation) represents certain time unit
- Airlines ***collect information*** about the profit they make, as well as information about activities of their competitors
- Based on this information ***airlines change*** markets, aircraft types, flight frequencies, and departure times
- Airlines ***change through the evolution***, from iteration to iteration, their ***operating strategy***

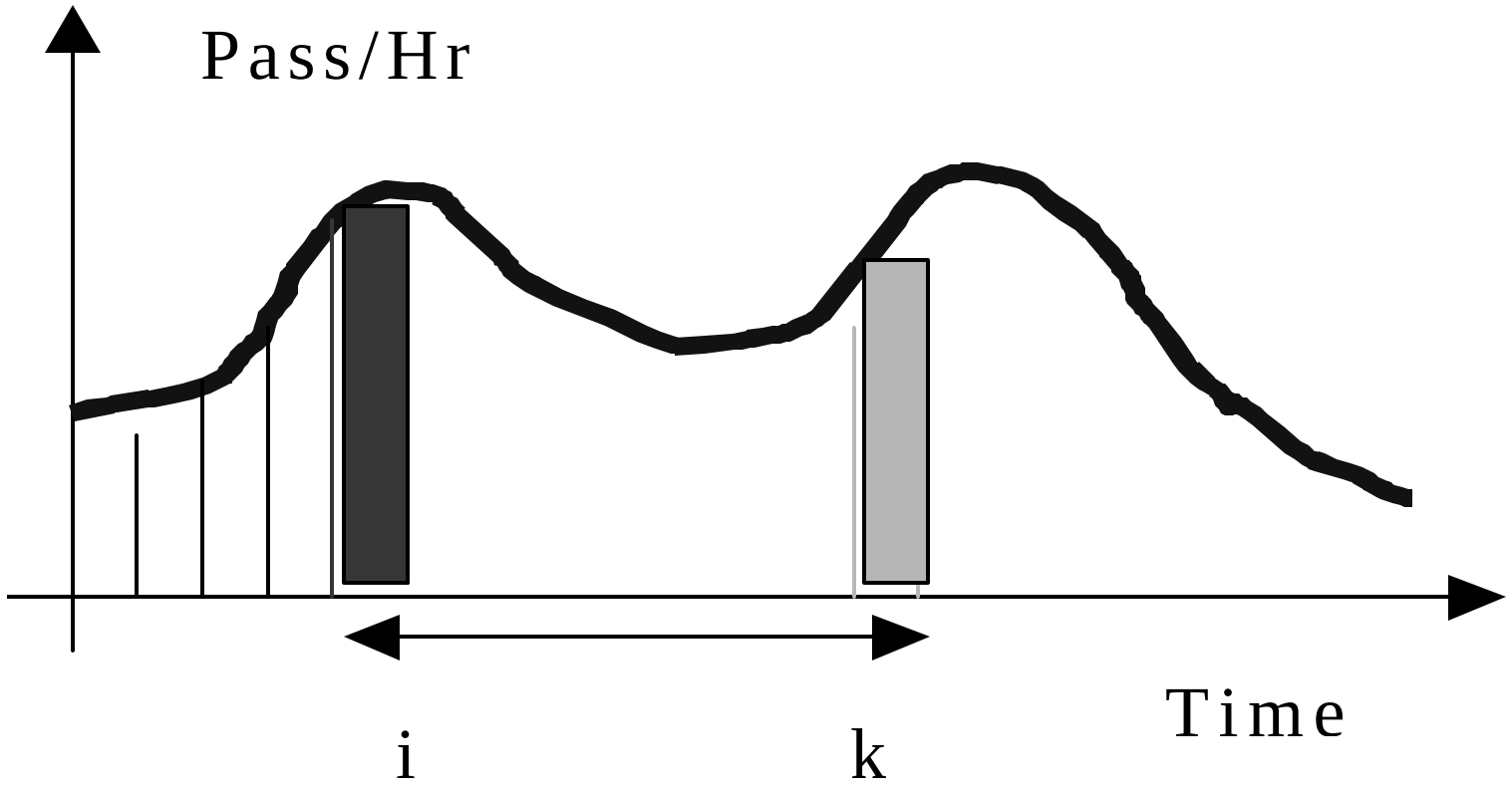
Representation of Airline Strategies



What we can determine

- Markets that airline serve
- Flight frequencies on all airline's routes
- Fleet assignment
- Aircraft departure times on all routes

Flight (Travel option) choice:



Passenger's Flight Choice based on Logit model

$$p_{ik} = \frac{e^{U_{ik}}}{\sum_{f \in F} e^{U_{if}}}$$

Passenger's Flight Choice based on Logit model (Continued)

Utility associated with the passenger from the *i*-th time slot who chooses flight that departs in the *k*-th time slot：

$$U_{ik} = a \cdot \left| T_{ik} \right| + b \cdot AT_k$$

Fuzzy Logic for Flight Choice Model

- If schedule delay is ***LOW*** and ticket price is ***ACCEPTABLE*** and total travel time is ***SHORT***

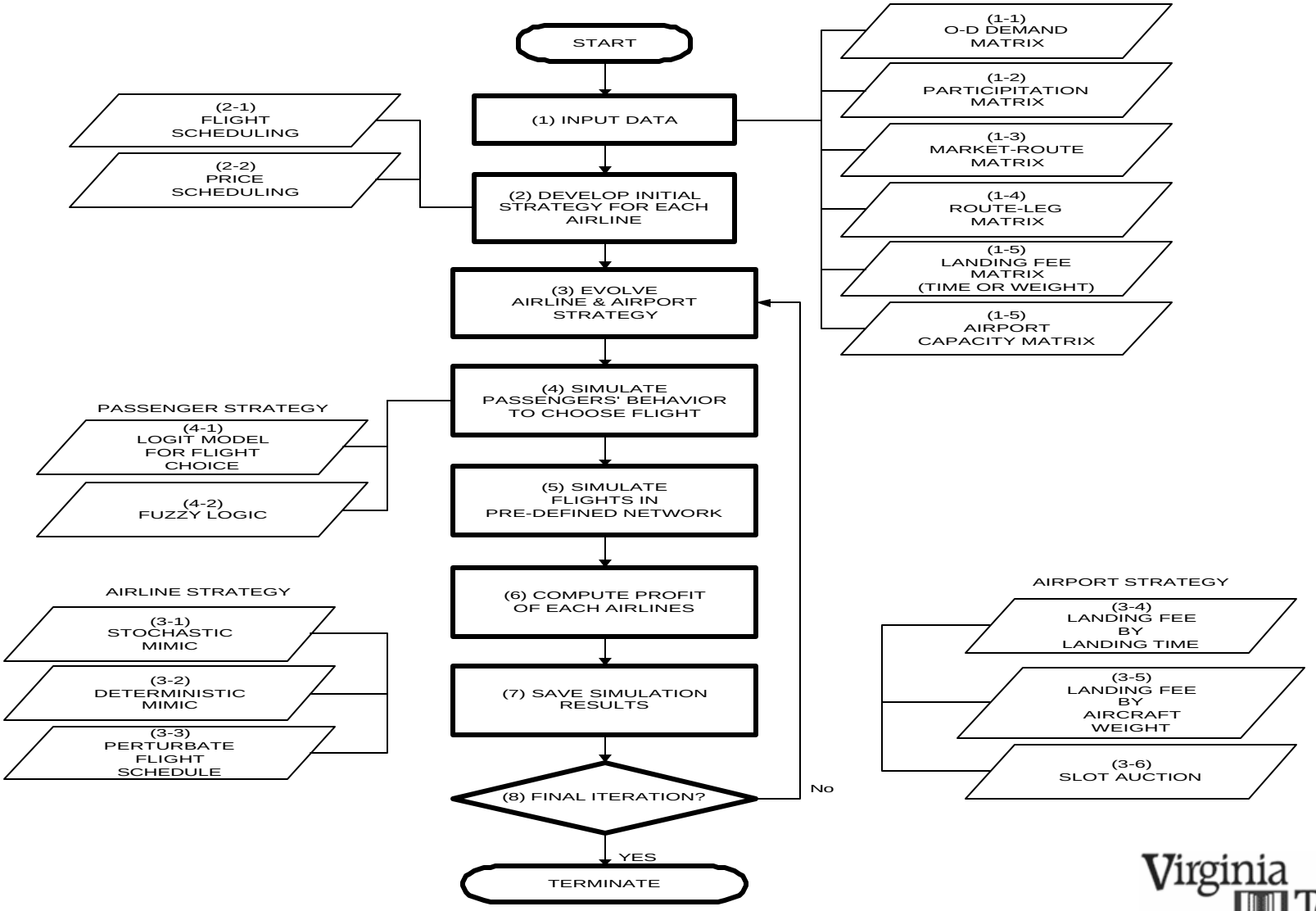
  Then passenger's preference to choose the considered flight is ***VERY HIGH***

Evolutionary Strategies

- ***Various evolutionary strategies*** (***mimic strategies***) are applied to compare profits of all airlines and also convergence ability

- Most of evolutionary strategies that we have explored are based on the logic that airlines in some way ***change*** flight schedule on the ***low performance*** markets

Model Procedure



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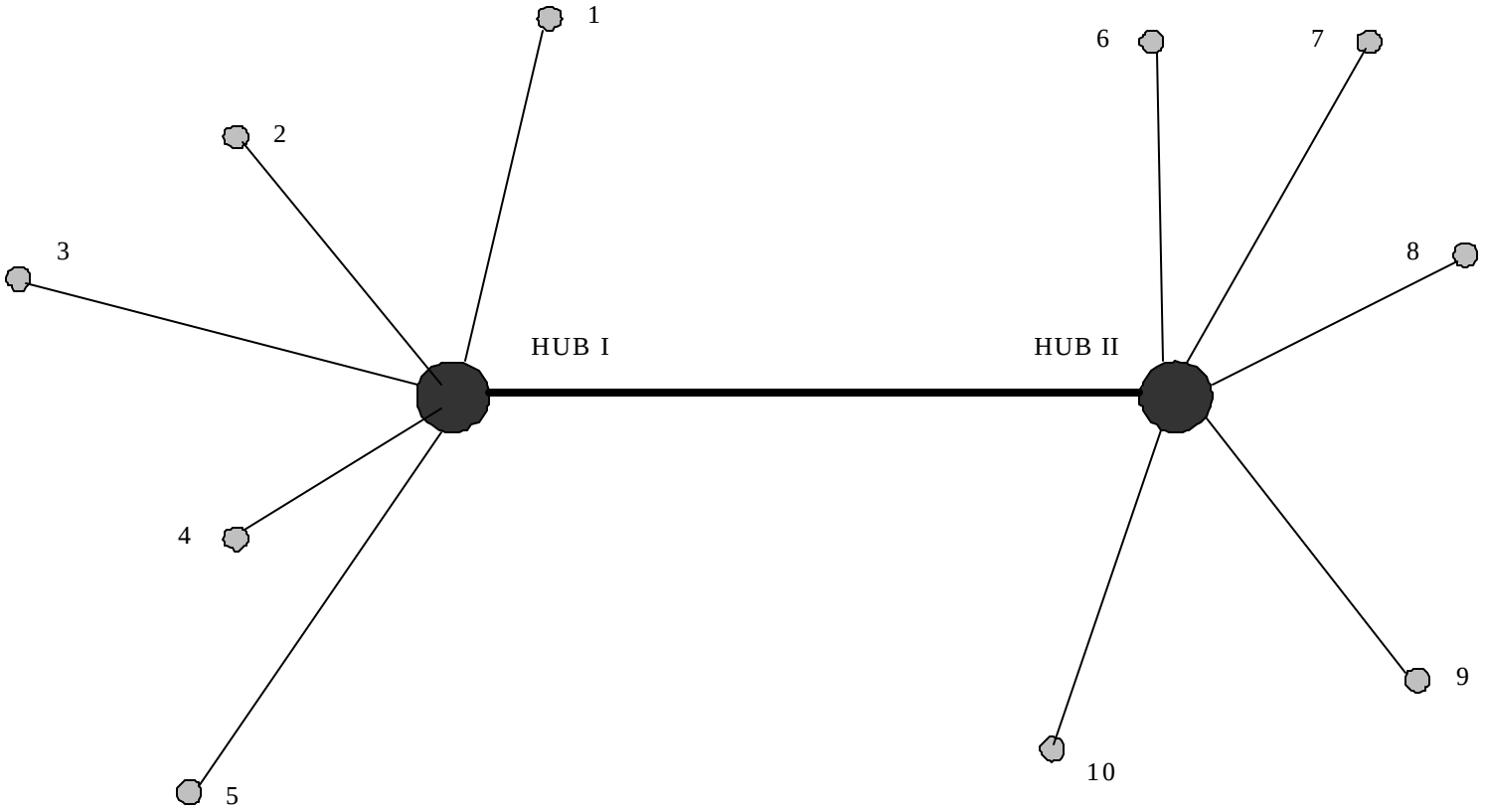
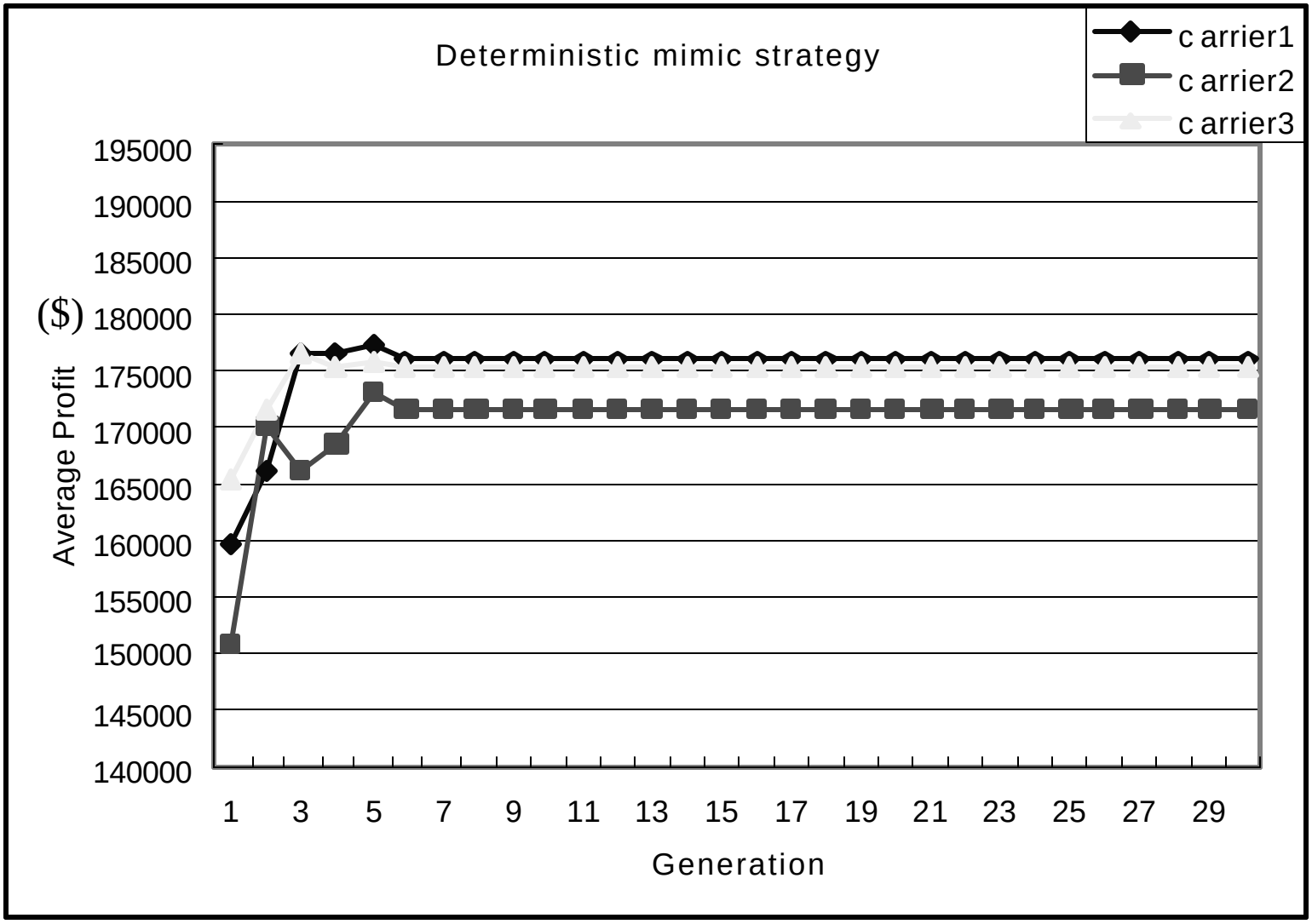
Sample Problem





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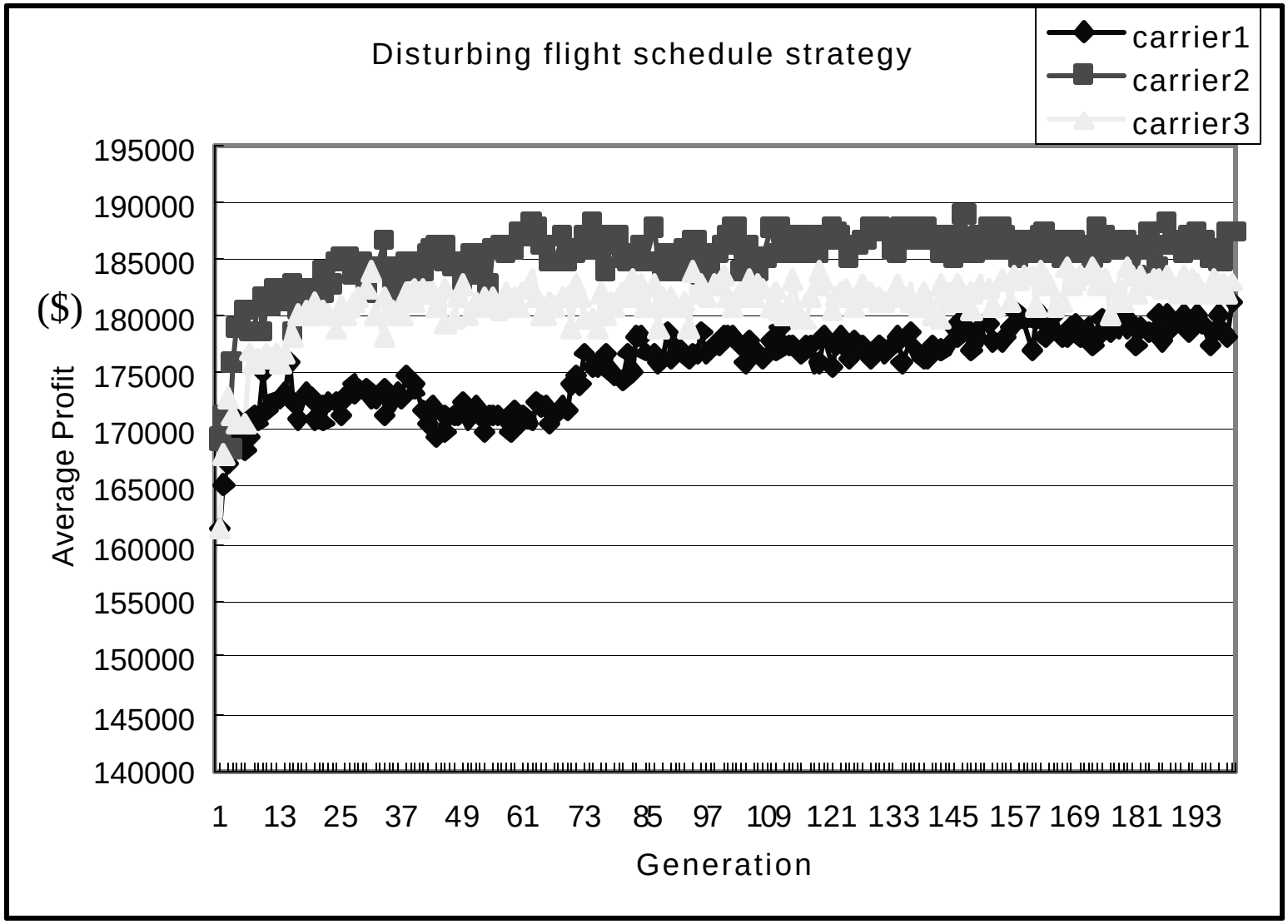

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Open questions

- Would different landing pricing strategies change the runway occupancy rate or average parking duration?
- Would airlines easily accept new landing pricing strategies?
- What is the most appropriate ***fare structure*** when introducing different landing pricing strategies?

Open questions (Continued)

- Would proposed systems significantly ***decrease*** the total number of flights during peak hours and ***increase*** the total number of flights outside peak-hours?

- How will ***regional carriers behave vs*** large carriers?

- How will ***certain classes of air passengers behave*** in the situation when direct operating cost and ticket prices increase for the peak-hour flights?