
Airline Operations

Lecture #1

1.206J

April 23, 2003

Outline

- **Airline planning complexity**
- **Schedule disruptions**
- **Schedule dependability**
- **CDM Ground Delay Program**
- **How do airlines recover the schedule?**
- **Traditional ARM; Model shortcomings**
- **Interdependency of passengers and aircraft operations**

Airline planning

- **Optimized schedule designs have resulted in squeezed schedule with little slacks (i.e., idle time)**
- **For examples:**
 - **FAM with TW: less aircraft slacks**
 - **Extended Crew Pairing Problem: less crew slacks**
- **Plan is more inclined to be disrupted**
- **Ongoing research in robust planning: are airlines ready to pay the cost?**

Feasibility constraints

- **Aircraft maintenance checks**
- **Pilot work rules**
- **Flights**
- **Passengers**

Aircraft maintenance checks

- **A: roughly once a week -- on average approximately every 60 flight hours**
- **B: once a month -- roughly every 300 to 500 flight hours**
- **C: Entire aircraft check**
 - **Narrow body: once a year;**
 - “Light C Check” (3 days)
 - “Heavy C Check” (3 to 5 weeks)
 - **Wide bodies: every 15 to 18 months;**
 - “Heavy C Checks” (2 weeks)

Pilot work rules (FAA regulation Part 135)

- **1,200 hours in any calendar year.**
- **120 hours in any calendar month.**
- **34 hours in any 7 consecutive days.**
- **8 hours during any 24 consecutive hours for a flight crew consisting of one pilot.**
- **8 hours between required rest periods for a flight crew consisting of two pilots qualified under this part for the operation being conducted.**
- **9 consecutive hours of rest for less than 8 hours of scheduled flight time.**
- **10 consecutive hours of rest for 8 or more but less than 9 hours of scheduled flight time.**
- **11 consecutive hours of rest for 9 or more hours of scheduled flight time.**

Flight regulation

- **You need a feasible aircraft and a crew to operate a flight**
- **Airports with slots**
- **GDP**
- **Airport curfew (e.g., Orange county, SNA)**

Rule 240 Contract of carriage (AA)

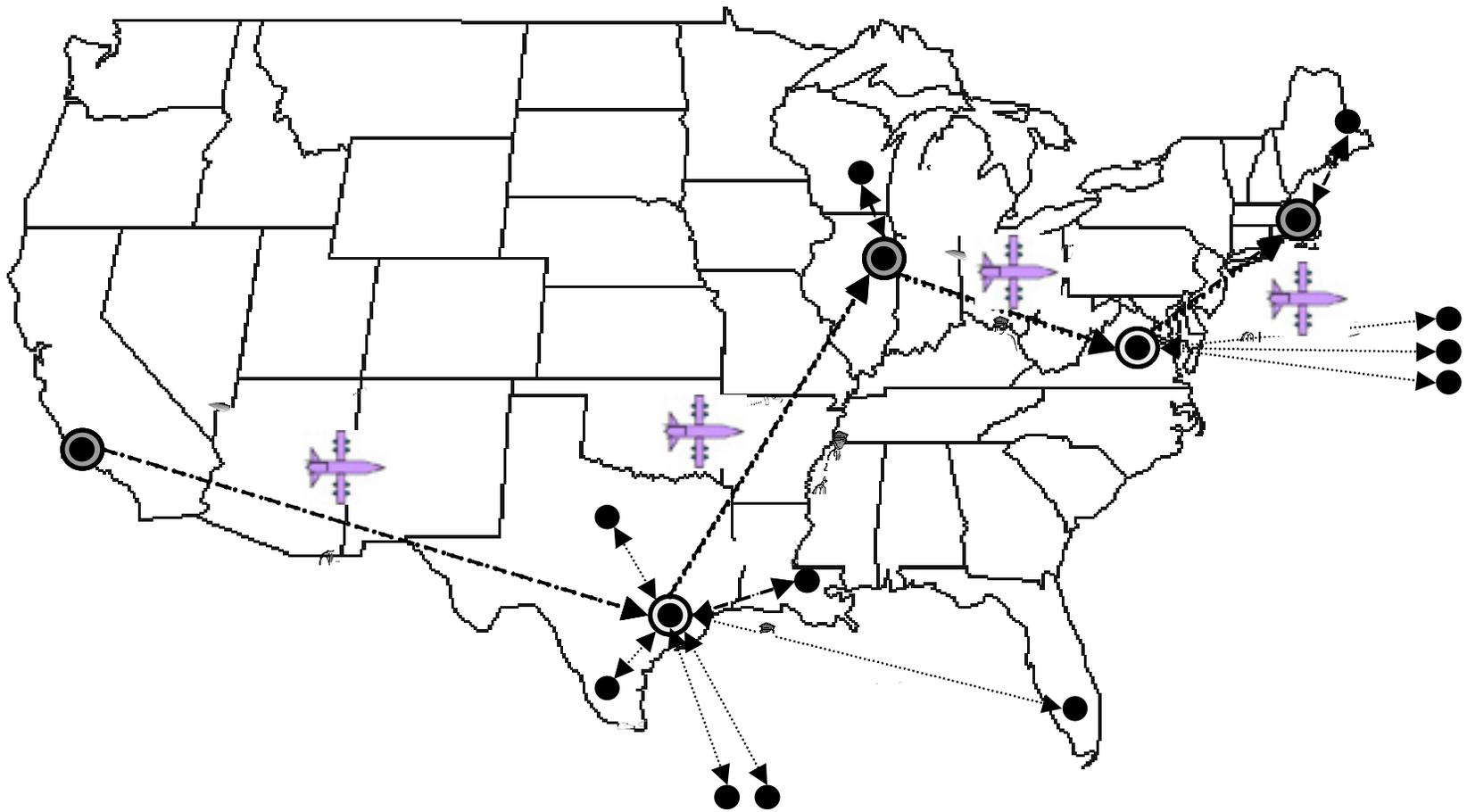
“If your flight is delayed, cancelled or you miss a connecting American Airlines flight, due to a schedule irregularity

- **American Airlines must confirm you on their next flight (on which space is available) at no additional cost.**
- **If there is an alternate American Airlines flight that will arrive at your destination earlier than the alternate you have been offered, you have the right to be confirmed on this American Airlines flight at no additional cost, even if first class space is all that is available.**
- **If the alternate American Airlines flight is not acceptable to you, you have the right to be confirmed on the flight of a different airline at no additional cost.**
- **If there is an alternate "different airline" flight that will arrive at your destination earlier than any alternate flight you have been offered, you have the right to be confirmed on this flight at no additional cost, even if first class space is all that is available.**
- **If no alternate flight (on American Airlines or a "different airline") is acceptable to you, American Airlines must refund your money - even if you have a non-refundable ticket.”**

Schedule disruptions

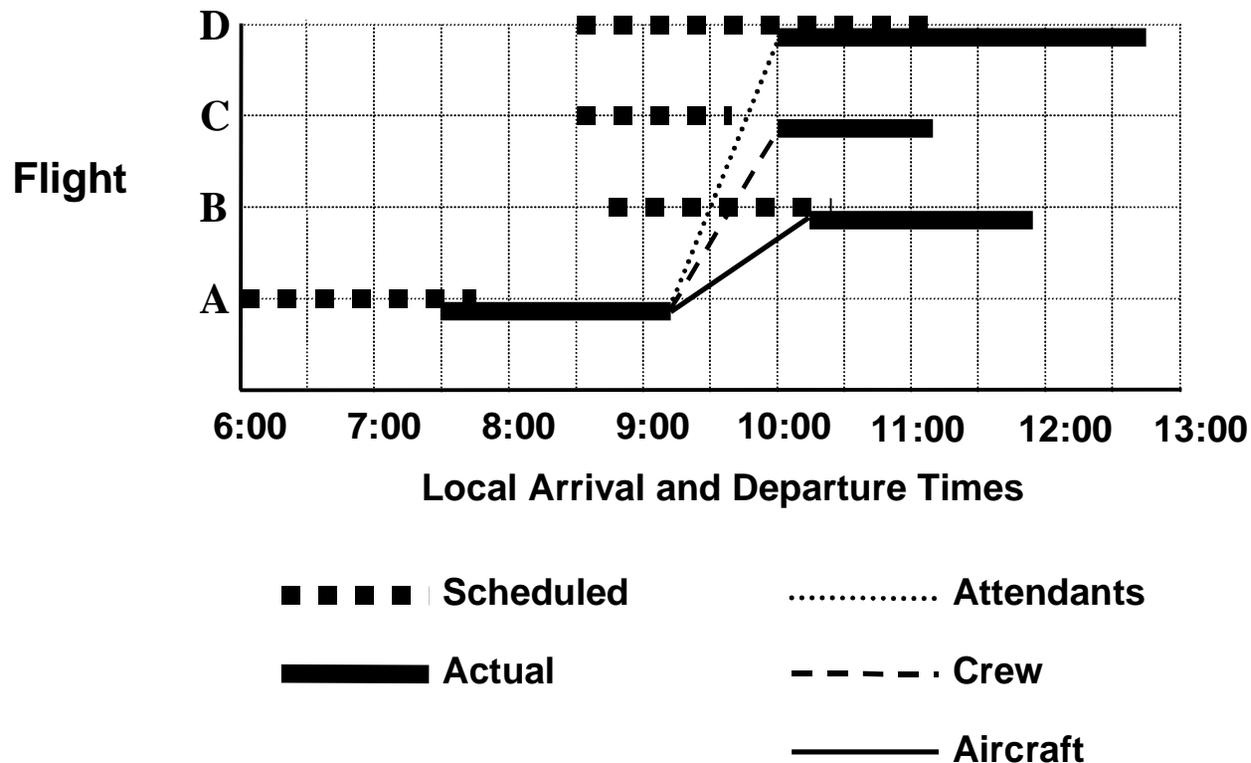
- **Schedule disruptions:**
 - **Aircraft: not on the schedule route**
 - **Crew: violates rules**
 - **Passenger: canceled flight or missed connection**
- **Shortages of airline resources:**
 - **Resource schedule dependability**
 - **Aircraft mechanical problem**
 - **Crew unavailability (misconnections)**
- **Shortages of airport resources:**
 - **Inclement weather: reduction in airport runway capacity; affect all aircraft flying through the airport**
 - **Airport security**
- **A dozen of disruptions happen on average every for Continental Airlines**

Schedule dependability



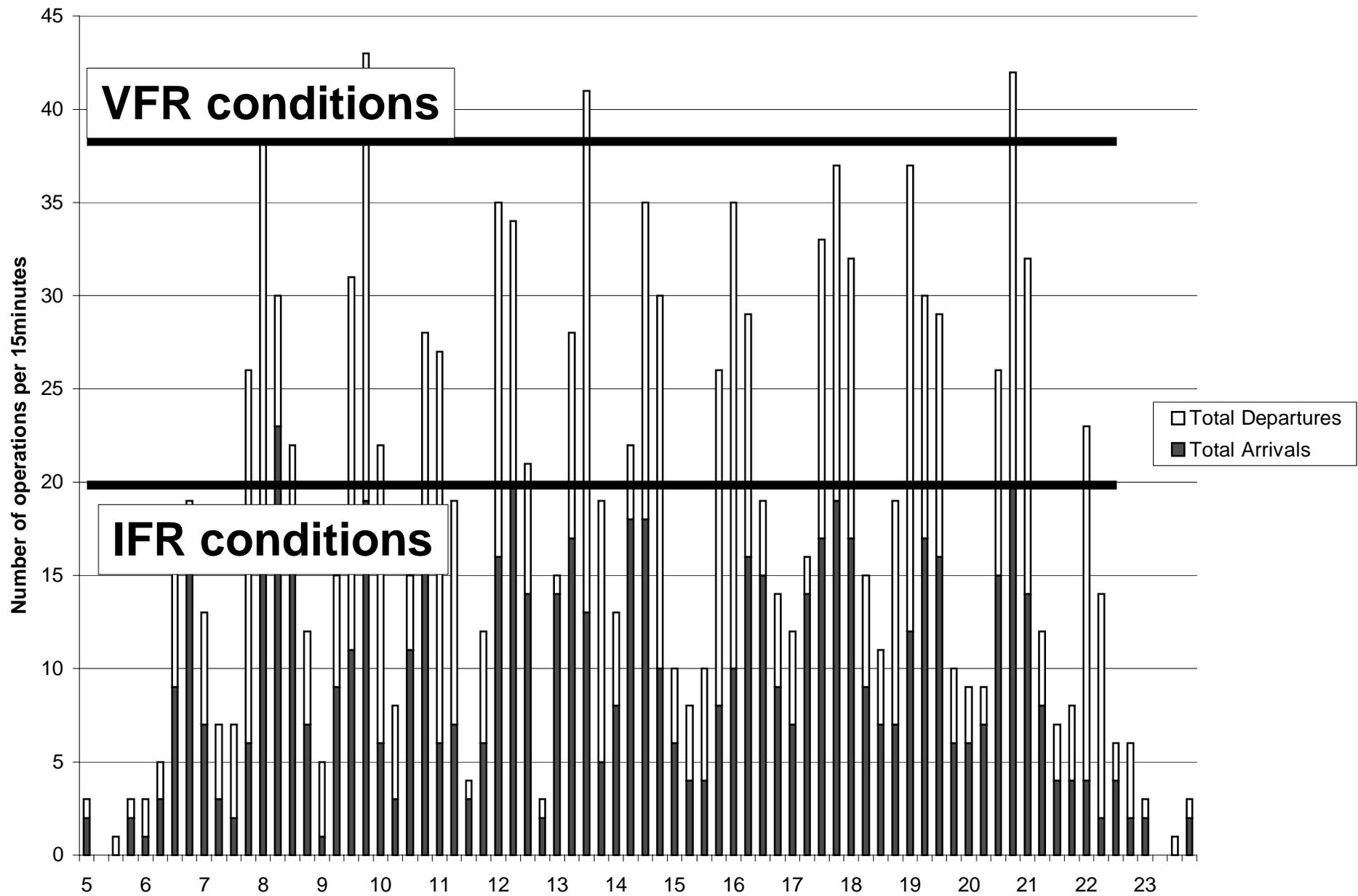
Delay chain

Arrival delays, especially those that occur early in the day, tend to propagate in the network.



Banked hub airport

- **In US, no schedule restrictions at all but 4 airports (which ones?)**
- **Major airlines use to schedule more flights than maximum airport hub airport capacity**
- **When adverse weather conditions happens, flight operations under IFR rules, greater Miles In Trail (MIT): minimum separation distance between two aircraft in terminal area**
- **When volume too high in a sector, flights are slowed down or delayed on the ground (Ground Delay Program)**



US Air traffic control centers

ZSE - Seattle
ZOA - Oakland
ZLA - Los Angeles
ZLC - Salt Lake City
ZAB - Albuquerque
ZMP - Minneapolis
ZKC - Kansas City
ZFW - Ft. Worth
ZHU - Houston
ZAU - Chicago
ZOB - Cleveland
ZID - Indianapolis
ZTL - Atlanta
ZJX - Jacksonville
ZMA - Miami
ZDC - Washington
ZNY - New York
ZBW - Boston
ZDV - Denver
ZME - Memphis

- **Air Traffic Control System Command Center**
- **Air route traffic control centers**
- **Terminal radar approach control - TRACON**
- **Air traffic control tower**

Ground Delay Program (GDP)

- **When capacity shortage is too large, ATCSCC issue a GDP to prevent airborne holding of arriving aircraft. (safety, workload, fuel)**
- **Instead, aircraft are better off waiting on the ground**
- **Example: Yesterday in BOS: *'Due to EQUIPMENT, RY 4R GS OTS/LOW CIGS/VSBY, there is a Traffic Management Program in effect for traffic arriving BOS. This is causing some arriving flights to be delayed an average of 1 hour and 3 minutes with some arriving flights receiving as much as 1 hour and 38 minutes delay.'***
- **How does a GDP work?**

GDP (Cont.)

- **Compare Airport Arrival Rate (AAR) to scheduled flight demand**
- **Calculate delay for each arriving flight, First Scheduled First Served (FSFS)**
- **Issue Expected Clearance Departure Time (ECDP)**
- **What are potential problems with this approach?**

Collaborative Decisions Making (CDM) ***- GDP***

- **Data exchange between ATCSCC and the Airlines Operations Control Centers (AOCC): CDM-Net**
- **Ration by schedule: gives more control to airlines to assign flights to slots**
- **Compression: removes disincentives to providing schedule updates**
- **Compression benefit example**

How Important is Schedule Recovery?

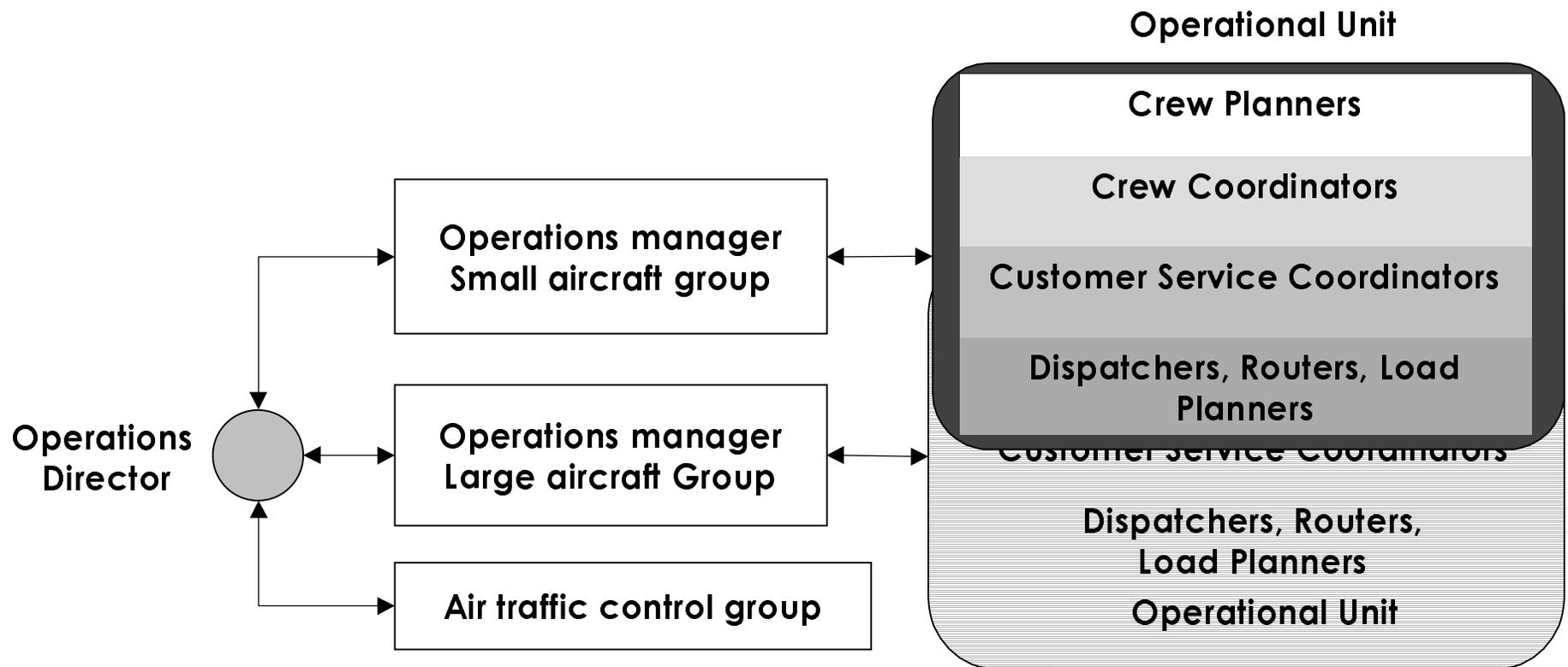
- ▶ **Estimates of the cost of airline disruption range from 2% to 3% of annual revenues**
- ▶ **Delta reports 8.5 million passengers affected, \$500 million lost per year**
- ▶ **Total industry revenue is over \$300 billion per year**
- ▶ **Disruption costs range from \$5 to \$10 billion per year**

How do airlines recover the schedule?

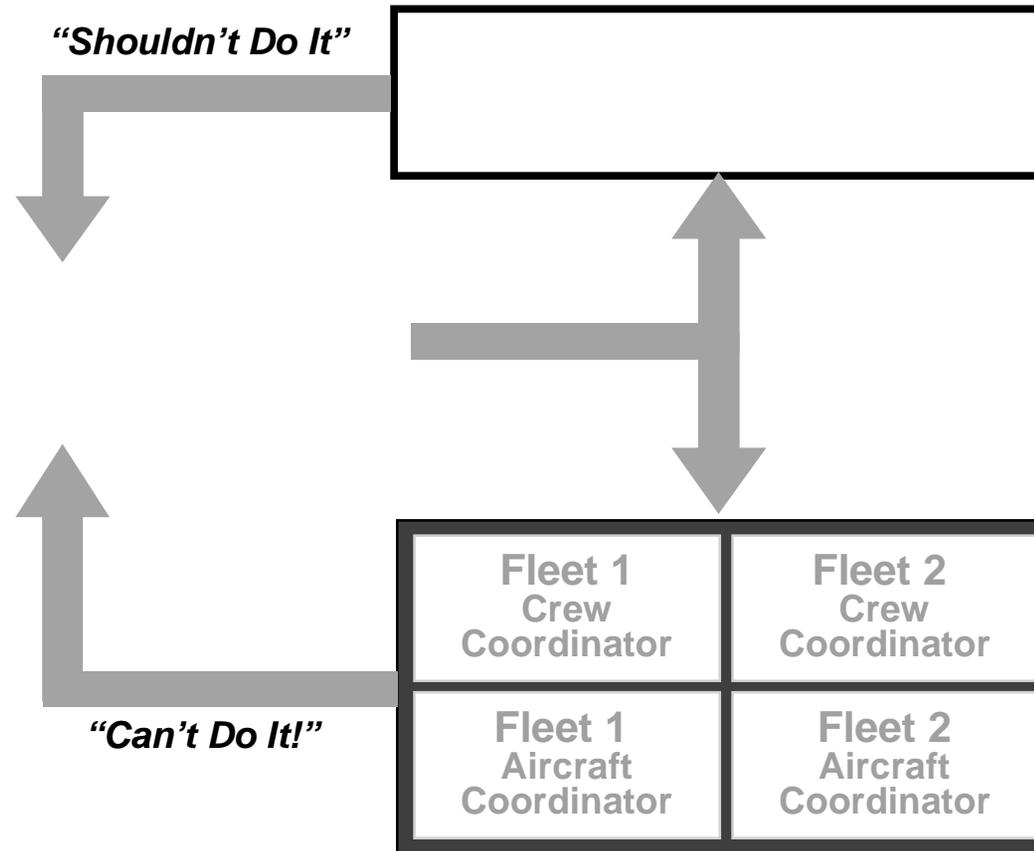
- **Airline Operations Control Center (AOCC): centrally manage operations of aircraft, crews and passengers**

- **Monitor flight irregularities, implement recovery plans**
- **Quickly return the schedule to on-time after major disruptions**

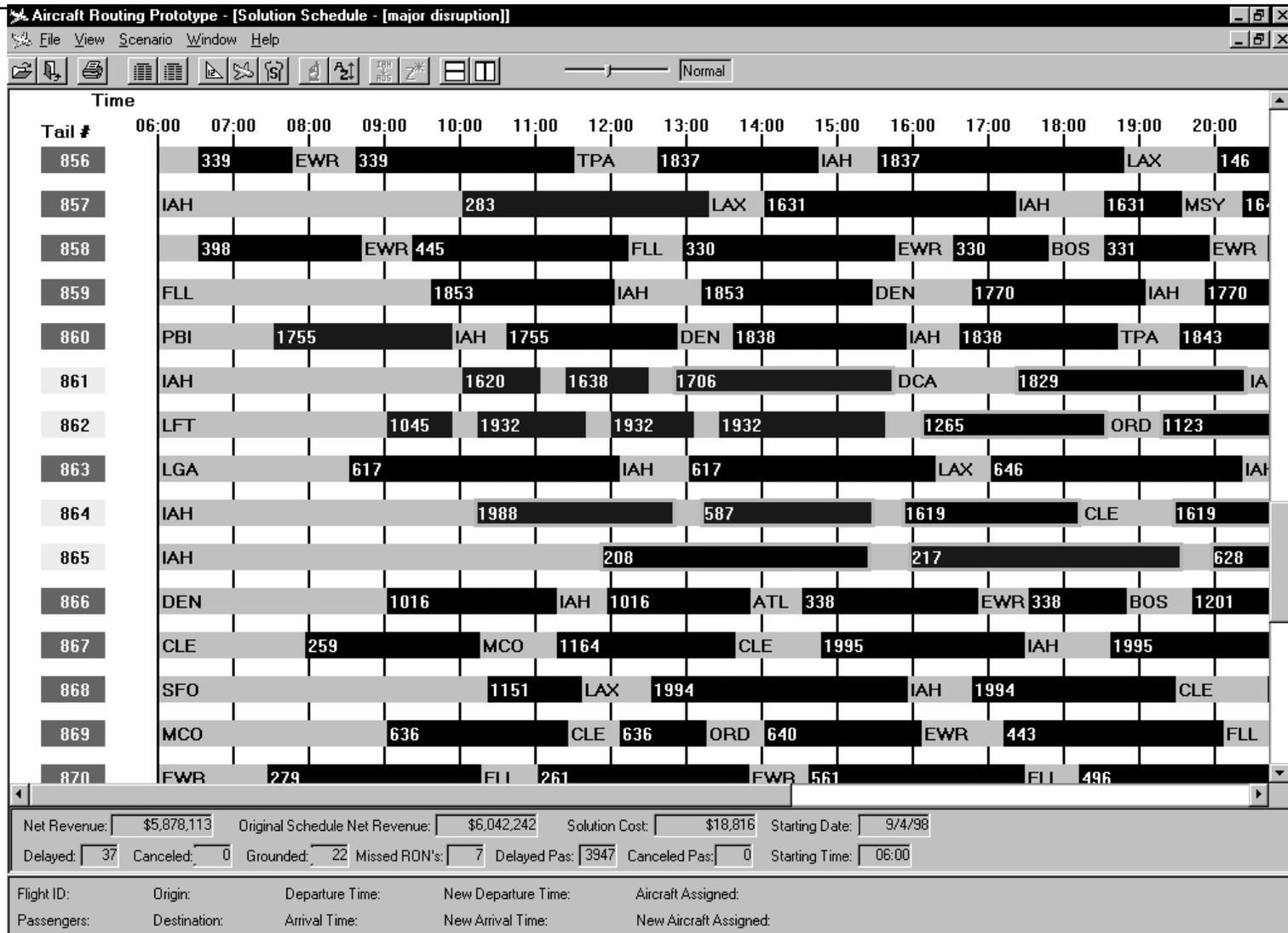
AOCC



Current Practice



Operations Controllers GUI: Gantt Chart



AOCC decisions to recover the schedules

- **Recovery priority:**
 - **Aircraft > Crews > Passengers**
- **Decisions:**
 - **Aircraft route swaps with no crew schedule disruptions enable to absorb flight delays**
 - **Flight cancellation:**
 - **Hub-and-spoke schedule enable almost always to find cancellation tour with only two flights.**
 - **Especially interesting when 2 flights belong to the same planned crew duty**
 - **Call reserve crews**

Airline operations recovery: challenges

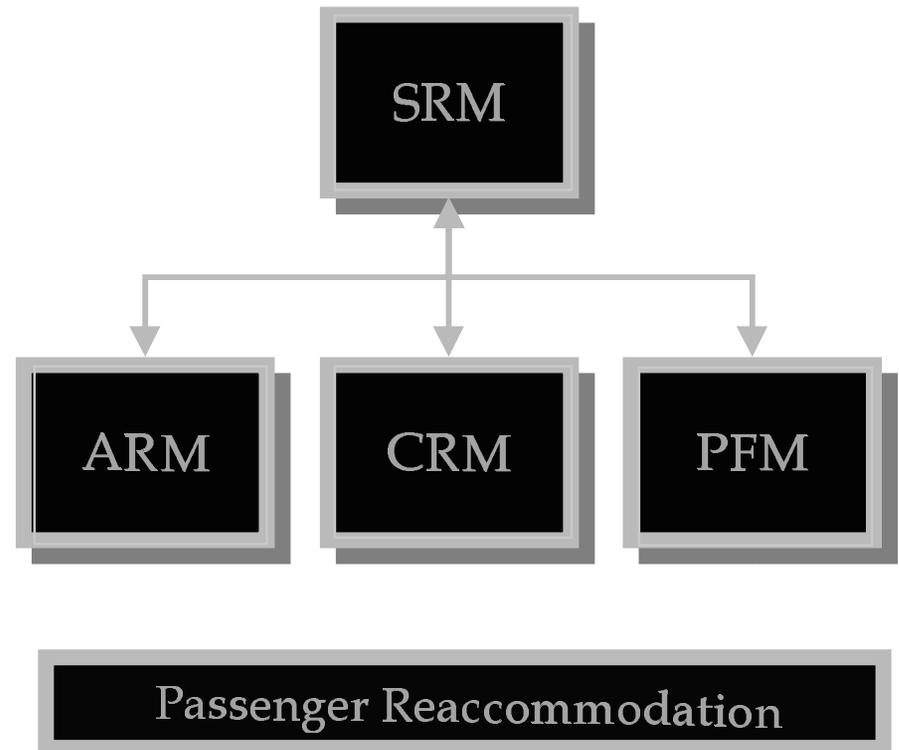
- **Airlines' plans are sophisticated**
 - Aircraft, crews and passengers have different route schedules
 - The objective of planning is to minimize operating costs, which result in maximizing resource utilization, leaving very little slack to recover disruptions
- **Following a disruption, choosing the best operational decisions are hard because:**
 - Size of the decision space
 - Real time; If wait too long, solutions might become obsolete
 - Complex restrictions (FAA, contractual)
 - interdependencies between airline resources and passengers

Challenges (Cont.)

- **Impact of delay depends on the state of the complex multi layer plan at a given time:**
 - **30 minutes flight delay may result in crew disruption, flight cancellations and severe passenger disruptions. The effect can last for more than a day**
 - **Conversely, a 30 minutes delay might benefit crews and passengers as both would have been disrupted had the flight departed on time**
- **What is the objective?**
 - **Can we assign a cost to one minute of flight delay?**
 - **Can we assign a cost to a flight cancellation?**

Airline Integrated Recovery

- ***Schedule Recovery Model (SRM)***
- ***Aircraft Recovery Model (ARM)***
- ***Crew Recovery Model (CRM)***
- ***Passenger Flow Model (PFM)***
- ***Journey Management***
 - ***Passenger Re-accommodation***



Airline Schedule Recovery Problem: Assumptions

- **At a given time of the day, we assume that airline controllers know the state of the system:**
 - **Locations and availability of resources**
 - **Aircraft**
 - **Pilot and flight attendant crews**
 - **Passenger states (i.e., disrupted or not) and locations/destinations**

Airline Recovery Model, ARM

(G. Yu et al.)

$$\min \left(\sum_{f \in F} \sum_{t \in T_f} d_f^t \times x_f^t + \sum_{f \in F} c_f \times z_f \right)$$

Ops cost + Cancellation cost

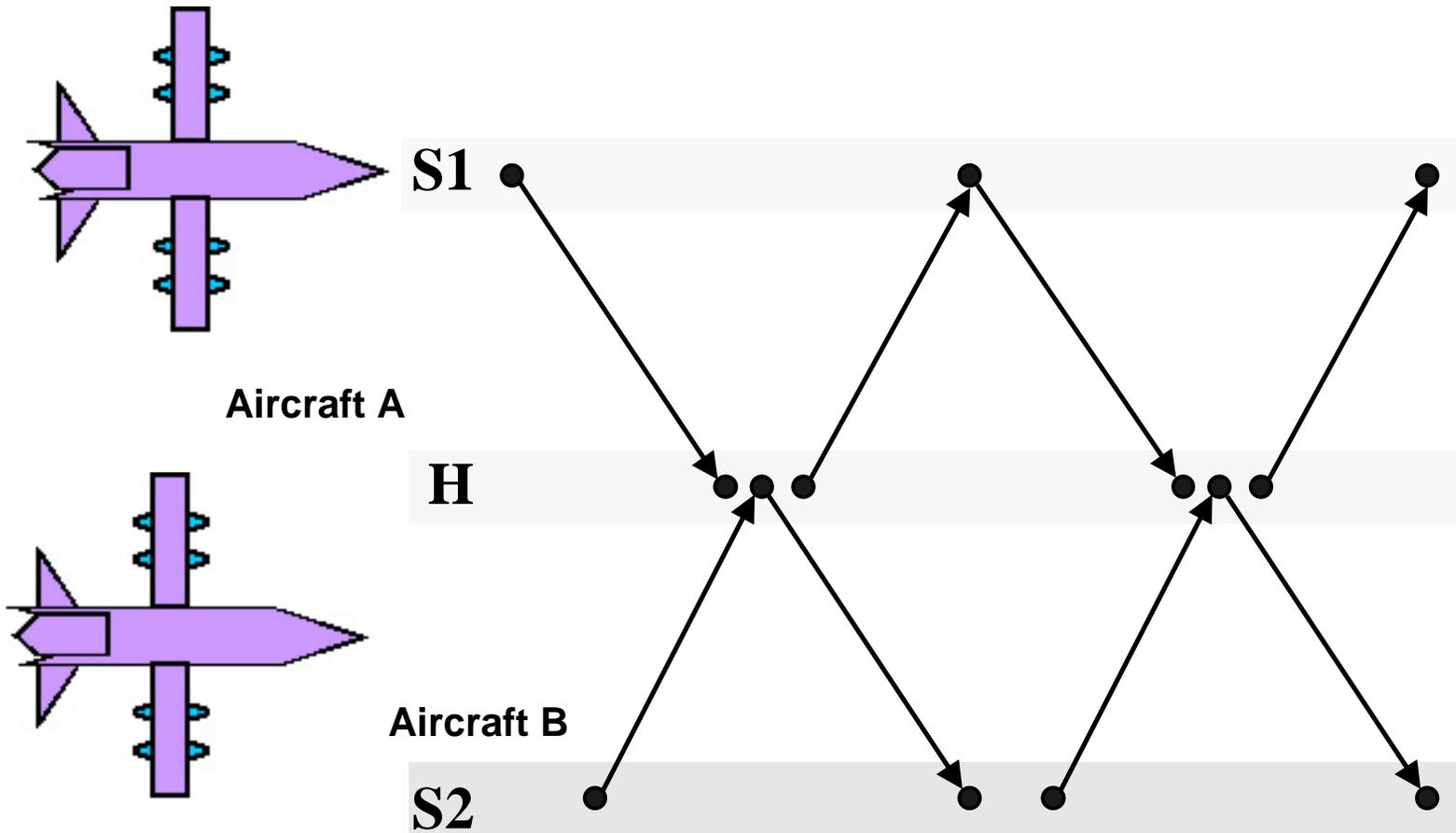
st :

$\sum_{t \in T_f} x_f^t + z_f = 1$	Flight coverage
$\sum_{f \in F_{dj}^t} x_f^t + y_f^{t-} = \sum_{f \in F_{oj}^t} x_f^t + y_f^{t+}$	Aircraft balance
$\sum_{f \in F_{oj}^0} x_f^0 + y_f^{0+} = j_0$	Initial resource at airports
$\sum_{f \in F_{dj}^-} x_f^- + y_f^{-} = j_-$	End of the day resource at airports

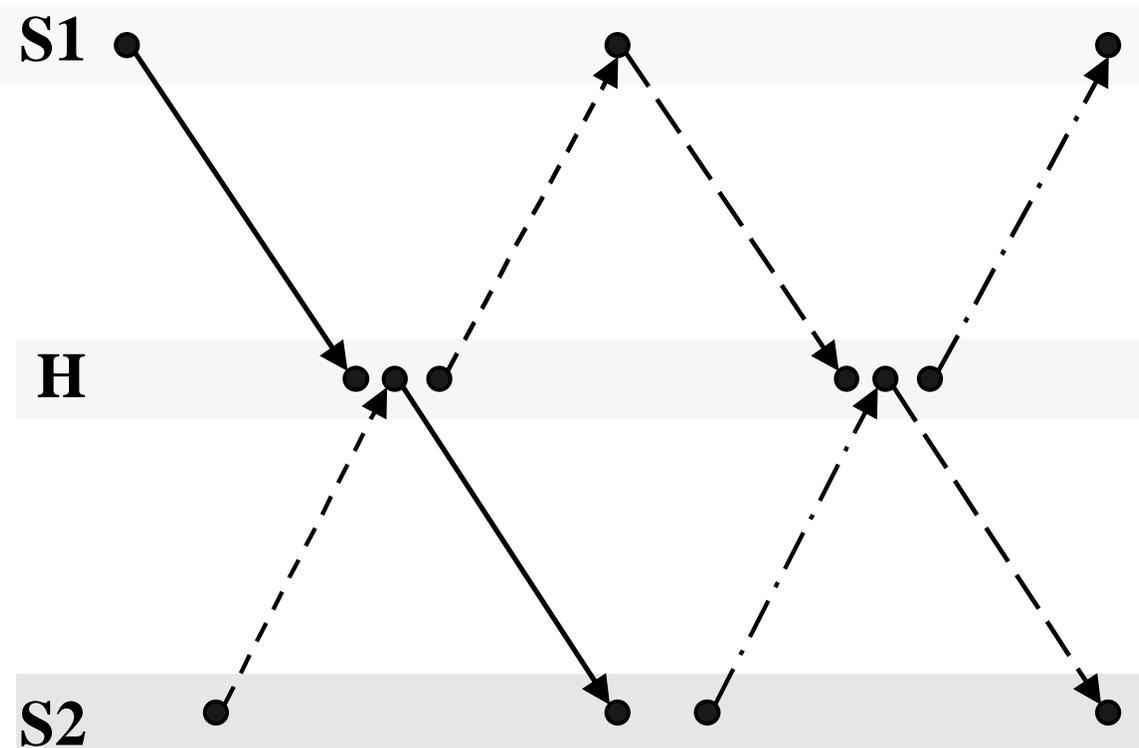
$x_f^t \in \{0,1\}; y_f^t \geq 0$

- **Objective is to minimize operating cost (flight delay and cancellation costs)**

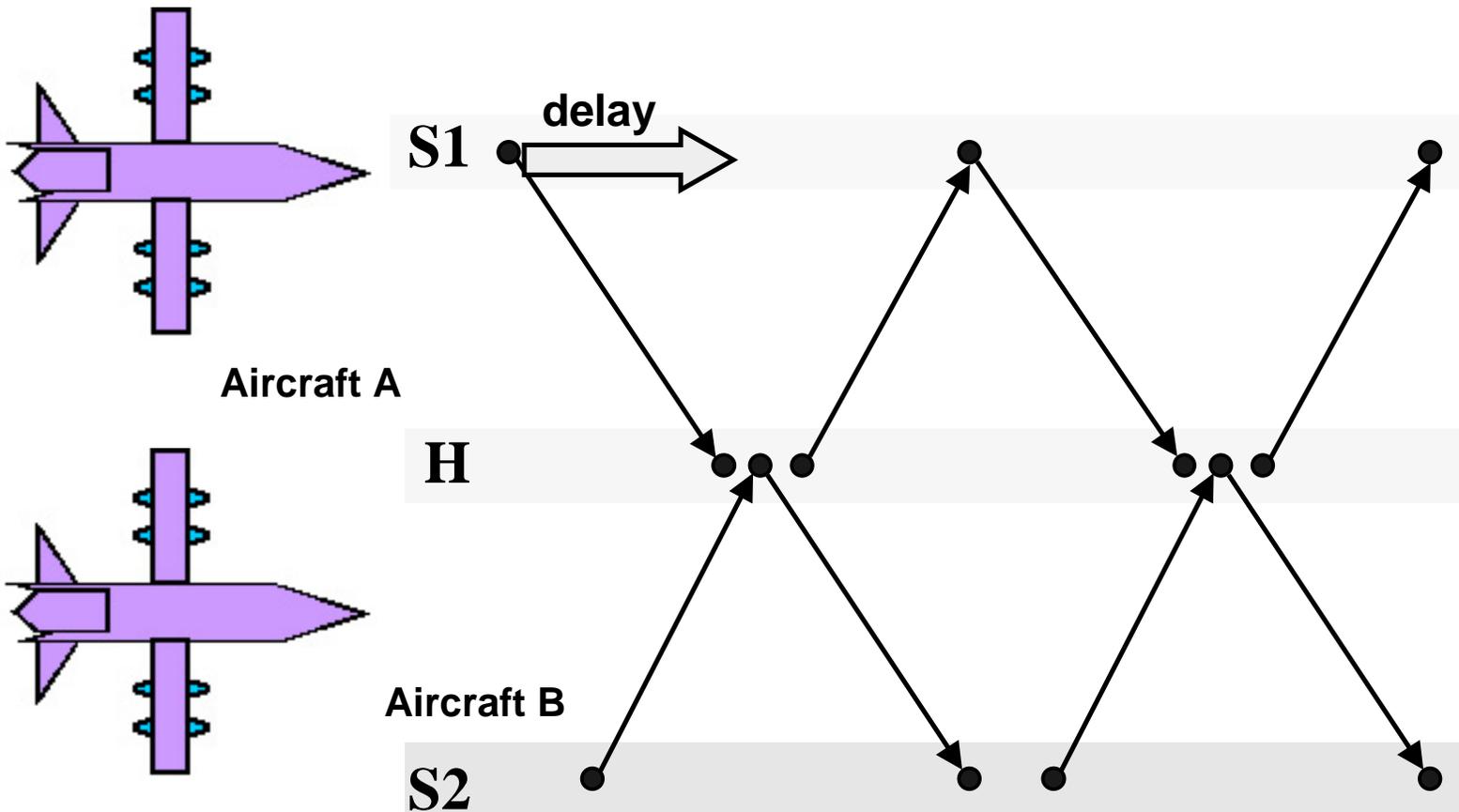
Aircraft route schedule



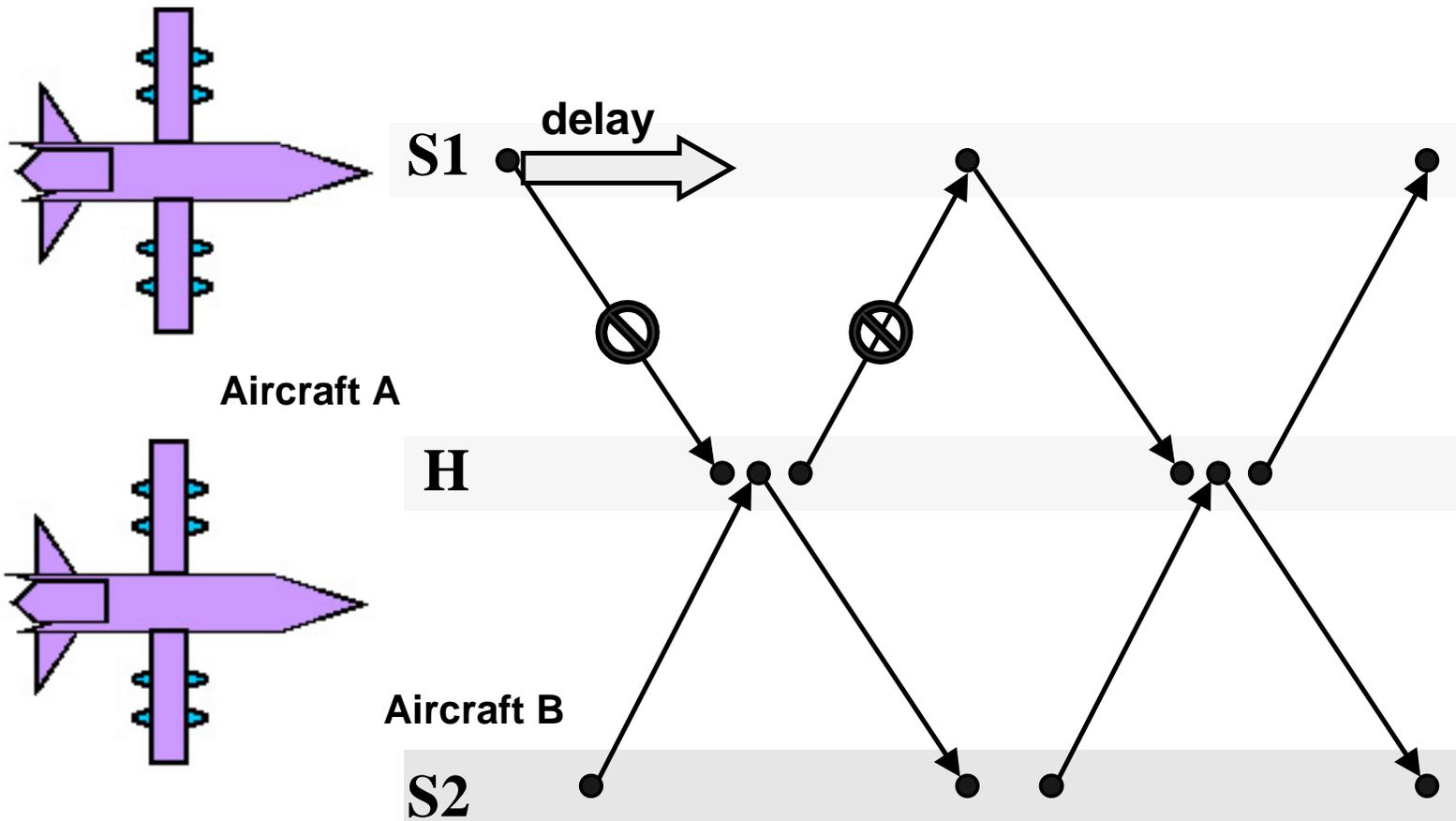
Passenger itinerary schedule



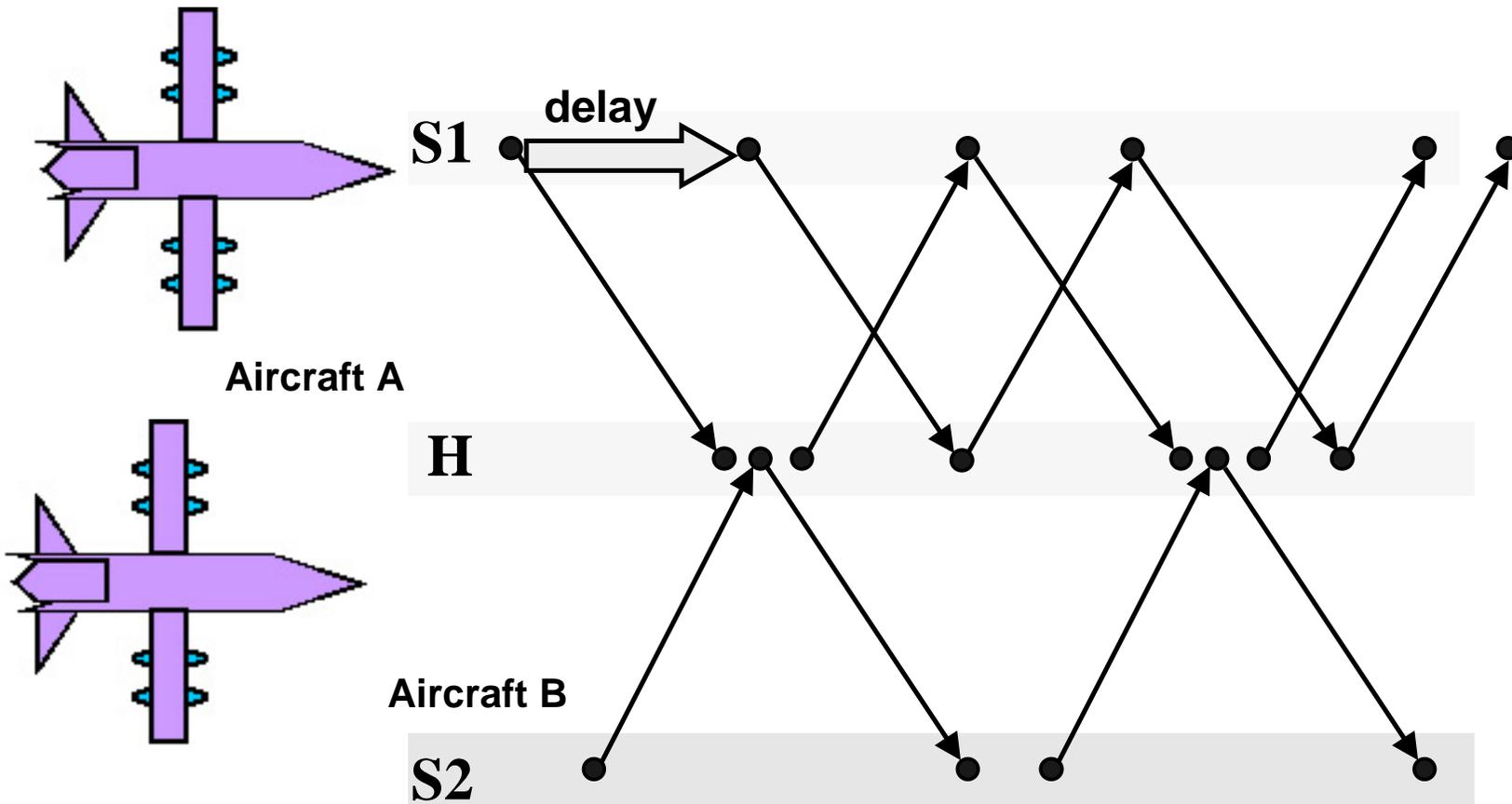
Aircraft actual operations: unexpected delay (e.g., aircraft technical problem)



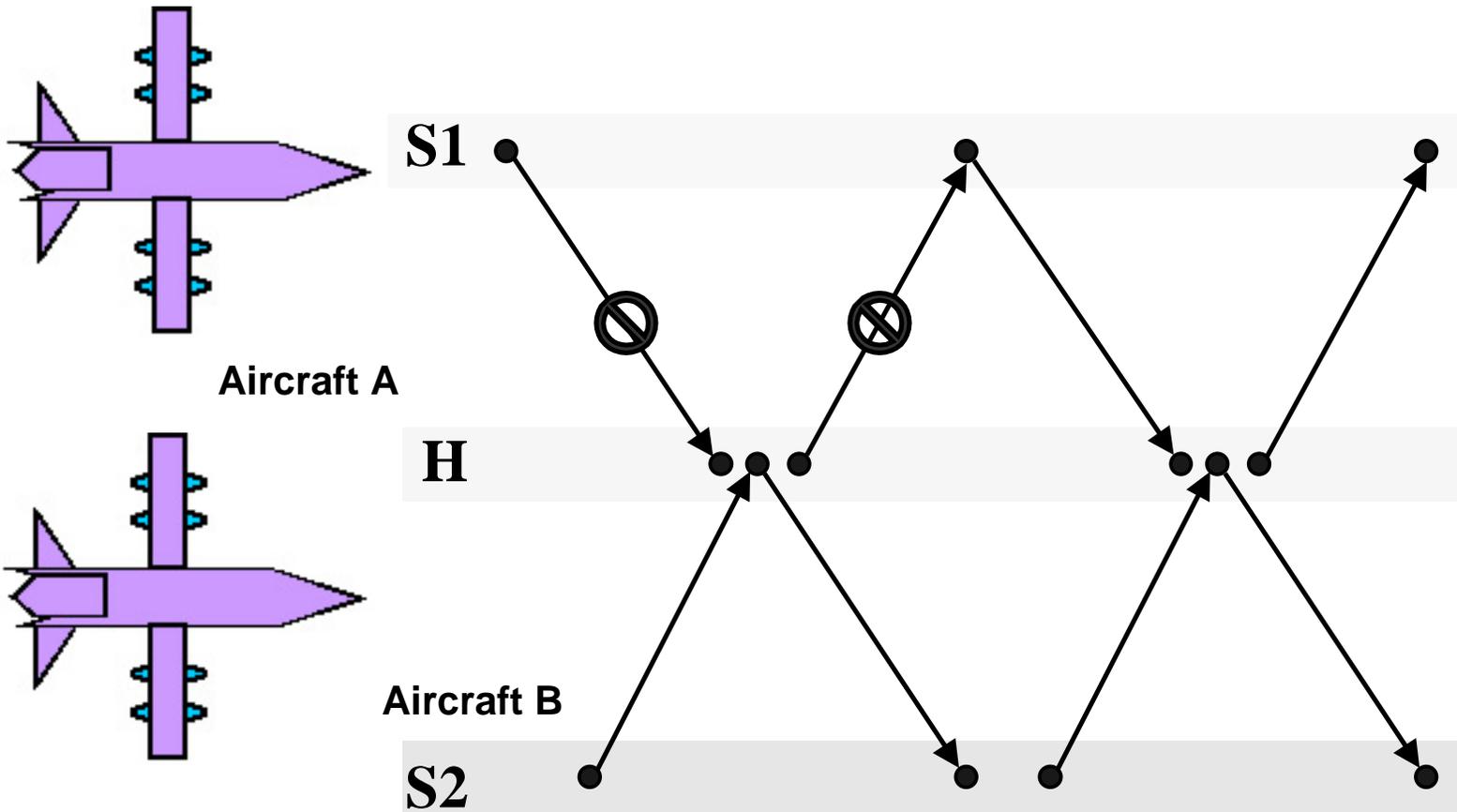
Operations decision #1: cancel



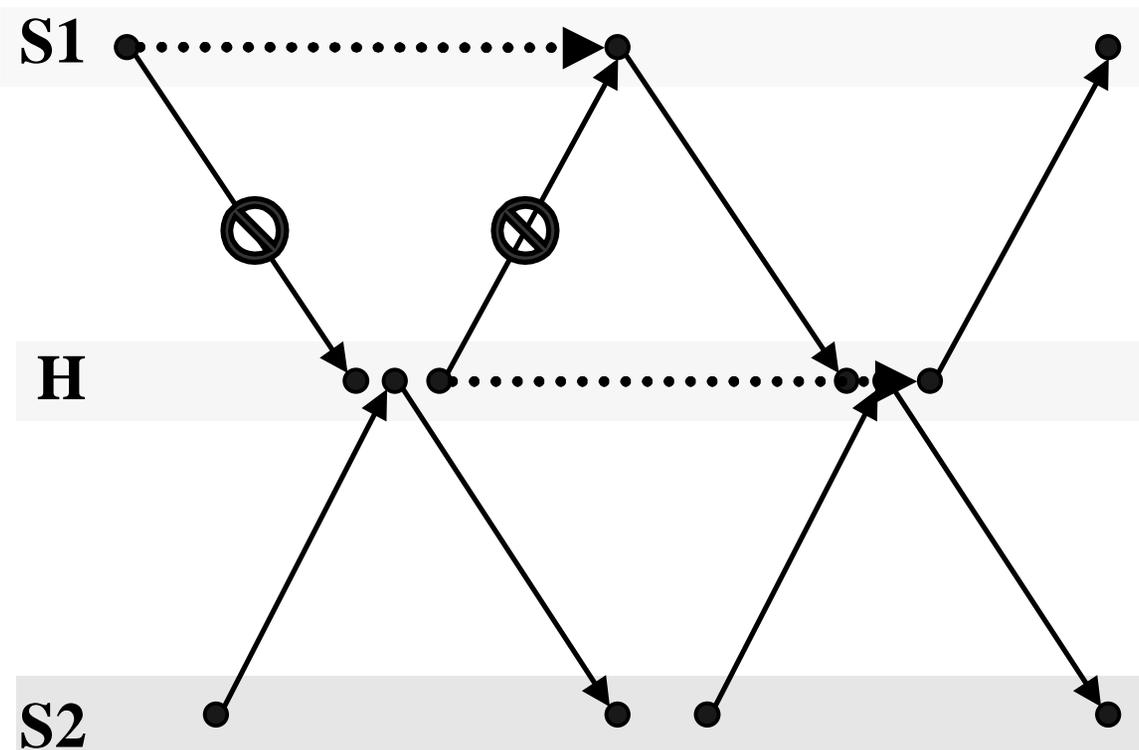
Operations decision #2: don't cancel; don't postpone aircraft B



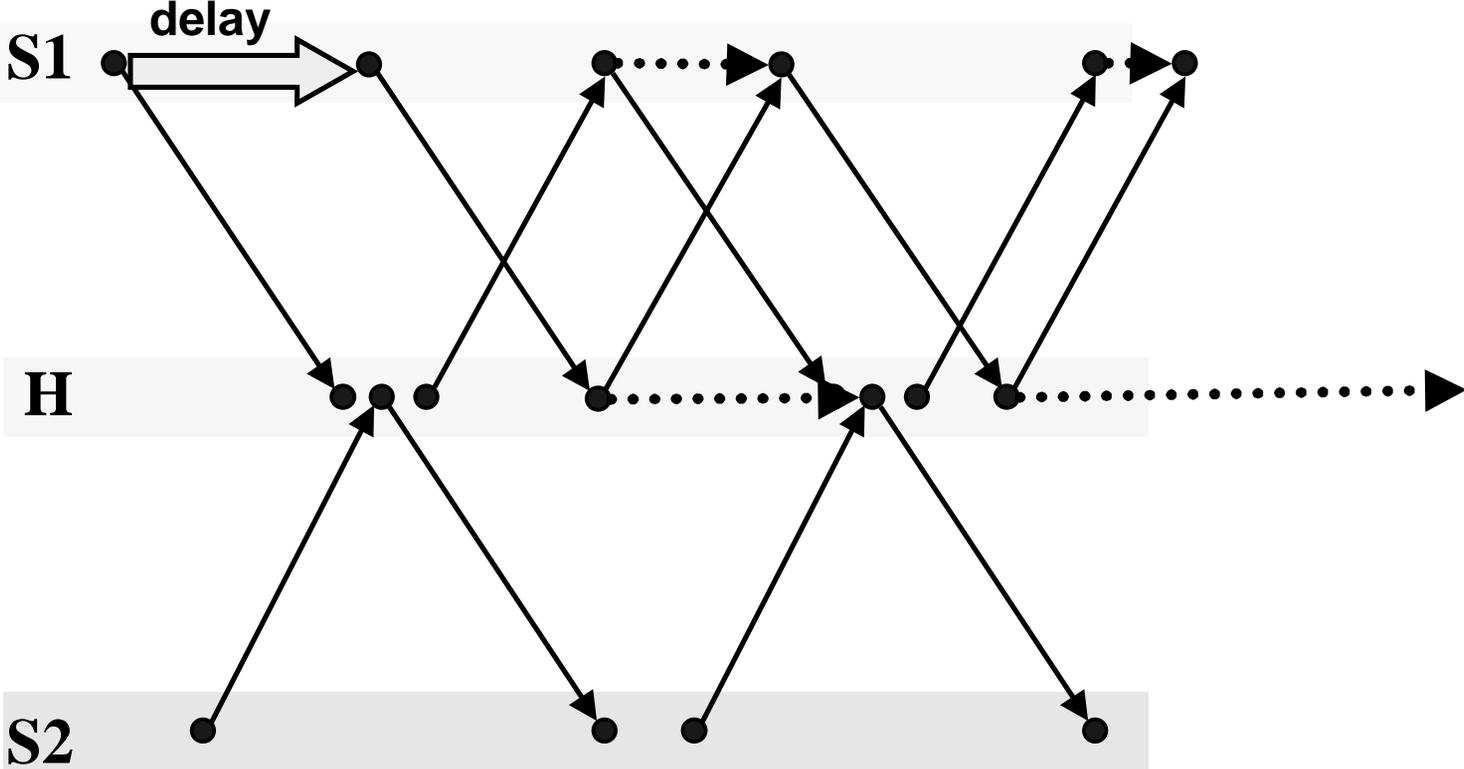
Operations decision #1: cancel Passenger actual itineraries



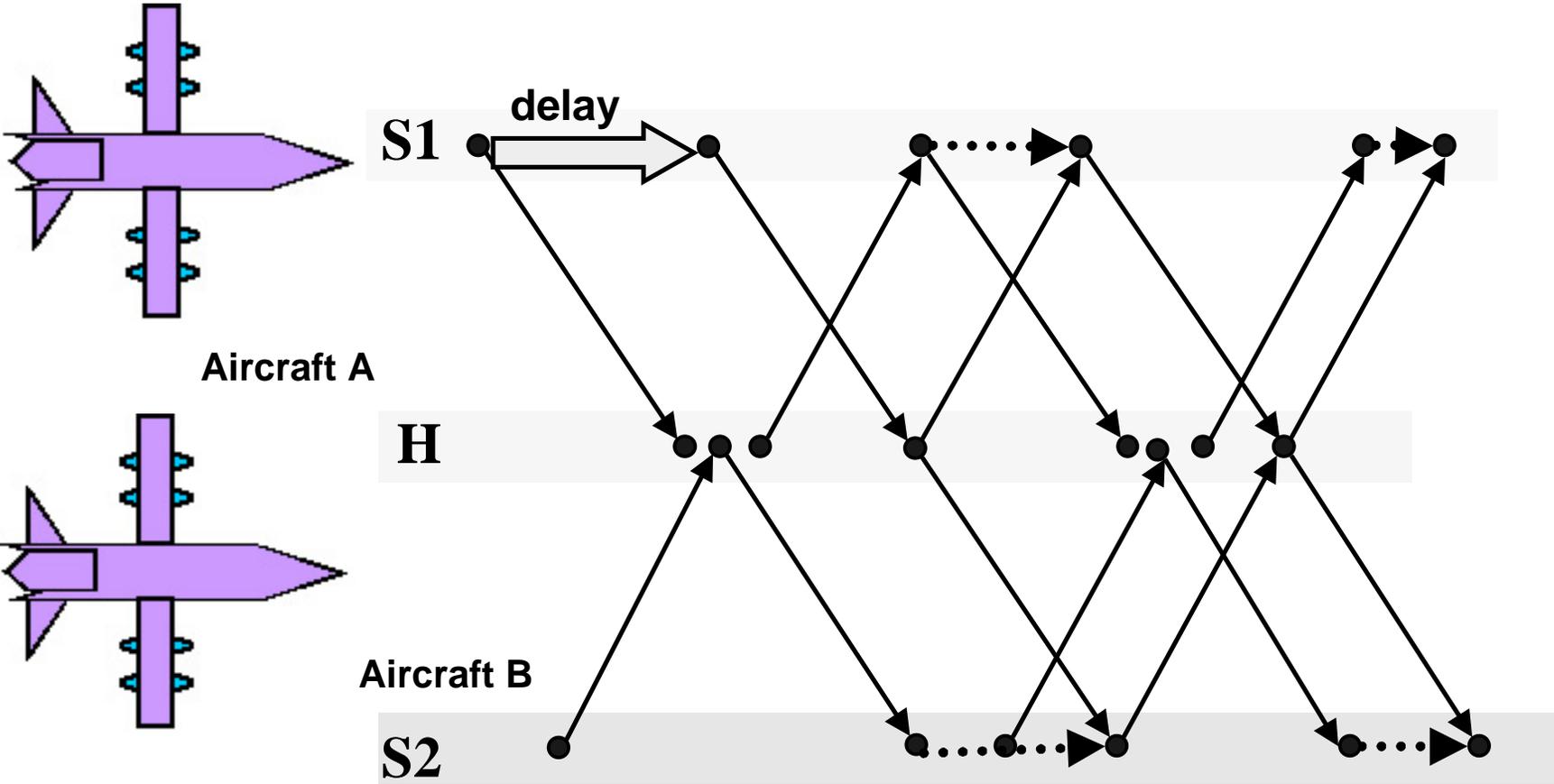
Passenger actual itineraries Operations decision #1: cancel



***Passenger actual itineraries Operations decision #2:
don't cancel & don't postpone aircraft B***



***Passenger actual itineraries Operations decision #3:
don't cancel & postpone aircraft B***



ARM shortcomings

What cost to assign to flight cancellations and flight delays?

- **Objective coefficients are fixed in the ARM but in actual operations they actually depend on the overall solution, for example:**
 - **Postponing a flight departure might reduce overhead crew cost and passenger delays and or conversely might disrupt crews and increase total passenger delay**
 - **A flight cancellation can benefit the passengers and reduce airline operating cost or conversely a flight cancellation can result in severe overhead costs to the airline**
- **Testing using actual airline data showing that the solution is highly sensitive to the objective coefficients**

The airline operations recovery problem: our objective

- **Reduce total passenger delay and the number of disrupted passengers by deciding on:**
 - **Flight departure times (or clearance)**
 - **Flight cancellations if necessary**
- while satisfying resource feasibility (crew and aircraft restrictions) and controlling actual operating costs**

Example's conclusion

Operational decision	Description
#1	Cancel 2 flights, aircraft A
#2	Postpone flights, aircraft A only
#3	Postpone both aircraft A and aircraft B

- **Decision #3 is the best decision for passengers**
- **The ARM would chose either decision #1 or #2 depending on the flight delay and cancellation cost coefficients:**
 - **The best decision for the passengers will never be chosen by ARM**
 - **Passenger direct operating costs not capture; overnight passengers create extra direct costs for the airline (e.g., hotels) and potential lost revenues**
 - **No passengers are disrupted in decision #3**

Questions?
Discussion items?