A Vision for Collaborative Routing

NEXTOR Symposium
November 2000

Robert Hoffman
Metron, Inc.

The Goal of Collaborative Routing

- To Apply GDP concepts and paradigms to the management of en-route airspace

Collaborative Routing vs. GDP-E

- GDP-E
  - Readily identified Problem
  - Needed a Tool
- Collaborative Routing
  - Readily identified Tool
  - Need a Problem

Not that there are no problems...

The Problem is...

- There are lots of problems!
  - Coordination/Communication of multi-objective organizations (ATCSCC, AOCs and ARTCCs)
  - Miles-in-Trail (MIT) restrictions in a more scientific, coordinated fashion
  - Convective weather activity and associated reroutes (Summer 1999, Summer 2000)
  - Equitable distribution of en-route resources

Need a Vision

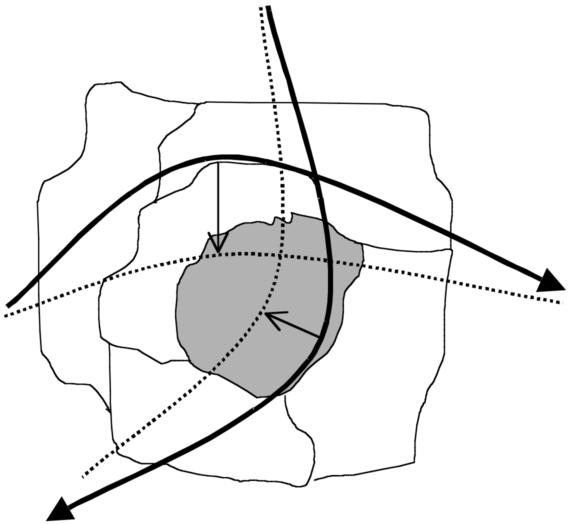
- Long-term CR group:
  - ops concept
  - framework
  - architecture
  - vision
- Short-term CR group:
  - SWAP, LAADR, Summer 2000, etc.

GDP ~ P as CR ~ NP Complete

- In GDP,
  - we can (and do) get away with simple queueing
  - project forecasted delays back to origin airport
  - impose ground delays
  - stretch out arrival stream over time

Why CR is harder than GDP (2)

- In CR,
  - spatial as well as temporal allocation
  - multiple resources (arrival fixes, sectors, routes)
  - convective weather
  - orders of magnitude more data
  - unpredictable demand
  - “unknown” capacity



Principals of CR Architecture

- P1. Continuous Control Process
  - continuously monitor NAS status
  - take congestion-relieving actions as appropriate:
    - minor route/schedule perturbations, or major resource allocations.
  - Unlike current “on/off” GDP process
- P2. Collaboration Criteria
  - Coordinated but distinct roles of ATCSCC, ARTCCs, and AOCs

Principals of CR Architecture

- P3. Real-time Distributed Database
  - NAS Status, ATC Controls, User intentions
  - Demand/Capacity Forecasts
- P4. Enhanced Airline Flight Planning
  - AOCs must update current systems with multi-route congestion-based planning, as opposed to single route optimization

Principals of CR Architecture

- P5. Post-departure Control Consideration
  - essential to coordinate control of a flight after its departure, not just before
- P6. Stochastic Demand Estimations
  - inherent uncertainty in demand and capacity
  - extended R&D project

Principals of CR Architecture

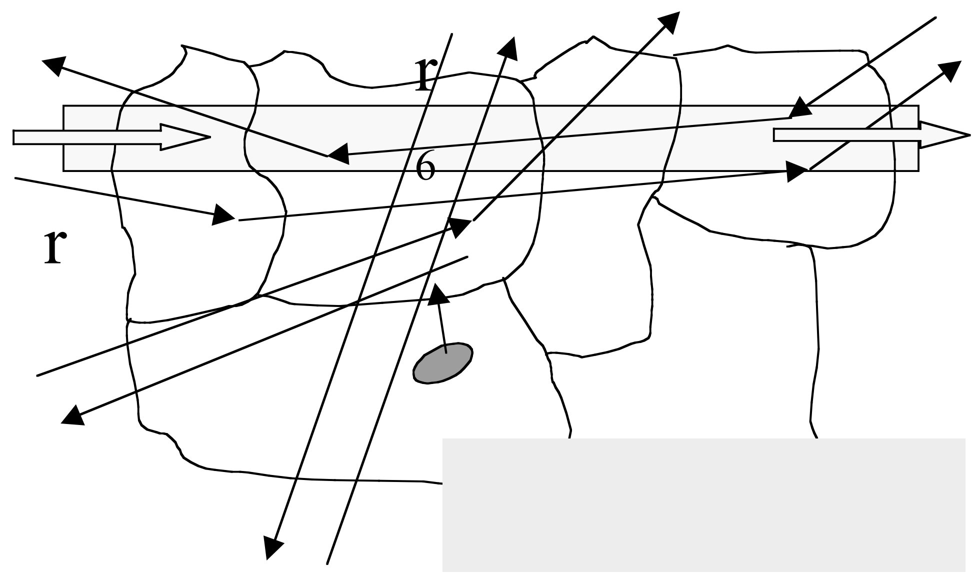
- P7. Equity Issues and Resource Rationing
  - Rewards for Submission of early and accurate information
  - Equity among traffic flow classes e.g., IAD departures, NYC-bound traffic
  - Schedule Deviation with System-wide Consideration

Potential Approach to Rationing (1)

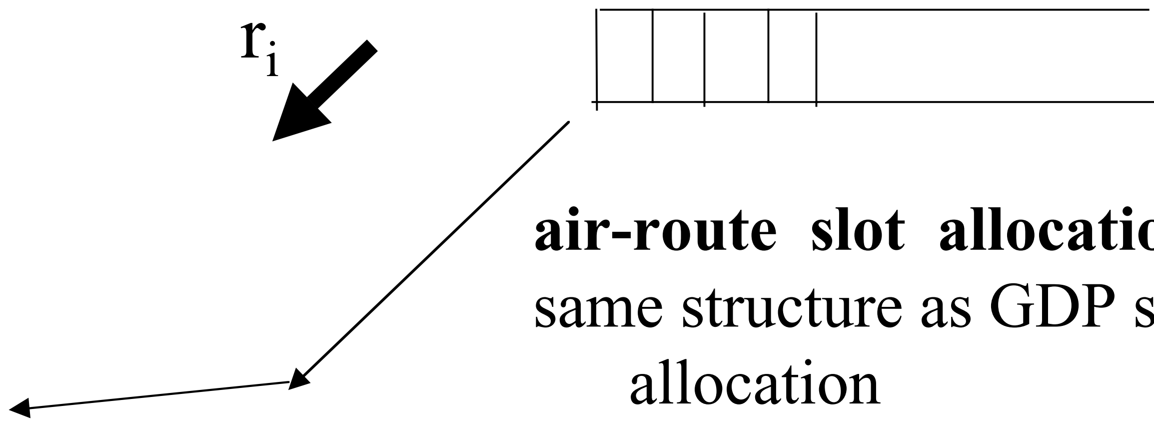
- Aggregate allocation of capacity to major traffic flows
- “Set”, not compute
  - determine capacity
  - balance/equity between classes

Potential Approach to Rationing (2)

- Interaction of Traffic Classes
  - some flows will merge
  - network flow problem
- Decision Aid Tools, R&D Project



Assign Flights to Routes

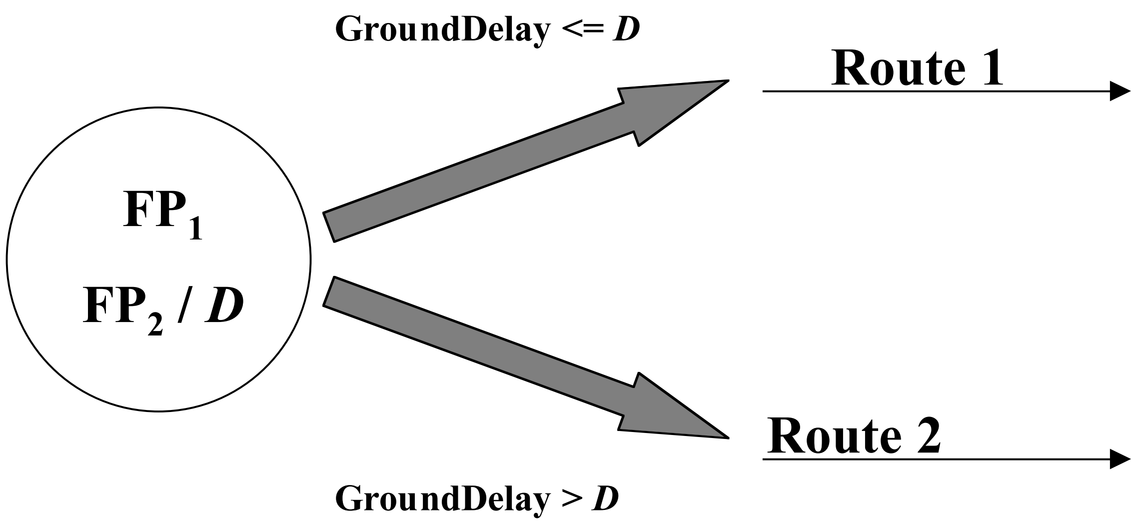


air-route slot allocation:
same structure as GDP slot allocation

Adapt all GDP features to this setting:
RBS, cancellations & substitutions, compression

User Preferences (M5.4)

- Input to Algorithm:
  - alternative flight plans (FP)
  - D = delay tradeoff specification



Schedule Deviation with System-wide Consideration (SDSC)

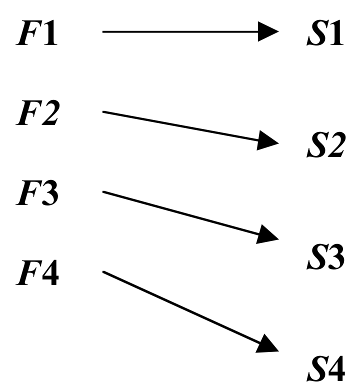
- Proposed rationing basis: assign resources to those flights that have assumed the most delay in the System
- All delay assumed by a flight is considered
- delay on *f* = departure delay + delay from other ATM initiatives

Minimize the Maximum Delay

Ration-By-Schedule

1. Delay = Deviation from Schedule
2. Order flights by schedule arrival time
3. Create arrival slots S_n)
4. $F1$ to $S1$, $F2$ to $S2$,...

Assignment Problem



Lexicographical Ordering

Maximum potential delay incurred by a flight is minimized; this property must hold recursively

RBS and SDSC are based on same principal: minimizing max delay

Priority Queues, a la RBS

- Multiple Queues
  - Queue 1 “early filers”:
    - flights filed < 4 hours in advance
    - order by SDSC
  - Queue 2 “late filers”:
    - filed   4 hours in advance
    - order by weighted combination of SDSC and file time
- Assign to Q1, then to Q2