MIT International Center for Air Transportation

MIT Extensible Air Network Simulation (MEANS)

Presented by
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Background

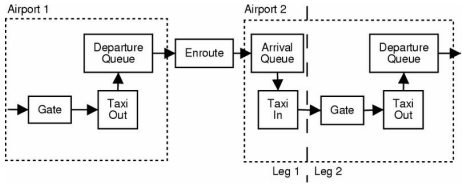
- **Development started at the beginning of 2001**
  - Developed initially as a tool to evaluate the effect of congestion at a hub airport on the network of an airline
  - Expanded soon thereafter to evaluate ideas related to CDM and airline scheduling
- **Other Features Added During Development**
  - GDP model
  - Pareto Frontier generation
  - Weather
  - Stochastic modeling
  - Human−in−the−loop airline operations interface

Overview

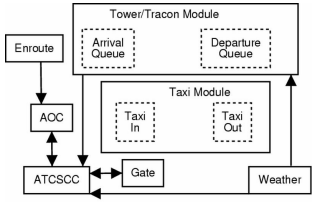
- **MEANS is an event−based simulation**
- **Tracks aircraft through several states**
  - Emphasis on ground−based effects
  - Also tracks passengers if desired
- **Arrival and departure rates at airports are constrained**
  - This produces delays which propagate throughout the system
- **Multiple runs with controlled distributions provide stochastic results**

Flight States and Data Flow

Flight Progression



Data Flow



Data Sources

- **Schedule**
  - ASQP database
  - CODAS ETMS database
- **Airport Capacities**
  - FAA Benchmark Report
  - Theoretical Generation
- **Airborne, Taxi, Ground Times**
  - Historical Data (ASQP)
- **Weather**
  - NOAA weather records

Modules

- **Aircraft Turn−Around**
- **Taxi−Out & Taxi−In**
- **Airborne**
- **Tower & TRACON**
- **Ground Delay**
- **Airline Operations**
- **Weather**
- **Passengers**

Module Implementations

- **Historical values/distributions**
  - Aircraft turnaround
  - Taxi in/out
  - Airborne
- **Queueing Systems**
  - Airport/TRACON
- **Agents/User Control**
  - Airline Operations
  - Ground Delay Programs/ATCSCC

Historical Data

- **Need "unimpeded" times**
  - Times recorded in historical data include time spent waiting in queue
- **Unimpeded data obtained by discarding data from "busy" times**
  - Look at service rate or service events
  - Algorithm for unimpeded taxi times developed by Francis Carr based on technique developed by Idris, Clarke, Bhuva and Kang

Queueing Systems

- Airport/TRACON is primary queue
- Coupled arrival/departure queues
- Several potential sources for rates
  - Arrival and departure rate from historical data
  - Pareto Frontier from historical data
  - Pareto Frontier from simulation

Passengers

- Passengers tracked individually
- Each passenger starts with desired itinerary
- Passengers can be disrupted/delayed
  - Delayed when final flight leg arrives late
  - Disrupted when flights are cancelled or flight is delayed such that connection cannot be made
- Passengers reacommodated on later flights when possible

Stochasticity

- Stochastic front−end repeats simulation with same data and different random seed
- Most modules have stochastic and deterministic implementations available
  - Selective use of stochasticity can decrease computation time
- Stochastic simulation runs parellelize well
- Adequate convergence for most purposes obtained in under 1000 runs

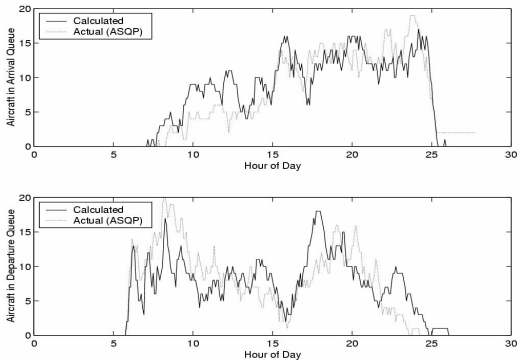
Raw Results

- Primary results for every flight
  - Provides information on aircraft state transition times, cancellations, etc.
  - Filtering available to select only desired flights
- Primary results for every passenger
  - Provides desired and obtained itineraries
- Secondary information as simulation runs
  - Detailed information about when decisions were made, operating conditions during simulation, debugging

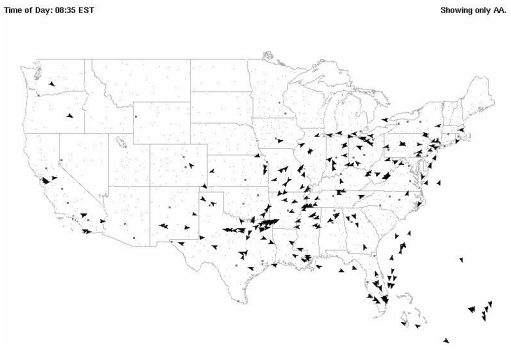
Processed Results

- **Airline performance information**
  - Delay percentages/averages
  - Cancellations, expected missed connections
  - Direct delay cost to airlines in dollars
- **Airport demand information**
  - Delay distributions
  - Plots of operations and/or delay over course of day
- **Visualization tools allow examination of bank structure and tracking of delayed flights**

Example − GDP at Boston



Visualization Example



Recent Updates

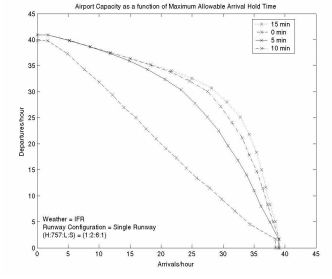
- **New Modules and Capabilities**
  - Pareto Frontier simulator
  - Aircraft equipment correlations
- **New Scenarios**
  - Degradable Scheduling, the dissertation of Laura Kang

Pareto Frontier Simulator

- Used to generate Pareto Frontiers through stochastic simulation using FAA rules
- Can produce detailed per−configuration Pareto Frontiers which are difficult to extract from historicla data
- Can be used to examine factors affecting capacity, and generate Pareto Frontiers for hypothetical situations with no historical data

Pareto Fronter Factors

- Best performance obtained by alternating arrivals/departures
- Ability to alternate affected by willingness to hold aircraft



Equipment Type Correlation

- ASQP has registration number for aircraft
- JP−Fleets is a commercial database with equipment type information
- Correlating the aircraft is not straightforward
  - Some airlines report truncated registration numbers
  - Some airlines report incorrect suffixes on registration numbers
  - Some airlines report their internal tracking numbers, adapted to a pseudo−tailno format
  - Contact me for more information this is work you're doing

Degradable Schedule

- MEANS used as testbed for work by JP Clarke and Laura Kang
- Basic Idea: pre−prioritize flights for preferential treatment
  - Select "core" of high−priority flights based on connections and passenger revenue
  - Favor high−priority flights in GDPs and other bottlenecks
  - Try to assign passenger itineraries entirely within set of high−priority flights

Degradable Schedule & MEANS

- Added hooks to allow airline to swap flights in departure queue
- Prioritizing airline agent favors high−priority flights in departure queue and ground delay program by swapping flights
- Results: Improvements to Prioritized Flights
  - In good weather, 4% fewer passengers missed connections, saving ~$6,000
  - In bad weather, savings from less lost revenue and reduced operating costs were $38,000

Current & Ongoing Work

- Improvements to airline agent
- Collaboration with NASA Ames' ACES
- Collaboration with Georgia Tech's SimAir
- Collaboration with Carmen System
- Improvements to weather forecasting

MEANS Team

- Prof. John−Paul Clarke
- Terran Melconian (Chief Engineer)
- Elizabeth Bly, S.M. '05 (Airport & TRACON)
- Fabio Rabbani, S.M. '04 (Airline Operations)
- Jason Loy, S.M. '04 (Airline Operations)