Advanced Stochastic Network Models Of The Impact Of 4D Aircraft Trajectory Precision

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Background-Motivation

- Develop Queuing Models that Predict Benefit of Increased Aircraft Trajectory Precision
  - Reduced inter-arrival time
  - Reduced variation in inter-arrival time
  - Reduced service time
  - Reduced variation in service time
  - Increased number of servers
- Develop Modeling and Visualization Environment to Allow
  - Validation of Queuing Model Results Against Simulation
  - Visualization of Benefit Mechanisms
- Validate Proposed Queuing Models
- Apply Validated Models to Next Generation Air Transportation System (NGATS) Concepts

Research Objectives

Modeling the Levels of Aircraft Trajectory Uncertainty

- Low Precision Case: Stochastic Queuing Models
  - Captures present-day system
  - Arrivals and service times are time-dependent Poisson process
  - Employ previously developed DELAYS & Approximate Network Delays (AND) models
- High Precision Case: Deterministic Queuing Models
  - Given
    - Arrival schedule (aggregate or disaggregate)
    - Capacity or deterministic minimum headways
    - Construct cumulative arrival and departure curves to obtain delay and queue length by time of day
    - Average and total delay
- Intermediate Case: Diffusion Approximation
  - Dynamics of joint probability density functions are analogous to dynamics of physical flows or other density problems
  - Continuous approximations using systems of coupled partial differential equations
  - Because derivatives of probability density functions are modeled, they can be integrated to produce moment estimates

Visualization

- Develop an Interactive Tool to Facilitate Visualization of the Ways that Trajectory Uncertainty Propagates

Application and Results

- Comparison of Delay Predicted by Stochastic and Deterministic Models for Atlanta Hartsfield-Jackson International Airport (ATL) under Different Capacity Scenarios

Next Steps

- Ensure results of queuing models are fully comparable with respect to how delay profile is constructed
- Run Airspace Concept Evaluation System (ACES) with arrival capacity constraints
- Increase complexity of ACES runs
  - Departure capacity constraints
  - En route capacity constraints
  - Network effects

Simulation and Validation

- Develop a Queuing Network Representation of the National Airspace System (NAS) Network Consisting of the Busiest Airports and their Associated Traffic

Very low Load

Low Load

Moderate Load

Heavy Load

05:00 EST 17:00 EST

09:00 EST 21:00 EST

13:00 EST 01:00 EST

Delay build-ups predicted by deterministic model lag delay build-ups predicted by stochastic model

Stochastic delay model predicts higher average delays
  - 11%-25% higher
  - Differences generally greater on low capacity days
  - Greater differences in peak delays