Elevator Scheduling

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Why is elevator scheduling important?

- Used multiple times by millions of people every day
- Exist in every building
- Waiting for elevators can be frustrating and wasteful

- Average elevator rider takes 4 trips per day, 250 days per year.
- In New York City, office workers spent a cumulative amount of 16.6 years waiting for elevator and 5.9 years elevators in 2010.

Basics about Elevators

- Non-homogeneous stochastic arrival of customers
- Two types of calls: internal and external
- Has a speed and direction at any point in time
- Doors open and close
- Stationary on a floor until doors close
- Customers can abandon call

Points of Interest

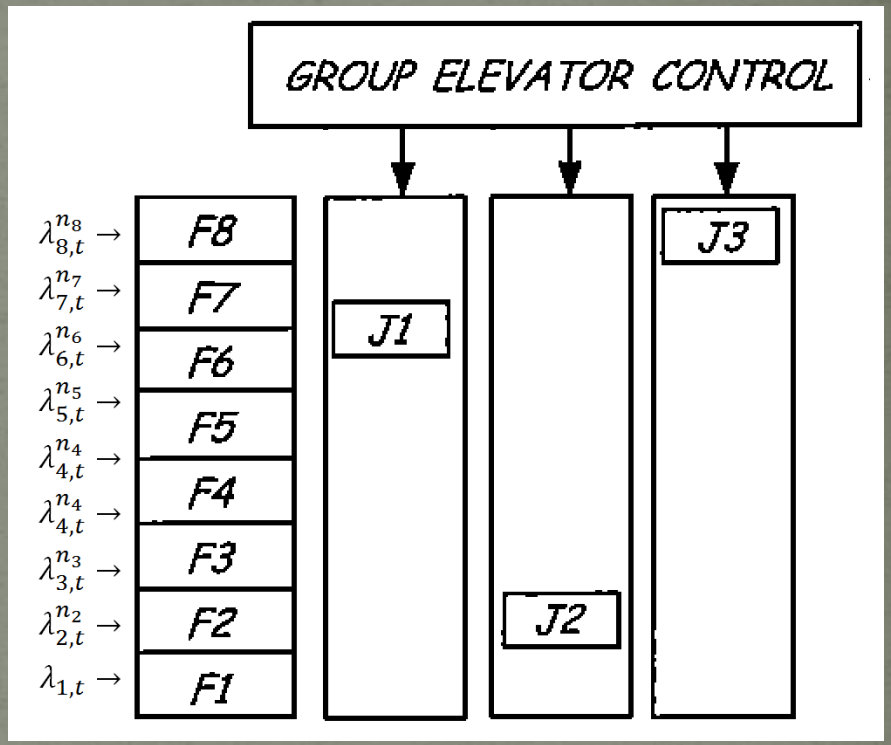
- Expected wait time of users in the system
- Maximum wait time
- Expected number of people whose wait time is substantially greater than the expected wait time (Quality of Service)
- Expected length of queue
- Energy used (Cost)

An NP Hard Problem

- Proved by Seckinger and Koehler for 1 elevator without capacity constraints
- Very large state space for solution
- Large number of constraints
- Reduces to a time dependent traveling salesman problem (TDTSP)

Model Formulation

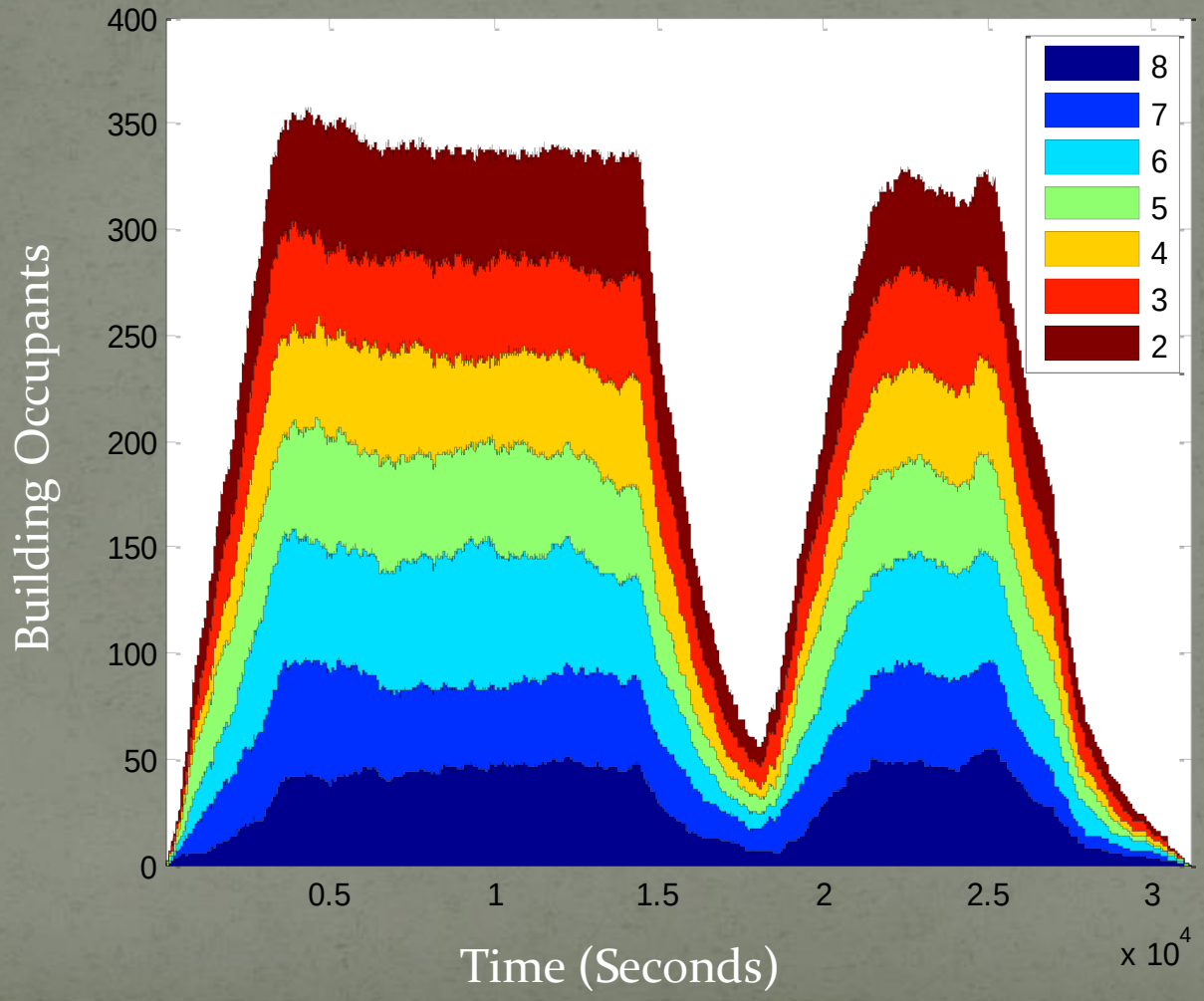
- Arrivals
  - State and time-dependent arrival rates
    - Exogenous arrival rates on ground floor
    - Arrival rates on floors 2-8 are time dependent and floor occupancy dependent
- Elevator System
  - 8 floors and 3 elevators
  - Doors remain open for 3 sec after last passenger enters
  - Elevators take 5 sec to traverse 1 floor
  - Elevator has a capacity of 8 passenger



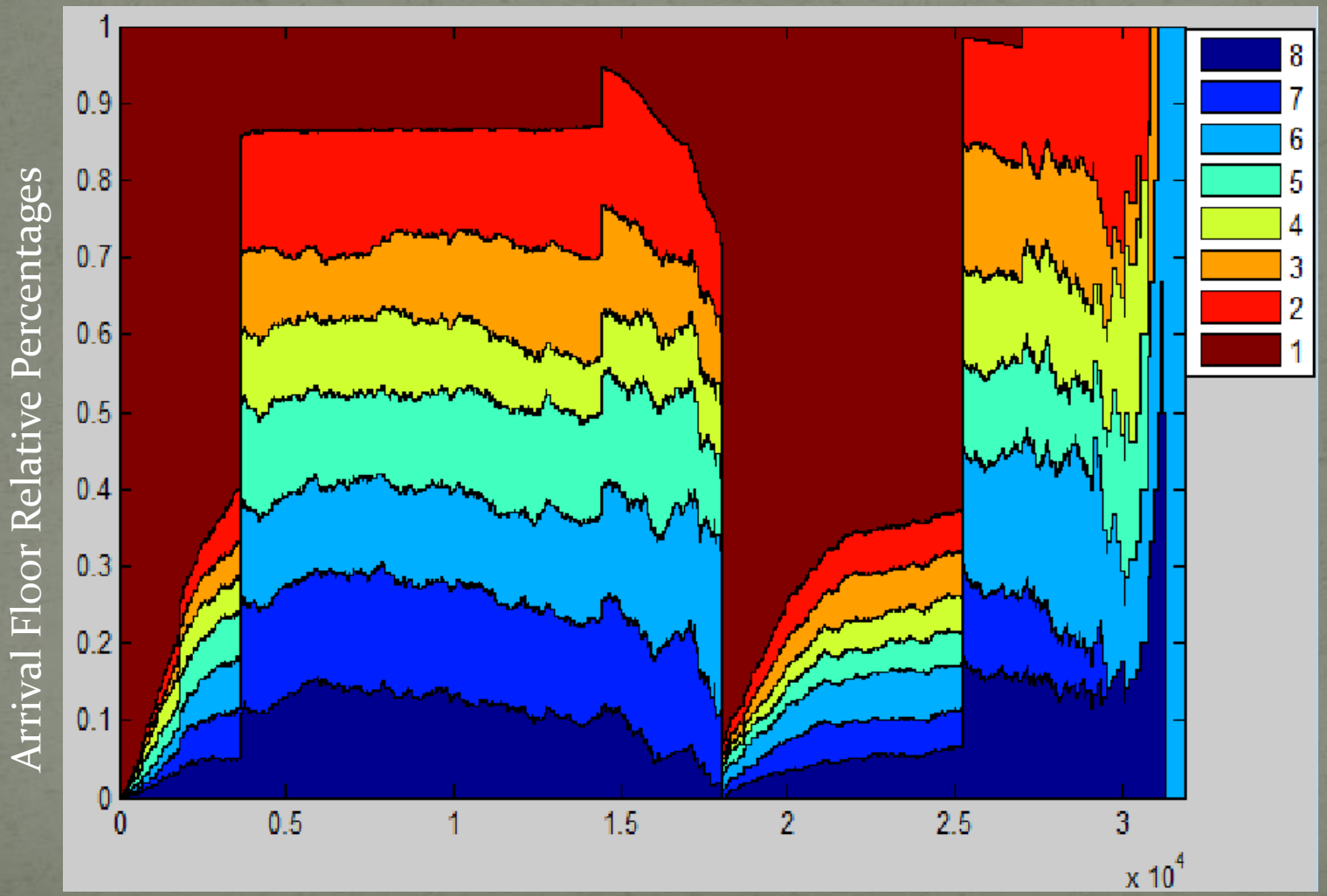
Model Assumptions

- Arrivals
  - Passengers arrive according to non-homogeneous, time-varying Poisson process
  - Passengers are very patient and do not abandon.
    - In fact, when passengers are blocked, they simply push the button again after the elevator departs.
- Elevator System
  - Passenger requests to go up or down
  - Western elevator system
    - Passenger assignments may not be changed
  - Destination floor distribution is time dependent
    - Beginning of day vs. lunch time & end of day

Simulation Results

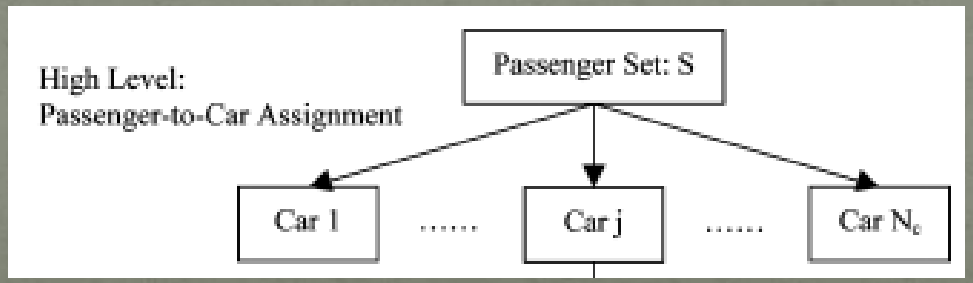


Simulation Results



Algorithms

- Sectors
  - Each elevator has its own sector, a subset of floors, and only services calls that originate from that sector
- Nearest Elevator
  - Each passenger is assigned the nearest elevator as determined by elevator position, direction of call, and elevator direction
- Nearest Elevator with Capacity Considerations
  - Similar to Nearest Elevator, but also takes into account the load in each elevator



Sectors

- Elevator 1: {1, 2, 3}
- Elevator 2: {1, 4, 5}
- Elevator 3: {1, 6, 7, 8}

- Each elevator can service ground floor since the ground floor generally has the highest arrival rate

	Waiting Time	Sojourn Time
Mean	53.08 seconds	95.92 seconds
Median	38.45 seconds	84.29 seconds
Max	334.39 seconds	464.82 seconds

Metrics	Percentages
Pr(Blocking)	7.30%
Pr(Wait = 0)	5.90%

Nearest Elevator

- Compute suitability score for each elevator when new passenger arrives
- (1) Towards a call, same direction
  - FS = (N + 2) - d
- (2) Towards the call, opposite direction
  - FS = (N + 1) - d
- (3) Away from call
  - FS = 1

- N = # Floors – 1;
- d = distance between elevator and call

	Waiting Time	Sojourn Time
Mean	24.76 seconds	68.21 seconds
Median	14.87 seconds	58.98 seconds
Max	219.54 seconds	316.54 seconds

Metrics	Percentages
Pr(Blocking)	11.74%
Pr(Wait = 0)	15.55%

Nearest Elevator with Capacity Considerations

- Compute suitability score for each elevator when new passenger arrives
- (1) Towards a call, same direction
  - FS = (N + 2) - d + C
- (2) Towards the call, opposite direction
  - FS = (N + 1) – d + C
- (3) Away from call
  - FS = 1 + C

- N = # Floors – 1;
- d = distance between elevator and call
- C = excess capacity of elevator

	Waiting Time	Sojourn Time
Mean	24.68 seconds	74.48 seconds
Median	14.40 seconds	65.74 seconds
Max	236.00 seconds	292.97 seconds

Metrics	Percentages
Pr(Blocking)	3.48%
Pr(Wait = 0)	12.70%

Results

	Sector		Nearest Car		Nearest Car Capacity	
	Waiting Time	Sojourn Time	Waiting Time	Sojourn Time	Waiting Time	Sojourn Time
Mean	53.08 seconds	95.92 seconds	24.76 seconds	68.21 seconds	24.68 seconds	74.48 seconds
Median	38.45 seconds	84.29 seconds	14.87 seconds	58.98 seconds	14.40 seconds	65.74 seconds
Max	334.39 seconds	464.82 seconds	219.54 seconds	316.54 seconds	236.00 seconds	292.97 seconds
Metrics	**Percentages**		**Percentages**		**Percentages**	
Pr(Blocking)	7.30%		11.74%		3.48%	
Pr(Wait = 0)	5.90%		15.55%		12.70%	

Conclusions + Remaining Questions

- There is no best algorithm!
- Designing effective algorithms is very difficult

- Can we do better?
  - Context Scheduling
  - Ant Colony Optimization
  - Forecasting

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