Intersection auctions and reservation-based control in dynamic traffic assignment

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Motivation
- Reservation-based intersection control increases capacity and reduces delay for single intersections (Fajardo et al., 2011)
- Auction priority may further reduce delay
- How are intersection auctions affected by user equilibrium (UE) behavior on city networks?

Contributions
- Intersection model of reservation-based intersection control compatible with general simulation-based dynamic traffic assignment (SBDTA)
- Computationally tractable for city networks
- Comparison of auctions with first-come-first-serve (FCFS)

Background
1. Vehicles communicate with the intersection manager and request a space-time reservation through the intersection
2. Intersection manager accepts or rejects reservation based on the occupancy of other reservations

Properties
- Greater use of intersection—including simultaneous use by conflicting turning movements
- Flexible priority strategies—FCFS, auctions, etc.
- Requires microsimulation of intersections. Previous work on networks of intersections was limited in size or used a single tile, and did not consider UE behavior

Assumptions
- Flow is discretized to assign vehicle priority
- All vehicles have the same physical characteristics
- In the absence of other demand, flow is restricted only by sending and receiving flows (to be independent of geometry)

Conclusions
- Intersection delay increased but congestion decreased, leading to a net benefit
- Each vehicle is assigned a random number that is their priority
- Little to no benefit for high VOTs vehicles from auctions

Future work
- Comparison of traffic signals and reservation-based control under UE behavior
- DTA model of shared roads (human drivers and autonomous vehicles)
- Optimal priority strategies for reservation-based control
- Possibility of Braess paradox-like phenomena due to higher capacity and/or reservation priority

Computational results—first come first serve priority
- On Sioux Falls network

Analysis of auctions
- On Sioux Falls network
- Histogram of travel times in auctions
- VOTs based on income distribution

Queue length (FCFS)

Queue length (auctions)

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Treatment of Demand Categories
- Capacity
- Flow
- VOT
- Queue length
- Time

Objectives
- Admit arbitrary priority strategies
- Retain simultaneous use by vehicles with conflicting paths
- Independent of specific intersection characteristics
- Satisfy invariance principle (Tampère et al., 2011)

Initialization
1. Set \( T = 0 \)
2. For all incoming links \( i \)
3. Sort \( S(T) \) by arrival time at \( t \)
4. Remove first \( v \) from \( S(T) \) and add them to \( V \)

Vehicle propagation
5. Sort \( F \) by \( f(v) \)
6. For all \( v \in V \)
7. Let \( (i,j) \) be the origin/destination link of \( v \)
8. If \( K(i) + \frac{y_{i}(j)}{\epsilon} \leq 1 \) and \( Q_{i}(j) + \frac{y_{i}(j)}{\epsilon} 
9. \quad y_{i}(j) = y_{i}(j) + 1 
10. For all \( c \cdot i, \quad x_{c}(i) = y_{i}(j) + \frac{Q_{i}(j)}{\epsilon} 
11. Remove first vehicle in \( S(T) \) and add it to \( V \)
12. Go to 5

Intersection algorithm

Sending flows
Receiving flows
Vehicle priority

Intersection algorithm

Vehicle priority

Comparison of traffic signals and reservation-based control under UE behavior

Vehicle priority

Intersection algorithm

Sending flows
Receiving flows
Vehicle priority

Comparison of intersection control under user equilibrium behavior

Downtown Austin, Texas

Convergence of DTA with reservation-based intersections

- On Sioux Falls network
- Comparison of First-come-first-serve (FCFS) and Reservation-based auction (RBA) for high VOT
- Little to no benefit for high VOT vehicles from auctions
- Intersection delay increased but congestion decreased, leading to a net benefit
- Comparison of queue lengths indicates that FCFS creates large queues on high demand links

Tiles \( \rightarrow \) conflict regions
- For computational tractability, tiles collision checks are simplified to conflict regions—larger intersection areas with limited capacity
- Turning movements pass through 1 or more conflict regions
- Determined by radial division of intersection—automated method

Comparative results—first come first serve priority

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