Multi-Modal Traffic Control for Sustainable Urban Living

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Project Site

Challenges

- Traffic congestion significantly degrades the quality of life in urban environments, resulting in lost time, wasted fuel resources, and reduced air quality for urban residents
- Multi-modal traffic flows: in addition to vehicles, pedestrians, bicyclists, and transit riders move in urban environments
- Sustainable urban living requires that all traffic modes be appropriately balanced, and walking is critical to the overall effectiveness of urban mobility in supporting other modes

Our Work

- Investigate multi-model urban traffic control in the context of SURTRAC, a **live, urban adaptive signal system testbed**
- Design extensions that enable real-time adaptive control of multi-modal traffic flows, especially vehicles and pedestrians
- Evaluate the effectiveness and impacts of these extensions using both simulations and analysis based on field data

SURTRAC (Scalable URban TRAffic Control) System

Schedule-Driven Intersection Control

– Treat each intersection as a single machine scheduling problem
– Use aggregate representation of traffic flows to identify input ***jobs***
– Use schedule to decide whether to extend or switch phase

Neighbor Coordination Mechanisms

– Communicate schedules to neighbors to extend visibility
– Layer mechanisms for coping with mis-coordinated situations

- Xie, X-F., S. Smith, G. Barlow, "*Smart and Scalable Urban Signal Networks: Methods and Systems for Adaptive Traffic Signal Control*", Patent Pending, Appl. No. 14/308,238, 2014.
- Xie, X-F., S. Smith, T.-W. Chen. Real-time traffic control for sustainable urban living. In *IEEE International Conference on Intelligent Transportation Systems*, 1863-1868, 2014.
- Xie, X-F., S. Smith, G. Barlow, "Schedule-Driven Coordination for Real-Time Traffic Network Control", *International Conference on Automated Planning and Scheduling*, 323-331, 2012.
- Xie, X-F., S. Smith, L. Lu, G. Barlow, "Schedule-Driven Intersection Control", *Transportation Research Part C: Emerging Technologies*, 24:168-189, 2012.

Accommodating Multi-Model Traffic

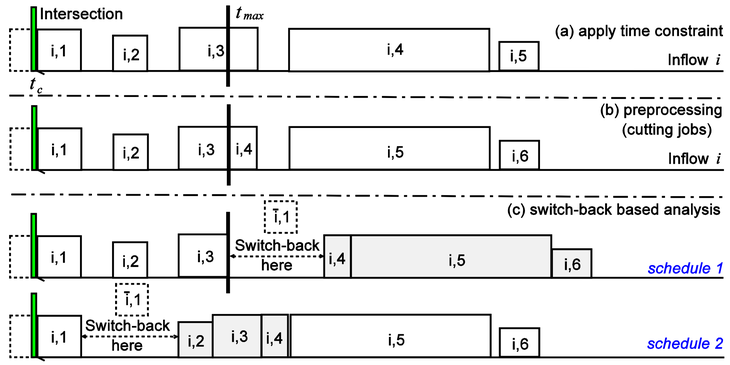
Multi-Model Formulation

$$normalized\ cost\ \text{of job}\ j = \sum_{m \in M} n_m^j\, V_m O_m L_m$$

m: a traffic mode in set M={*Ped*, *Veh*, …}; n: the number of entities
V: relative time value; O: average occupancy; L: coordination flag

Maximal Wait Time Constraint

- Set a maximum wait time limit (at t_{max}) as pedestrian is detected
- Augment the scheduling process with *phase switching analysis*

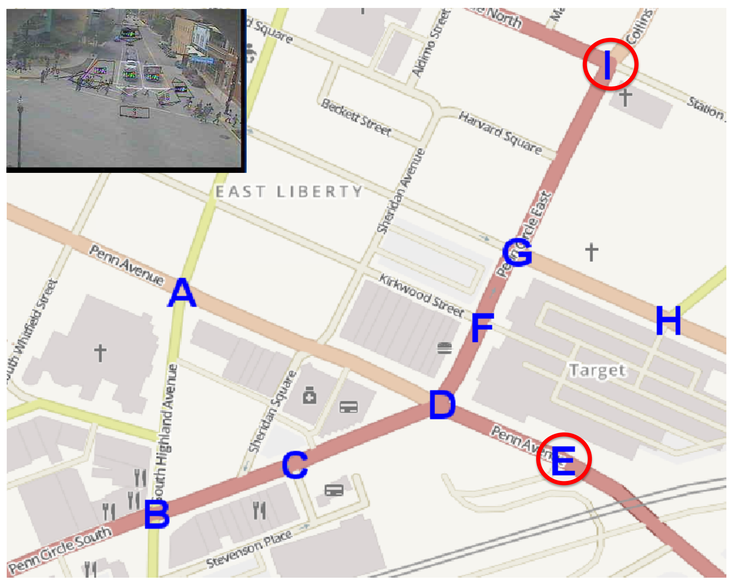


Vehicle-Pedestrian Mixed Coordination Protocol

- Coordinate major vehicle flow through a "subordinate" neighbor
- Response to pedestrians waiting at side streets of the neighbor

Integration: *MTC*(*n* of *Ped*, wait time limit) or Coordination Protocol

The East Liberty Adaptive Signal Testbed



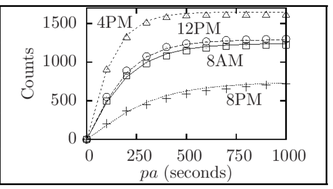
Simulation Results: Wait Time under Different Control Strategies

Intersection **E**	$\lambda = 1/(2.5$ seconds)			$\lambda = 1/(10$ seconds)			$\lambda = 1/(40$ seconds)		
	pw	*vw*	*ww*	*pw*	*vw*	*ww*	*pw*	*vw*	*ww*
Fixed-Time	46.18	36.20	38.85	47.85	36.20	37.12	43.69	36.20	36.36
Vehicle-Actuated	52.83	49.81	50.61	53.02	49.81	50.06	40.63	38.36	38.40
$MTC(0, max)$	57.52	22.04	31.46	59.23	21.58	24.57	56.94	21.66	22.38
$MTC(0, 60s)$	21.74	22.74	22.47	24.16	22.20	22.36	28.31	21.83	21.97
$MTC(3, 60s)$	17.14	22.76	21.27	16.26	22.73	22.22	14.80	22.44	22.28
$MTC(actual, 60s)$	12.50	23.49	20.57	16.07	22.76	22.23	21.36	22.33	22.31

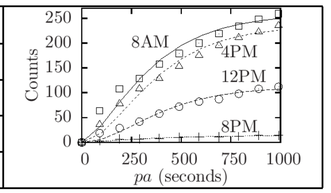
Intersection **I**	$\lambda = 1/(2.5$ seconds)			$\lambda = 1/(10$ seconds)			$\lambda = 1/(40$ seconds)		
	pw	*vw*	*ww*	*pw*	*vw*	*ww*	*pw*	*vw*	*ww*
Fixed-Time	34.75	36.20	35.83	36.92	36.20	36.26	32.05	36.20	36.11
Vehicle-Actuated	12.00	37.25	30.66	12.66	37.29	35.30	13.01	36.58	36.06
$MTC(0, max)$	55.55	20.63	29.75	57.24	20.59	23.56	53.84	20.62	21.35
$MTC(0, 60s)$	23.76	20.88	21.63	27.22	20.88	21.39	29.37	20.94	21.13
$MTC(3, 60s)$	13.40	20.97	19.00	14.84	20.72	20.24	17.79	20.65	20.58
$MTC(actual, 60s)$	9.07	21.60	18.32	14.91	21.32	20.80	26.27	20.77	20.89

Field Pedestrian Arrival Statistics: Gamma(θ, k) Distribution

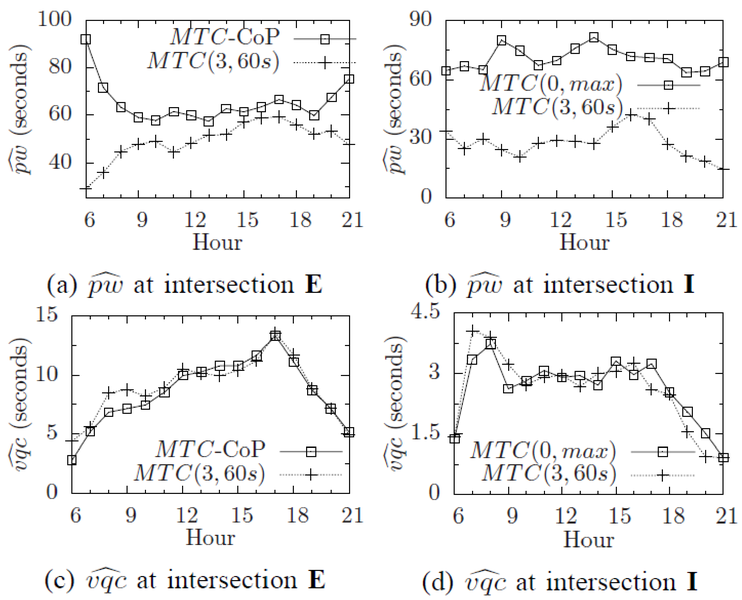
E	θ	k	sq. err
8AM	159.3	1.17	1.5E-4
12PM	135.5	1.30	9.2E-5
4PM	96.7	1.24	1.2E-4
8PM	216.7	1.29	5.8E-4



I	θ	k	sq. err
8AM	218.1	1.67	3.3E-3
12PM	176.2	2.42	2.4E-3
4PM	188.2	2.12	2.8E-3
8PM	232.1	1.54	6.1E-3



Field Results: pedestrian wait time & vehicle queue clearance time



(a) $\widehat{pw}$ at intersection **E**
(b) $\widehat{pw}$ at intersection **I**
(c) $\widehat{vqc}$ at intersection **E**
(d) $\widehat{vqc}$ at intersection **I**