Real-Time route guidance in stochastic networks

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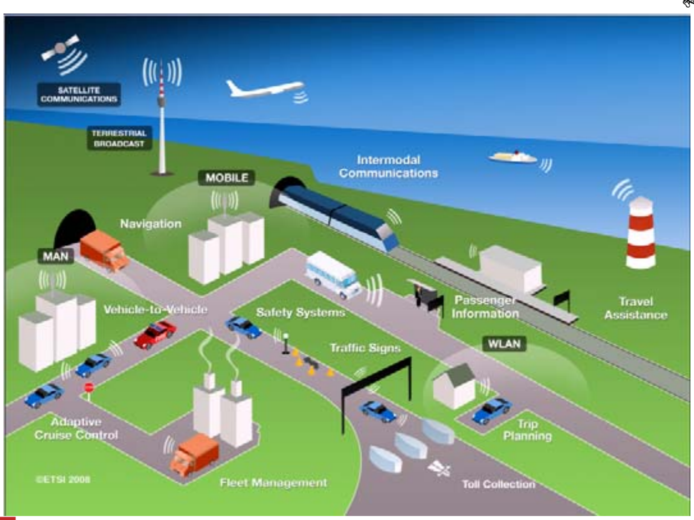
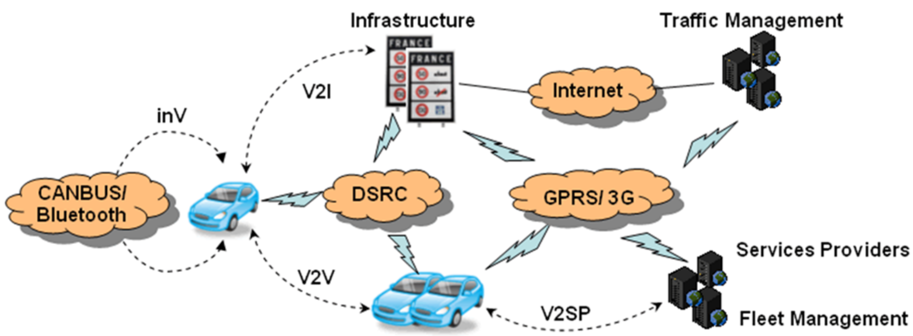
Intelligent Transport Systems (ITS)



Source: www.etsi.org/WebSite/document/Technologies/ETSI-ITS.jpg

ITS Architecture



DSRC: Dedicated short range communications

ITS Apps

Commuters
- Route guidance
- Travel information

Traffic managers
- Incident management
- Traffic control and plan

Freight Operators
- Routing
- Scheduling

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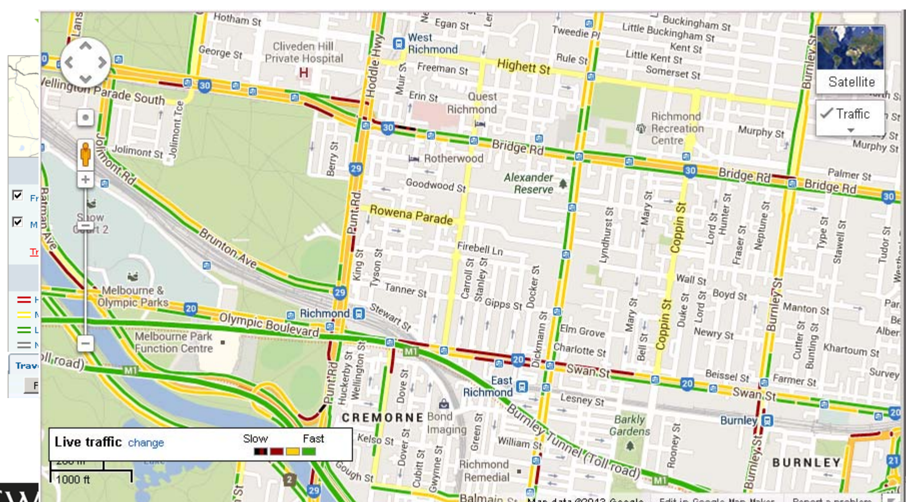
Example: Almost real time info



Outline

- Shortest path: Real-time application
- Framework for shortest path in stochastic time-dependent networks
- Numerical results
- Conclusion

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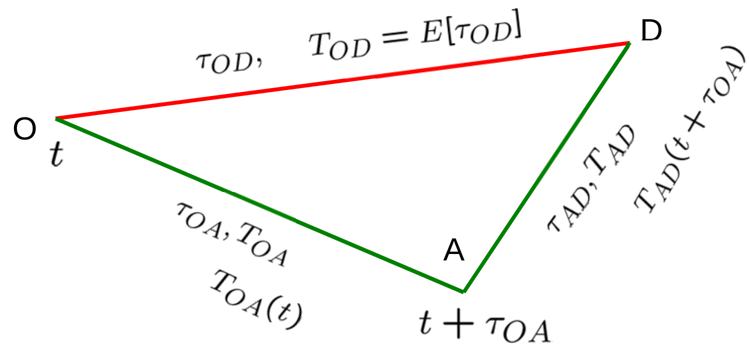
Shortest Path: Real time application



Shortest path (least expected travel time): $T_{OA} + T_{AD} < T_{OD}$

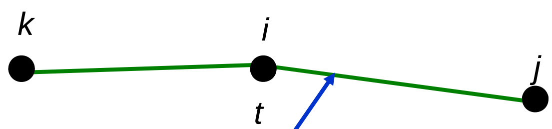
Congestion level (network state)

Time-dependent network state: $T_{OA}(t)$ $T_{AD}(t + \tau_{OA})$

Link is congested if DS>0.95 and Vk/Vo >2.4

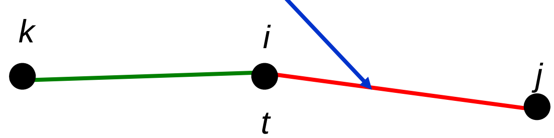
Vo: # cars passed the detector (Vo), DS: degree of saturation value,
Vk: estimated traffic count having the same DS under free flow conditions

Spatial dependency



Real Time LET

$$u_{ki}(t) = \min_{j \neq i}[\alpha_{kij}(U_{ij}(t) + u_{ij}(t + U_{ij}(t))) + (1 - \alpha_{kij})(C_{ij}(t) + c_{ij}(t + C_{ij}(t)))]$$



LET: Least Expected Travel time

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The Framework

Bellman's optimality equation:

$$u^s_{ki}(t) = \min_{j \neq i}[\sum_{r=1}^{M} p^{sr}_{kij}(U^r_{ij}(t) + u^r_{ij}(t + U^r_{ij}(t)))]$$

$$u^s_{kD}(t) = 0$$

- $u^s_{ki}(t)$: LET between node i and the destination node D at time t if the incoming link (k, i) is in state s

time dependent

- $U^r_{ij}(t)$: expected travel time between nodes i, j at time $t \in [\tau_h, \tau_{h+1})$ under link state r

time independent

- p^{sr}_{kij}: the prob. that link (i, j) is in state r if the incoming link (k, i) is in state s

Framework Cont.

$$u^s_{ki}(t) = \min_{j \neq i}[\sum_{r=1}^{M} p^{sr}_{kij}(U^r_{ij}(t) + u^r_{ij}(t + U^r_{ij}(t)))]$$

$$p^{sr}_{kij}(t) = \int_{t_{h(i,j)^{r-1}}}^{t_{h(i,j)^r}} P_{ij}(t, \xi) d_\xi \approx p^{sr}_{kij} \qquad \sum_{r=1}^{M} p^{sr}_{kij} = 1$$

$P_{ij}(t, \xi) d_\xi$ is the prob. traveling from node i to j requires time between ξ and $\xi + d_\xi$, $t \in [\tau_h, \tau_{h+1})$ given (k, i) is in state s

$t_{h(i,j)^r}$ is the travel time threshold for link (i, j) to be in state r

Temporal Dependency

$$U_{ij}^{r}(t) = \tau_{h+\eta} - t + \frac{l_{ij} - l_{ij}^{\eta-1}}{v_{h+\eta(i,j)}^{r}}$$

l_{ij} length of link (i,j)

$\eta \geq 1$ number of time zones a car crosses while traveling link (i,j)

$$l_{ij}^{\eta-1} = l_{ij}^{\eta-2} + v_{h+\eta-1(i,j)}^{r}(\tau_{h+\eta} - \tau_{h+\eta-1})$$
$$l_{ij}^{-1} = 0$$

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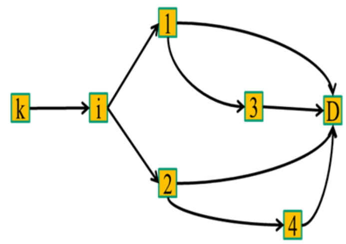
Simple Network



Time interval	Link	*w1* (0.5)	*w2* (0.3)	*w3* (0.2)
0	(i, 1)	4	4	5
	(i, 2)	5	5	6
	(1, D)	5	5	4
	(1, 3)	4	4	3
	(3, D)	3	3	5
	(2, D)	4	4	5
	(2, 4)	4	4	5
	(4, D)	4	4	5
1	(i, 1)	15	15	16
	(i, 2)	14	16	14
	(1, D)	15	15	17
	(1, 3)	16	15	15
	(3, D)	15	16	14
	(2, D)	14	16	16
	(2, 4)	15	16	16
	(4, D)	14	16	15

Results 1

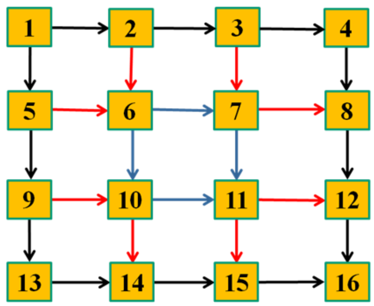
	Route	Actual travel time (*w2*)	Percentage difference
Method 1	Node i-1-D	19	0
Method 2	Node i-1-D	19	0
Method 3	Node i-2-D	21	0.11

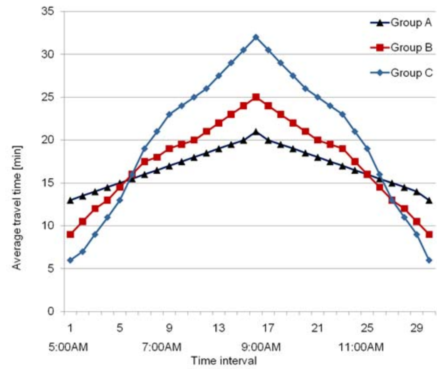
Method 1 utilizes both temporal and spatial dependences (our framework)
Method 2 uses full travel time distribution [1]
Method 3 utilizes spatial travel time correlation only and is time-independent [2]

[1] Gao, S. and I. Chabini, "Optimal routing policy problems in stochastic time-dependent networks," Transportation Research Part B: Methodological, Vol. 40, No. 2, 2006, pp. 93–122.

[2] Fan, Y. Y., R. E. Kalaba, and J. E., "Moore, Shortest paths in stochastic networks with correlated link costs," Computers and Mathematics with Applications, Vol. 49, No. 9-10, 2005, pp.1549–1564.

Grid Network





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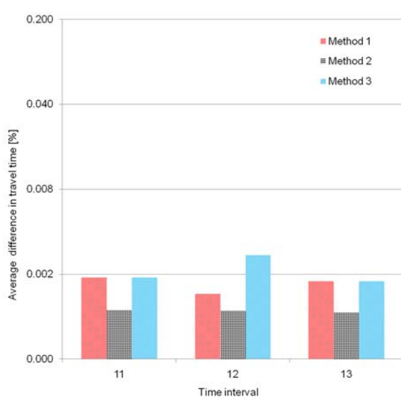
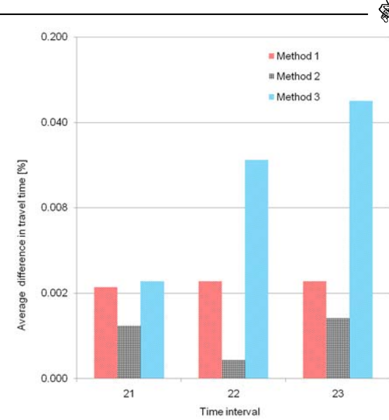
Results 2



Average difference in travel time using different methods (middle 10 time intervals)



Average difference in travel time using different methods (last 10 time intervals)

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Conclusion

- The proposed framework can achieve similar accuracy with a much smaller set of parameters compared to the case when the full joint distribution of network travel times is required.
- Both temporal and spatial correlations are handled while the framework remains simple.
- Improvements in optimal route choice decisions are shown via examples.

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THANK YOU