Efficient coupled Energy-Transport Management for Smart Cities

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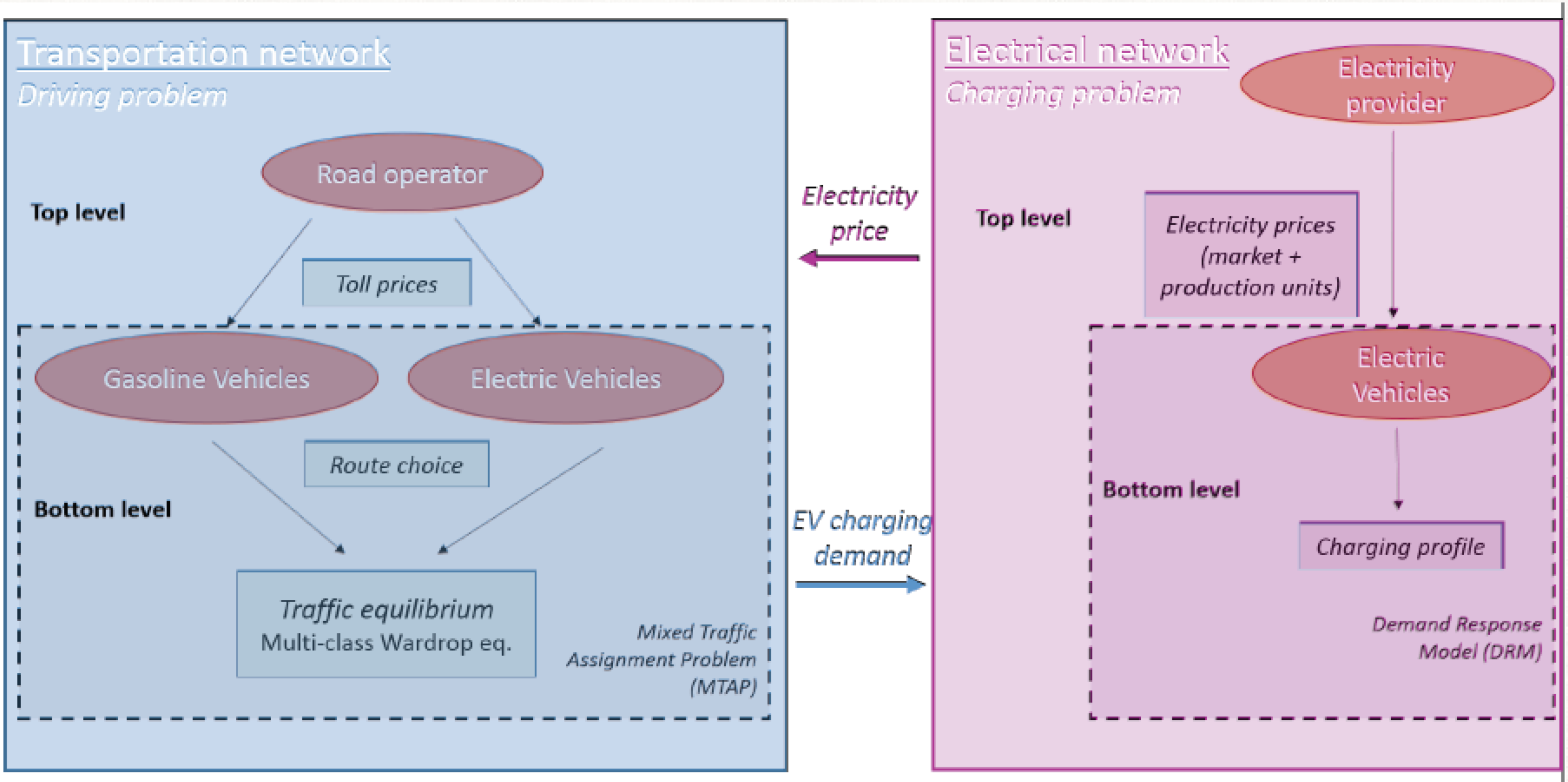
Context

- Integrated network management and energy planning
- Coupled two main actors in Smart cities: Transportation Planner and Energy Department
- **Goal**: design a model which integrates the couple decision processes of these actors, taking into account consumers (particularly EV) behaviors.

Figure: Urban transportation in London (www.c40.org)

Global problem



Mixed Traffic Assignment Problem

- Two types of cars : gasoline and electric.
- For each O-D pair k two demands: σ_g^k and σ_e^k.

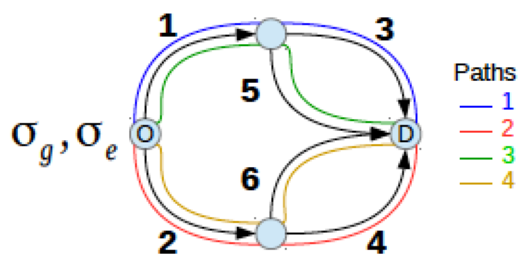


Figure: Network 1

$x_{a,e}$ EV flow on arc a

$x_{a,g}$ gasoline flow on arc a

$$x_a = x_{a,e} + x_{a,g}$$

X_e total EV flow

X_g total gasoline flow

- Travel cost function = travel time + operating cost.
- Operating cost depends on the car's type and on the link.
- Typical of operating cost: energy cost, tolls .

The generalized traffic cost function

$$d_a(x_a) = d_a^0.(1 + \alpha.(\frac{x_a}{C_a})^\beta), \forall a \in \mathcal{A}$$

$$c_{a,i}(x,t) = t_{a,i} + \tau d_a(x_a)$$

€ (€/h)*h

Resolution method

- Equilibrium can be found using CCM like Frank-Wolfe method
- This method is very slow (>250 000 iterations).
- Based on the observation that many flows are null on several arcs at equilibrium, we proposed an heuristic

➔ **170** iterations

From Wardrop equilibrium to EV charging need

Output of the bilevel transport problem gives

– Time-based charging need as:

$$L_e = \sum_a \frac{x_{a,e}}{X_e} d_a(x_a) m_e$$

(kWh) (kWh/h)

OR

– Distance-based charging need as: length of arc a

$$L_e = \sum_a \frac{x_{a,e}}{X_e} l_a \tilde{m}_e$$

(kWh) (kWh/km)

EV electricity consumption scheduling problem

Following [Mohsenian-Rad 2010]

$$\min_{(l_{e1},\ldots,l_{eT})} \sum_{t=1}^{T} f_t(l_{e,t})$$

[Impact / cost for electricity system expressed with fare / flexibility signal f_t]

s.t.

(i) $\sum_{t=1}^{T} l_{e,t} = L_e$

[EV energy need (next trip)]

(ii) $\forall\, t, l_e^{min} \le l_{e,t} \le l_e^{max}$

[Charging power constraints]

(iii) Other charging constraints

[EV battery aging, …]

[Mohsenian-Rad 2010] A.-H. Mohsenian-Rad, V. W. S. Wong, J. Jatskevich, R. Schober, and A. Leon-Garcia. "Autonomous Demand Side Management Based on Game-Theoretic Energy Consumption Scheduling for the Future Smart Grid". *IEEE Trans. On Smart Grid*, vol.1, no. 3, pp 320-331, 2010.

From EV charging to EV driving… again !

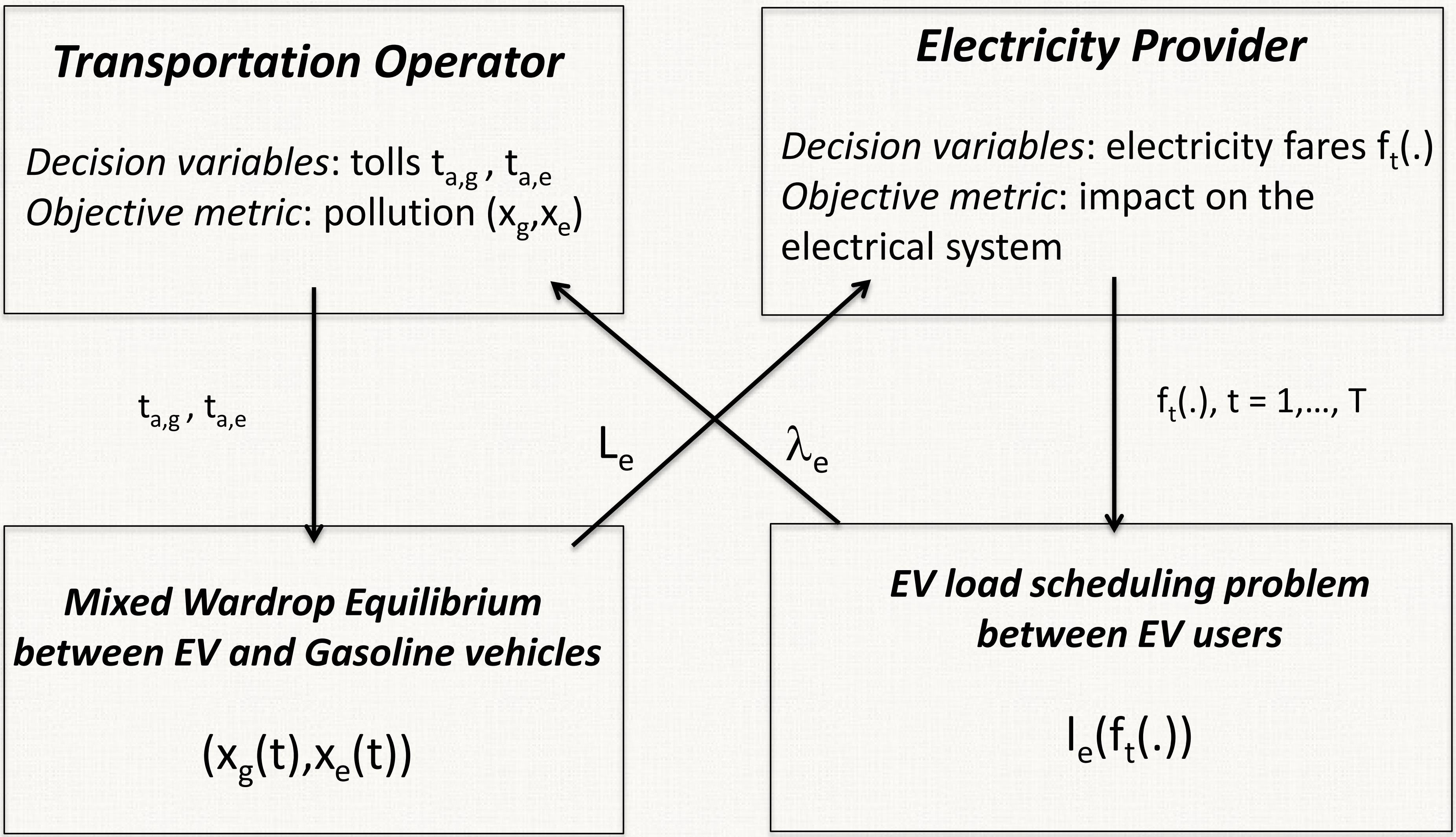
Price of kWh when driving…

$$\lambda_e = \frac{\sum_{t=1}^{T} f_t\left(l_{e,t}\right)}{X_e\, L_e}$$

… in your driving generalized cost

$$c_{a,e}(x,t) = t_{a,e} + \tau d_a(x_a) + \lambda_e m_e d_a(x_a)$$

Coupling factors and bilevel problems



On the (research) road…

Thank you