Path selection methods and network performance: a sensitivity analysis

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Dynamic traffic assignment methods play a crucial role when estimating a network performance by simulation. Such methods can be decomposed into two parts: definition of the possible routes and determination of the path flow distribution between each OD (Origin/Destination) pair. While the second component has been extensively studied in the literature in connection with network equilibriums (UE, BRUE, SUE, SO…) (Abdulhafedh, 2017; Szeto and Lo, 2005; Peeta and Ziliaskopoulos, 2001), the selection method that reduces the huge number of possible paths in meshed network to a candidate set of paths has received less attention. In particular, to the authors' best knowledge, no extensive sensitivity analysis (SA) has been conducted to assess how such selection methods influence the network performance predicted by simulation.

In this paper, we are considering a toy network that mimics a Manhattan town with a ring road, see fig.1. This network corresponds to 14x14 2-way regular roads with speed limit 50km/h and intersections controlled by traffic lights. These roads delimit blocks that are grouped 3 by 3 to form 5x5 zones. The 2-way ring road with speed limit 90km/h has 12 interchanges with peripheral zones.

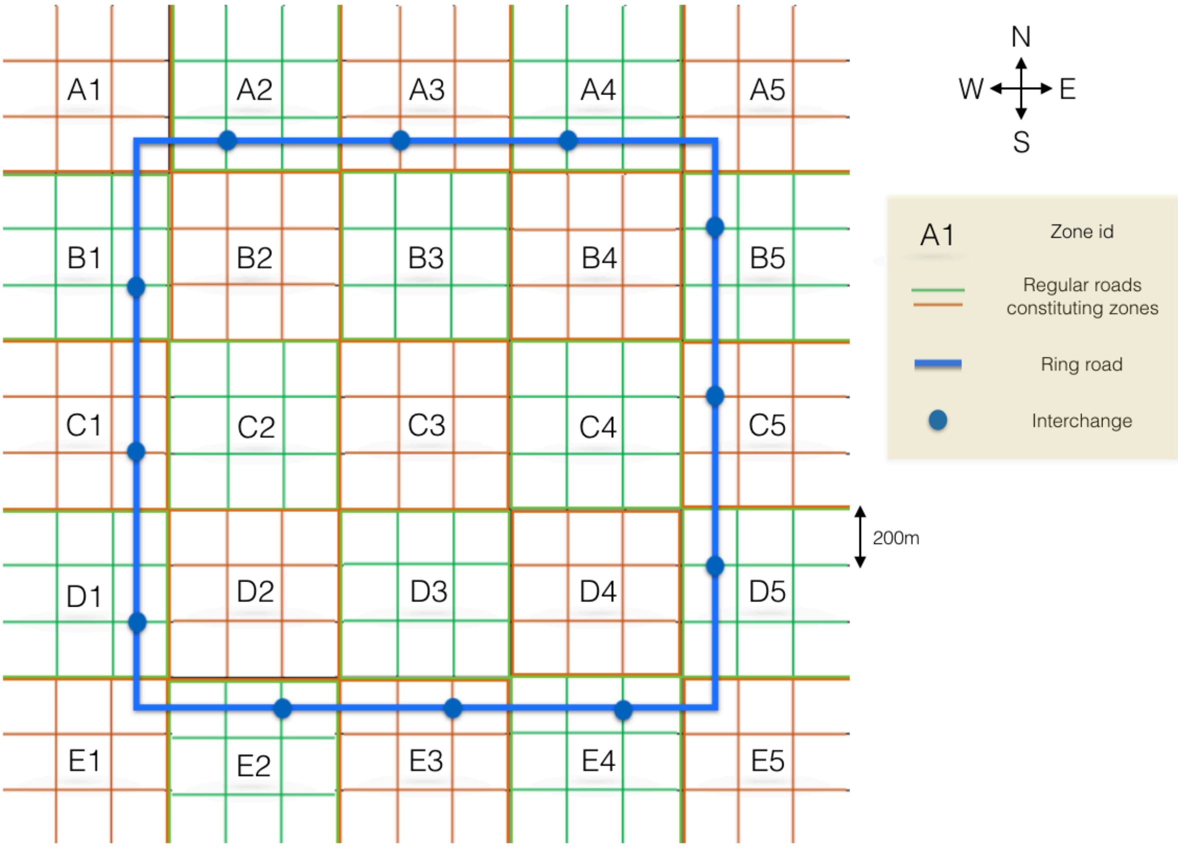

Figure 1: Studied network (Manhattan-like with ring road)

As opposed to classical OD pair descriptions based on punctual network entries and exits, the OD matrix size is reduced by considering zone to zone demand patterns, see fig. 1. Several demand distribution patterns are considered to investigate the influence of path selection methods under various network loadings: uniform distribution between OD zones, exocentric (from periphery to center), endocentric (from center to periphery). Distribution patterns are combined with different values of the total demand to reproduce both free-flow and saturated traffic conditions.

Traffic dynamics is calculated by the Symuvia simulation tool developed by the LICIT laboratory. This dynamic and microscopic platform is founded on Newell's car-following rule (Newell, 2002), which is the Lagrangian resolution of the LWR model (Leclercq et al., 2007) and includes most features (multiclass, lane-changing, intersections…) required to simulate urban traffic.

To overcome the high dimensionality of the problem, routes selection is going to be defined between zone borders. We introduce the notion of junction points as the list of all network entry or exit points for each zone. The set of all possible paths from an origin to a destination zone gathers all possible paths between the related junction points. Upon simulation, vehicles are assigned a random position departure (resp. arrival) point within their origin (resp. destination) zone and are then automatically connected to the junction points related to their assigned path by the local shortest paths. For each OD, the selection method aims to narrow the set containing all possible paths to a candidate one, on which the demand OD flow is distributed. Our overarching objective is to analyze the network sensibility to the selection method for various OD demand patterns.

The selection process is based on 2 criteria: paths overlapping and paths length, quantified by free-flow travel time to balance the ring-road over regular roads. Three strategies are considered to select in the end n=3 to 10 candidate paths per OD pair. They consist in applying the k-shortest paths algorithm with an eventual constraint of overlapping score at local (i.e. OD) or global (i.e. network) level. Note that for a given OD pair, not all junction points are necessarily connected after the selection process.

In practice, the first strategy simply consists in selecting the n-shortest paths without considering path overlapping. The second and third strategies start with a bigger set of candidates (around 40-50 paths) and will then reduce the number to n in order to obtain different levels of overlapping. The common factor CF_k of path k defined by Cascetta et al. (1996), see eq. (1), is used for strategy 2 as a local overlapping score to select candidates for each OD pairs:

$$CF_k = \beta \; ln \sum_{l \in I} \left(\frac{L_{lk}}{L_l^{1/2} L_k^{1/2}} \right)^{\gamma} \qquad (1)$$

where I is the initial set of paths, L_{lk} is the length of sections shared between paths l and k, while L_l and L_k are the length of paths l and k. In this work, we assume $\beta=\gamma=1$. The lower the targeted paths overlapping between 2 zones, the lower the CF_k score is selected. Interactions between paths sets of distinct ODs are not taken into account into this second strategy. Thus, the third strategy aims to focus the path selection on the degree of overlapping at network level. Now, paths between OD pairs are selected all at once in function of the resulting global overlapping score:

$$\sum_{link\ i} \left(\frac{p_i - p^*}{\sum_{k \in S} L_k} \right)^2, with\ \ p^* = \frac{\sum_{k \in S} L_k}{\sum_{link\ i} L_i} \quad (2)$$

where k is a path of S, the set of selected paths and p_i is the number of paths passing by link i. This score reflects the gap between the distribution of the selected paths over the network and an ideal even distribution.

Once paths are selected, we apply dynamic path flow distribution from different classical traffic assignment models: deterministic (Wardrop and Bounded Rationality) as well as stochastic (Logit and Probit). Note that convergence to equilibrium is achieved dynamically by applying the Method of Successive Averages (Sheffi, 1985). The model choice is considered as one of the entry variables of the SA.

Simulated network performances are assessed by the following indicators: Total Travel time, Total Travel Distance, mean network speed and standard deviation of link speeds to qualify network heterogeneity.

With regards to the SA method, we will investigate a new screening method (Roustant et al., 2016) estimating Sobol indices with Poincaré inequalities on intervals, designed to balance simulation computational cost and quantitative interpretability.
The simulation study and analysis are currently in progress. Results will be presented during the conference.

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