A Hybrid Cooperative Routing Control Strategy for Network-wide Traffic Congestion Avoidance

Cecile Daniel, Andres Ladino, Angelo Furno, Nour-Eddin El Faouzi, Salima Hassas

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Cecile Daniel[1], Andres Ladino[1], Angelo Furno[1], Nour-Eddin El Faouzi[1], Salima Hassas[2]

[1] Univ. Gustave Eiffel, Univ. Lyon, ENTPE, LICIT, F-69518, Lyon, France.
{cecile.daniel,andres.ladino, angelo.furno, nour-eddin.elfaouzi}@univ-eiffel.fr
[2] Univ. Claude Bernard Lyon 1, F-69100 Villeurbanne, France
salima.hassas@univ-lyon1.fr

1 Introduction

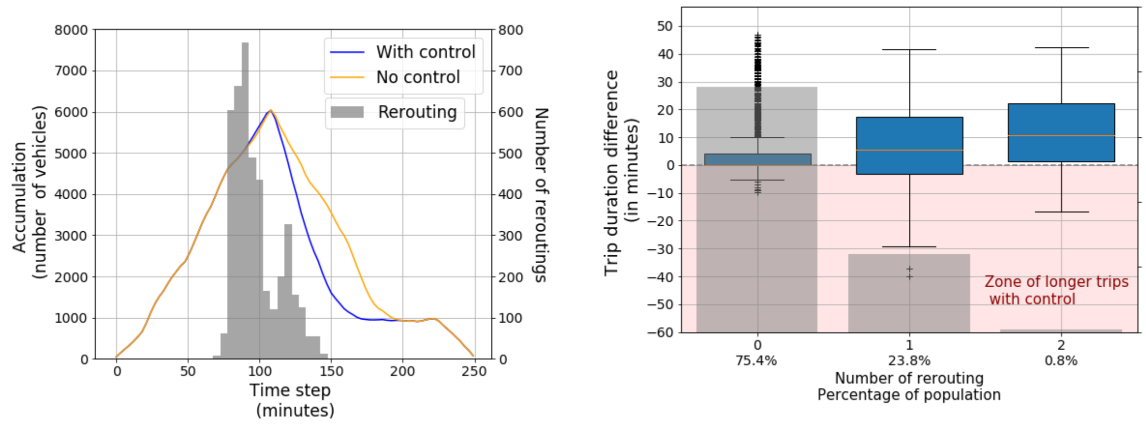
The growing number of connectivity services in transportation along with a deluge of data collected from different sources, make new control approaches possible to reduce traffic congestion inside urban areas by leveraging V2I (vehicle to infrastructure) communication. Inspired by [2], our approach aims at reducing congestion via a (real-time) dynamic rerouting of a fraction of vehicles. The infrastructure broadcasts aggregated speed information for predefined zones, then a cooperative strategy allows the qualification of each zone in terms of traffic performance. This information is then asynchronously used by each of the vehicle agents to determine new paths and achieve their destination. For the sake of scalability, our solution is distributed, using multi-agent interaction and computation based on a framework that is similar to the one described in [2]. Note that a slightly different strategy targeting optimal routing enforcement has been developed in [1]. The validation of the whole framework, as well as the evaluation of the effectiveness of the proposed approach, are performed using a traffic micro-simulation tool.

2 Methodology and framework

Given a road network, represented as a graph with a set of nodes (intersections) and edges (roads), we partition the network into areas, connected sub-networks defining a *hyper graph* of the initial one. Each vehicle starts at a source node and ends at a destination, with a given path. Travel time shortest paths preset the *user equilibrium* scenario as baseline. Our framework defines a hierarchical interaction: on a first level, each zone disseminates its current traffic state along with its residual capacity (ability to accommodate new vehicles). On a second level, a fraction of vehicles update their routes based on zones' states and residual capacities.

Zones provide features such as *total flexibility*, defined as the number of vehicles to be allocated within an area before observing degradation of the network throughput (from the Macroscopic Fundamental Diagram theory), and the *flexibility* as the number of vehicles an area is willing to accept (or evacuate). When the total flexibility is lower than zero, the area is in a congested state. The higher the total flexibility is, the more vehicles can drive through the zone. After communicating their current state and computing the total remaining flexibility of the network, zones disseminate the number of vehicles to receive, knowing the number of vehicles already inside them. The final number of vehicles to allocate is computed from the local and neighbors' flexibility, along with the total flexibility of the network, making this approach cooperative. At each time step, areas compute an error e_i (i denoting the area index), as the difference between the number of vehicles that were supposed to drive in them and the actual number.

This error provides a measurement of reliability of the area. Area updates are mapped to the corresponding roads by increasing the link travel time for low flexibility values hence inducing area avoidance in case of congestion. Vehicles update schedules for rerouting based on e_{i+1}



(a) Accumulation comparison

(b) Boxplots of trip duration difference depending on the number of rerouting per vehicles

FIG. 1: Results on grid network of 5X5 areas

($i + 1$ being the next area in the path). For high values of the error, the vehicle will compute a new path, based on hyper graph information as a predictive mechanism to congestion. In case the area is congested, the macro route would likely not include the area (and other congested areas). A vehicle will thus quickly change its path to reach another area with better traffic conditions and avoid congestion.

3 Results & Concluding Remarks

We evaluate our strategy on a Manhattan grid network, partitioned into 25 zones (5X5). The implemented stategy reduces the accumulated total travel time up to 13% (see fig. 1a). It can be observed the proactive vehicle scheduling of the proposed approach before step 100, when vehicles start to be rerouted by accelerating the reduction of the peak of accumulation with respect to the baseline condition. At an individual level (see fig. 1b), the actual benefit can be observed on the reduced travel time within the network. In total 86% of the vehicles have shorter or equal trip duration. For vehicles with a longer trip, the mean loss is 4 minutes and the median 3 minutes (the mean trip duration without control is around 40 minutes). Less than 25% of vehicles have been rerouted at least once. The total distance difference is +0.09%, which is quite low compared to the gain of travel time. Dividing the surplus of distance of the control strategy by the number of rerouting, the mean distance of one rerouting is equivalent to 55 meters.

One of the benefits of our solution is that rerouted vehicles actually reduce their travel time inside the network, giving them a reward for the effort of rerouting. Thus, our strategy does not penalize drivers accepting to collaborate with the areas. In conclusion, our solution performs well for large networks and the micro-macro scale approach allows efficient global strategy with a low impact on the micro scale level (vehicles). This approach is robust and dynamic, allowing real-time control on a large scale.

References

[1] Ludovic Leclercq, Andres Ladino, and Cecile Becarie. "Enforcing optimal routing through dynamic avoidance maps." In: *Transportation Research Part B: Methodological* 149 (2021), pp. 118–137.

[2] Victor Lequay et al. "Ajustement diffus et adaptatif de la consommation électrique résidentielle par un système multi-agent auto-adaptatif". In: *Revue des Sciences et Technologies de l'Information-Série RIA: Revue d'Intelligence Artificielle* 31.4/2017 (2017), pp. 427–447.