COMBINING DRIVERS’ REROUTING RESPONSE AND MARGINAL COMPUTATION FOR VARIABILITY STUDIES AND TRAFFIC MANAGEMENT APPLICATIONS

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ABSTRACT
In this paper, two relatively new developments, marginal Dynamic network loading (DNL) and hybrid route choice modeling are combined to allow realistic and computationally efficient modeling of drivers’ response to unexpected traffic conditions. This is valuable in numerous applications, foremost studies that aim at quantifying (travel time) variability arising from stochastic travelers’ demand and network supply and dynamic traffic management applications that might invoke considerable rerouting such as incident management, ramp metering and evacuation planning.

Keywords: Marginal Dynamic Network Loading, En-route rerouting, Hybrid route choice model, Variability, Dynamic traffic management

INTRODUCTION
Variability (of travel times) greatly influences the choice behavior of travelers regarding modal, departure time and route choice (see De Palma & Picard [1], Lam & Small [2], Liu et al. [3], Noland et al. [4], Bates et al. [5]). Accounting for travel time variability in Dynamic Traffic Assignment (DTA) models poses several challenges. An important challenge is the quantification of travel time variability - arising from variations to the input (e.g. travel demand, weather and incidents) - in the Dynamic Network Loading (DNL) component of DTA models. The Monte-Carlo simulation needed to quantify the variability, combined with relatively high computation times of dynamic models, is difficult using traditional DNL models. Particularly real-time applications may be infeasible. Therefore, Corthout et al. [6]-[8] introduced marginal DNL models. With marginal models, Monte-Carlo simulation can be performed much more efficiently by computing only the change to a base simulation’s output for each input variation.

Furthermore, the response of travelers (modal choice, departure time choice and route choice) to the observed variability should be accounted for. An elaborate discussion on the challenges regarding how to realistically model the choice behavior of travelers is presented in Viti & Tampère [9]. Typically, the drivers’ choices (whether or not the influence of variability is accounted for) are only determined a priori, i.e. as a fixed input to the DNL that propagates the traffic onto the network (e.g. in Corthout et al. [7]). Especially route choice has a much more dynamic character. Drivers do not only determine their route prior to departure, but may deviate from their initial route if unexpected traffic conditions are met. This strategy is aided by various information systems available to drivers en-route. In turn, this en-route (re)routing behavior will influence the traffic conditions. This means that – at least for some applications – this behavior should be incorporated into the DNL model. By doing so, the mutual dependency between traffic conditions and drivers’ rerouting can be modeled. This could enhance real-time applications that might invoke considerable rerouting such as incident management by allowing to optimize rerouting guidance around an incident (or road works) so that the impact on the system’s performance is minimized. Similarly, other dynamic traffic management applications such as ramp metering could be optimized. For evacuation planning, Pel et al. [10]-[11] propose to combine en-route rerouting with pre-trip route choice into a hybrid route choice model.

Currentl, en-route rerouting is not considered in most existing DNL models. This is also not the case for the marginal models presented in Corthout et al. [6]-[8]. Due to their computational advantage, marginal DNL models are very well suited for application in variability studies and real-time applications – where modeling en-route rerouting behavior is (arguably) most necessary. Therefore, including an en-route rerouting model – or rather a hybrid route choice model; continuing the terminology introduced by Pel et al. [10]-[11] - constitutes an important addition.

In this paper, a hybrid route choice model and the modeling of the impact of the resulting rerouting behavior on the traffic conditions is incorporated into the Marginal Computation (MaC) Model of [8]. That way, the rather stringent assumption that drivers always choose the same route as they do in the base situation (no matter what the current conditions are) is relieved. In result, MaC is now capable of quantifying the variability due to demand and supply variations as well as the response of drivers – in the form of rerouting behavior - to these perturbations. This enhances the realism of the model in variability studies. Furthermore, the door is opened towards (real-time) application of MaC in e.g. evacuation planning and incident management. Therein, MaC could be used to stochastically predict the impact of a recent incident, an upcoming event or road works, or to evaluate possible route guidance strategies prior to implementation.

In the next section, the MaC model of Corthout et al. [8] is briefly introduced. Then, it is explained how en-route rerouting is added with a hybrid route choice model. Finally, some summarizing conclusions are formulated.

THE MARGINAL COMPUTATION MODEL

The idea behind MaC is to only calculate the changes in traffic flow and congestion propagation that arise from a local variation (in demand or supply) to a so called base simulation. For each variation, calculations are only performed for the activated part of the network and
simulation period, i.e. that part where the traffic flows (are expected to) differ from the base flows. The links on which different flows are detected are the affected links, constituting the affected area. Hence, calculations are limited in time end space, rendering Mac very computationally efficient. Especially for large-scale problems, MacC provides significant computational advantages. Meanwhile, MacC avoids the drawback of static models since it is a dynamic model based on first-order traffic flow theory (after Newell [12]), thus exhibiting a realistic representation of congestion formation and spillback. MacC can be used for a wide range of applications such as real-time traffic management, reliability and vulnerability studies, network design and dynamic origin-destination (OD) estimation.

INCORPORATING EN-RUTE REROUTING INTO MAC

The en-route rerouting procedure is based on the hybrid route choice modeling introduced in Pel et al. [10]. Herein, drivers frequently re-evaluate their initial route (determined pre-trip) compared to attractive alternatives. A single parameter is introduced to express drivers’ reluctance to move away from their initial route. This concept is adopted in Mac to account for drivers rerouting due to variable traffic conditions. Hereby, rerouting takes place at active nodes. The main questions that need answering when introducing the hybrid route choice model into Mac are the following:

- At what moment in time should rerouting be initiated at a specific node in the network?
- Which route alternatives – to the original, pre-trip chosen route – should be considered?
- How should the various route alternatives be evaluated by drivers when reconsidering their route choice?
- How are the resulting changes in route flows modeled in Mac?

Regarding the first question, an easy to implement solution would be to always allow rerouting whenever a node is activated in the marginal simulation. This would however not be the most efficient solution, since (non-negligible) rerouting can probably be assumed to only occur in case of unexpected congestion. Thus, the hybrid route choice model will be initiated at an active node, only if congestion that was not present in the base situation – and is thus unexpected, i.e. drivers did not account for it in their pre-trip route choice - reaches this node, by spilling back upstream over an affected link. Arguably, the rerouting could be initiated somewhat earlier since drivers might anticipate the downstream congestion if information on the current traffic conditions is provided (e.g. on the radio). The hybrid route choice model is run for all routes that have the affected link as their next downstream link. That way, only drivers that are headed towards the unexpected congestion – according to their originally chosen route – will reconsider their route choice.

For the second question, there are again multiple plausible answers. A k-shortest path search algorithm could be run to identify valuable route alternatives $a$ for each original route $r$, headed towards the affected link; naturally, all route alternatives $a$ starting at the current node and heading towards the same destination as the original route $r$. More easily implementable and more computationally efficient, a predefined selection of route alternatives – again, from the current node to the same destination as $r$ - could be considered. This might be an interesting approach if several options for rerouting guidance (e.g. around an incident or road works) are to be compared. For now, only the latter approach with a predefined selection of route alternatives is implemented in Mac.

Thirdly, it needs to be decided how to weigh the different route options in the hybrid route choice model. Therefore, the well-known logit route choice model is used. The cost function in the logit route choice model contains the instantaneous route travel times and, for the alternative routes $a$, an additional term to account for drivers’ reluctance to reroute (as in Pel et al. [10]). For a route alternative $a$ to an original route $r$ (chosen pre-trip), the following cost $c_{ar}$ results:

$$c_{ar} = \bar{\tau}_a + \frac{\omega}{1 - \omega} \epsilon_{ar}$$  \hspace{1cm} (1)

In (1), $\bar{\tau}_a$ denotes the instantaneous travel time for route $a$, from the current node to its destination. In reality, drivers will have incomplete – and possibly incorrect - information about current and future traffic conditions and travel times. Therefore, the instantaneous travel time is arguably a better representation of knowledge drivers have of the travel to be expected. In any case, it is preferable over just using a fixed travel time (e.g. free flow travel time). The second term represents drivers’ reluctance to move away from their initially chosen route. As in Pel et al. [10], $\epsilon_{ar}$ is defined as the length of the part of route alternative $a$ that is non-overlapping with $r$, relative to the length of $r$:

$$\epsilon_{ar} = \frac{\sum_{i \in ar} l_i}{\sum_{j \in r} l_j}$$  \hspace{1cm} (2)

Herein, $l$ is the length of a link $i$ or $j$. The weighting parameter $\omega$ can be varied between 0 and 1, expressing absolute determination to sticking to the original route and to always rerouting respectively.

Given the cost (1) for each predefined route alternative $a$ and their corresponding original route $r$ headed towards
the affected link with unexpected congestion, the hybrid logit route choice model determines the new route choice behavior of drivers at the considered node. This immediately yields the resulting (desired) route flow changes. Finally, these changes have to be propagated correctly through the network. This is done by updating the turning fractions at link ends along the path of each route for which the flow has changed. For example if a route flow has increased, at each of its links the turning fractions (dividing traffic from this link over the downstream links) are increased accordingly. Hereby, the exact same procedure as described in Corthout et al. [8] to propagate demand variations is followed.

CONCLUSION

An addition to MaC, a computationally efficient marginal DNL model introduced in Corthout et al. [8], is presented, namely the implementation of a hybrid route choice model. This allows for the modeling of drivers’ response to unexpected traffic conditions by deviating from their original route. This improves the applicability of MaC in studies aiming to quantify the variability (e.g. of travel times) due to stochasticity in the travelers’ demand and the network supply. Furthermore, the inclusion of en-route rerouting is an important step towards dynamic traffic management applications, possibly in real-time, such as incident or road works management, ramp metering and evacuation planning. For one, MaC could be used to evaluate the impact of incidents, road works, events or disasters on the network conditions – in absence of management interventions. Secondly, MaC could assist in comparing and choosing between several possible strategies for route guidance.

REFERENCES