MOTORWAY TRAFFIC MANAGEMENT AND TRAFFIC PARAMETERS ESTIMATION FROM MOBILE PHONE COUNTS

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1 INTRODUCTION

The amazing growth of mobile communications in Europe and especially in Italy allows the application of new technologies for traffic parameter estimation in real time. In this paper the main lines of a new method for motorway traffic monitoring is presented. Cellular networks allow to obtain accurate and detailed information on the position of motorway traffic users from mobile phone localization systems and this allows to estimate traffic flow parameters (speed, density, and flow) given the hypothesis that the information obtained from the system allows to track the time-space trajectory of some "instrumented" vehicles. This hypothesis is justified by the extraordinary diffusion of mobile phones, the implementation of E-911 in USA and the potential economical interest of mobile phone producers and mobile phone network operators for mobile phone localization systems.

Some implementation on the field of mobile phones application in traffic management and control can already be found with the "i-mode" system developed by NTT DoCoMo (see Kurokawa, 2000 and Natsuno et al., 2000)

2 ESTIMATION OF TRAFFIC PARAMETERS

The estimation of motorway traffic parameters (traffic flow, traffic density and speed) from the localization and counting of mobile phones moving along the road involve knowledge in traffic flow theory and in other specific fields relative to mobile phone communication. Some works have already been presented on this subject (Astarita, 2002; Bolla et al. 2000; Smith et al. 2001; Lovell, 2002), among them in Bolla et al.(2000) it is presented an algorithm for traffic parameter estimation on motorway from phone localization information.

In the work of Bolla et al.(2000) it is supposed that the vehicles moving along a motorway are counted at the entry and exit toll stations and in addition to this all "instrumented" vehicles are counted also along the motorway at the moment of cell (radio base station)
changing on the cellular network. It would be possible in that case estimate the ratio of "instrumented" vehicles on the total number of vehicles as a function of time and space and from this obtain and estimate all traffic flow parameters. But in the paper of Bolla et al. (2000) some elementary principles of traffic flow theory have been neglected resulting in a poor prediction algorithm. It should, though, recognised that the paper discuss a specific situation for traffic parameter estimation that is very common in many toll roads (especially in Italy): the use of motorway entrance flow measurements coupled with cellular volumes measured along the road to obtain traffic parameters. In this paper a new algorithm has been developed for this and other situations by applying standard traffic simulation macroscopic methodologies to obtain better estimation of traffic parameters.

The algorithm can estimate traffic speed, density and flow along a motorway line based on the projection of the flow rate of monitored cellular on the total flow rate. This first algorithm has been applied to the same situation that is studied in Bolla et al. (2000), allowing a comparison for some test scenarios with different rate of cellular market penetration using the vehicle trajectories obtained from a microscopic traffic simulation. Different scenario with different cellular market penetration (also varying the dimension of radio base cellular cells) are simulated with a microscopic simulator to make comparison between different estimation algorithms.

3 A NEW ALGORITHM FOR TRAFFIC PARAMETER ESTIMATION

In the proposed algorithm the road network is divided into segments (or cells), and for each segment is possible to count "instrumented vehicles" entering and exiting. For each segment it is known also the total number of vehicles entered and exited by on and off ramps in each time interval. The concentration of mobile phones (i.e. the ratio of "instrumented" vehicles on the total number of vehicles) is evaluated with a forward propagation mechanism applied on a discretized network with regards to space and time. The concentration of mobile phones is used to obtain an estimate of average speed, density and traffic flow for each interval of time in each cell of the network.

The algorithm has been applied with different scenarios on a test network composed of 20 arcs (cells) as in figure 1.

Fig. 1 – Test network with a single on ramp (A) and a single off ramp (B).
For brevity sake the formulation of the algorithm is omitted and only one scenario is presented: a recurrent oversaturated condition due to a bottleneck in the last cell (all arcs are 3 lanes segments of road and arc 20 has only 2 lanes). Traffic flow entering the network is constant for all the simulation so that in this scenario a queue builds up starting on cell 19 and propagates backwards.

The mean percentage errors (on the whole simulation period) between the real (on the microsimulated reality) and the estimated values of traffic speed, density and flow are presented for different average concentration of instrumented vehicles (40% and 80%) are in figures 2, 3 and 4.

Fig.2- Mean percentage error on traffic density estimation (for an average ratio of "instrumented" veic./veic. Equal to 0.40 and 0.80).

Fig.3- Mean percentage error on traffic flow estimation (for an average ratio of "instrumented" veic./veic. Equal to 0.40 and 0.80).
It is clear from results that (as expected) the estimation gets better with an increasing ratio of "instrumented" vehicles. It can be noted also that the estimation of density and traffic flow has the same quality on all the network. The poor quality (relative to other cells) of traffic speed estimation on the cells upstream cell 20 is due to the queue building up that creates a very dispersed distribution of speeds among drivers exiting the cell, that affects a little the estimates. For example with a ratio of "instrumented" vehicles of 40% on cell 19 there is an average error in speed estimation equal to 2.5% compared to an error of less than 0.25% in cell 1 where speeds dispersion among driver is lower. In Astarita (2002) a percentage of 40% was found in an experimental survey on Italian suburban roads for the ratio of turned on cellular per vehicle.

How the speed estimation changes over time on cell 19 (the most critical location) is showed in figure 5 for an average ratio of "instrumented" veic./veic. of 0.4 and 0.8.
4 CONCLUSIONS

This paper presents an algorithm for motorway traffic parameter estimation based on flow measurements coupled with information obtained by cellular volume counts. The algorithms proposed are tested by using vehicle trajectories generated from a microscopic traffic simulator.

Results of different simulated scenario show that this kind of techniques can give very accurate real time estimation of traffic parameters. It should be noted, though, that in the simulation there are no error measure or failure in some of the measurement device. The research will be continued to evaluate the accuracy of estimation in real situations where the level of uncertainty in the measured parameters is greater.

REFERENCES


Bolla R., Davoli F., Giordano F. (2000); Estimating road traffic parameters from mobile communications. 7th World Congress on ITS. Torino.


