Floating car data adaptive traffic signals

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Abstract—Two new technologies are going to shape the future of traffic management and control: "connected" and "autonomous" vehicles. The possibility of gathering information from vehicles travelling on the road and the use of this information for better traffic management is receiving a growing attention from the scientific community. The purpose of this study is to present the architecture of a dedicated system for traffic signal real time regulation based on data coming from "connected" vehicles. The system presented in this paper has been implemented on the field in a dedicated experimental intersection site to assess performances of the system in actual use. Results of the experiments carried on with the presented system will establish the feasibility and the advantages of FCD adaptive traffic signals and will help to develop better regulation algorithms for this kind of new "connected" intersections.

Keywords—adaptive traffic signals, floating car data, connected vehicles.

I. INTRODUCTION
Traffic signal regulation often is not perfectly conducted. Many administrations are opting to modify signal regulated intersections in roundabouts since many problems arise from a bad regulated intersection.

Wireless internet and the introduction of "connected" vehicles could help administration to regulate traffic signal and optimize them according to real-time traffic measures coming directly from vehicles. Many papers have been presented where "connected" vehicles act as floating probe vehicles. The whole concept is commonly defined as that of: "Floating Car Data" (FCD). First FCD works have been experimenting the use of specific Radio-frequency identification (RFID) systems [1], [2].

Connected vehicles, with all sensors they will be able to carry on them, will become an important element of the forthcoming Internet of Things (IoT) and of Intelligent Transportation Systems [3]. In the meanwhile, smartphones have been already used in many cases to connect vehicles in on-field applications. Connected vehicles will be able to originate a dense flow of information while they travel around the cities and this is already happening with the information coming from GPS-equipped smartphones. Most mobile phones nowadays have a GNSS satellite receiver which can be used in FCD applications to communicate vehicle speeds and positions in real-time.

All previous applications of FCD to adaptive traffic signals have been conducted in simulation. In this paper we intend to describe a system which is devoted to implement FCD adaptive traffic signal regulation in real-time on the field. A dedicated experimental site was developed with a dedicated signal regulated three legs intersection. The experimental site allows testing different algorithms in a realistic setting. This paper describes the experimental site and the design of the controlling system. Results of the experiments carried on with the presented system will establish the feasibility and the advantages of FCD adaptive traffic signals and will help to develop better regulation algorithms for this kind of new "connected" intersections.

II. METHODS
The general logic of the proposed system was introduced, discussed and evaluated in simulation in [4]. The implementation that we are going to deploy on-field is based on a mobile phone application as the instrumentation to transform a vehicle into a "connected" vehicle. Adaptive commercial systems for adaptive traffic signals are based on flow measurements that are carried on usually with magnetic loop detector. In our system information on traffic flows are extrapolated from the vehicle trajectories. The data which can be used is much more detailed than what can be obtained with traditional systems. In fact, from the vehicle trajectories it is possible also to evaluate the queue length for every maneuver at the intersection. The GNSS feature of smartphone will be also tested in our experimental test of the system to establish the accuracy in estimating traffic queues at the intersection.

The system is composed of the following physical parts: A) the traffic lights of the intersection that are actuated by a local controller; B) the local electronic controller (Raspberry) that is connected on the internet and that acts as a web server regulating the traffic signals at request; C) a central server that collects data from "connected" vehicles" and establishes the best traffic signal cycle according to data processing and the algorithm that are described in the following; D) the "connected" vehicles with a smartphone application that receive data relative to positions and speeds from the GNSS system and transmit them to the central server (on the common local wireless phone data network).

Connections between the local controller and the traffic lights is cable based while the connections directed to the central server from the mobile applications and the local controller are through wireless internet data phone lines.

Two control algorithms will be experimented in the system and compared with a static optimized cycle. It must be noted that
the vehicles will circulate in the experimental intersection in such a way that every driver will have an assigned circular path to repeat again and again. The flows that will present at the intersection will be a function of the chosen cycle. A bad regulated traffic signal would, in fact, bring up the waiting times and consequently reduce the traffic flow through the intersection. A greedy algorithm which was introduced in [4] will be confronted with a Nash bargaining based algorithm also used in [5].

The Greedy algorithm on the base of how many "connected" vehicles are queued on approaching lanes establishes green times in such a way that the longest queue of connected vehicles is served with priority with a green time that is enough to let flow, past the intersection, all the queued vehicles plus the other vehicles that may be arrived since the moment this last vehicles has stopped. The procedure is similar to that applied in [6]. In other words, connected vehicles are treated like priority vehicles.

III. THE EXPERIMENTAL SITE

A dedicated experimental site, which is schematically illustrated in Fig. 2, was set up in a parking lot area of University of Calabria.

The intersection is a three legs intersection with single lanes approaches so that the three traffic lights control all maneuvers of an approach at the same time for a single shared lane. The traffic signal phases are the three depicted in Fig. 5. Drivers were instructed to repeat the same path. To avoid the formation of cluster of vehicles moving along the same path it was possible to identify 9 different paths which were assigned to a total number of 10 drivers. The same experimental setting could be used for more complicated intersections with a different lane structure. Since the main objective of this first implementation is mostly the demonstration of feasibility of such a prototype system it was decided to keep the intersection lay out as simple as possible.

![Fig. 2. The system implemented in the experimental site.](image)

IV. RESULTS AND DISCUSSION

The system described in this paper has the scope to demonstrate the feasibility of regulating traffic signals with "connected" vehicles. Many works have been suggesting that the convergence of IoT, Intelligent Transportation Systems, "connected" and "autonomous" vehicles could help improve traffic conditions in cities. Many papers have specifically been published on adaptive traffic signals based on FCD, yet there is no on-field real-time system of this kind that has been experimented with the deployment of a real prototype system such as the one described in this paper. The prototype system developed art University of Calabria was realized without specific funding with the aid of mostly existing technologies and with an extremely reduced cost. Results of the proposed prototype system suggest that with very low cost and with just the right knowledge it would be possible to better regulate existing traffic signals taking advantage of the already developed wireless phone internet data infrastructures. Moreover, the experimental setting at the University of Calabria and the prototype system developed could help to test, in a real on-field laboratory, different traffic signal control algorithms based on FCD. Classical algorithms for real-time control of traffic signals are based on measures of traffic flows generally coming from loop detectors. The use of FCD data allows controlling traffic signals according to much more detailed data of speeds and positions of single vehicles. This new methodology requires though new algorithms and control logics that need to be tested in laboratory settings such as the one proposed in this paper before they can be deployed in our cities.

V. CONCLUSIONS

This document demonstrates the feasibility of using FCD to regulate traffic signals. The infrastructure costs of using FCD for traffic signal regulation are extremely low compared to traditional adaptive traffic signal system infrastructures. Moreover, since with FCD regulated traffic signals only "connected" vehicles are counted and given green light, it is important to complete a performance analysis for such a system also when traditional non "connected" vehicles are present. Results based on simulation have shown that when over 30% of vehicles are "connected" the benefit are for the whole traffic while when less than 30% of vehicles are connected then the traditional vehicles not participating in the system would receive little delays with respect to the time savings of connected vehicles. In other words no matter what is the penetration rate of the system simulations showed that with the implementation of FCD adaptive traffic signals (FCDATS) the whole traffic flows better with reduced travel times and reduced pollution emissions and fuel consumption. These results though have still to be produced for real vehicles on the road. The proposed experimental prototype system and the proposed experimental setting can answer to this kind of doubts demonstrating the feasibility and convenience of such systems and paving the way for the introduction of real FCDATS in our future smart cities.

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