# A Game-Theoretic Approach to Distributed Control of Traffic Signals

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## Abstract

Game-theoretic techniques have been proved useful in modelling the conflict of interest and the cooperation among agents. This work aims at applying such an approach to model interactions in the domain of decentralized traffic signal control where either cooperative or noncooperative interactions arise. Case-studies are described in which agents have been assigned either to intersections or to lanes. They act mainly as decision-makers who choose signal plans to cope with the given traffic situations.

Due to the need of quickly liberating congested lanes, agents try to assign them as much green time as possible, leading to a conflicting situation with the neighbors.

In the traditional philosophy of traffic signal control, in which traffic elements are centrally controlled, the reaction of the system to changes is not fast enough. With the increasing of traffic network size and complexity, there is a trend towards decentralization. In a decentralized philosophy, each agent is able to process local information and to decide on actions in order to minimize delays. There is no central entity to solve the conflicts between single units. Therefore the units must have a means to model their neighbors and to reason about them before acting. This reasoning process is based on the principle of the rationality of the agents, which pick one of the equilibrium points of the game, leading them to coordinate towards an action. The best known ways of computing the equilibria of the game are the iterated dominance and the Nash equilibrium along with its refinements. These constitutes the common rules agents follow when coordinating towards an action. When iterated dominance does not solve the game, the Nash equilibrium is proposed as the general solution concept. Information sets are used to represent local knowledge. They are simple data structures allowing agents to reason about the current state of the interaction.

In real situations agents are often not informed about the rules of the game, about the payoffs and previous moves of the other players. For instance some lack information concerning other's traffic situations. This situation characterizes a game of incomplete information and is modelled by means of the Harsanyi's transformation. At each time agents have prior beliefs about the others and update them by observing the neighbors' moves.

Two granularities are modelled, namely agents associated with lanes and with intersections. In both cases it is shown that cooperative and noncooperative interactions can arise. Concerning the generation of signal plans, the model provides a means for agents to bargain the division of a given green time among the lanes.

Five real situations are described as two-player games in which agents have different and incomplete knowledge and update their beliefs with time. First the traffic situations of both agents (in this case, lanes) are common knowledge. In another situation, the traffic situations are private information. The next case modelled is that of the traffic situation of only one agent being common knowledge. The fourth example refers to agents assigned to intersections and negotiating the setup of signal plans for each of them. The fifth refers to the generation of signal plans, a typical bargaining problem.

The above model tackles two main concerns of traffic signal control: traffic-responsive signal plan selection and signal plan generation. The major contribution of it is the modelling of situations in the domain of traffic signal control in a decentralized fashion in which interactions are mapped by means of game-theoretic techniques.

One concern of the model is whether the communication decreases compared to that required in centralized philosophies. The number of times an agent has to communicate with neighbors increases since they must exchange payoff values, mainly at the beginning of the interaction when they do not have such information. In the majority of the daily situations agents have private information. Therefore games with incomplete information are meaningful. In this case the need for communication decreases. Another concern is whether the absence of a unique equilibrium leads to more communication. In order to avoid this, rules for the process of equilibrium selection were proposed which lead agents to coordinate towards an equilibrium point.

After working on real situations it was concluded that the game-theoretic approach eases the modelling of the interaction among agents, both in cooperative and in noncooperative situations. The increase of local communication can be seen as a minor shortcoming compared to the need of communication in the classical, centralized architecture.