A Microscopic Traffic Simulation Platform for Coordinated Charging of Electric Vehicles

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Abstract. Gridlock is a microscopic traffic simulation platform and is now extended with electric vehicle support. Simulations for coordination mechanisms concerning on-line charging of electric vehicles on highway networks are performed using this simulation platform. The platform offers a means for gathering and processing simulation data and the real-time visualisation of simulation state aspects such as traffic density and charging station occupation.

1 Introduction

Electric vehicles (EVs) are gaining in popularity in an effort to reduce the carbon footprint of vehicular transportation by creating environmentally friendly alternatives in the form of Plug-in Hybrid EVs and fully battery-powered EVs but the limited driving range is still considered as one of the main causes for the limited adoption of EVs, together with the long time needed to recharge the battery. Electric charging infrastructure will need to be built. These networks will, however, be subject to capacity constraints.

If there is too much traffic on the network, congestion becomes unavoidable. Increasing the load on the charging infrastructure by increasing the number of vehicles that need to charge, causes the waiting times and queueing to increase rapidly. Prolonged peak loads on these infrastructure elements can also adversely affect the lifespan of the transformers in the electricity grid, driving up the financial cost for the grid operators.

More efficiently using the available infrastructure by use of ICT-based coordination strategies offers a solution to mitigate the symptoms of these capacity problems. The primary goal of the work in [1] is finding coordination strategies capable of guiding the charging behaviour of individual agents to globally minimize waiting and queueing times and to avoid excessive peak loading of charging stations in the network.

2 Main Purpose

This paper demonstrates the simulation platform used for evaluating coordination mechanisms for on-line allocation of electric vehicles to fast charging

Fig. 1. Structure of simulation platform

infrastructure in [1]. The simulation platform is based on **Gridlock** [2] and has been extended to support EVs, fast charging stations, charging behaviour and coordination mechanisms. Afterwards, a realistic scenario is implemented in the simulator and multiple simulation experiments are performed with rudimentary visualisations.

3 Demonstration

3.1 Gridlock

Gridlock is a microscopic traffic simulator and simulates vehicles in traffic on a microscopic scale. Consecutively, the platform allows for macroscopic evaluation of simulation experiments. In a microscopic simulation, all vehicles are represented as separate entities with their own behaviours. Every second in simulation time the effects of these behaviours are calculated and updated throughout the model. This platform also allows for the implementation of custom event listeners using a Publish-Subscribe model to gather and aggregate simulation data. The platform architecture is represented in Figure 1.

3.2 Topology

The simulation scenario implemented for the experiments in [1] is chosen for its real-world relevance and this section will demonstrate how it is constructed. A highway network in Flanders, Belgium is virtually rebuilt into a format suitable for input into the simulation platform. Different points-of-interest (POI) are identified along the highway such as gas stations, truck stops and highway access points. The distances between these POI are measured by using the average of measurements by different on-line map tools. These point coordinates and their inter-point distances are then converted into an annotated weighed graph

Fig. 2. The road net in Flanders, Belgium, used to perform simulations on. The used network segments are stroked in green while a red $\times$ marks a charging station.

structure wherein the weights represent the real world distances between nodes. The coordinates themselves are artificially created for easy visualisation purposes. This explains why the visualised graph does not look completely similar to the real-world highway topology but for simulation purposes the represented distances are accurate. Figure 2 shows the real-world highway network and chosen charging stations while Figure 3 displays the road network as visualised by the simulation platform.

3.3 Visualisation

Traffic Density. Besides drawing the network graph, the visualisation also represents how many vehicles are present on the different edges in the graph. A vehicle driving on an edge has the coordinates of the nodes that edge connects distorted by a small amount of Gaussian noise. These distorted coordinates are connected and stroked in red. Figure 4 shows this effect where no two vehicle paths on the same edge are drawn between the same two points on screen. More vehicles present on a certain edge will show as a more pronounced *glow* compared to edges with less traffic present.

The specific amount of vehicles on the road is determined by a traffic generator which takes an input file with the relative amount of vehicles on an hourly basis. This relative amount is in relation to a global fleet size set in the simulation configuration file.

Charging Station Load. The nodes in the graph that function as a representations of charging stations are colour coded. The possible colours can range from blue meaning no vehicles have charged here to green, yellow and red representing $<33,3\%$, $<66,6\%$ and $<100\%$ occupation relative to the maximum amount of station load observed in the system so far. This is therefore a relative representation of the current load in relation to the maximum observed load for the whole simulation run. The nodes that remain blue for the duration of a simulation are

Fig. 3. The visualisation of the bare high-

Fig. 4. The visualization of the highway traffic densities and station loads

indicative that these stations might actually be obsolete because they are not used by vehicles to charge at.

4 Conclusion

This paper shows some aspects about the real time visualisation capabilities of the **Gridlock** simulation platform and its extension for electric vehicles. **Gridlock** is used as a simulation tool for research concerning coordination mechanisms for on-line charging of Electric Vehicles in traffic and for evaluating possible charging station topologies. The simulation tool is demonstrated by using a scenario based on a real-world highway network with real world traffic data.

References

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