Governing Energy for Parked Cars

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Vehicular networks offer service coverage for urban environments that would be too expensive for infrastructure-based networks to provide. Distributed networks of vehicles have been proposed to enhance local services, ultimately providing relief of some of the stress on the infrastructure. Since connectivity between cars is challenged by high mobility and uncoordinated deployment, the inclusion of parked cars has been proposed to improve network stability and so system and service performance [1, 2].

Parked vehicles are for example very helpful when they act as relays for extending the coverage of indoor access points to the cars that are moving on the streets, as proposed in LoadingZones [1]. This approach offers a higher bandwidth with respect to a solution in which moving vehicles connect directly to an access point, as proposed in [3]. While introducing parked cars seems to be a straightforward extension, in reality energy management becomes a serious challenge. Essentially, if there is not enough energy in the battery to power the system for the whole duration of the stop, energy must be saved by shutting down the services for part of the stop duration. To support a service such as LoadingZones during extended parking periods, with a limited energy availability, it is necessary to implement a sleep-active cycle. To determine a *schedule* that indicates when the system should be active, we designed an energy governor based on monitored system metrics (i.e., time or battery level) and metrics specific to LoadingZones (i.e., density of cars) that determine the utility of the service. For example, a good schedule for LoadingZones would be to provide the service when the traffic flow is high. Essentially, the schedule does not specify the time at which the system should be active, but rather the conditions that trigger its activation.

Our demo will present an energy management system that schedules active and sleep times for LoadingZones with the goal of maximizing the benefits over cost ratio. This is accomplished by activating the service when its utility is maximum, which is when the density of vehicles is higher. In this case, LoadingZones serves the largest number of vehicles per time unit. Our prototype energy governor bases its decision on an estimate of the parking duration, which is based on historical information, and on an estimate of the traffic density at the specific location where the car is parked, and the time of the day. This information is available in several databases, such as [4], but of course it is affected by errors and temporal variation. For this reason, rather than choosing the active times based on the estimated density at a specific hour, the energy governor first measures the available energy and the estimated duration of the stop, and determines for what fraction of the parking time LoadingZones can be active. It then looks at the CDF of the estimated traffic density for the current time, location and stop duration, and determines a density threshold over which the system should be activated. Using this information, and a low-power radio to periodically monitor the traffic density even when the device is in power-saving mode, LoadingZones is active for the right amount of time, and when it is most needed.

Our demo will show the basic functioning of LoadingZones and its energy governor. We will setup one of our prototype devices, posing as the parked car, connected to the internet with one radio, and ready to relay internet access with a second radio. Another device will act as a moving car. A phone connected to this second device will be capturing pictures which will then be delivered first to the parked car, where LoadingZones will use its store and forward approach to deliver them to our server, from which the pictures will be eventually displayed on a map. The energy governor will be controlling the active-sleep cycle of the parked car, using our custom designed hardware to simulate the changing traffic density.

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[3] B. Hull, V. Bychkovsky, Y. Zhang, K. Chen, M. Goraczko, A. Miu, E. Shih, H. Balakrishnan, and S. Madden, "CarTel: a distributed mobile sensor computing system," *Proc of ACM SenSys*, 2006.

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