An Architecture for Power Management in Automotive Systems

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Abstract. This paper presents an architectural model for power management in automotive systems. It is based on recent advances in cyber physical and cybernetic control systems. Based upon a previous model of power management, formal interactions in between a hierarchical structure are characterized. In the architecture, strategic decisions allow coordinated adjusting of power management plans as well as local autonomy in subsystem scope.

Keywords: automotive systems, power management, system architecture, cyber physical systems.

1 Introduction

With rising fuel prices and stricter regulations, the automotive industry is putting increasing effort into lowering vehicle consumption. With lower consumption, one can achieve a greater range, or reach further with the same money.

Next to optimizing the drive-train, electric loads can be optimized. An electric load of 100W roughly amounts for an additional 0.1 liter of fuel consumption per 100km in regular vehicles with combustion engines \cite{4}.

Upcoming vehicle generations feature hybrid or fully electric drive-trains. The main enabler for this is battery technology. Still, batteries with high capacity are very expensive or very large and heavy. Next to improving battery technology, minimizing energy consumption is the other important factor in making these vehicles affordable.

Current automotive systems are increasingly complex. In luxury class cars, more than 70 electronic control units (ECUs) are being implemented \cite{10}. These control units form a distributed system. It is characterized by many interactions of the contained subsystems.

Due to the heterogeneity of automotive systems, it is a great challenge to implement effective measures of power management. Typically, many of the control
units come from different suppliers. They all have to interact with each other and must be combined into a hierarchical system.

In order to tackle the problem of heterogeneity, the automotive industry is driving an evolving standard called AUTomotive Open System ARchitecture [1]. AUTOSAR is a collection of specifications for ECU operating systems and the interactions in between the components. The AUTOSAR consortium is working on specifications for coordinated power management called ECU degradation and partial networking. As part of the AUTOSAR operating system specification, fine-grained ECU states can be defined and used for power management.

The problem of power management and state derivation can be split in two phases:

1. One has to aggregate local state of each subsystem and form a state and strategy for the whole vehicle.
2. The global aggregation should ideally affect each subsystems plans for power management.

1.1 Related Work

The topic of power management has been quite long discussed. Related work ranges from classical power management in personal computers, to active power distribution in self-sufficient systems, and ultimately in the novel topic of cyber physical systems.

**Classical Power Management.** The classical power management is described, e.g., in the survey paper by Benini et al. [3]. One simple yet important concept described in there is the power state machine. It describes the power states and transitions a system can incorporate.

![Power State Machine Diagram](image)  
**Fig. 1.** Exemplary power state machine. Depicted are three states along with their power consumption and transition times in between.

Figure 1 depicts an exemplary power state machine. The power state machine consists of annotated edges connecting the power states.