Chapter VIII
The Role of Communications in Cyber–Physical Vehicle Applications

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ABSTRACT

Cyber-physical systems use sensing, communications, and computing to control the operation of physical devices. Sensing and computing devices have been embedded in automobiles and in the transportation infrastructure. Communications adds a new dimension to the capabilities of these systems. The embedded computers and sensors in both vehicles and the infrastructure will be networked into cyber-physical systems that reduce accidents, improve fuel efficiency, increase the capacity of the transportation infrastructure, and reduce commute times. The authors describe applications that improve the operation of automobiles, control traffic lights, and distribute the load on roadways. The requirements on the communications protocols that implement the applications are determined and a new communications paradigm, neighborcast, is described. Neighborcast communicates between nearby entities, and is particularly well suited to transportation applications.
INTRODUCTION

Cyber-physical systems use sensing, communications and computing to control the operation of physical devices. Sensing and computing devices have been embedded in automobiles to improve their fuel efficiency and safety. For instance, automobiles have several computers that are embedded in engines to improve gas mileage and detect faults; cruise control is used to maintain a constant velocity; antilock brakes use sensing and computing to prevent skids and stop cars as quickly as possible; and computing is combined with GPS systems to plan routes. Sensing and computing are also used in traffic lights to reduce travel times and fuel consumption by changing signals only when traffic is waiting and by timing signals to permit traffic to flow in a dominant direction unimpeded.

New applications of sensors are being introduced in automobiles. Sensors detect obstacles behind a car that is backing up and warn the driver when there is a car in a blind spot or when he is following too close to the car in front. The front, back and side sensors are also used to assist drivers when parallel parking. Sensors will transform cruise control from a simple device that maintains a constant speed to a more intelligent system that controls the maximum speed, but reduces the target speed as a function of nearby automobiles (Heddebaut et al., 2005; Vahidi & Eskandarian, 2003; Zhang et al., 1999). The speed will be decreased when the preceding car is traveling at less than the target speed to avoid a rear end collision, or when cars in adjacent lanes are traveling at much lower speeds to give a driver sufficient time to respond to vehicles that change lanes.

Communications adds a new dimension to systems and applications. The embedded computers and sensors in both vehicles and the infrastructure will be networked together to improve the operation of existing applications and to make new classes of applications possible. These cyber-physical systems will change the way we use transportation.

Communications between nearby vehicles will enable cooperative control paradigms that reduce accidents more than computing and sensors alone. For instance, a distributed anti-lock brake system will not only allow a car to brake more quickly by preventing skids, but will negotiate with surrounding vehicles to avoid collisions while stopping (Liu & Ozguner, 2003). In instances where accidents cannot be avoided, the system will select a stopping speed that minimizes the damage. Side sensors can provide a warning when there are cars in adjacent lanes, while communications can negotiate with those cars to safely change lanes. Vehicle control systems will increase the capacity of highways by allowing cars on congested roadways to safely travel faster and with less space between vehicles. The communications procedures that are used in automotive applications are described in the sections Centralized Control and Distributed Control.

Communications between vehicles and the infrastructure will improve the scheduling of traffic signals and route planning. Instead of relying on sensors to detect cars that are waiting at a light, communications will notify the computers that control the lights before the vehicles arrive. On congested roadways, traffic lights at adjacent intersections will be coordinated to minimize the stopping time for cars traveling in all directions. The use of communications for controlling traffic signals is described in the section, Interaction of Automobiles with Traffic Signals. Route planning computers will communicate with a traffic control center to determine congested regions and may also cooperate with other route planning computers to avoid creating new congested regions, as described in the section, Cooperative Route Planning. Recently, sensors have been installed in parking spots in San Francisco and communications with drivers reduces the time and fuel consumed to search for parking spots.