Automated “Train” of Cars
Outline

• The Safety Problem
• Active Safety Systems
  – Motivation
  – Examples
    • Advanced Snowplow
    • Transit Frontal Collision Warning
• Vehicle-Infrastructure Integration
  – Cars and Roads that Talk to Each Other, Defined
  – Examples
    • Cooperative Collision Warning
    • Cooperative Intersection Collision Avoidance Systems
• Last Words
Analysis of the Safety Problem

- Rear-End: 29%
- Intersection Crossing Path: 26%
- Single Vehicle Road Departure: 21%
- Lane Change/Merge: 9%
- Other: 15%
The Safety Problem

Causal Factor Distribution

- Driving Task Error: 76%
- Road Surface: 8%
- Vehicle Defects: 3%
- Driver Physiological State: 14%
The motivation for Active Safety Systems

- Each year, more than 6 million vehicle crashes occur on our nation's highways. Crashes kill more than 41,000 people, injure approximately 3.4 million others, and cost more than $150 billion per year.

- Driver error is the primary cause of about 90% of reported crashes involving passenger vehicles, trucks, and buses.
Advanced Snowplow

Changes for ASP 2:
Two radar sensors
Better sensor bracket
ASP Driver Interface

- Simple
- Minimal glance time
- Control dynamics
Development of a Prototype Frontal Collision Warning System for Transit Buses
Frontal Collision Warning System
Requirements Definition
Transit Bus Collision Warning System
Frontal Collision Warning System

Driver's decision

Vehicle Sensor measure

Frist Layer Radar & Lidar Data Fusion

Real-time Image processing

GPS Proc.

Warning System - Optimal Decision Making

DVI

Driver side Radar

Eaton Vorad Radar

Right side Radar

Road Preview

Traffic

Desired speed

Relative speed

Relative dist

Road geometry, Traffic & environment

Target $w, acc/dcc, v, L$

Target $w, acc/dcc, v, L$

Target $w, acc/dcc, v, L$

Multi-Trgt $w, acc/dcc, v, L$

Multi-Trgt $w, acc/dcc, v, L$

Multi-Target $w, acc/dcc, v, L$

Warning Algorithm - Optimal Decision Making

Subject-Veh. model

?Adaptive driver model For prediction?

Data Fusion Between Radar-Lidar, Video Camera & Vehicle Sensor

Frontal Collision Warning System
Therefore Wireless has become attractive ……. 

- **Prior Approach**: Needs multiple sensors and significant cost to achieve 360° coverage
- **Wireless Approach**: One transceiver per vehicle to achieve 360° awareness
We are cognizant of the substantial efforts by both government and non-government entities to develop, in response to Congress’ transportation legislation, a national ITS plan and Architecture addressing ways of using communication technologies to increase the efficiency of the nation’s transportation infrastructure. The record in this proceeding overwhelmingly supports the allocation of spectrum for DSRC based ITS applications to increase traveler safety, reduce fuel consumption and pollution, and continue to advance the nations economy.

FCC Report and Order, October 22, 1999, FCC 99-305
DSRC as per FCC Ruling in 2004

- DSRC has 75 MHz Spectrum (1 control channel, 6 service channels)
- DSRC supports the non-exclusive geographic area licensing
  - Each licensee can operate any of the service channels
  - A license is for an area-of-operation (e.g., county, state...)
- Control channel is for safety messages and service announcements
  - Three levels of priority: Safety of Life, Safety, Non-Safety
- The service channels are used for non-safety related data traffic (e.g. e-commerce, infotainment)
- ASTM standards committee voted in 2000 to base it on 802.11a
  - Now IEEE 802.11p

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DSRC Applications and Constituencies

- Vehicle-vehicle/roadside-vehicle safety messages
  - Automotive OEMs
    - Formed VSCC under CAMP (NHTSA)
  - DOTs
    - Formed Infrastructure Consortium (FHWA)
    - *Justifies free spectrum and a DOT role*

- Traffic Management, Signal priority or preemption, tolling
  - Thruway authorities, DOT’s, Toll tag industry (DSRC Industry Consortium)

- Drive-by Electronic Commerce, Infotainment
  - Gas stations, McDonalds, ...
  - Want licensed operation for cheap
WAVE Radio Module Interfaces

- Power Connector
- Ethernet Connector
- SMA Antenna Connector
- Cigarette Lighter Plug
- 12V Power Adapter
- SMA Antenna Connector

US: 5.25-5.35 GHz, 5.725-5.850 GHz
US DSRC: 5.85-5.925 GHz
DSRC OBE And RBE Connectivity

ON BOARD UNIT (OBU)

ROAD SIDE EQUIPMENT (RSE)

ON BOARD EQUIPMENT (OBE)

In-vehicle devices

WIRELESS LINK

ROAD SIDE UNIT (RSU)

COMPUTER

INTERNET And/or TMC

ISP?
Current Hardware Installation

- PC104 computer running QNX6 real-time Operating System
- Denso Wireless Access in Vehicular Environment (WAVE) Radio Module (WRM)
- Currently no outside communication outside except WRM (no backhaul)
Cooperative Collision Warning
Now:
Wireless for Active Safety Systems

- **Conventional Approach**: Needs multiple sensors – and significant cost – to achieve 360° coverage

- **Wireless CCW Approach**: One transceiver per vehicle to achieve 360° coverage
CCW System: Components and Architecture (2)

In-vehicle Display

Safety Applications

Forward Collision Warning

Blind Spot /Lane Change Assistant

Intersection Assistant

Neighboring Vehicle Map

Vehicle Data Exchange Protocol

Communication Protocol

Vehicle A

Vehicles B, C, D, E
Demonstrated CCW decision support to driver

- Forward direction
- Extendible to 360° decision support through symmetry

Right-side
In-Vehicle Display

- Position of CCW Vehicles
- State of Other CCW Vehicles
- Self State
- Heading
- Warning Diagnostic
- Satellites Received
Blind Spot/Lane Change Assistant
Cooperative Intersection Collision Avoidance Program
Infrastructure based sensors

Vehicle

Inputs

- Infrastructure state information (e.g. intersection type, signal state, etc);
- Vehicles state information (e.g. speed, position, etc);

State Map Generator

Predictors

- Gap predictor
- Stop predictor
- Conflict predictor

Future State Predictor

Future State

State map

Driver Interfaces

DII manager

Drivers

Outputs

Traffic Signal
Traffic sign. contr.
Traffic sign. manag.

In-vehicle display devices

In-vehicle sensors

Infrastructure based sensors

Signal controller
A Focus Area: Left Turn Across Path / Opposite Direction (LTAP/OD)
Schematic of California Approach

Characterize Intersection Driving
  • Roadside Observations
  • Driver Observations

Implement RFS Test Intersection

Develop Wireless Communication System

Evaluate COTS Technologies

Design IDS Alert System

Develop Simulation Tool

Develop DII

Driving Experiments At RFS Intersection

Diagram:

- Characterize Intersection Driving
  - Roadside Observations
  - Driver Observations
- Implement RFS Test Intersection
- Develop Wireless Communication System
- Evaluate COTS Technologies
- Design IDS Alert System
- Develop Simulation Tool
- Develop DII
- Driving Experiments At RFS Intersection
Observations and Experiments

- Characterizing Driver Behavior at Intersections
  - Four sites
    - Two in Berkeley
    - Pinole
    - Burlingame (near SFO)
    - San Francisco
  - Two approaches
    - Roadside
    - In-Vehicle
  - At least three warning algorithm approaches
    - Dynamic (Shladover)
    - “BMI-based”/Statistical (Ragland)
    - Neural net (Misener)
  - Transcends LTAP/OD
Instrumented Ford Taurus for Driving Data Collection

- Wireless connection from laptop to PC104 in traffic signal control cabinet
- Intended Field data collection and controlled tests at RFS
MLK Turning Left onto University
(+/- 15 m from stop bar & < 2 m/s)
PATH RFS Test Intersection

- Embedded Loop Detectors
- Traffic Controller Cabinet
- 60 Meters of 3M Microloops
- Signal Poles
- Radar Poles
Implementation at the PATH Intelligent Intersection
Elements of Cooperative System at the PATH Intelligent Intersection

• 40-ft Bus at PATH/RFS
  – DVI at driver console, with identical display for passengers
  – Wireless implementation of simultaneous DII and DVI
    • In practice, need not be simultaneous – a tricky research item
  – Demonstrated to Barbara Sisson, Associate Administrator for Research, FTA
We know the status of every communicating entity.
Vehicle-Intersection Wireless Testing – Current Status

- Wireless infrastructure used to communicate between vehicles and intersection (DSRC)
- DSRC test radios installed in vehicles and at intersection
- Messages exchanged with approaching vehicle
Providing Vehicle Information to Intersection

- GPS receivers installed in vehicles to obtain speed, position, and heading information
- Information transmitted to intersection to be relayed and used in alert generation
- Left turn alert issued by intersection in response to data received from vehicles and sensors placed at intersection
Relay of Traffic Signal Status to Vehicle

- Real time traffic signal status is relayed to vehicle
- Video shows display inside vehicle
Vehicle-Infrastructure Integration ↔ Vehicle-Highway Cooperation

- “Revolution” in ITS services
  - Traffic and highway management
    - Use of probe vehicles (traffic, weather, road surface condition)
  - Active safety warning systems
    - “Cooperative” safety (intersections, curves)
  - Crash and incident response
    - Immediate response and situational assessment
  - In-vehicle travel information
    - Dynamic route advisory, advance warning information, highway-rail intersection safety

Enabled by evolving communications technologies and standards – DSRC