Context-Aware Channel Coordination for DSRC

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Overview

- DSRC multichannel structure
- Channel Coordination and traffic density
- Empirical traffic density study
- Context-aware channel coordination
- Conclusions and open issues
The Promise of DSRC - Road Safety

• Vehicles routinely broadcast their position, velocity, acceleration using built-in DSRC communication system
• With the knowledge of nearby vehicles' status, the onboard DSRC alerts the driver of impending threats
• Drivers take actions in time to avoid accidents
Co-existence of Safety and non-safety

• To be viable, DSRC needs to support non-safety as well
  - E-toll, digital map, entertainment, etc.
• IEEE solution: multichannel structure
  - The 75MHz spectrum is divided into 7 non-overlapping channels
• Safety in control channel, non-safety in service channels
IEEE1609.4 Multichannel Operation

- Conventional radio operate with one channel at a time
- Safety/non-safety co-existence
  - Switch between safety interval and non-safety interval
- Synchronization through GPS
- Cyclic transmission
  - Safety tx followed by non-safety tx in a cyclic fashion
DSRC Shares in Cyclic Transmission

- Safety and non-safety share the limited DSRC resource
- Increasing non-safety share decreases safety share (and vice-versa)
- Shares are controlled by the length of safety/non-safety intervals
- IEEE1609.4 has not specified the values of these intervals
DSRC Shares in Cyclic Transmission

• Safety first
  - Safety applications have higher priority
  - The intervals have to be set to satisfy safety applications

• Sync Interval: 100ms
  - Vehicles must exchange status 10 times a second

• Safety Interval
  - Has a direct influence on reliability
  - Quantitative study through simulations
Simulation Results
Reliability vs. Safety Interval

- Larger the safety interval, lower the reliability
- For a target reliability, there exists a lower bound of safety interval
- Larger the traffic density, lower the reliability
Simulation Results
Safety Interval vs. Traffic Density

- To achieve a certain level of reliability, the safety interval is an increasing function of traffic density.
- Fixed interval value vs. context (density) aware.
- How does the density change in real world?
Traffic Data from Sydney Roads
Traffic Volume Data from RTA

• The Road and Traffic Authority (RTA) of NSW takes traffic survey in the Sydney region
• The survey results, Annual Average Daily Traffic (AADT) data, are released to the public
  - Pneumatic counter counting the # of vehicles passing the survey location
  - Data are recorded for each hour of day
    • traffic flow: vehicles/hour
• We need to estimate the traffic density (veh/km) from traffic flow (veh/hr)
From Flow to Density: Traffic Theory

- Traffic theory:
  \[ q = ku \]
  - \( k \): density (veh/km)
  - \( q \): flow (veh/hr)
  - \( u \): speed (km/hr)

- \(~k\) relationship varies with the traffic condition
  - Free flow: when density is low, vehicles move freely at constant speed, \( q \) increases with \( k \)
  - Congested flow: when density reaches a certain level, vehicle speed drops, \( q \) decreases with \( k \)

- For the case of free flow: density can be easily calculated

- 5 survey locations are selected for density calculation
  - 6-lane suburban roads
  - The traffic generally flows well (free flow is assumed)
Traffic Densities from two locations

- Three distinct categories: peak hours, off-peak hours, night hours
- The “three categories” pattern are found in all five locations
- The actual densities vary significantly across locations
- Traffic densities are highly dynamic in both time and space
Context (Traffic Density) - Aware

• If the channel coordination is not context-aware
  - Fixed safety interval for high density: resource wasted
  - Fixed safety interval for low density: reliability sacrificed

• Ideal context aware:
  - Safety intervals are adjusted by all vehicles in real time
  - Most resource efficient, but...
  - Difficult to achieve:
    • Measure the density in real time
    • All vehicles must have the same safety interval value
• The safety interval is set to satisfy the highest density of each category
• Use time-of-day context instead of traffic density context
  - Easy to achieve because it’s a global knowledge for all vehicles
  - But not efficient because densities are also dynamic in space
• Each location has its own “time-of-day” profile (safety interval rules)

• With the knowledge of the profile, vehicles can update the safety interval setting according to the rules for each location
Performance Evaluation

- Performance metric: Daily Non-Safety Share (DNSA)
  - At a given location, the daily DSRC air time available for non-safety use
  - Higher DNS, more efficient

- DNSA calculation: \( \sum_{i=1}^{24} \frac{t_i}{T} \)
  - \( t_i \): Safety interval at hour \( i \)
  - \( T \): Sync interval (100ms)
Performance Evaluation

- Ideal Adjustment
- Time-of-Day with Location Awareness
- Time-of-Day
- Static Safety Interval

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Conclusions and Open Issues

• Conclusions
  - Context-aware channel coordination can significantly increase the non-safety use of DSRC
  - Time-of-day with location awareness scheme is resource efficient and easy to implement

• Open issues
  - The time-of-day profile for each location is based on average measurement, how to deal with burst density?
  - How to prevent out-of-sync when vehicles are at the boundary of to locations?