How Much of DSRC is Available for Non-Safety Use?

Zhe Wang and Mahbub Hassan
School of Computer Science and Engineering
University of New South Wales, Sydney, Australia

Overview

- Understanding DSRC multichannel structure
- Formulation of non-safety share of DSRC
- Simulation experiments
- Observations and conclusions
The Promise of DSRC

Could road-accident be the thing of the past?

- 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 & Non-Safety

- To be viable, DSRC needs to support non-safety as well
  - E-toll, music download, etc.
- Non-safety should not interfere with safety
- IEEE solution: multichannel structure for DSRC
  - Divides entire DSRC spectrum into 7 non-overlapping channels
- Safety on control channel (CCH), non-safety on service channels (SCH)
IEEE 1609.4 Multi-Channel Operation

- Conventional radios operate with one channel at a time
- Safety-non-safety coexistence → switch bw CCH/SCH
  - vehicles must switch to CCH several times a second
- 1609.4 requires all vehicles to synchronize the switching
  - Concept of Sync Interval (SI) which in turn is divided into CCH interval (CCHI) and SCH interval (SCHI)
- Result: cyclic transmission
  - Safety tx followed by non-safety tx in a repetitive fashion

1609.4 has not specified values for these intervals

---

DSRC Shares in Cyclic Transmission

- Safety and non-safety share the limited DSRC resource
- Increasing non-safety share decreases safety (vice-versa)
- Shares are strictly controlled through CHI/SCHI/SI
- Non-safety share = \( SCHI/SI \), safety = \( CHI/SI \)
  - Note that \( SCHI+CHI=SI \) (ignoring GI)
- 1609.4 has not specified values for these intervals
Safety First

- Performance of safety has to be guaranteed
- Selection of SI and CHI has performance implications for safety applications

How SI relates to safety performance?

- Concept of updating frequency
  - Vehicles must exchange status $f$ times a second
  - Must switch to CCH $f$ times a second $SI = \frac{1}{f}$
  - Most researchers believe that $f=10$ $SI=100\text{ms}$
  - Setting SI=100ms guarantees that every vehicle will get a chance to broadcast its status every 100ms
How CCHI relates to safety performance?

Concept of reliability

- SI=100ms is only part of the safety requirement
- A safety broadcast may get lost due to collision
  - DSRC is contention based (CSMA/CA - 802.11p)
  - ACK/Retx and RTS/CTS not applicable to broadcast
- CCH interval has a direct influence on reliability
- Larger the CCHI, lower the collision probability
- Reliability req. imposes a lower bound on CCHI

How Much of DSRC is left for non-safety?

- Set CCHI to the lower bound (CCHI_min)
  - Maximize non-safety share

\[
\frac{SCHI}{SI} = \begin{cases} 
\frac{1}{f} - \frac{CCHI_{\text{min}}}{f}, & CCHI_{\text{min}} < \frac{1}{f} \\
0, & \text{otherwise}
\end{cases}
\]

- The share could be ZERO!
Simulation Experiments

Simulation
DSRC patch for *Qualnet* simulator

- **MAC/PHY parameters** (802.11p)
  - Carrier frequency: 5.9GHz
  - Channel bandwidth: 10MHz
  - Symbol duration doubled

- Add-on module for multi-channel (IEEE 1609.4)

- Broadcast packets generator/collector
  - Generate 100-byte pk uniformly distributed in [0, CCHL]
  - $f = 10$Hz
Simulation Vehicular Environment

- Simulate a 1km long, 4-lane road
  - Long enough to capture hidden node effects
  - Statistics collected for central 200m (avoid edge effect)
- Varying traffic density
  - average # of nodes in tx range (200m): 40, 80, and 160
  - at 160, vehicle-vehicle gap is about 10 meters
- Reliability calculated at 100m from the transmitter

Simulation Results
Reliability as a function of CCHI

CCHI (ms)

50 60 70 80 90 100

n=40
n=80
n=160

Theoretical bound for CCHI: 0.25n
Simulation Results
How reliability is linked to non-safety share

Non-safety Share (k=1)

- 50-50 share at low traffic density
- A mere 10% at medium density
- Non-safety not possible (high density) when needed most!

How good is a 10% share?
Simulation of music download

- MP3 file download (FTP)
  - 3.65MB (128kbps, 4min)
  - Data rate: 27Mbps
- Download takes 20 sec
- At 90kph, vehicle travels 500m in 20 sec.
- 10% share could be good for nothing if road-side-units have less than 500m coverage!
- Situation gets worse when SCH is shared by multiple vehicles
Is there any hope?
Simulation of redundant broadcasting

Non-safety share jumps from 10% to 50% in medium density traffic (95% reliability)

Non-safety share (optimal k)

Observations and Conclusions

- Non-safety use of DSRC may have to be restricted in peak hours when it is needed most
- In peak hours, it may not be even possible to support safety, let alone non-safety (reliability requirements)
- Broadcast reliability will be a key research issue
- Improving 802.11 broadcast reliability not only helps automotive safety, but also maximizes the commercial use of DSRC

THANK YOU