Performance Evaluation of Inter-vehicle Packet Relay for Fast Mobile Road-vehicle Communication

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Outline

- Background & goal
- Problems of road-vehicle communication in fast mobile environments
- Our inter-vehicle packet relay technique
- Simulation results
- Conclusion
Background & goal

Background:

• Road-vehicle communication on highways
  – Applications: safety services, location-aware services, content delivery etc
  – Requirements:
    • High throughput
    • Wide communication coverage

Goal:

• To satisfy the above requirements
Problems of road-vehicle communication in fast mobile environments

- Mobile stations (MSs) have to connect to fixed roadside access points (APs).

- Large relative speed between MSs and APs causes ...
  1. Time-varying fading caused by large Doppler shift
  2. Wide dynamic range of path loss
  3. Short period of being within coverage of an AP
Problems of IEEE802.11a WLAN in fast mobile environments

- Long frame transmission
- Time-varying fading by Doppler shift
- Not correctly compensated!

As moving speed increases, transmission rate decreases
Proposed method: **Inter-vehicle packet relay technique**

Receiving packets via other, slower vehicles

**Relative speed per hop decreases**

\[ V_{MS} > V_{RS} >> (V_{MS} - V_{RS}) \]

- Reducing Doppler shift
- Reducing dynamic range of path loss

Channel-quality improvement => Increased throughput and coverage

RS: Relay Station
## Simulation parameters

### IEEE802.11a WLAN

<table>
<thead>
<tr>
<th>Parameters</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Frequency band</td>
<td>5GHz</td>
</tr>
<tr>
<td>Data length</td>
<td>1500 Bytes</td>
</tr>
<tr>
<td>Transmission power</td>
<td>12 dBm</td>
</tr>
<tr>
<td>Noise figure</td>
<td>10 dB</td>
</tr>
<tr>
<td>Overhead per frame</td>
<td>96 μsec</td>
</tr>
<tr>
<td>Overhead for handover</td>
<td>100 msec</td>
</tr>
<tr>
<td>Moving speed of MS/RS</td>
<td>100 / 80 km/h</td>
</tr>
<tr>
<td>RS interval (crowded and not)</td>
<td>100 / 400 m</td>
</tr>
<tr>
<td>AP interval</td>
<td>100 ~ 2000 m</td>
</tr>
<tr>
<td>AP / vehicle height</td>
<td>6 / 1.5 m</td>
</tr>
<tr>
<td>Lane width</td>
<td>3.5 m</td>
</tr>
<tr>
<td>Route selection phase</td>
<td>5 msec</td>
</tr>
</tbody>
</table>

[Diagram of IEEE802.11a WLAN network with vehicles and APs]
Simulation model

- The observed MS ran from $P_1$ to $P_2$, adaptively choosing a communication route that maximizes the throughput from an AP to the MS (including direct route from AP).
- RSs ran with constant speed and equal intervals.

**Diagram:**

- Lane 1 (RSs): 100-2000m
- Lane 2 (MS): 100/400 m
- $V_{RS}=80\text{km/h}$
- $V_{MS}=100\text{km/h}$
Geometric propagation model

Received signal=
+ a direct path
+ a road reflection path
+ several delay paths

Sharply fluctuated
Simulation result: connected time (coverage metric)

- Time during which frame success rate of the MS exceeds 5%
- Frame success rates of both links of two-hop routes have to be over 5%

Increased communication coverage
Simulation result: average throughput (quality metric)

Average throughput $\theta_{AV}$ is given by

$$\theta_{AV} = \frac{1}{D_{RS}} \int_0^{D_{RS}} \frac{Nl}{t(p_{23}) - t(p_{12})} \, dx.$$ 

- All possible default positions of RSs are considered
- $t(p)$: time when MS is at position $p$
- $D_{RS}$: RS interval
- $N$: number of success frames
- $l$: data length

Normalized by conventional method only using direct route

Increased average throughput
Conclusion

• Inter-vehicle packet relay technique for road-vehicle communication in fast mobile environment
  Reducing relative speed
  – Improved channel quality
  – Increased throughput and communication coverage

• Future work
  – Testing our method in multi-user environment
    • MAC
    • Route selection algorithm

[IEEE Globecom06, IEICE Trans vol.E90-B no.9, IEEE CCNC08]
Thank you for your attention.
Problems in multiple access environment

What problems are caused?
   Frame collision
   Interference

Solutions to avoid the frame collision are
   [Between neighboring areas]
   – To assign different channels to neighboring areas
   [Within coverage of a single AP]
   – To use point coordination function (PCF)
   – To limit number of hops to two

But … there is still an interference problem.
Interference problem

- Comparison with conventional method
  - Additional interference by RSs between neighboring areas

- Features of our method
  - Seldom choosing the RSs near the border and far from AP due to low transmission rate
  - Ability to shorten MSs' transmission time per frame by choosing RS-MS links of high transmission rate

![Diagram showing interference problem with APs, channels, and RS-MS links]
Evaluation results:
Interference between neighboring areas

Normalized by conventional method only using direct route

Our method does not cause additional interference between neighboring areas.