A HiperLAN/2 based MAC Protocol for Efficient Vehicle-to-Infrastructure Communication using Directional Wireless Mesh Backbone

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Introduction: Smart Antenna based Vehicular Network

Figure: Smart Antenna based Vehicular Network
Vehicle to Infrastructure Communication
Introduction: Smart Antenna based Vehicular Network

- Vehicle to Infrastructure Communication
- Wireless Mesh Backbone: Advantages:
Vehicle to Infrastructure Communication

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Vehicle to Infrastructure Communication

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Vehicle to Infrastructure Communication

Wireless Mesh Backbone: Advantages:

- The wired backbone is replaced with wireless mesh backbone. This reduces network management cost and increases network reliability and scalability.
- The wireless mesh backbone gives the advantage of increased coverage with easy and low-cost deployment.
- Use of smart antenna at wireless mesh backbone increases the capacity of the network with similar coverage that of omni-directional antenna.
Protocols for Mesh Backbone

- IEEE 802.11s Mesh Standard
Protocols for Mesh Backbone

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- Static TDMS (STDMA) Network
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- IEEE 802.11s Mesh Standard
- Static TDMS (STDMA) Network
- Dynamic TDMA Network: HiperLAN, HiperLAN/2
The IEEE 802.11 based MAC protocol faces severe deafness, head-of-line blocking and hidden terminal problems with directional antenna based wireless mesh and ad-hoc network which degrades overall network throughput. Directional Network Allocation Vector (DNAV) based solutions can solve deafness problem, however, the network capacity is underutilized because of MAC layer capture problems.
The IEEE 802.11 based MAC protocol faces severe deafness, head-of-line blocking and hidden terminal problems with directional antenna based wireless mesh and ad-hoc network which degrades overall network throughput. Directional Network Allocation Vector (DNAV) based solutions can solve deafness problem, however, the network capacity is underutilized because of MAC layer capture problems.

Direct STDMA based MAC protocols are not well suited for vehicular networks because of dynamic traffic load. A conflict free STDMA schedule has to be generated based on network traffic load, which is a hard problem to solve with partial network information.
Figure: HiperLAN/2 Frame Format
Figure: Communication Framework
 Beam Scheduling for Directional Mesh Backbone

- Interface Estimation
Beam Scheduling for Directional Mesh Backbone

- Interface Estimation
- Communication Scheduling
Let, Number of interfaces to be used for vehicular communication $= I_v$ and Number of interfaces to be used for mesh forwarding $= I_f$
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So, $I = I_v + I_f$
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So, $I = I_v + I_f$

Total uplink request received from vehicular clients in previous RCH = $r^u_v$
Let, Number of interfaces to be used for vehicular communication $= I_v$ and Number of interfaces to be used for mesh forwarding $= I_f$

So, $I = I_v + I_f$

Total uplink request received from vehicular clients in previous RCH $= r_v^u$

Total downlink requests pending at the interface queues (for different vehicular clients) $= r_v^d$
Let, Number of interfaces to be used for vehicular communication = $I_v$ and Number of interfaces to be used for mesh forwarding = $I_f$

So, $I = I_v + I_f$

- Total uplink request received from vehicular clients in previous RCH = $r_u^v$
- Total downlink requests pending at the interface queues (for different vehicular clients) = $r_d^v$
- Total request received from neighboring mesh points for data forwarding = $r_f$
Let, Number of interfaces to be used for vehicular communication = \( I_v \) and Number of interfaces to be used for mesh forwarding = \( I_f \)

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Total downlink requests pending at the interface queues (for different vehicular clients) = \( r_v^d \)

Total request received from neighboring mesh points for data forwarding = \( r_f \)

Total requests for traffic forwarding to neighboring mesh points = \( r_v^u + r_f \)
Let, Number of interfaces to be used for vehicular communication = \( I_v \) and Number of interfaces to be used for mesh forwarding = \( I_f \)

So, \( I = I_v + I_f \)

Total uplink request received from vehicular clients in previous RCH = \( r^u_v \)

Total downlink requests pending at the interface queues (for different vehicular clients) = \( r^d_v \)

Total request received from neighboring mesh points for data forwarding = \( r_f \)

Total requests for traffic forwarding to neighboring mesh points = \( r^u_v + r_f \)

Total load for traffic forwarding = \( 2 \times (r^u_v + r_f) + r^d_v \). For relayed traffic, the mesh point has to receive data from its neighboring mesh points, and then has to forward it. So \( 2 \times r_f \) amount of traffic load is added. Similar logic is applicable for uplink data. However, for downlink data, only \( r^d_v \) amount of load is added, because traffic is already received by the mesh point.
The value of $I_v$ and $I_f$ can be obtained from equation (1) and equation (2) respectively.

$$I_v = \frac{r_v^u + r_v^d}{2 \times (r_v^u + r_f) + r_v^d}$$  \hspace{1cm} (1)

$$I_f = \frac{r_v^u + 2 \times r_f}{2 \times (r_v^u + r_f) + r_v^d}$$  \hspace{1cm} (2)
Interface Estimation

As discussed earlier, the DiL phase overlaps with UL phase and DL phase. However, the UL Phase and DL phase is separated using TDD. The length of UL phase ($L_{ul}$) and the length of DL phase ($L_{dl}$) can be estimated using equation (3) and equation (4) respectively.

$$L_{ul} = \frac{r_v^u}{r_v^u + r_v^d}$$  \hspace{1cm} (3)

$$L_{dl} = \frac{r_v^d}{r_v^u + r_v^d}$$  \hspace{1cm} (4)
Communication Scheduling: Circular Arc Graph Coloring

Figure: Circular-Arc Graph
## Simulation Setup

**Table: Simulation parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Antenna Properties</strong></td>
<td></td>
</tr>
<tr>
<td>SNIR Threshold</td>
<td>4 dB</td>
</tr>
<tr>
<td>Transmit Power</td>
<td>2.0 mW</td>
</tr>
<tr>
<td>Main Lobe gain</td>
<td>7 dB</td>
</tr>
<tr>
<td>Side Lobe gain</td>
<td>-5 dBi</td>
</tr>
<tr>
<td>Beam Width</td>
<td>20°</td>
</tr>
<tr>
<td><strong>Channel Properties</strong></td>
<td></td>
</tr>
<tr>
<td>Number of Channels</td>
<td>1</td>
</tr>
<tr>
<td>Channel Carrier Frequency</td>
<td>5.2 GHz</td>
</tr>
<tr>
<td>Channel Encoding’</td>
<td>64-QAM</td>
</tr>
<tr>
<td>Channel coding rate</td>
<td>3/4</td>
</tr>
<tr>
<td>Data rate</td>
<td>54 Mbits/s</td>
</tr>
<tr>
<td><strong>Client Mobility</strong></td>
<td></td>
</tr>
<tr>
<td>Mobility Type</td>
<td>Highway Mobility</td>
</tr>
<tr>
<td>Mean Vehicular Speed</td>
<td>2.0 m/s</td>
</tr>
<tr>
<td>Acceleration</td>
<td>Random(+0.5m/s,-0.5m/s)</td>
</tr>
<tr>
<td><strong>Application layer Traffic</strong></td>
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</tr>
<tr>
<td>Traffic Type</td>
<td>CBR</td>
</tr>
<tr>
<td>Transport Protocol</td>
<td>UDP</td>
</tr>
<tr>
<td>Traffic Generation Rate</td>
<td>1Mbps</td>
</tr>
</tbody>
</table>
Simulation Results

Figure: Average Network Throughput
Simulation Results

Figure: Effect of Client Mobility
Simulation Results

Figure: Average per flow Packet Delay for Uplink Traffic
Figure: Average per flow Packet Delay for Downlink Traffic
Simulation Results

Figure: Average per flow Fairness Index for Uplink Traffic
Simulation Results

Figure: Average per flow Fairness Index for Downlink Traffic
Simulation Results

Figure: Average Percentage of CPT
A new framework is proposed for efficient vehicle infrastructure communication.
Conclusion

- A new framework is proposed for efficient vehicle-to-infrastructure communication.
- HiperLAN/2 Protocol is extended to suit the proposed framework.
Conclusion

- A new framework is proposed for efficient vehicle to infrastructure communication.
- HiperLAN/2 Protocol is extended to suit the proposed framework.
- Simulation results show the effectiveness of the proposed framework.
THANK YOU!

QUESTIONS?