Contextual Pedestrian-to-Vehicle DSRC Communication

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Pedestrian Safety

Credit: youtube.com/carcrasheshweekly
Reports say..

- National Highway Traffic Safety Administration:
  - 4884 pedestrians are killed in 2014 in the US
  - ~65000 pedestrians are injured

- World Health Organization (WHO):
  - 1/3 of all vehicle involved fatalities are pedestrians
Sensor-Based Technologies

**LIDAR**

**RADAR**

Camera-based detection

Primary limitation:
Need Line-of-Sight to work!
Communication-Based Safety Systems

- RFID Tags
  - A proximity detection technique, uses Road Side Units to detect pedestrians
  - Communication range is short

- DSRC-based communication:
  - Vehicle-to-Vehicle communication standards have been under development for many years
  - DSRC-enabled smartphones are going to be available at no additional cost
  - Communication range is up to several hundred meters
DSRC–Based Safety Systems

Demo Credit: West Virginia University and Hyundai
Research Question

• What if there are many other pedestrians around?
  • What would the channel load look like?

• Is the system still reliable?
  • Channel congestion control (CCC) is needed

• Does everybody need to be monitored equally?
  • Application requirement should be considered
  • Most V2V congestion control algorithms are not able to consider application requirements
  • European CCC standards suffer channel load oscillation

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  - Most V2V congestion control algorithms are not able to consider application requirements
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Case Study and Scenarios

- performance of a P2V link depends not only on the channel propagation environment
  - aggregated interference from other transmitters
- The case study has to be a crowded, yet realistic scenario
- Times Square is identified as one of the priority intersections in city government safety action plan
  - AND it’s crowded!
  - It is located at the center of the Manhattan Killed and Severely Injured (KSI) heat map
Case Study and Scenarios (Cont.)

We used SUMO simulator to generate pedestrian and vehicle traffic for the Times Square neighborhood

• How we did it:
  • Random trip with experimental parameter calibration
    • i.e. Parameters such as the density of nodes at the center of the map
  • Compare the result with the photos to validate
    • i.e. The number of pedestrians crossing a street per minute
Pedestrian-Vehicle Accident Scenarios

1. A vehicle moves straight with a pedestrian walking against/along traffic

2. A pedestrian crossing the street where could be hidden by objects, leaving not enough time for the vehicle to brake once detected

→ These scenarios represent almost 67\% of the total pedestrian fatalities [1]

Propagation Environment

1. **No Building Shadowing (NBS):**
   If the direct path between two transceivers does not intersect any of the building edges

2. **Building Shadowing (BS):**
   If two transceivers are sharing an intersection, while blocked by two adjacent edges of a building

3. **Building Blocked (BB):**
   The link between two transceivers is blocked by a building without sharing an intersection.
Transmission Trigger Policies

• Technology assumptions:
  - Recognize outdoor environment (O)
  - Movement detection (M)
  - Approaching road detection (A)
  - In-vehicle phone detection (I)

• Algorithms:
  - Baseline (O,I): Everybody transmits
  - MovingPed (O,I,M): Moving pedestrians transmit
  - Multiple Tx Rates (O,I,M): Moving and stationary, but with diff. rates
  - In-StreetPed (O,I,A): Pedestrians inside streets transmit
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Rate = $r_1$ Hz
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Rate = r₁ Hz
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Rate = $r_1$ Hz
Rate = $r_2$ Hz
$r_2 < r_1$
Transmission Trigger Policies

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Rate = r₁ Hz
Simulation Settings

- Channel load measured every 100ms over all nodes
- Simulation time = 10sec

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Transmission Power</td>
<td>20 dBm</td>
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<tr>
<td>Cenergy Detection Threshold</td>
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<tr>
<td>Noise Floor</td>
<td>-98 dBm</td>
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<td>CW min</td>
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<td>AIFSN</td>
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<tr>
<td>Packet size</td>
<td>316 bytes</td>
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<tr>
<td>Data Rate</td>
<td>6 Mbps</td>
</tr>
<tr>
<td>Transmission Power</td>
<td>10 dBm</td>
</tr>
</tbody>
</table>
Performance Metrics

• Packet Error Ratio (PER)
  – the ratio of the number of missed packets at a receiver from a particular transmitter to number of packets sent by that transmitter

• 95th Percentile Inter-Packet Gap (95% IPG)
  – Near worst-case elapsed time between successive successful packet receptions from a particular transmitter

• Channel Busy Percentage (CBP)
  – the percentage of the time during which the wireless channel is busy over the period of time during which CBP is being measured
    – Sampling is done every 100 msec
    – Averaged all samples over simulation time
Evaluation – Channel Load

Average CBP over 10 seconds of simulation for different rates and different transmission trigger

- The channel easily gets over saturated when the frequency of safety message transmission grows.
- Can pedestrian performance targets be met in crowded environments?

![Graph showing CBP for different rates and transmission triggers.]

<table>
<thead>
<tr>
<th>Rate</th>
<th>20%</th>
<th>40%</th>
<th>60%</th>
<th>80%</th>
<th>100%</th>
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<tbody>
<tr>
<td>On-StreetPed</td>
<td></td>
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<tr>
<td>MovingPed</td>
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<tr>
<td>Baseline</td>
<td></td>
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<tr>
<td>MulTxRates</td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>
Evaluation – Performance Metrics

Packet Error Ratio

Baseline
On-StreetPed
MovingPed
MulTxRates*

95% IPG (sec.)

Baseline
On-StreetPed
MovingPed
MulTxRates*
Impact of Link Type on the Performance

Special Case: The pedestrian *is not in the driver’s sight* when the first situation awareness transmission is needed

- the system functionality might mostly rely on BS links
- 40% to more than 100% jump in 95th% IPG
Conclusion & Future Work

• We designed and validated a realistic high-density scenario

• We evaluated the channel load under different trigger policies
  - Can vulnerable road user performance targets be met in crowded environments?
  - Significant potential exist to improve the network performance through context-aware transmissions policies

• On going phase of the project is considering feasible contextual trigger policy design.
Thank You