High-Fidelity Application-Centric Evaluation Framework for Vehicular Networks

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Desired Capabilities of Evaluation Technique (I)

- **Realism**: capability of
  - running operational softwares
  - real applications, protocol implementations
  - setting up close to reality physical environment
  - distribution of roadside units and vehicles, mobility, wireless channel

```
simulation  emulation  physical testbed
```

realism
Desired Capabilities of Evaluation Technique (II)

- **Flexibility**: easiness and cost to
  - realize various scenarios
  - normal day-to-day operation, congestion, failure, emergency
  - evaluate application and protocol at different stages
  - algorithm design, prototype, deployment
Comparison of Evaluation Techniques

- **physical testbed**
- **emulation**
- **simulation**

- **realism**
- **cost**
- **flexibility**
Related Work

• Physical testbeds
  • Drive-Thru (TZI), CalTel (MIT), [Wu,VANET’05] (Gatech), InMotion (Intel Research Cambridge), FleetNet (IBR)

• Simulators
  • GrooveSim (CMU), ns-2 (ISI), QualNet (SNT)
Our Approach

Hybrid emulation testbed TWINE

- Run real application
- Simulate or Emulate protocol stack
- Simulate physical environment
  - Incorporate real deployment data of roadside APs, vehicle mobility traces
WHYNET Testbed: TWINE System Architecture

[Zhou et al, Infocom’06]
Use Case

- Execute real applications by emulating end hosts
- Model large scale vehicular networks by simulation
- Run prototype/deployment by having emulated or physical subnets
Realistic Physical Environment

• Represent realistic vehicle mobility
  • Vehicle movement traces
    • e.g. 24-hour movement pattern of a total number of 259,978 vehicles in Switzerland (area of 41,559 km²)
      [lst.inf.ethz.ch/ad-hoc/car-traces]

• Represent realistic vehicular network topology
  • Road maps [map.search.ch/index.en.html]
  • GPS coordinates of currently deployed APs [www.jiwire.com], [www.wifimaps.com]

• Represent wireless channel effects
  • e.g. multi-path fast fading in urban environment, impact of vehicle speed on channel
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Application-Centric Evaluation
Measure PSNR of Streaming Video

- Peak Signal to Noise Ratio (PSNR)

\[
PSNR = \frac{\text{max. power of a video signal}}{\text{power of corrupting noise}}
\]

Simulated multi-hop vehicular network

Original video clip → Displayed video clip

Emulated end host

Original

Displayed

VirtualDub

Wavelet

PSNR
Experiment Setup

- Examine PSNR of video streaming application
  - Video streaming application: VLC
  - Network-layer routing protocols: AODV and GPSR
  - MAC/PHY rate adaptation: fixed rate (11 Mbps) and Auto Rate Fallback (ARF)

**Experiment parameters**

<table>
<thead>
<tr>
<th>Vehicular Network Environment Parameters</th>
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<tbody>
<tr>
<td>Vehicle topology (mxm)</td>
<td>10x2000</td>
</tr>
<tr>
<td>Vehicle density (nodes/area)</td>
<td>23, 45, 91</td>
</tr>
<tr>
<td>Vehicle average speed (m/s)</td>
<td>30</td>
</tr>
<tr>
<td>Vehicle relative speed (m/s)</td>
<td>0 - 6</td>
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<table>
<thead>
<tr>
<th>Workload Parameters</th>
<th></th>
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<tr>
<td>Video rate (Kbps)</td>
<td>56, 112, 256</td>
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<tr>
<th>Channel Fading Parameters</th>
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<tbody>
<tr>
<td>Fading model</td>
<td>no fading, Rayleigh</td>
</tr>
<tr>
<td>Max fading velocity (m/s)</td>
<td>15, 30, 60</td>
</tr>
</tbody>
</table>
Direct & Reliable Application Performance Results

- Difficult to correlate perceived video quality with throughput, delay, jitter and loss
- Hard to discriminate performance difference between AODV and GPSR

- Better video quality at high PSNR
- AODV outperforms GPSR

100dB, no distortion

PSNR: AODV  PSNR: GPSR

AODV vs. GPSR: network-level performance
New Insights into Cross-layer Interaction (I)

AODV: PSNR at different video rates w/ and w/o ARF

- Application requirements play a role in determining how the use of rate adaptation affects performance of routing protocols
- Performance of AODV improved by ARF at video rates 56 and 112Kbps
- At high video rate 256Kbps, ARF decrease performance of AODV
AODV: throughput and loss w/ and w/o ARF

- Application awareness is important in determining rate adaptation strategy
- Random loss by the use of ARF reduces application-level performance of AODV
GPSR: PSNR at different video rates w/ and w/o ARF

- Performance of rate adaptation is influenced by mix of application requirements and operation details of routing protocol
- Routing and rate adaptation should share information
Impact of vehicle density on application-level performance depends on the specific choice of routing protocol.

- Little impact on AODV
- GPSR performance decreases significantly as density grows
- Choosing stable links exhibits high resilience to density variation

Impact of Physical Environment

PSNR of AODV and GPSR at different vehicle densities
Conclusions

• Propose high-fidelity application-centric evaluation framework for vehicular networks
  • Contain high realism and flexibility
  • Enable application-centric evaluation
• Demonstrate benefits of evaluation framework by measuring PSNR of video streaming
  • Produce direct and reliable application performance results
  • Provide new insights into cross-layer interaction
Ongoing Work

- Integrate transportation simulator with network simulator
  - Provide close-loop interaction between transportation and network simulation
- Realistically represent radio and wireless channel in vehicular networks
- Include vehicular network specific applications, network architectures and protocols
Thank You!

Questions or Comments?