

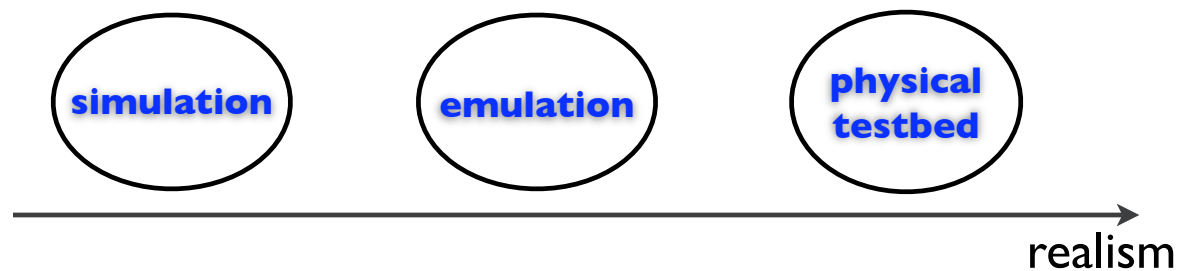
# High-Fidelity Application-Centric Evaluation Framework for Vehicular Networks

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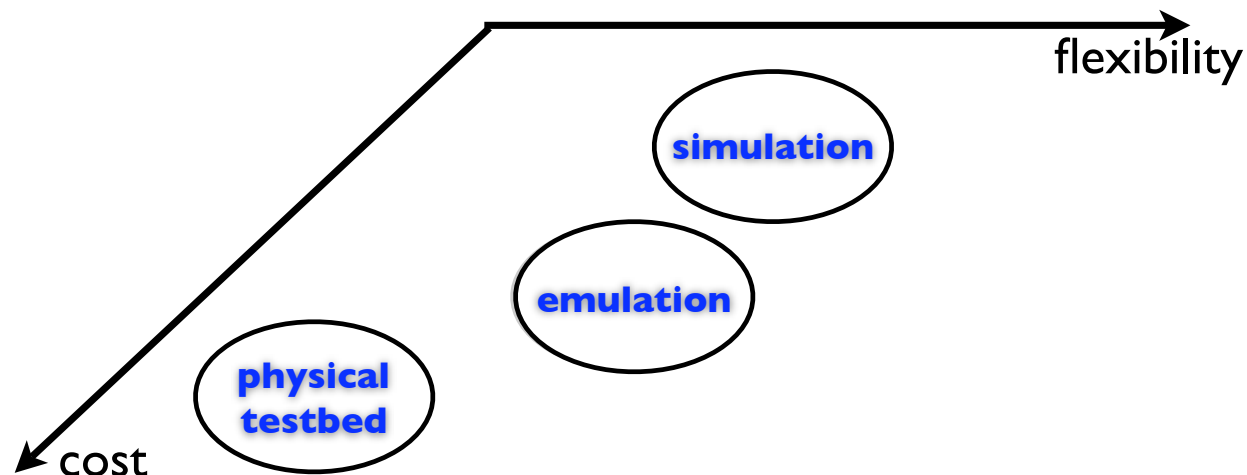
# Desired Capabilities of Evaluation Technique (I)

- **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

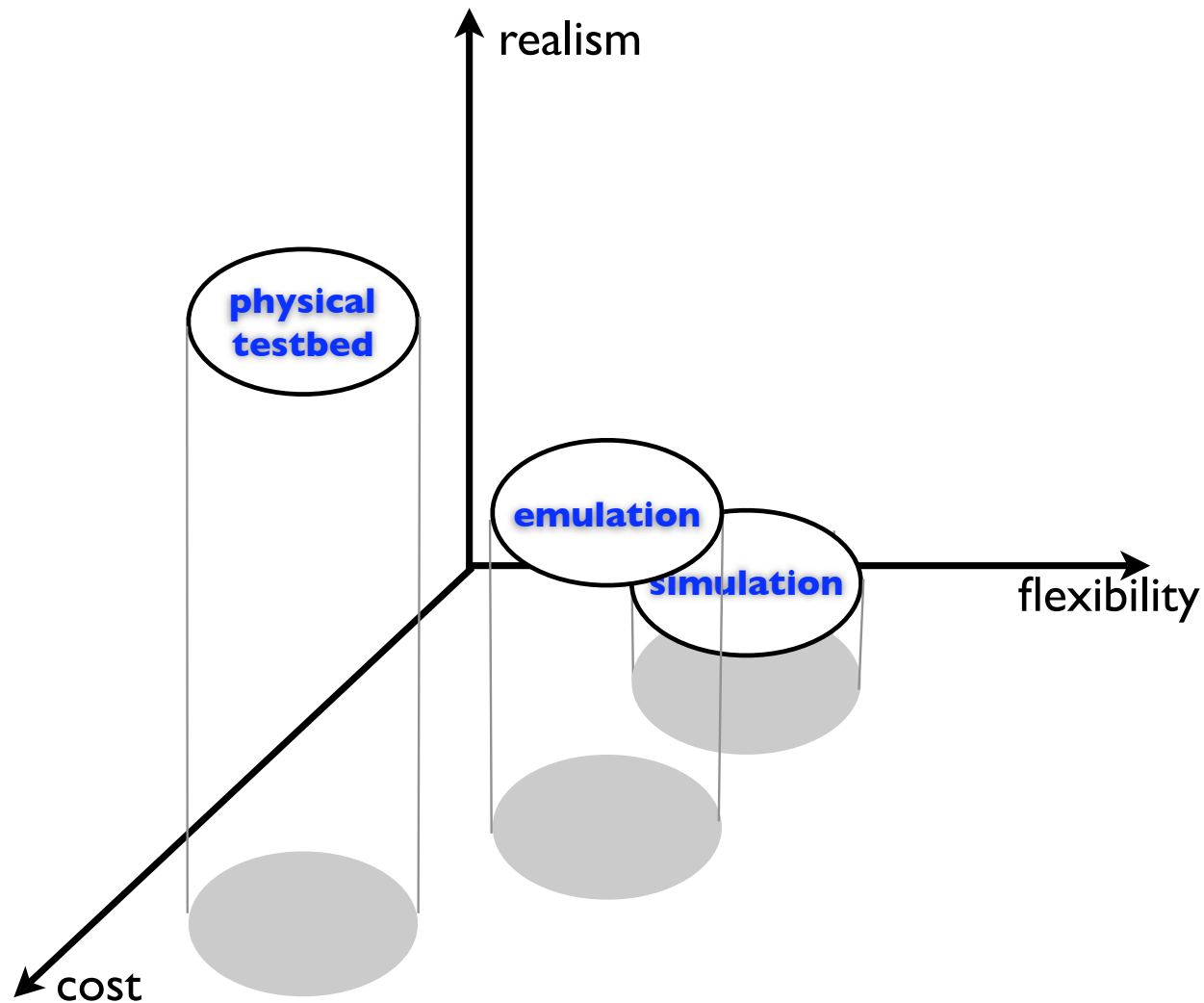


# Desired Capabilities of Evaluation Technique (II)

- **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



# 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*)

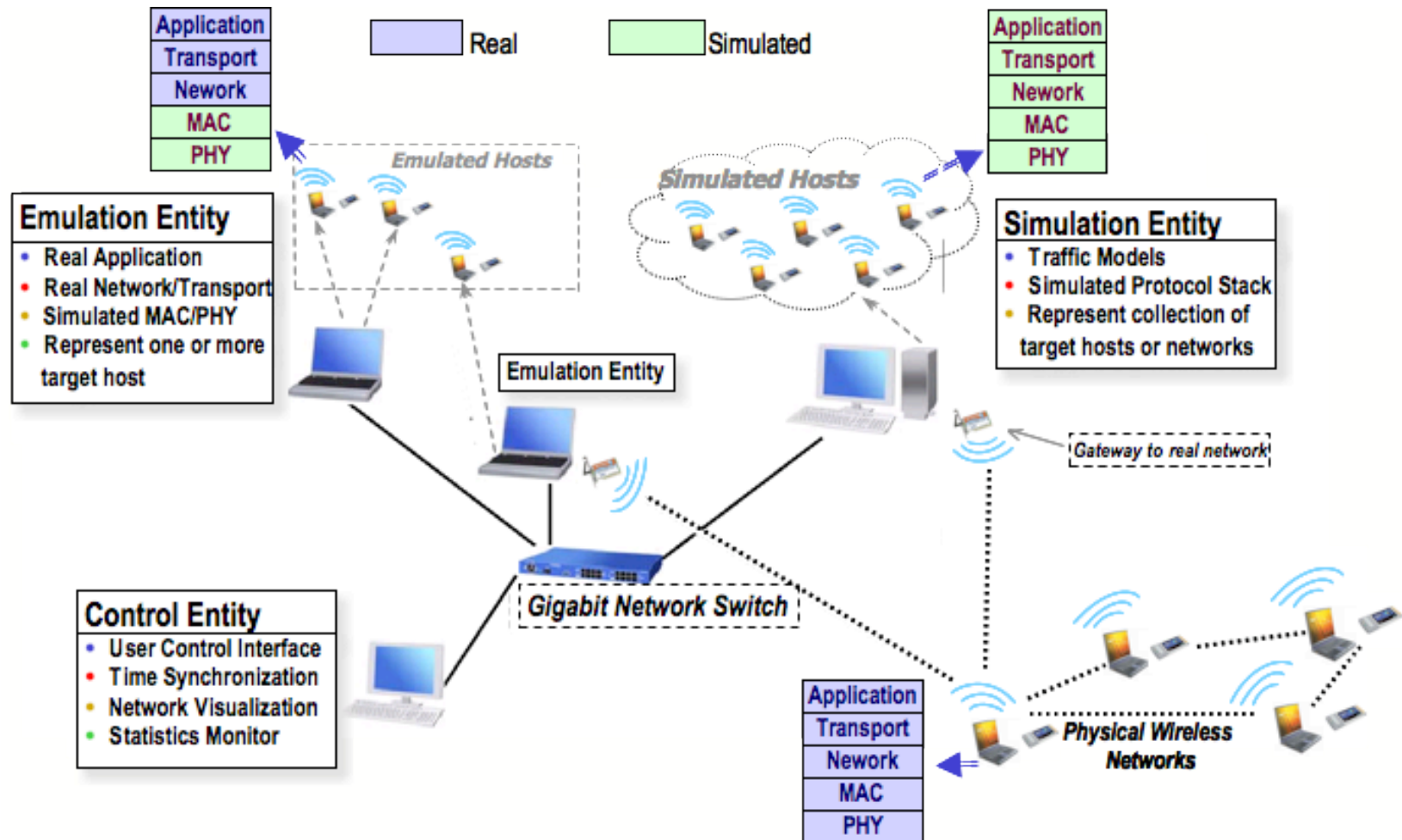
# Our Approach

## 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

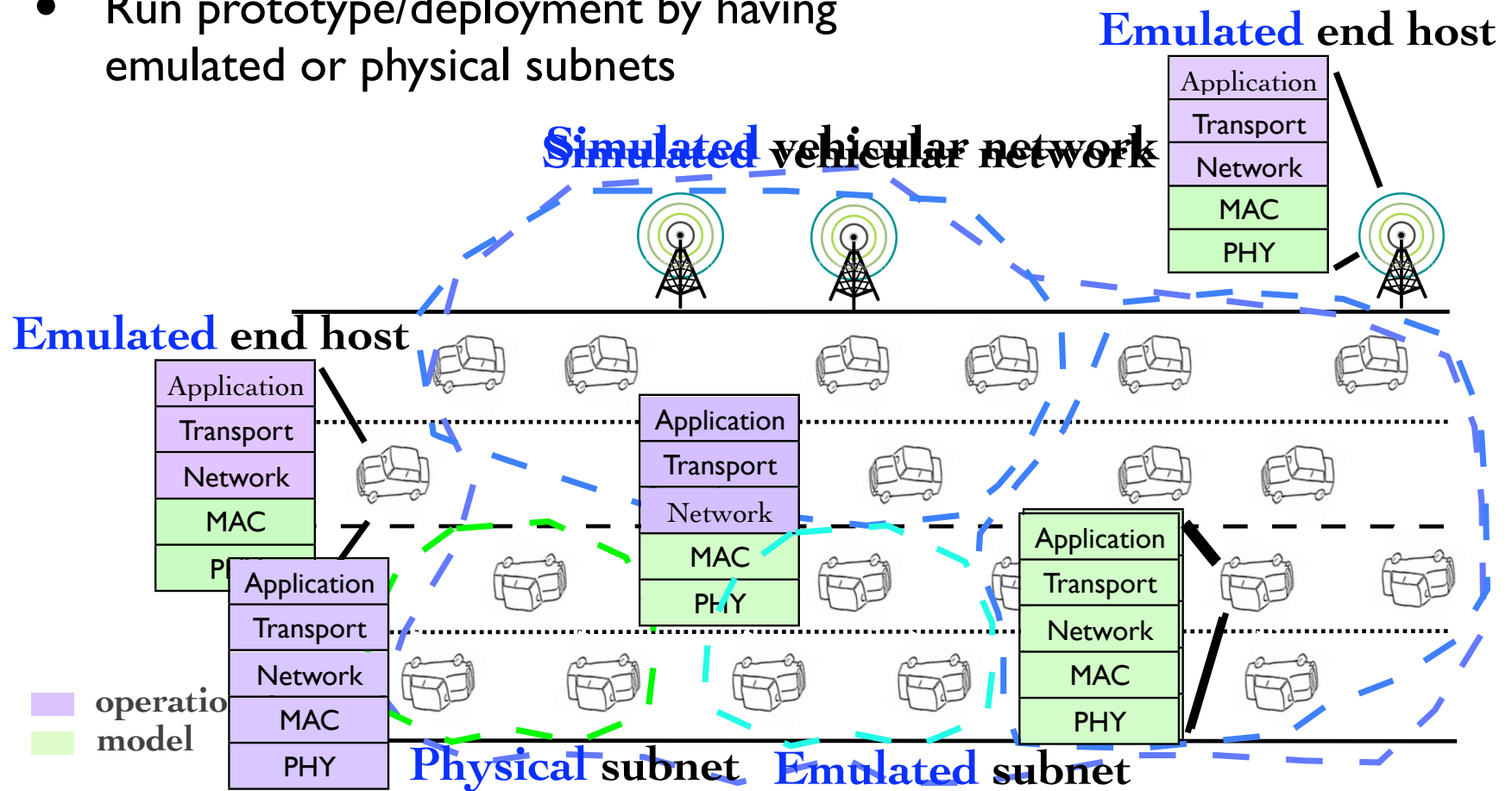
# WHYNET Testbed: TWINE System Architecture

[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



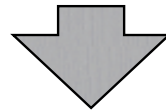
# Realistic Physical Environment

- 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 km<sup>2</sup>)  
[[lst.inf.ethz.ch/ad-hoc/car-traces](http://lst.inf.ethz.ch/ad-hoc/car-traces)]
- Represent realistic vehicular network topology
  - Road maps [[map.search.ch/index.en.html](http://map.search.ch/index.en.html)]
  - GPS coordinates of currently deployed APs [[www.jiwire.com](http://www.jiwire.com)], [[www.wifimaps.com](http://www.wifimaps.com)]
- Represent wireless channel effects
  - e.g. multi-path fast fading in urban environment, impact of vehicle speed on channel

# Our Approach

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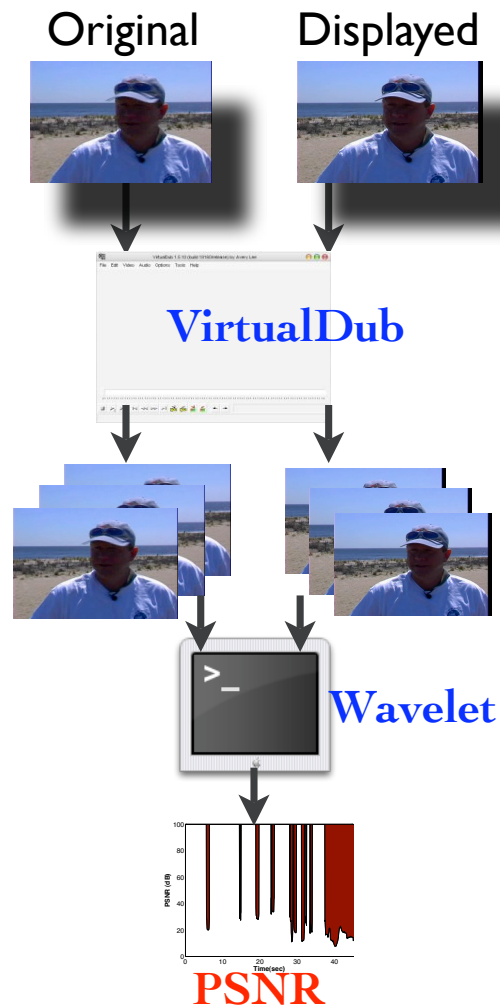
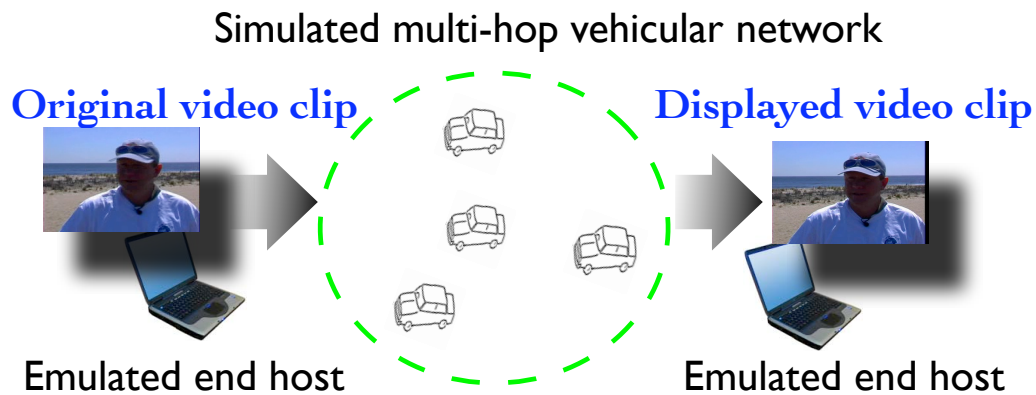


**Application-Centric Evaluation**

# Measure PSNR of Streaming Video

- Peak Signal to Noise Ratio (PSNR)

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



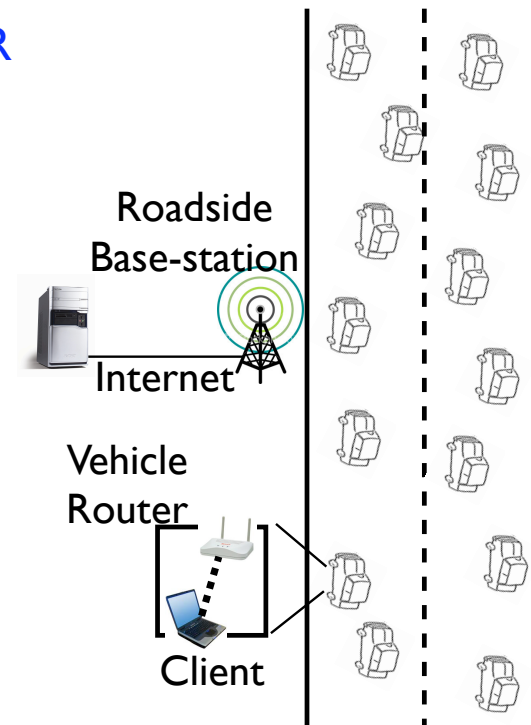
# Experiment Setup

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

## Experiment parameters

Vehicular Network Environment Parameters	
Vehicle topology (mxm)	10x2000
Vehicle density (nodes/area)	23, 45, 91
Vehicle average speed (m/s)	30
Vehicle relative speed (m/s)	0 - 6
Workload Parameters	
Video rate (Kbps)	56, 112, 256
Channel Fading Parameters	
Fading model	no fading, Rayleigh
Max fading velocity (m/s)	15, 30, 60

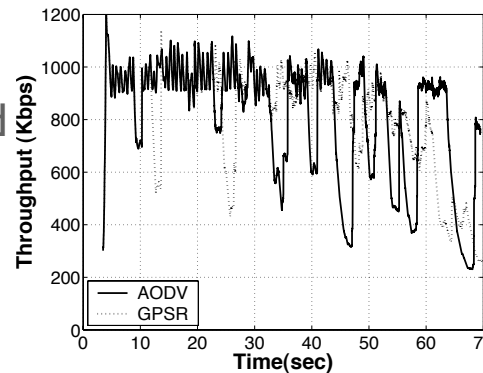
## Vehicular network scenario



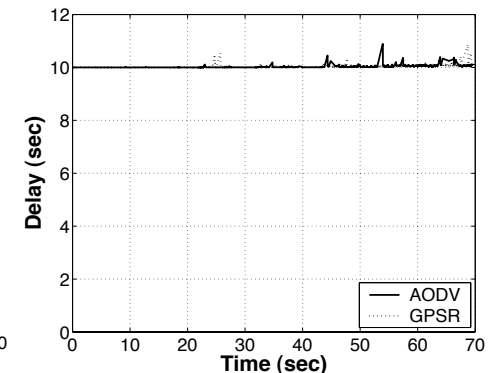
# Direct & Reliable Application Performance Results

## AODV vs. GPSR: network-level performance

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

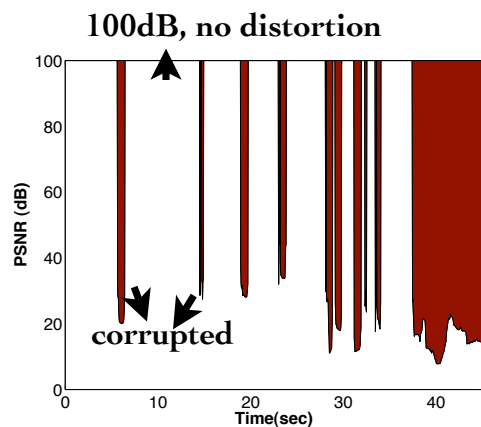


Throughput

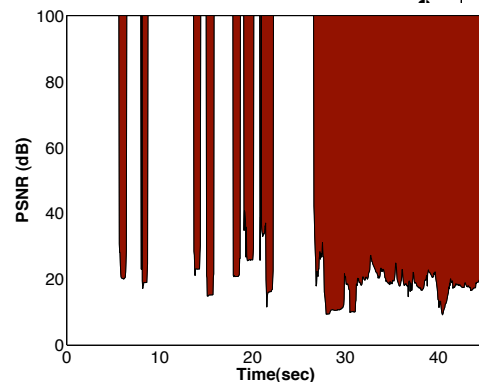


Delay

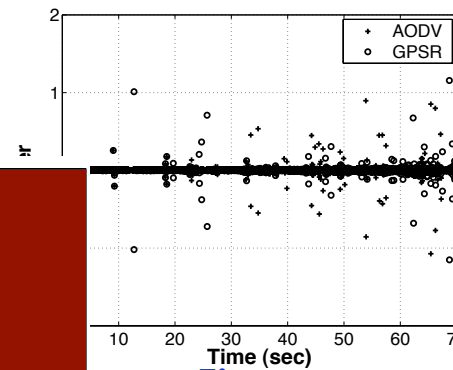
- Better video quality at high PSNR
- AODV outperforms GPSR



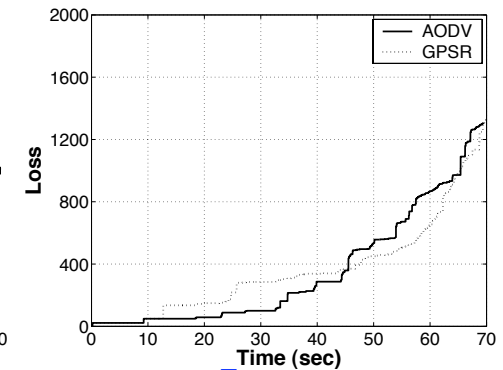
PSNR: AODV



PSNR: GPSR



Jitter

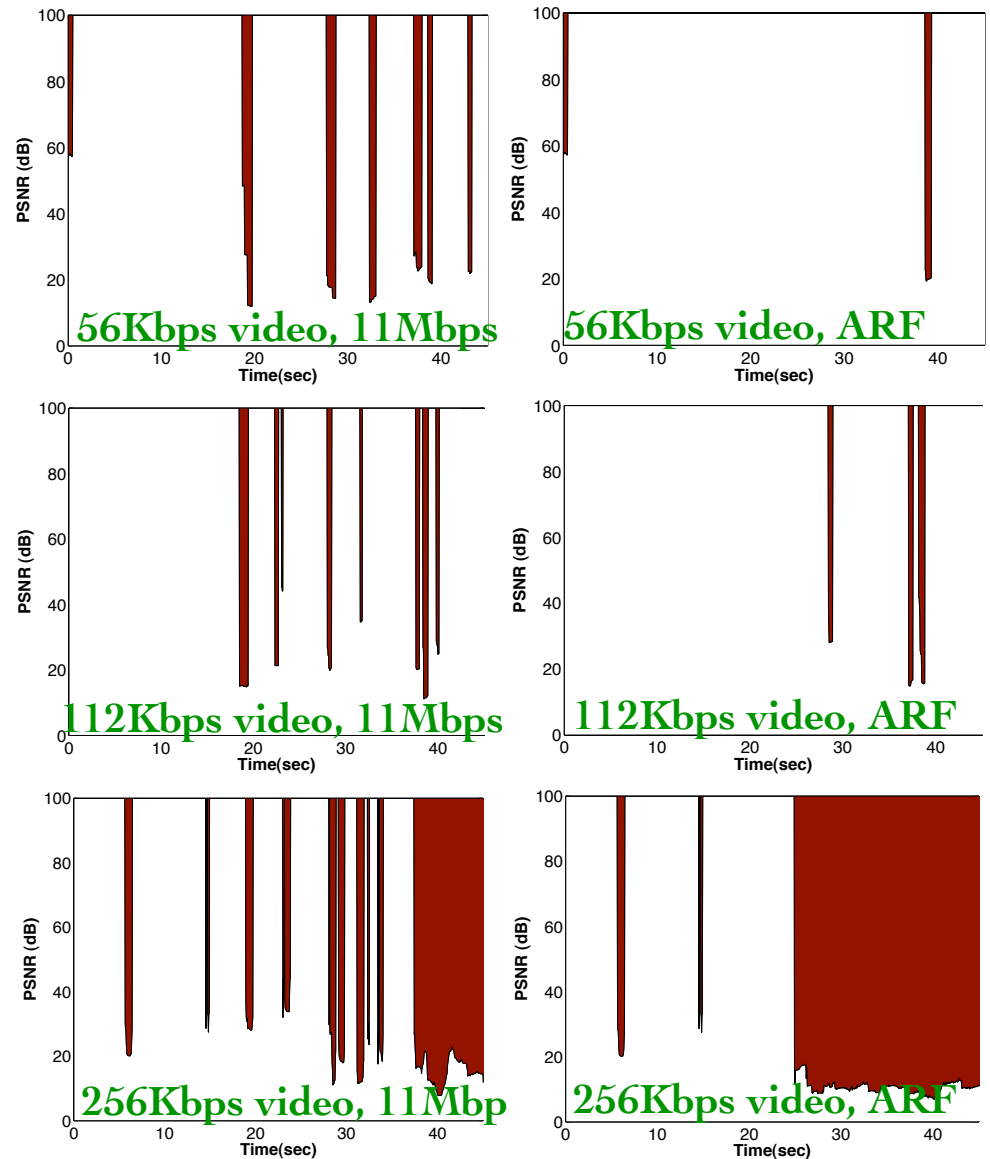


Loss

# 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



# Reason ARF Decreases AODV Performance

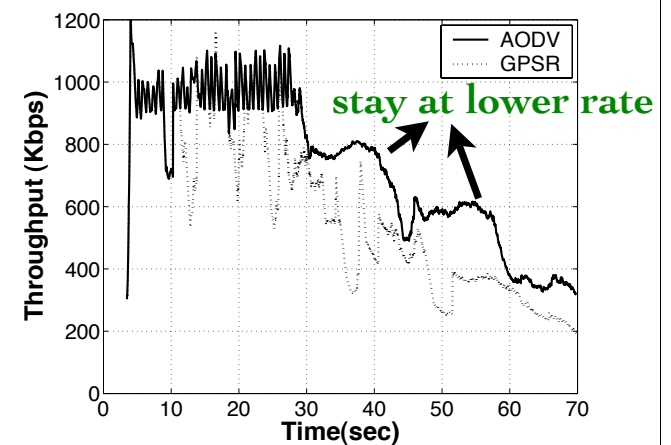
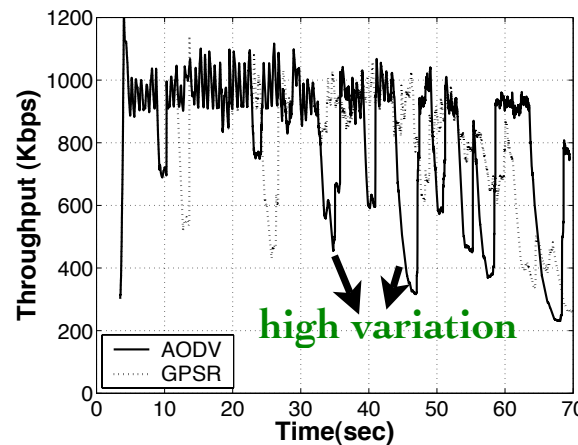
AODV: throughput and loss w/ and w/o ARF

- Application awareness is important in determining rate adaptation strategy
  - Random loss by the use of ARF reduces application-level performance of AODV

256Kbps video

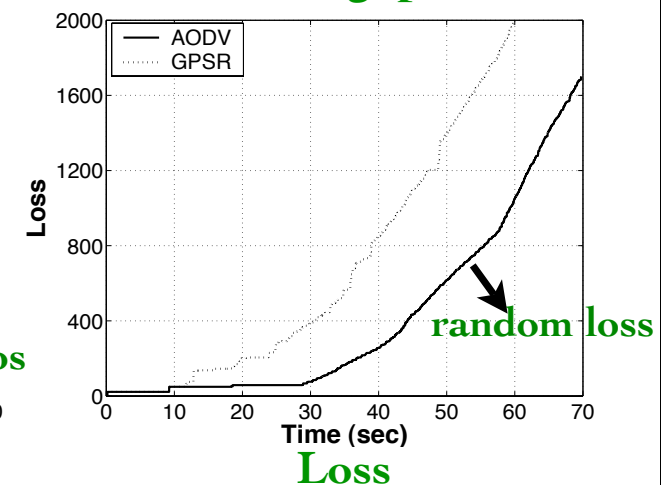
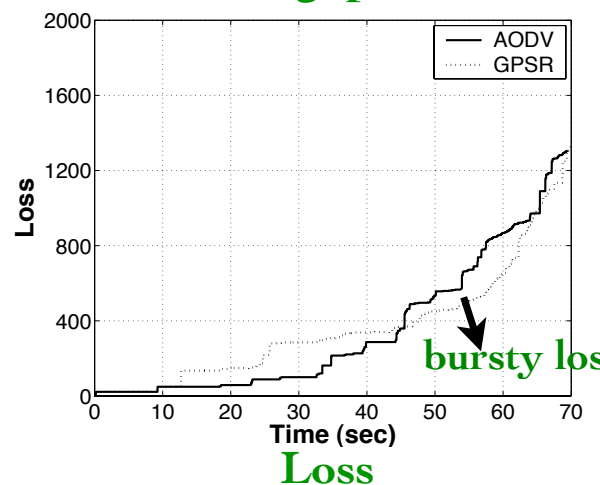
fixed rate 11Mbps

ARF



Throughput

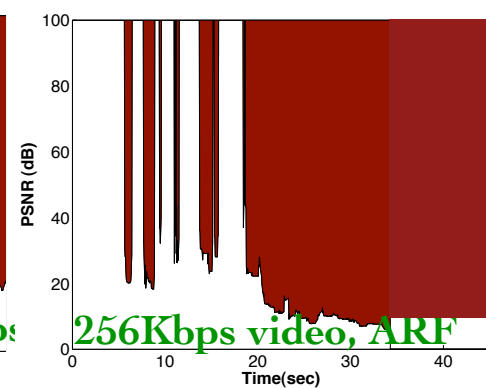
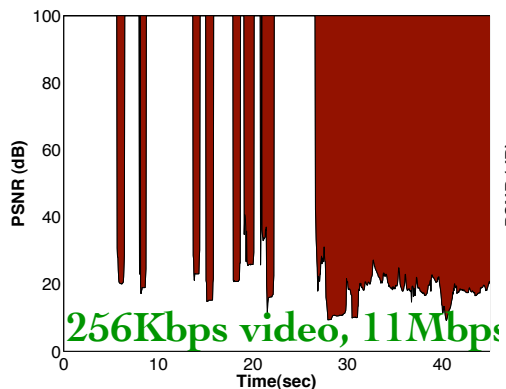
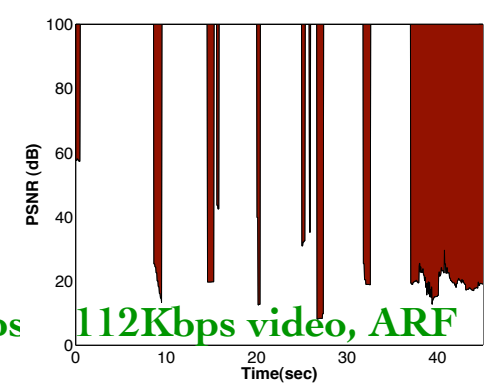
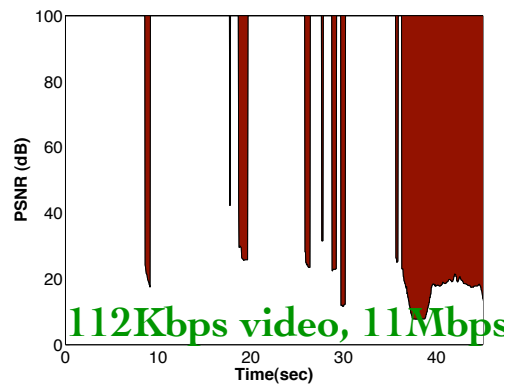
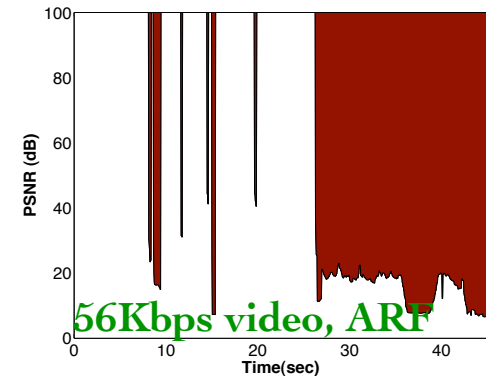
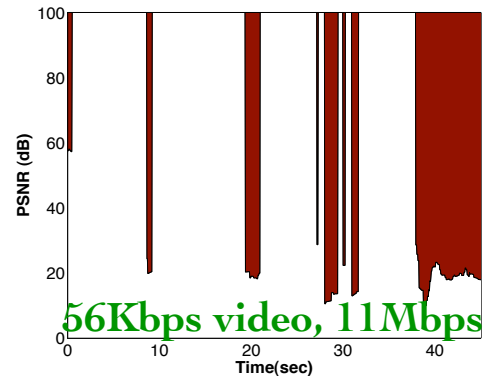
Throughput



# New Insights into Cross-layer Interaction (II)

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

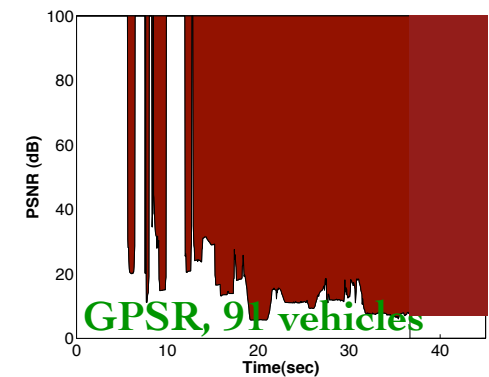
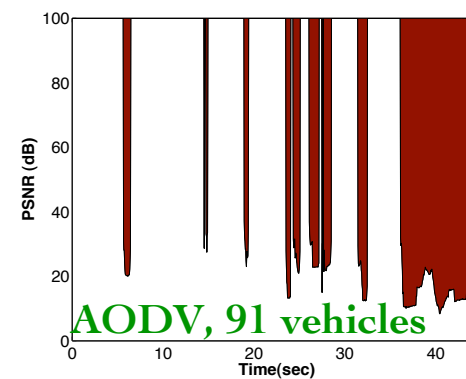
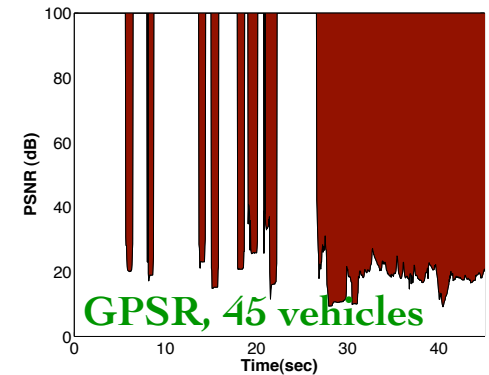
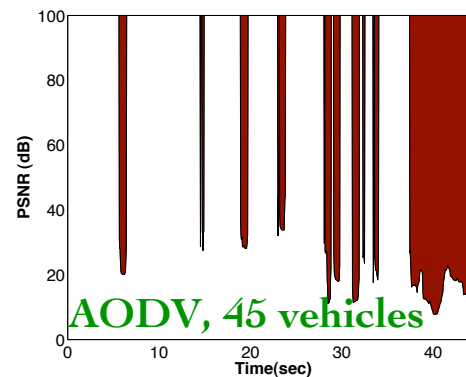
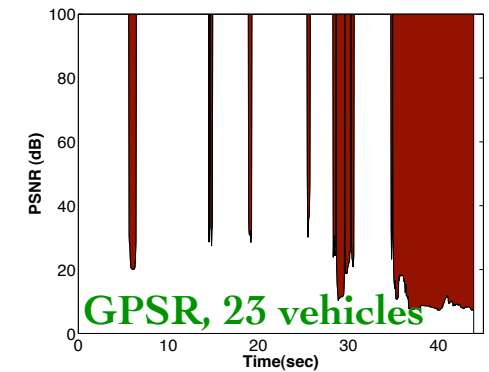
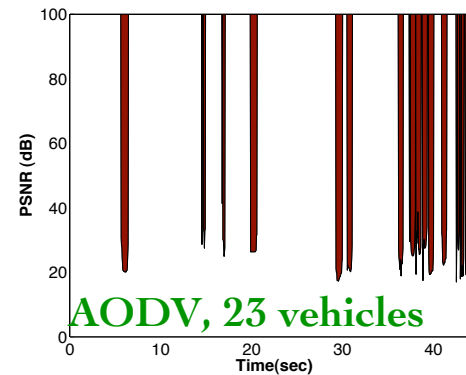
- Performance of rate adaptation is influenced by mix of application requirements and operation details of routing protocol
- Routing and rate adaptation should share information



# Impact of Physical Environment

PSNR of AODV and GPSR at different vehicle densities

- 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



# 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?**