MV-MAX

Improving Wireless Infrastructure Access for Multi-Vehicular Communication

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Application Scenario

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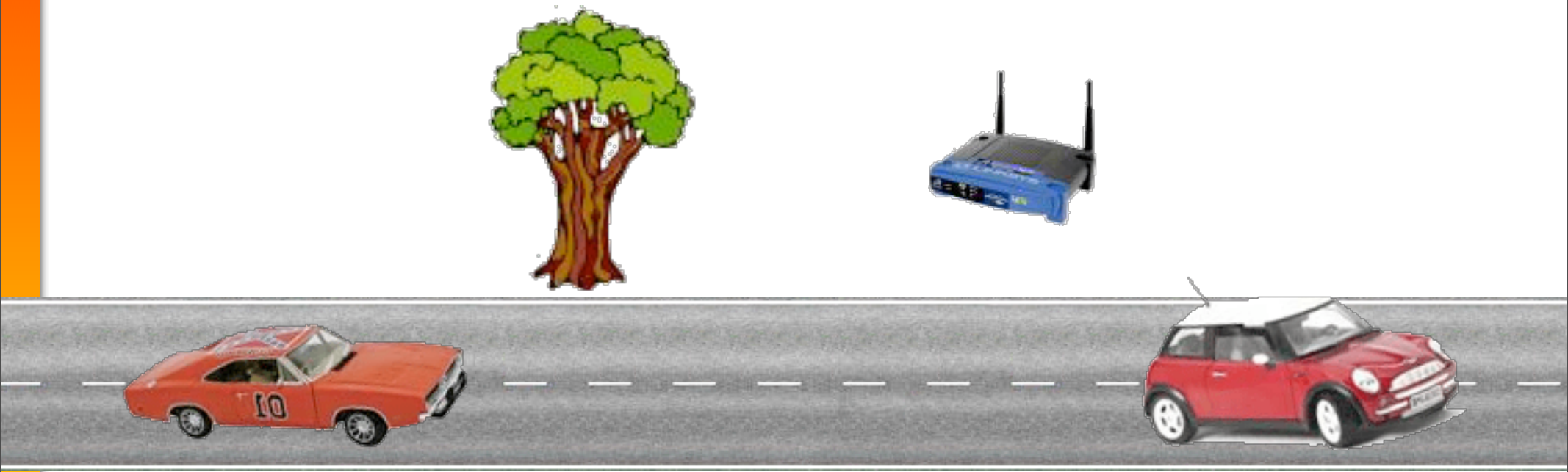

Multiple vehicles in range of a roadside access point

Results Preview

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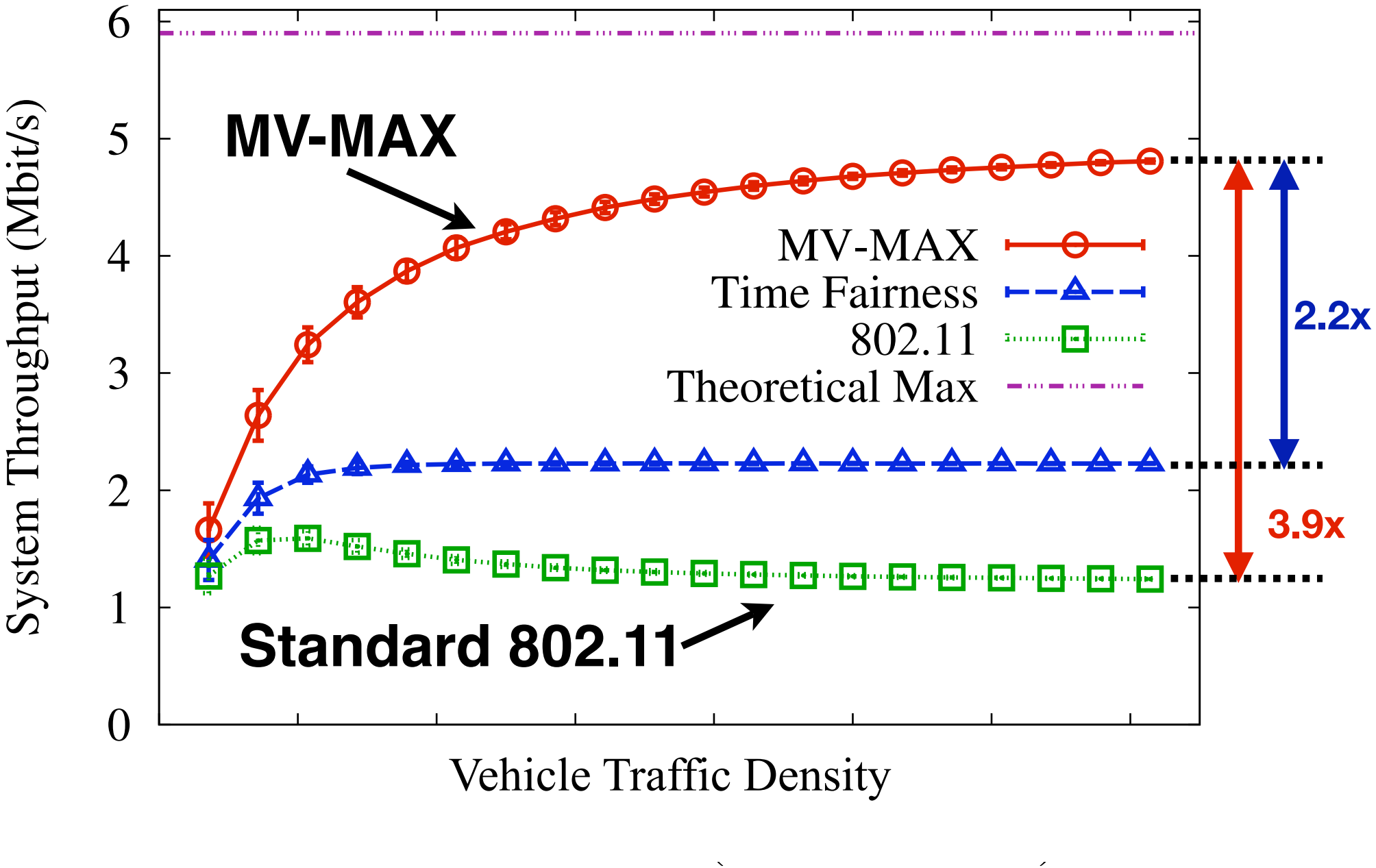

Outline

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- Application Scenario
- Problem Overview
- Vehicular MAC Scheduling
- Simulations
- Sneak Peak of Implementation

Application Scenario

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- Extreme case of mobile Internet access:
  - Vehicular users (passengers) on the highway
- Applications
  - Rich media (e.g. football highlights)
  - Location-specific travel information
    - Catered to user preferences
    - "Welcome to Pisa" mp3 advertisement
  - Unload digital camera

Bulk Data on the Road?

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- These needs can be met by a mix of:
  - Faster cell service (3G, 4G)
  - WiFi on the road
- WiFi is cheap and fast but small coverage
  - Can be used to supplement "always-on" cell service
  - Requires new ***opportunistic*** mode of access
    - Users batch requests
    - Access point acts as a cache

WiFi Potential

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- Single vehicle experiments:
  - 15 MB of bulk TCP data per pass at 100 km/h using 802.11b [Hadaller 2005]
    - 8.5 MB with no external antenna [Gass 2006]
  - 70 MB using 802.11g [Ott 2005]

[Hadaller2005] D. Hadaller, H. Li, and L. G. A. Sung. Drive By Downloads: Studying Characteristics of Opportunistic Connections. In USENIX NSDI Poster Session, 2005.

[Ott2005] J. Ott and D. Kutscher. A Disconnection-Tolerant Transport for Drive-thru Internet Environments. In IEEE INFOCOM, 2005.

[Gass2006] R. Gass, J. Scott, and C. Diot. Measurements of In-Motion 802.11 Networking. In IEEE Workshop on Mobile Computing System and Applications (HOTMOBILE), 2006.

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Performance Anomaly

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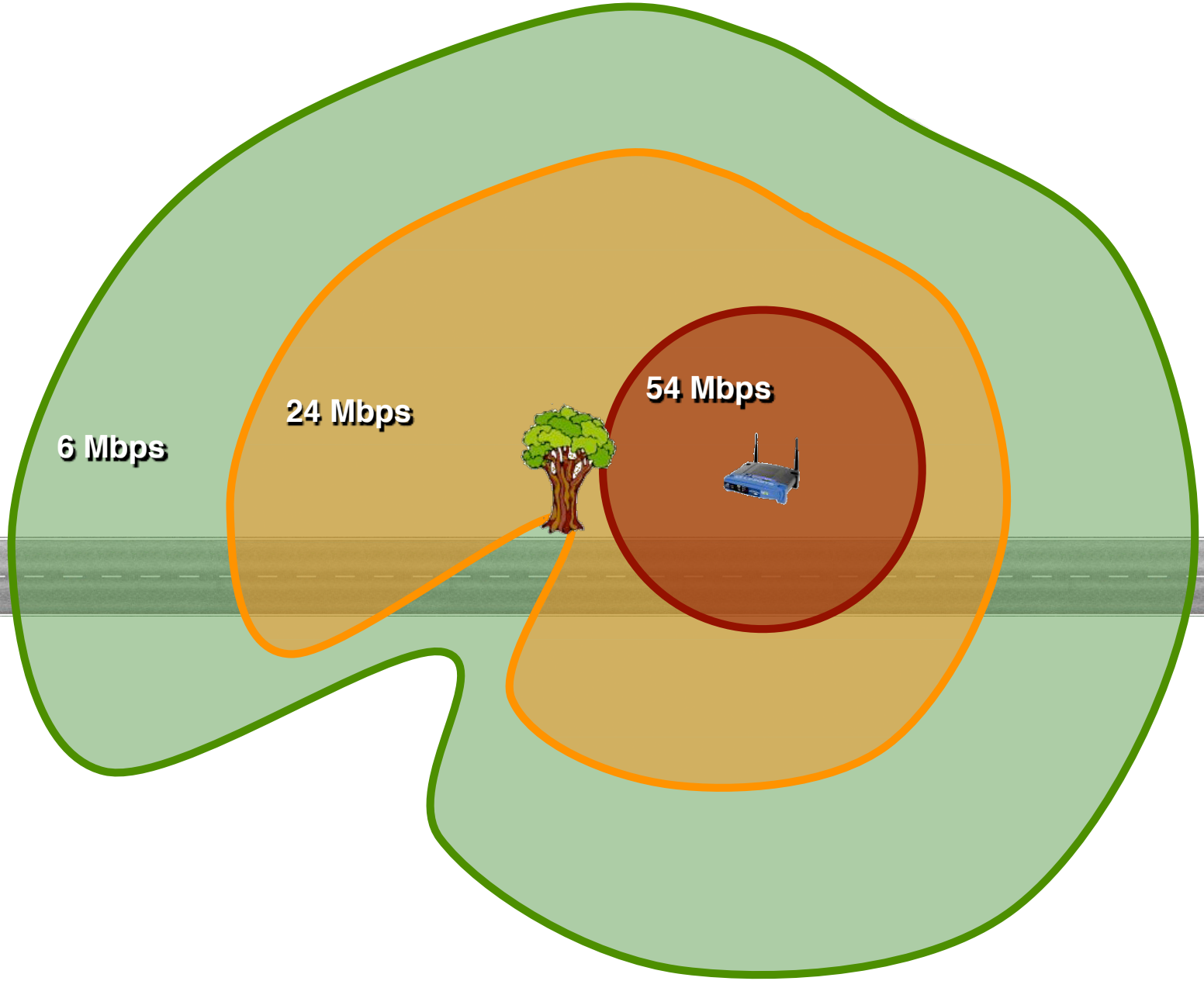
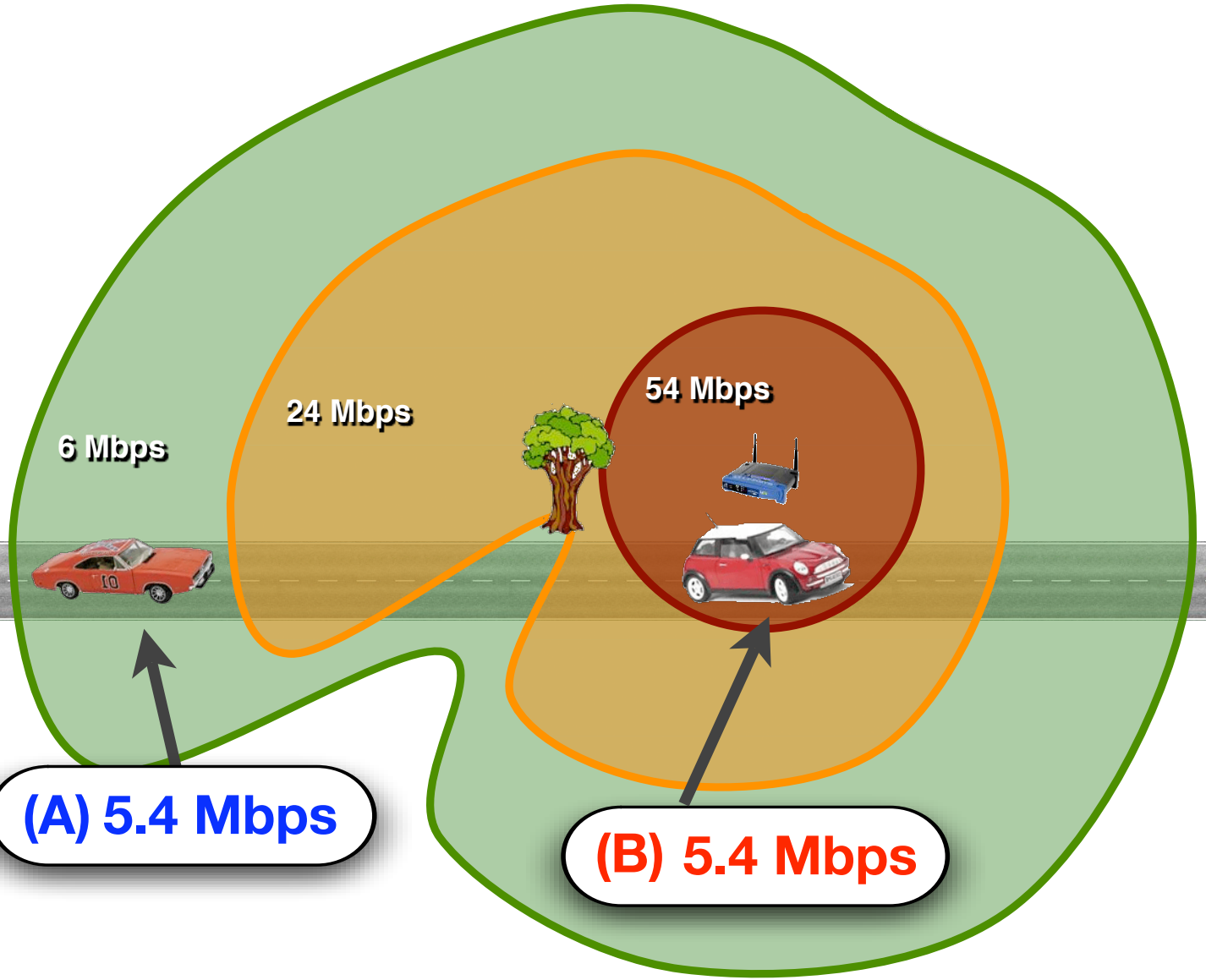
- 802.11 (WiFi) suffers from a performance anomaly [Heusse 2003]
  - A slow user will slow down a faster user
  - Especially prevalent in vehicular scenario

[Heusse2003] M. Heusse, F. Rousseau, G. Berger-Sabbatel, and A. Duda. Performance Anomaly of 802.11b. In IEEE INFOCOM, 2003.

Example Coverage Area



Example Scenario: 802.11



System Rate

802.11

10.8 Mbps

Time Fairness

MV-MAX

Medium usage with shown vehicle positions (802.11 MAC Scheduling):

Example Scenario: Time Fairness

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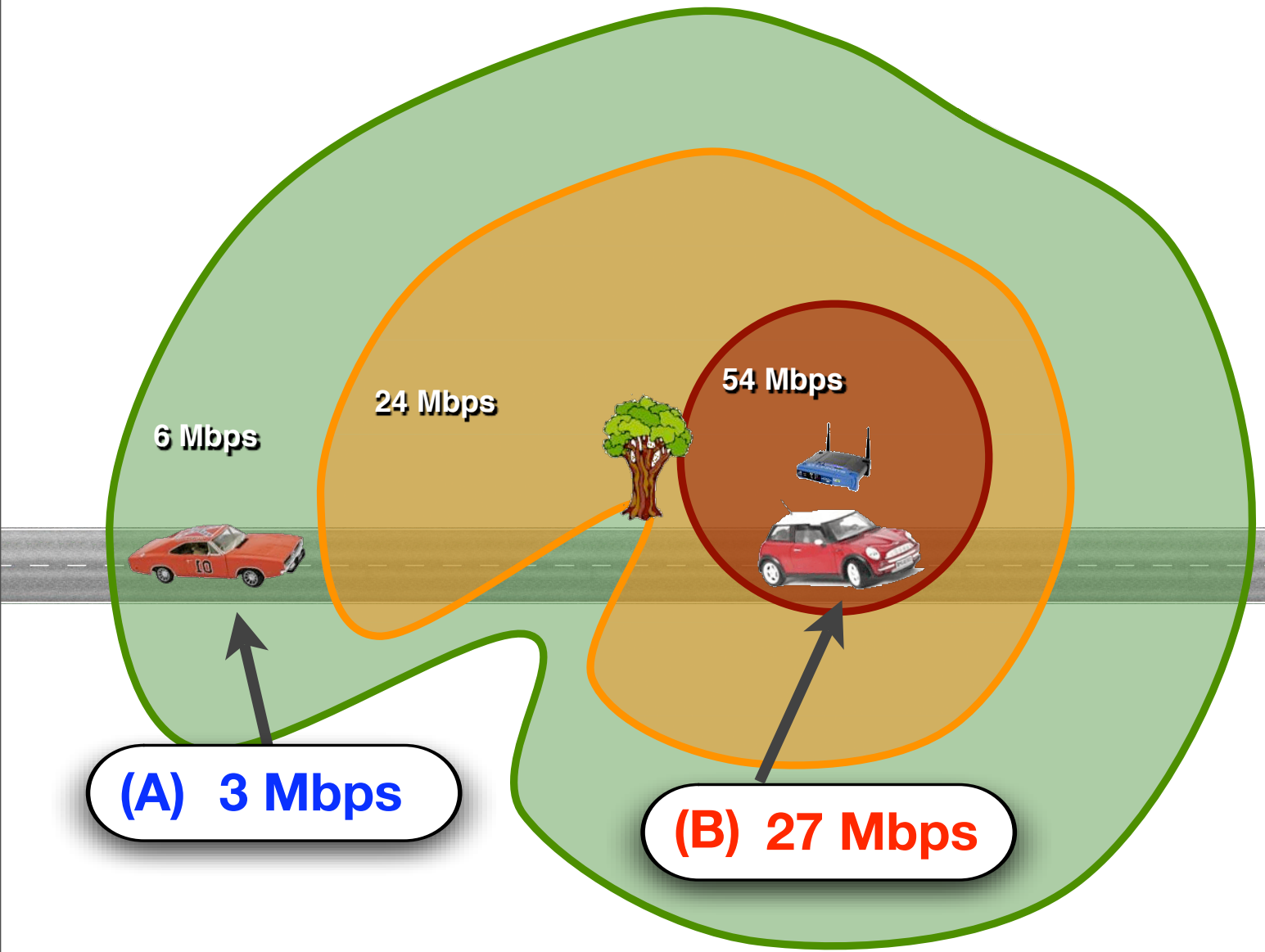

System Rate

802.11

10.8 Mbps

Time Fairness

30 Mbps

MV-MAX

Medium usage with shown vehicle positions (Time Fair Scheduling):

MV-MAX

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- MV-MAX assigns the wireless medium to the user experiencing the best signal quality
  - Intuition: take full advantage of periods of good signal quality
  - Maximizes system throughput
  - But at what cost to user fairness?
    - Premise: all users will eventually experience good signal quality on the highway

Example Scenario: MV-MAX

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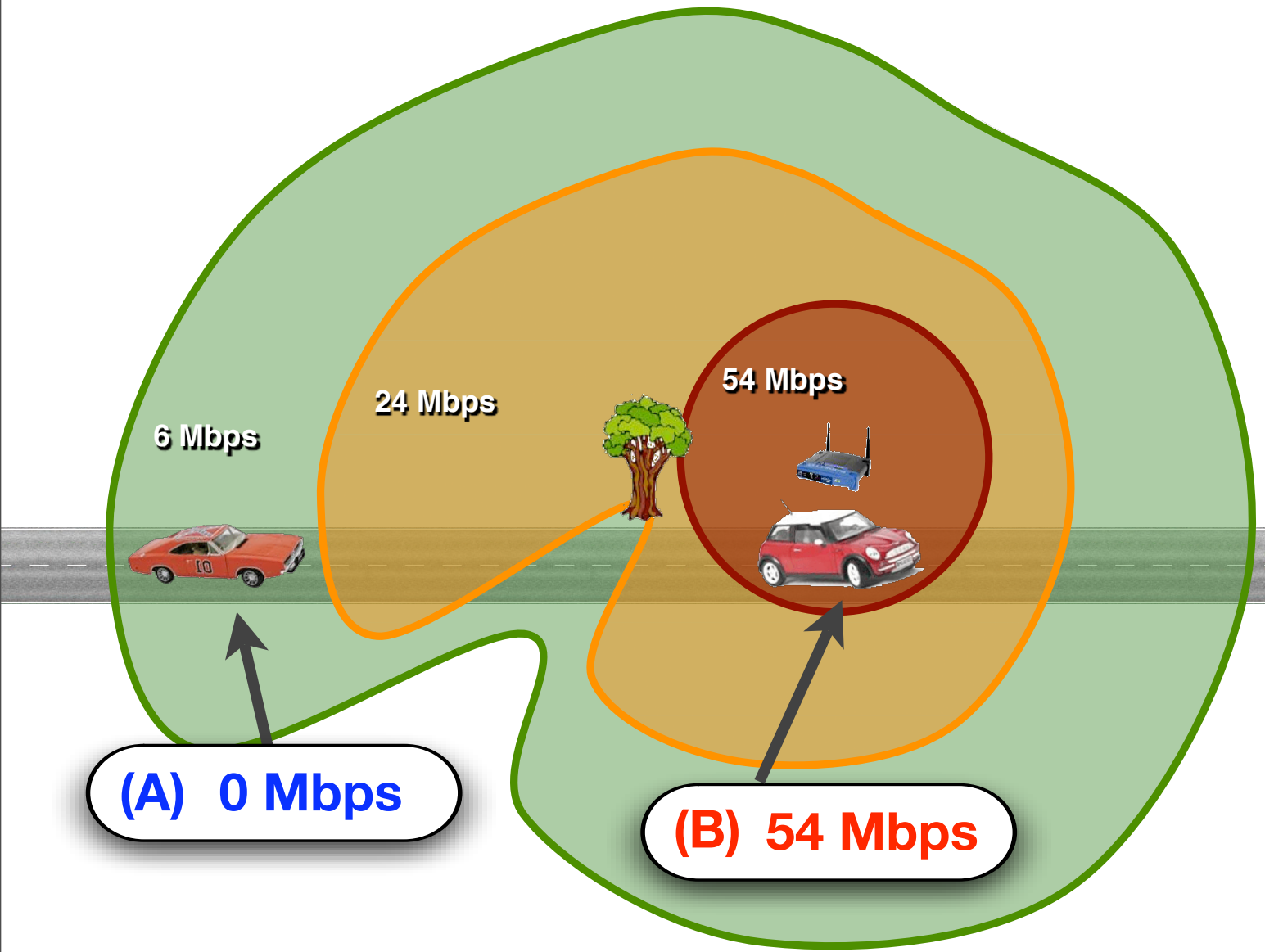

System Rate

802.11

10.8 Mbps

Time Fairness

30 Mbps

MV-MAX

54 Mbps

Medium usage with shown vehicle positions (MV-MAX):

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Simulation Assumptions

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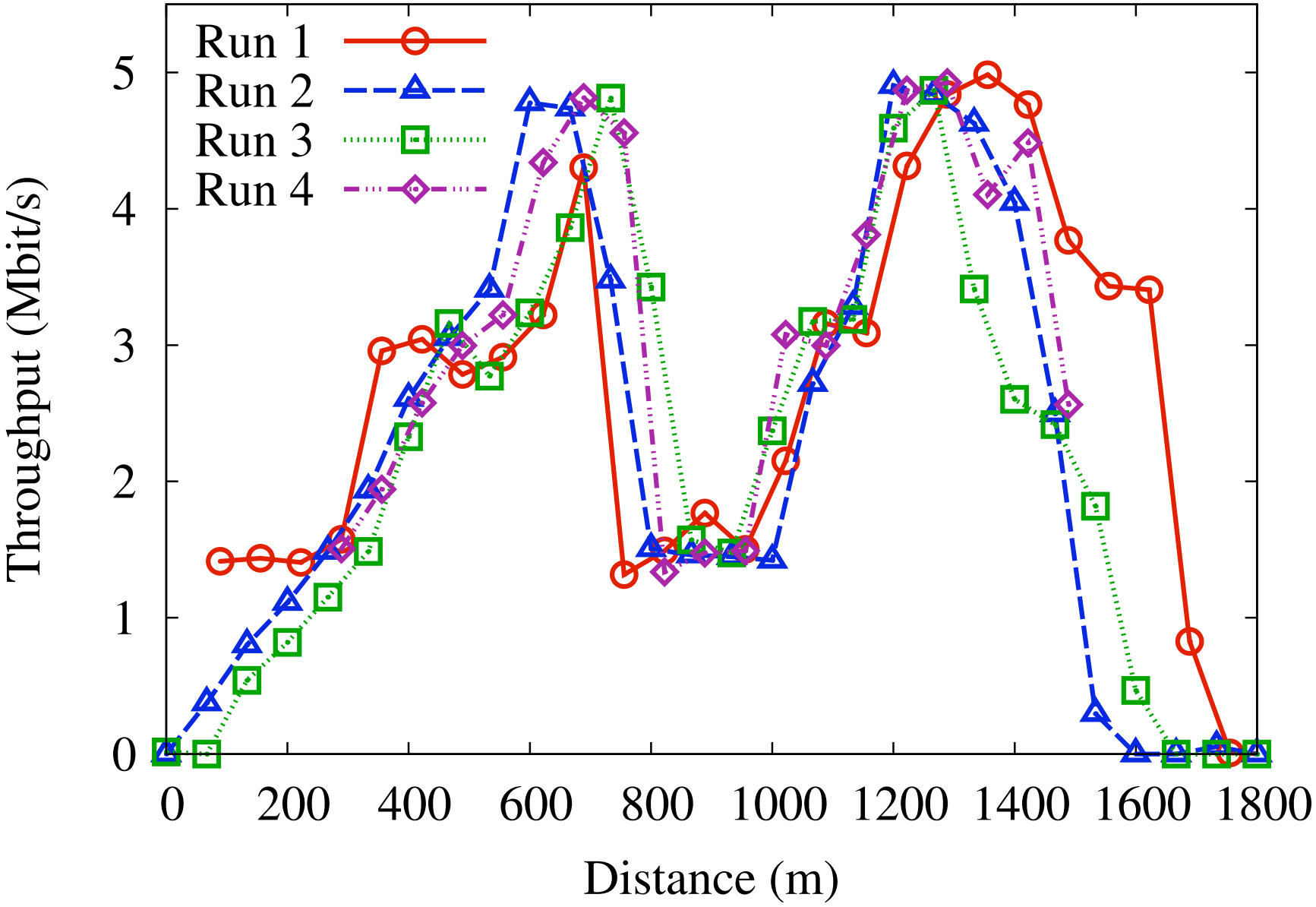
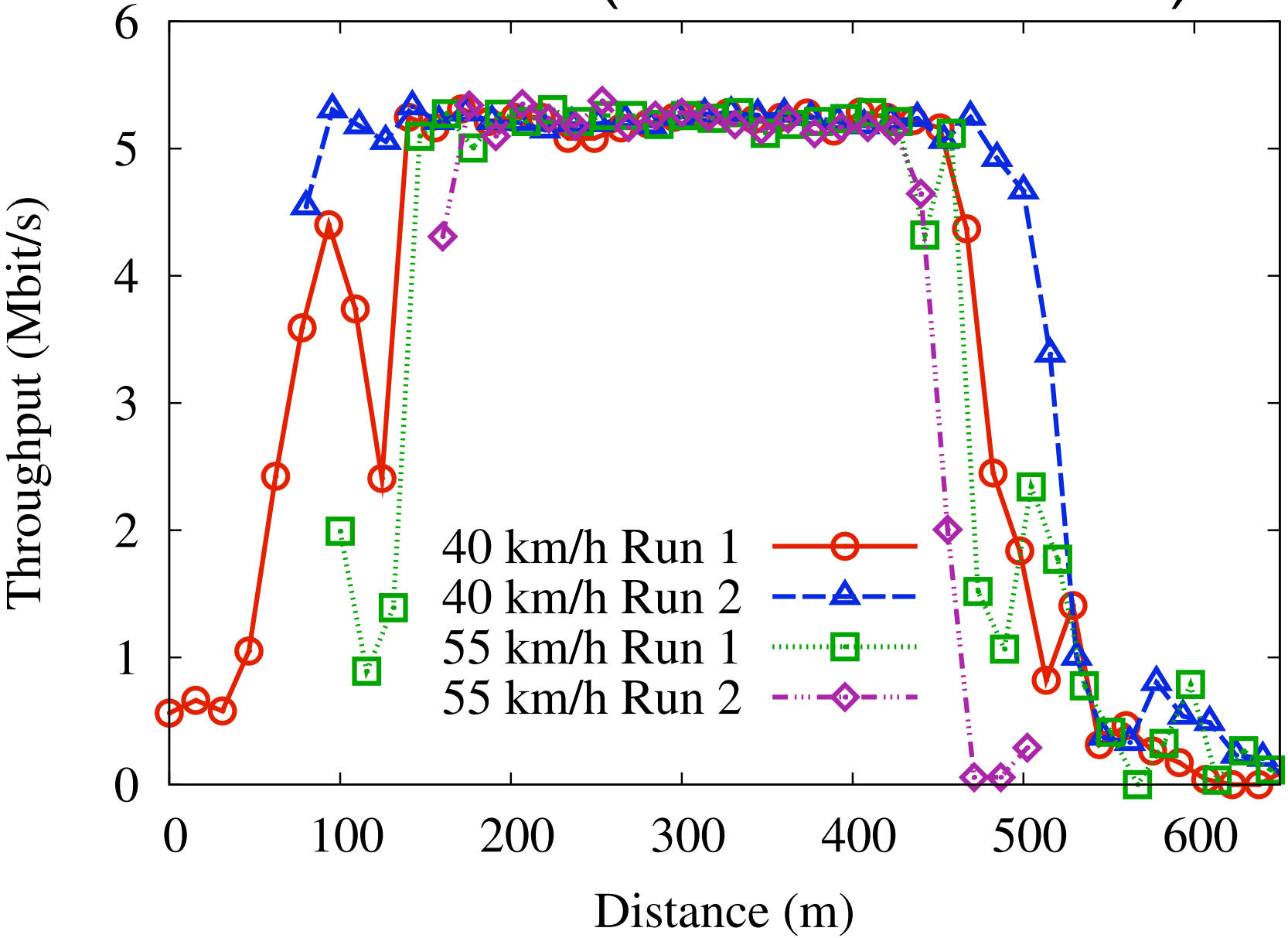
- Highway scenario
  - Vehicles move in the same direction and at the same speed
- All vehicles experience the same signal profile

Our Data (TCP over 802.11b)



Our data: single vehicle passing an AP [Hadaller 2005]

Intel Data (TCP over 802.11b)



Intel data: single vehicle, no external antenna [Gass 2006]

Simulation Set-up

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- Simulate vehicles passing a roadside AP
- Individual vehicle throughput is determined by MAC rate of all vehicles in range
  - Computed using rate coupling functions based on vehicle position, e.g.
    - rateCouple[802.11](54,6) = 5.4 + 5.4 = 10.8 Mbps
    - rateCouple[Time Fairness](54,6) 27 + 3 = 30 Mbps
    - rateCouple[MV-MAX] (54,6) = 54 + 0 = 54 Mbps
- Vary vehicle arrival rate

System Throughput (Our Data)

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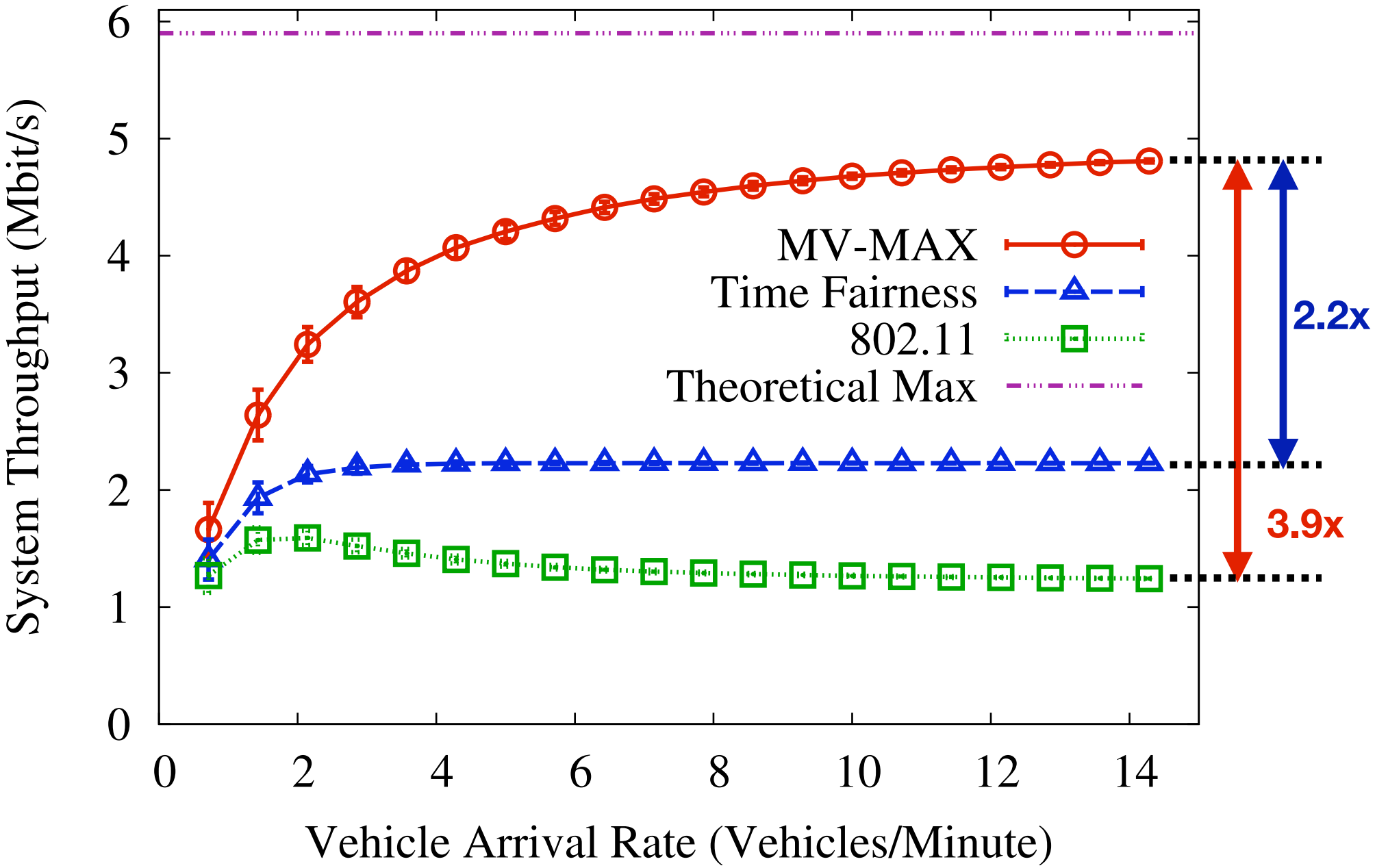
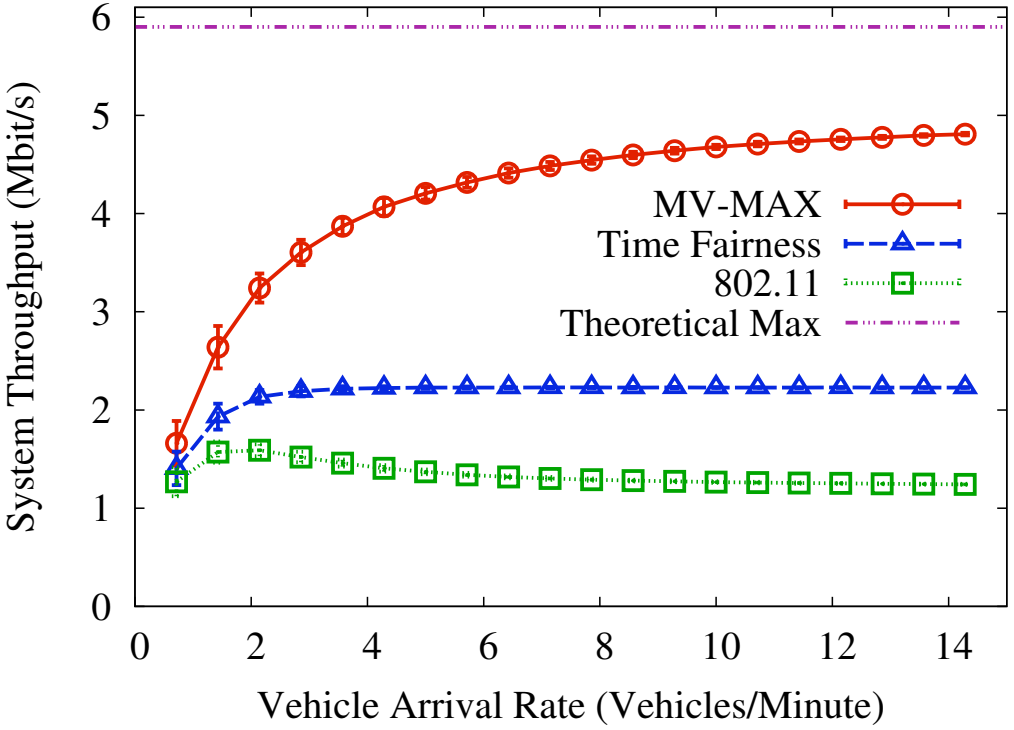
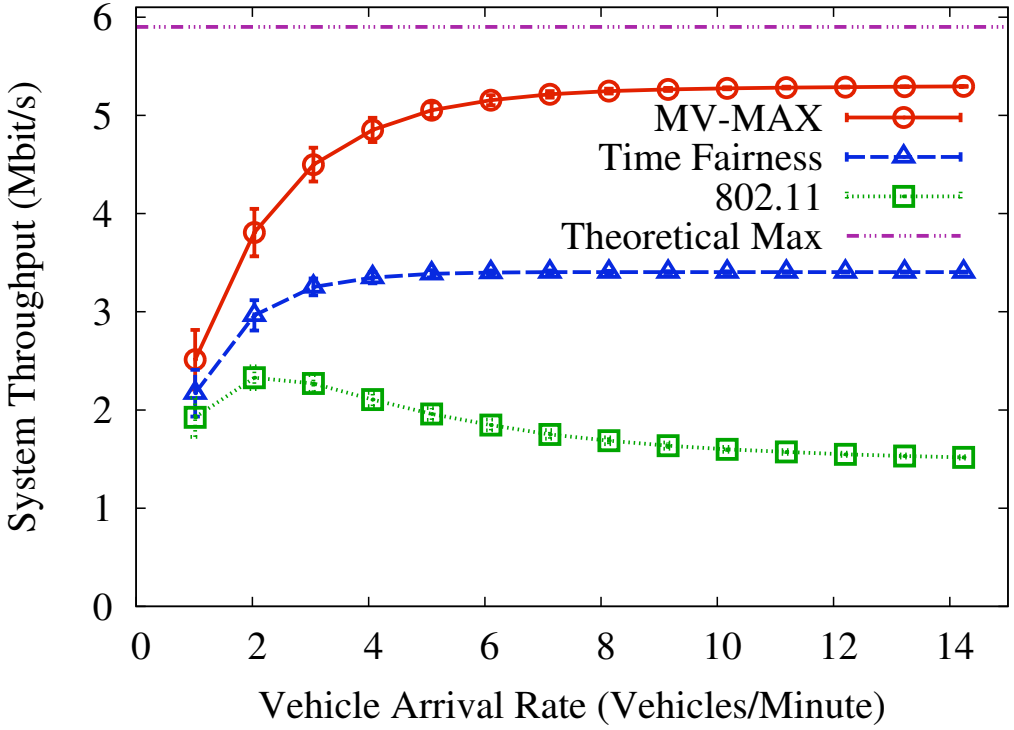


System Throughput



Our Data



Intel Data

Fairness

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- Do some vehicles take a large performance hit?
  - Are some vehicles starved?
- User Experience =~ Amount of Data Transferred
- Per-Vehicle Improvement Ratio
  = Data transferred vs 802.11

Improvement vs. 802.11

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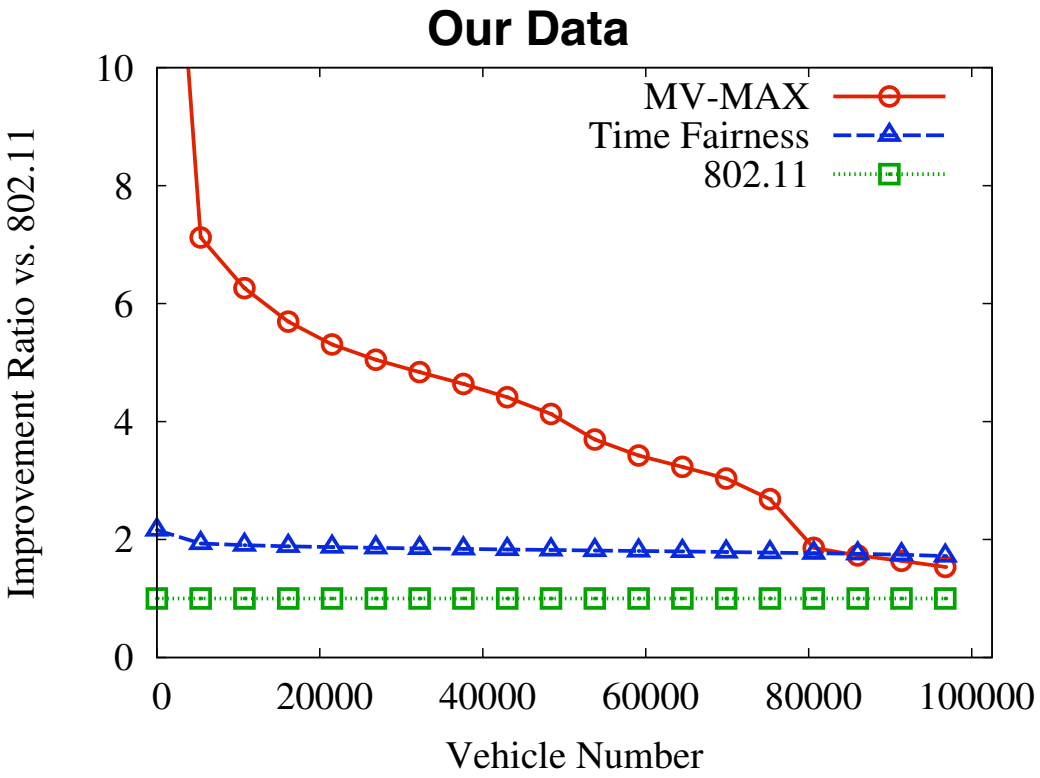

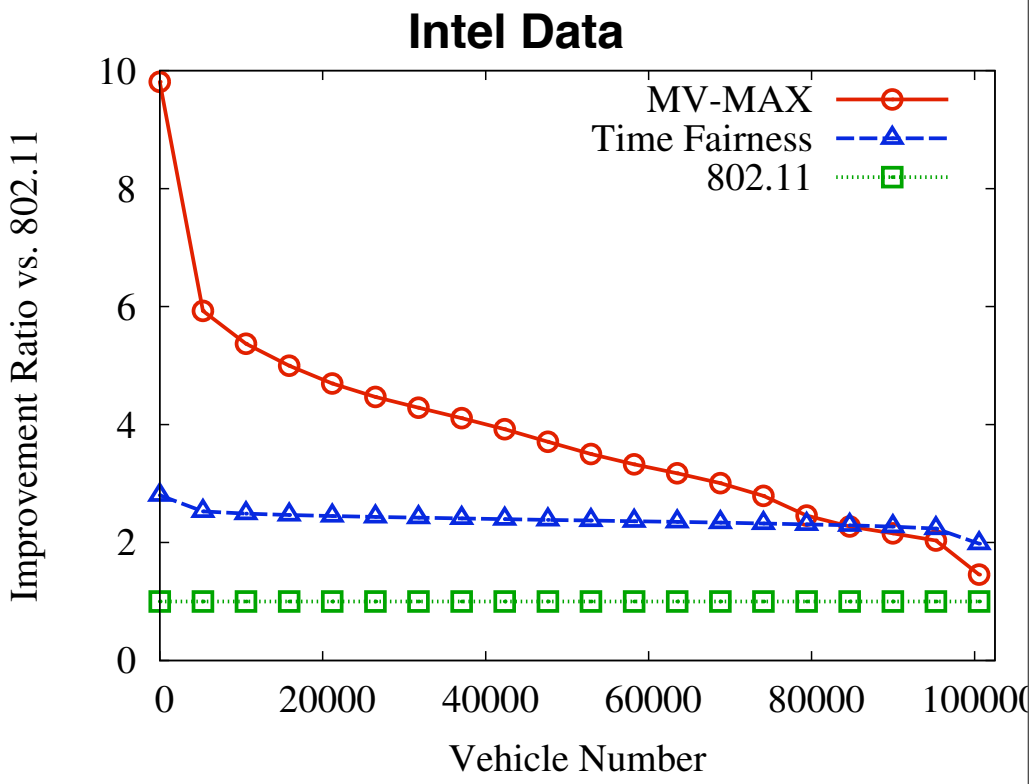

Using either MV-MAX or Time Fairness, compared to 802.11, every vehicle is able to transfer more data.
(dense vehicle traffic)

Vehicles Improved w/MV-MAX

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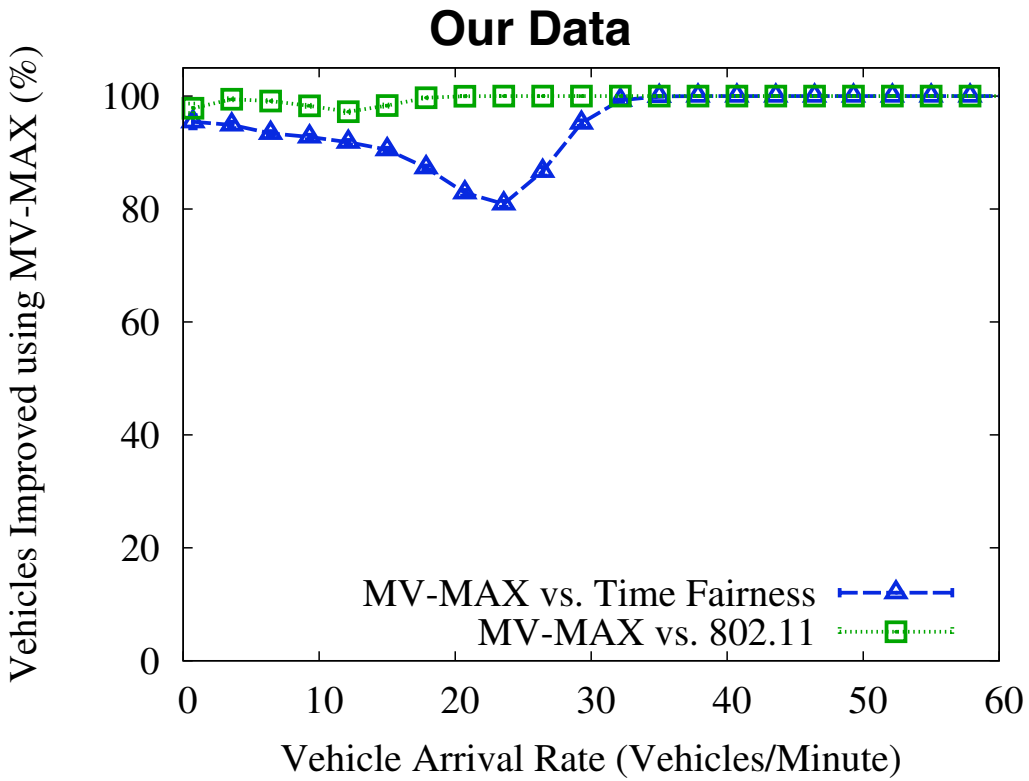

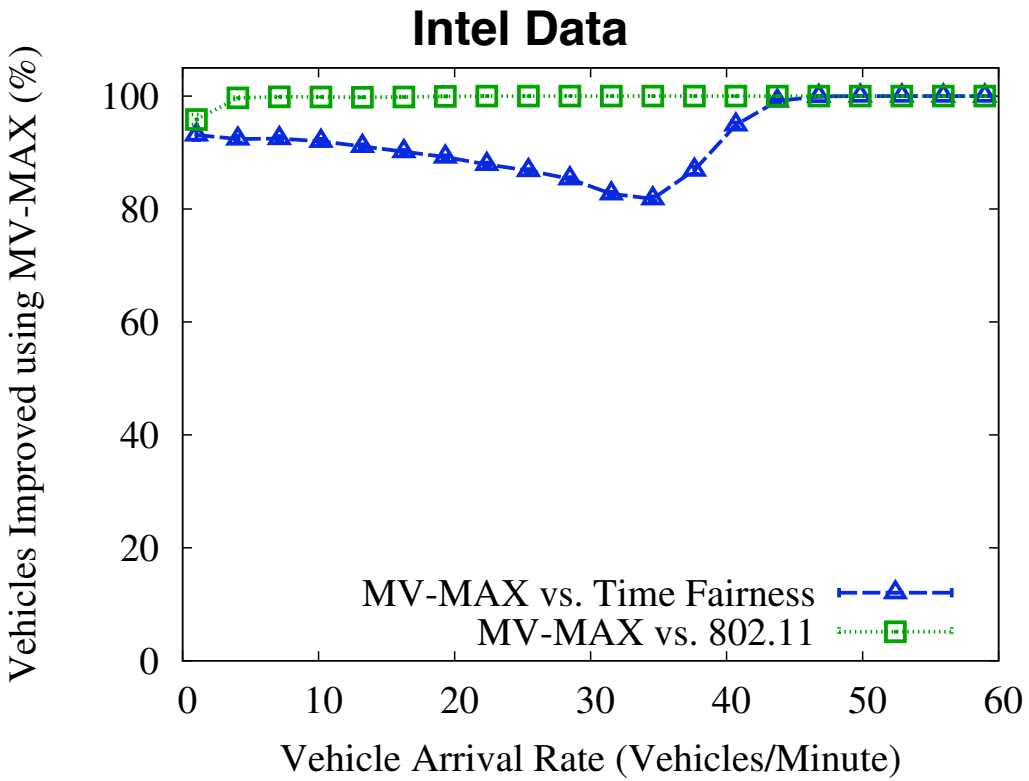

MV-MAX increases data transferred of:

>80% of vehicles vs. Time Fairness

>96% of vehicles vs. 802.11

Lorenz Fairness Curve

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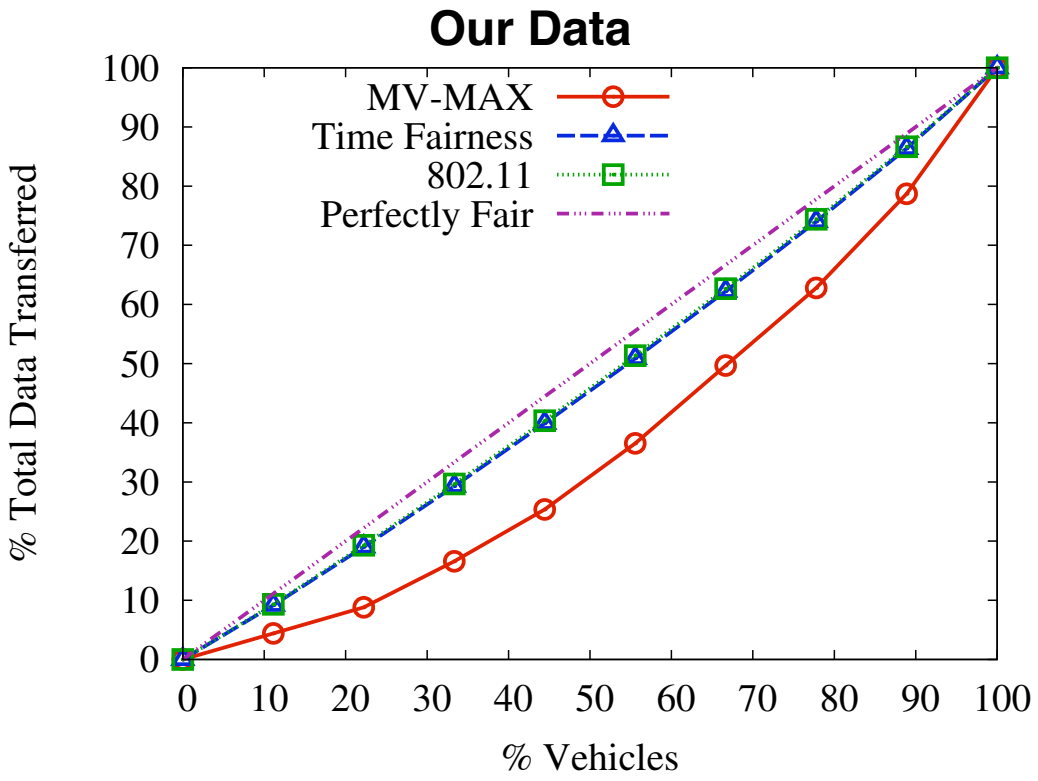

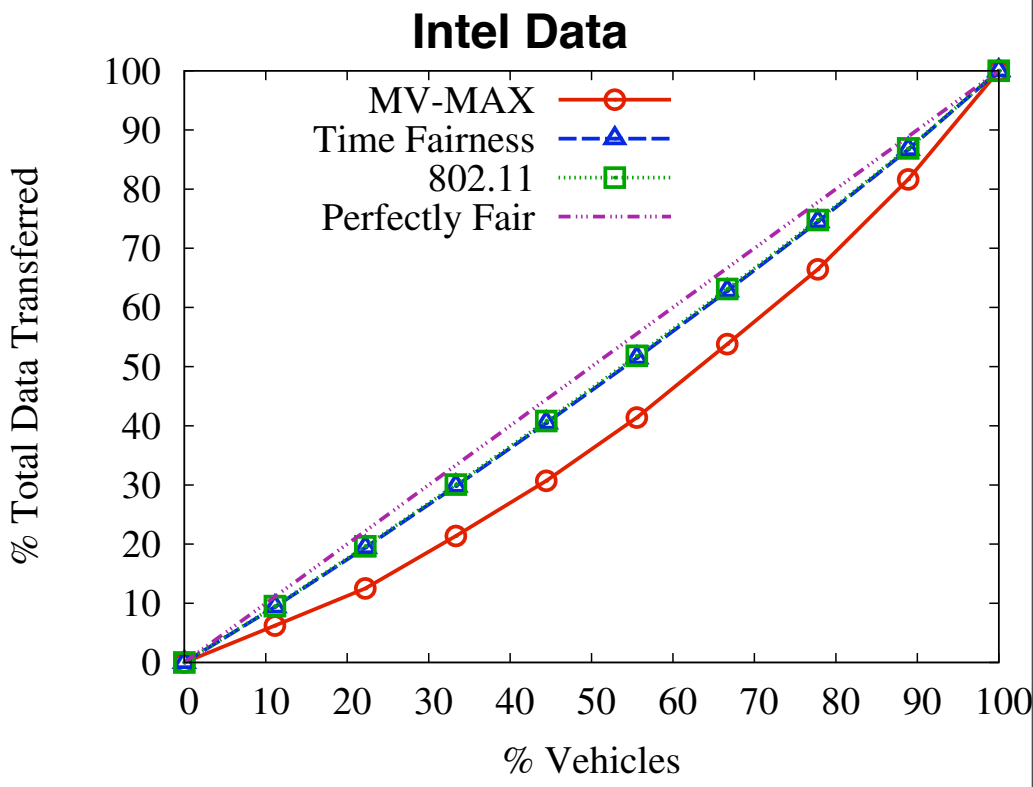

MV-MAX is only marginally less fair.

(dense vehicle traffic)

Ongoing Work

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- What if signal profiles are not identical?
  - Equipment: user with biggest antenna wins
  - Environment: intersecting highways / city
- Balancing fairness with throughput:
  - Could use proportional scheduling
- Implementing MV-MAX

Sneak Peak: Testing MV-MAX

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Two Vehicles using 802.11b

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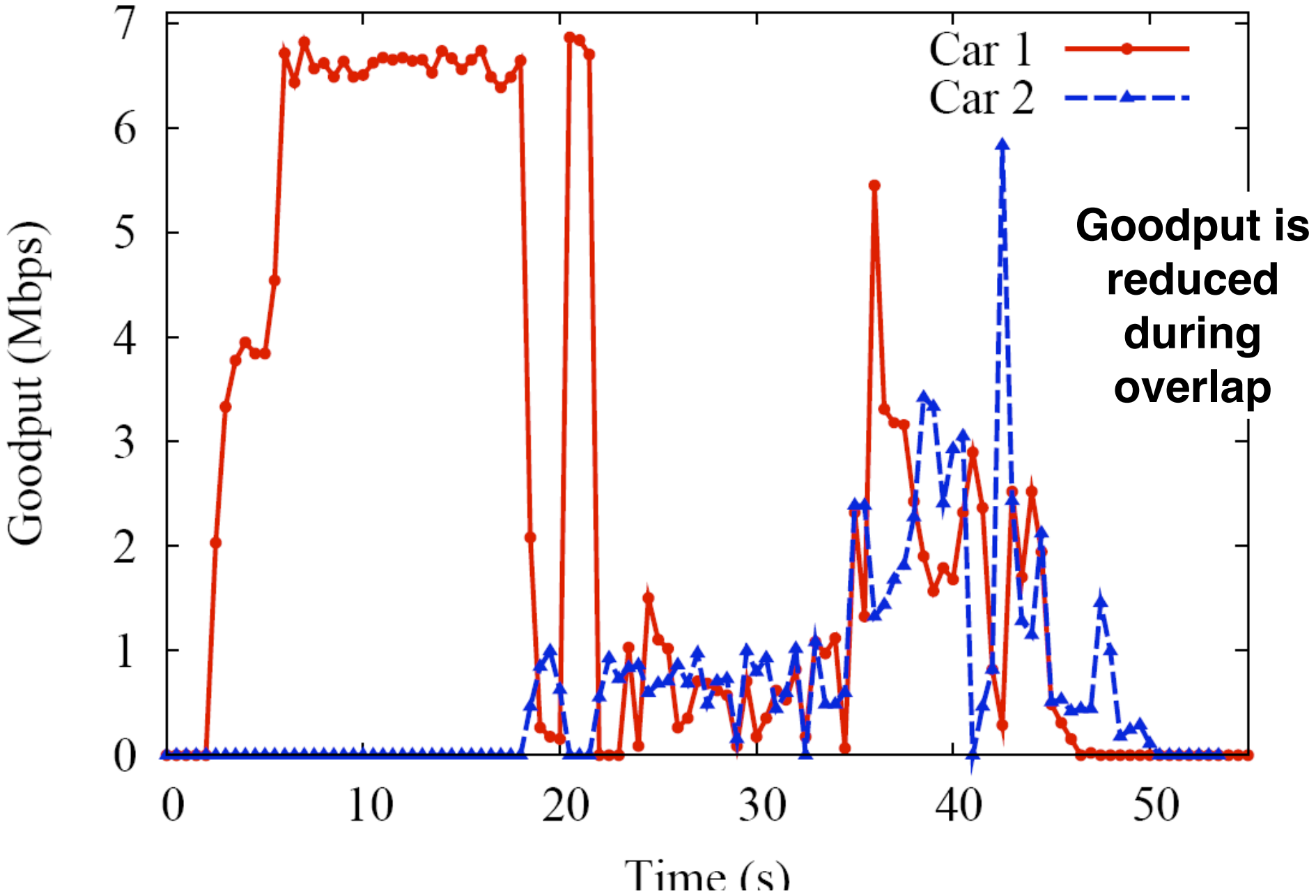

Goodput is reduced during overlap

Two Vehicles using MV-MAX

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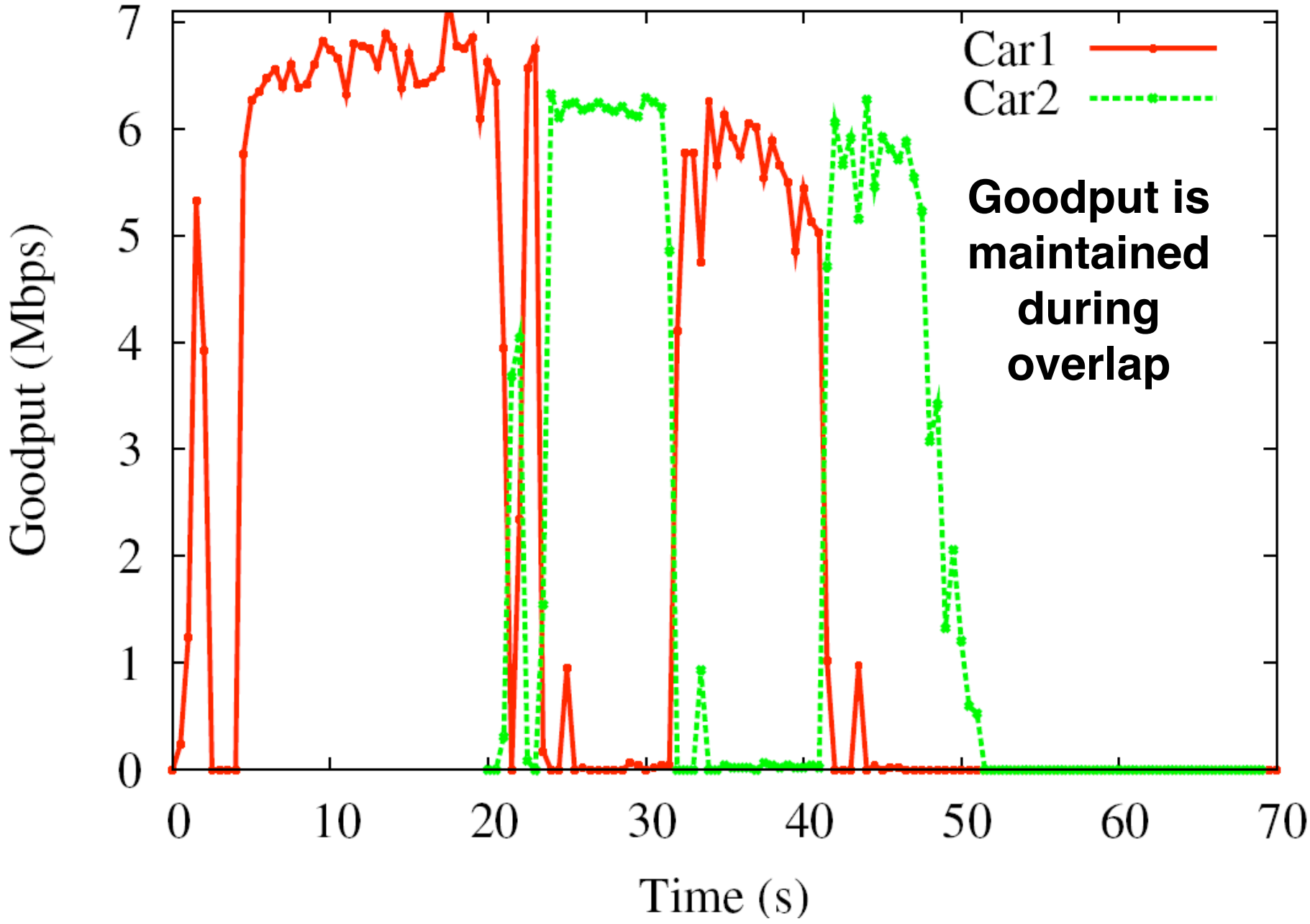

Aggregate Goodput

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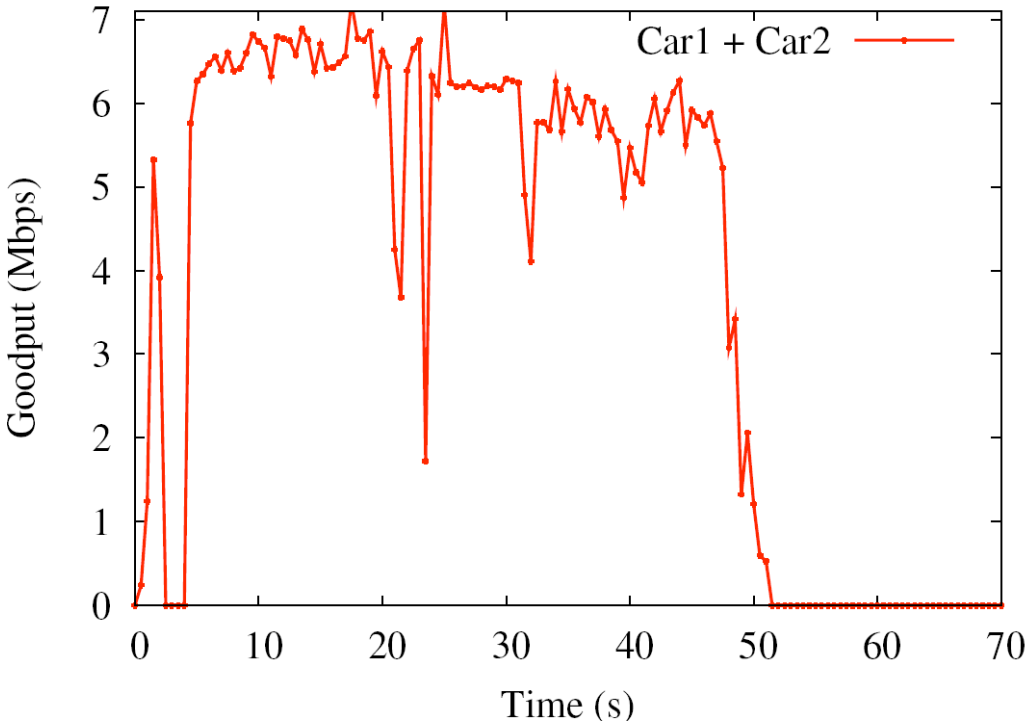
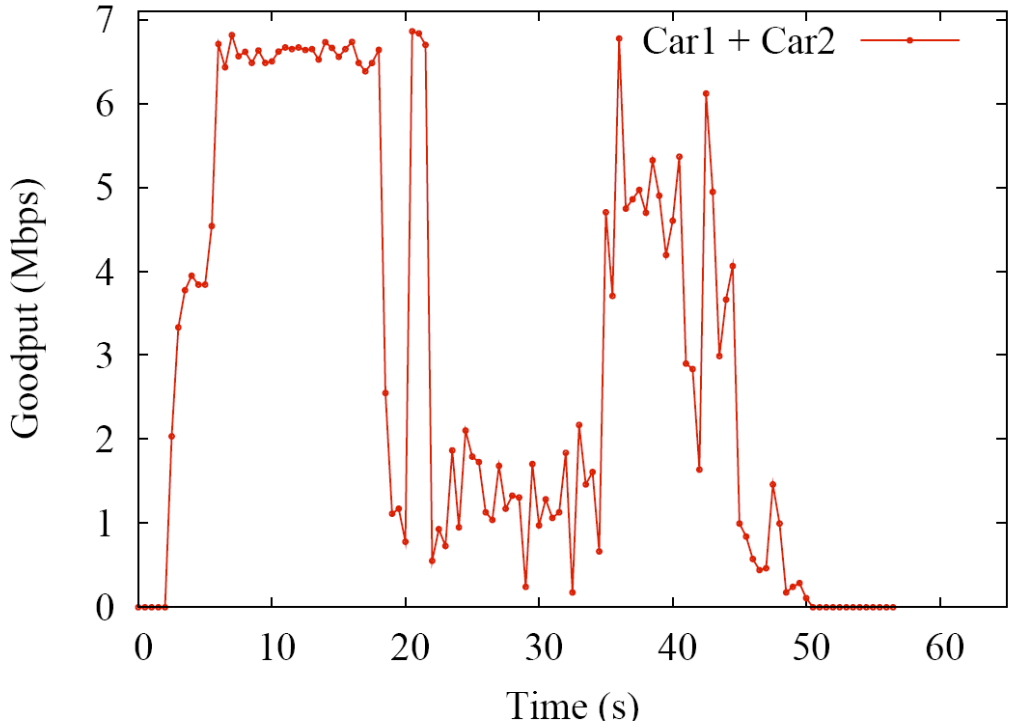


MV-MAX



802.11

Conclusion

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- In the multi-vehicle scenario, vehicular users suffer from the 802.11 performance anomaly
- Proposed solutions (Time Fairness) aren't optimal
- Significant scheduling gain can be achieved due to repeatable signal patterns
  - MV-MAX improves throughput by up to 4x vs. 802.11, and up to 2x vs. Time Fairness