An Infrastructure-less Vehicle Counting without Disruption

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Outline

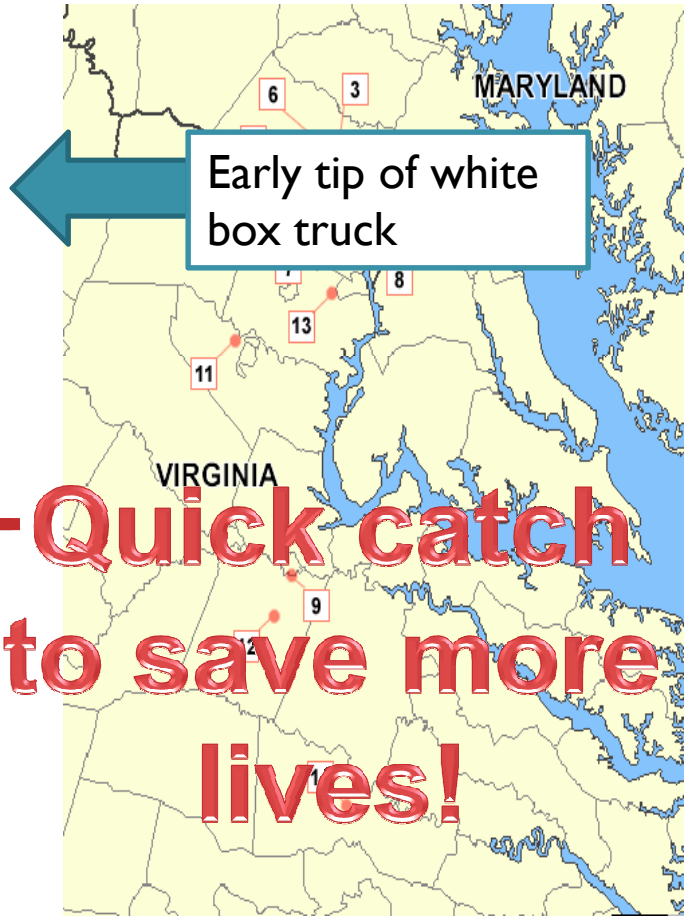
- Introduction
- Target Problem
- Challenges
- Our Approach
- Experimental Results
- Conclusion

Introduction

- Motivated by the lessons we learnt from security tragedies

Name	Status	Date of Attack	Location
James Martin	Killed	October 2, 2002, 6:04 p.m.	Wheaton, Maryland
James Buchanan	Killed	October 3, 2002, 7:41 a.m.	Rockville, Maryland
Premkumar Walekar	Killed	October 3, 2002, 8:12 a.m.	Aspen Hill, Maryland
Sarah Ramos	Killed	October 3, 2002, 8:37 a.m.	Silver Spring, Maryland
Lori Ann Lewis-Rivera	Killed	October 3, 2002, 9:58 a.m.	Kensington, Maryland
Pascal Charlot	Killed	October 3, 2002, 9:20 p.m.	Washington, D.C.
Caroline Seawell	Survived	October 4, 2002, 2:30 p.m.	Fredericksburg, Virginia
Iran Brown	Survived	October 7, 2002, 8:09 a.m.	Bowie, Maryland
Dean Harold Meyers	Killed	October 9, 2002, 8:18 p.m.	Manassas, Virginia
Kenneth Bridges	Killed	October 11, 2002, 9:40 am	Fredericksburg, Virginia
Linda Franklin	Killed	October 14, 2002, 9:19 p.m.	Falls Church, Virginia
Jeffrey Hopper	Survived	October 19, 2002, 8:00 p.m.	Ashland, Virginia
Conrad Johnson	Killed	October 22, 2002, 5:55 a.m.	Aspen Hill, Maryland

Listed in chronological order, these are the names of the victims who were murdered or wounded in the Beltway sniper attacks.



Map of Beltway sniper attacks.

First blast, on 2:49:43 pm EDT, April 15, 2013
Second blast, on2:49:57 pm EDT, April 15, 2013

FBI took over the investigation …

In the news conference at 5:20 pm on April 18, photograph of suspects are released

A few hours later, tip from Mercedes-Benz owner, which allows the police to focus their search on Watertown

At 8:42 pm, on April 19, suspect is caught!

Map of Boston Marathon Bombings

Costly search!

- **Residents stay indoors (Watertown, and adjacent cities and towns)**
- **A 20-block area was cordoned off**
- **Helicopters, SWAT teams in armed vehicles, go with officers door-to-door**
- **FBI, and other 8 departments and offices**
- **Entire public transit network is suspended, as well as Amtrak**
- **Universities, schools, local businesses, and other facilities are closed**

Target Problem

- A cost-effective way to catch the target vehicle
  - Identify the exterior feature of each vehicle in coming (easy, out of our scope of this paper)
  - Complete the check of all vehicles moving in the entire area (challenging work)

Challenges

Checked or not?

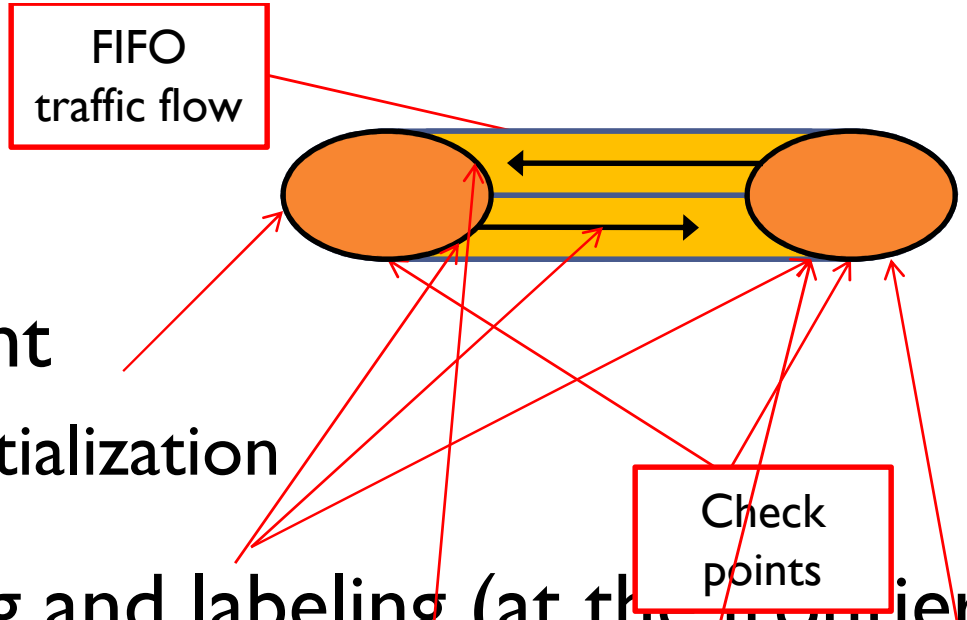
Do we still need the focus there?

- Miss-counting
  - Unpredictable trajectory and speed
  - Unexpected parking
  - No global surveillance to cover the entire area (e.g., to cover both Maryland and Virginia in Washington Sniper attack)
- Double-counting
  - Unnecessary delay to converge
  - Wasted time, resource, and work force
  - Inaccurate information (e.g., disaster evacuation)

Our approach

- Dye in water current
  - Color changes at the frontier of wave.

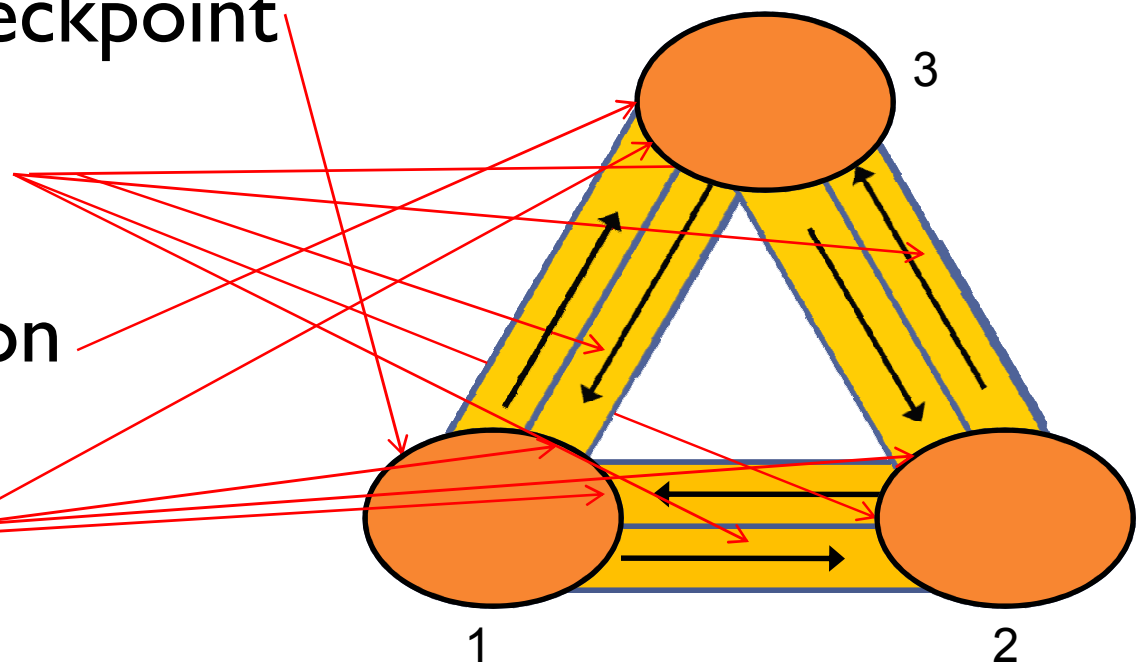
Algorithm



- Seed checkpoint
  - Activated in initialization
- Active counting and labeling (at the frontier along outbound direction)
  - Except for the coming direction of activation label
- Activation of inactive checkpoint
  - Upon receiving active label
- Ending the active counting (of inbound)
  - Upon receiving active label

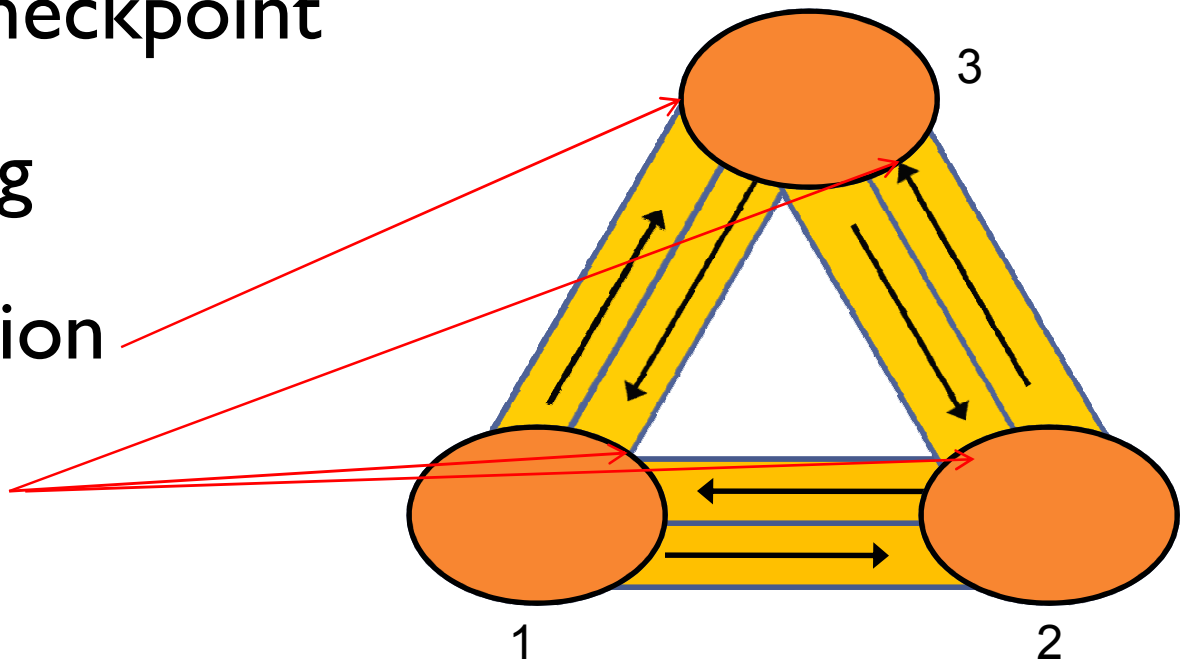
More complicate case

- Seed checkpoint
- Labeling
- Activation
- Ending



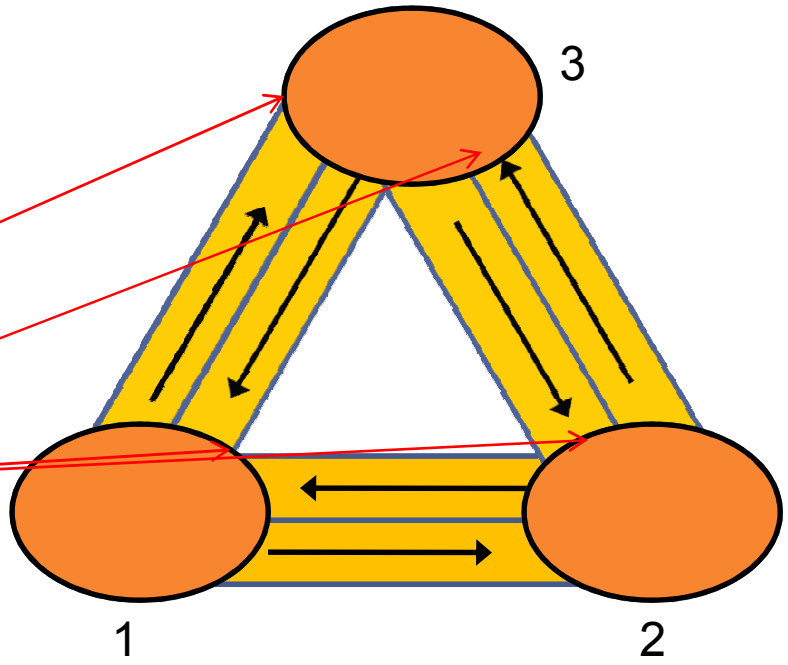
2 & 3 activated individually

- Seed checkpoint
- Labeling
- Activation
- Ending



Different ending time

- Seed checkpoint
- Labeling
- Activation
- Ending



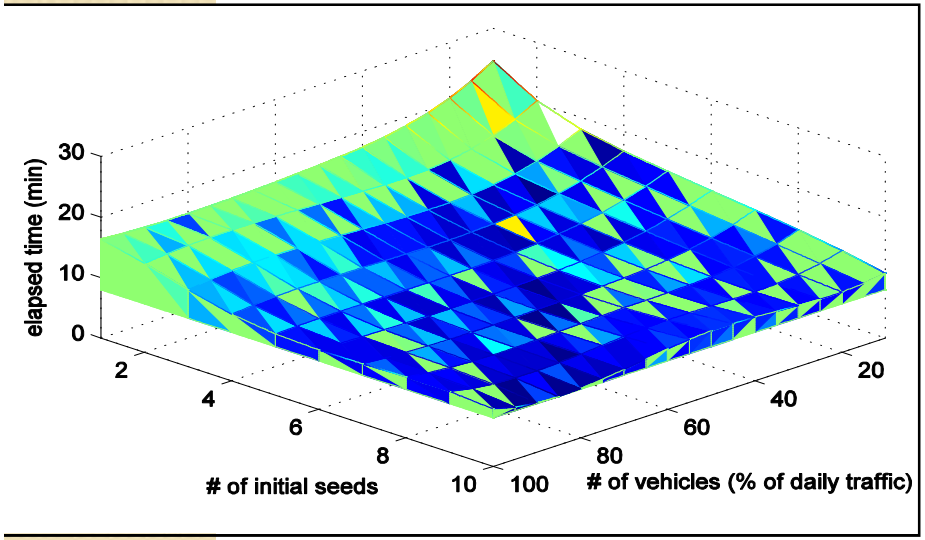
- Extensive adjustments for those dynamic changes along road segments
  - Non-FIFO road segment
    - Surpassing (+1) or being surpassed (-1) is allowed
  - Multi-targets (checked at intersections or roundabouts)
  - One-way street
  - Other odd traffic pattern
  - Multi-seed
  - Open system
    - Boundary

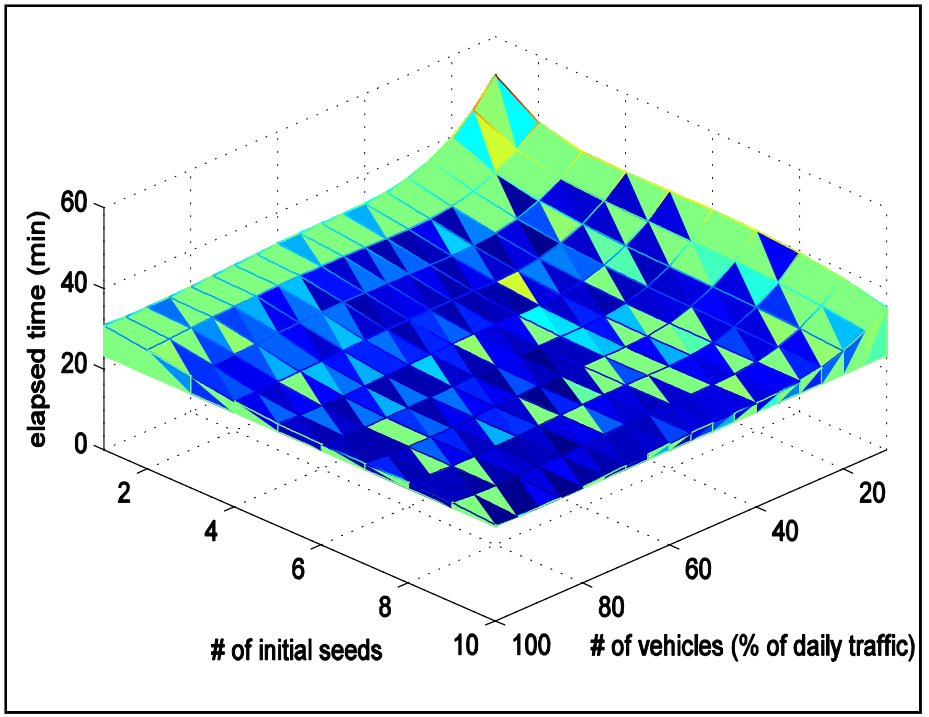
Experimental Results

New York Midtown

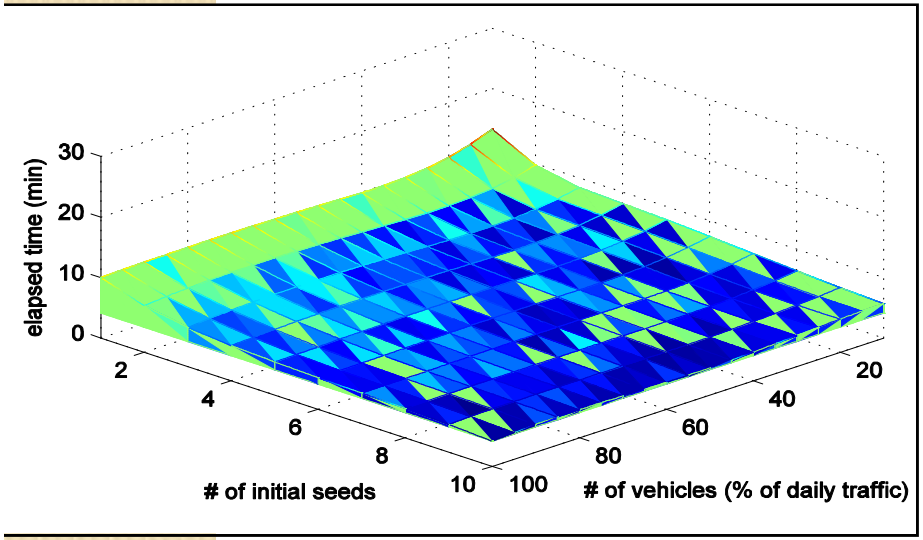
- Daily traffic
- Different volume and speed
- Multiple lanes and overtakes
- Speed limit
- V2V unreliable communication

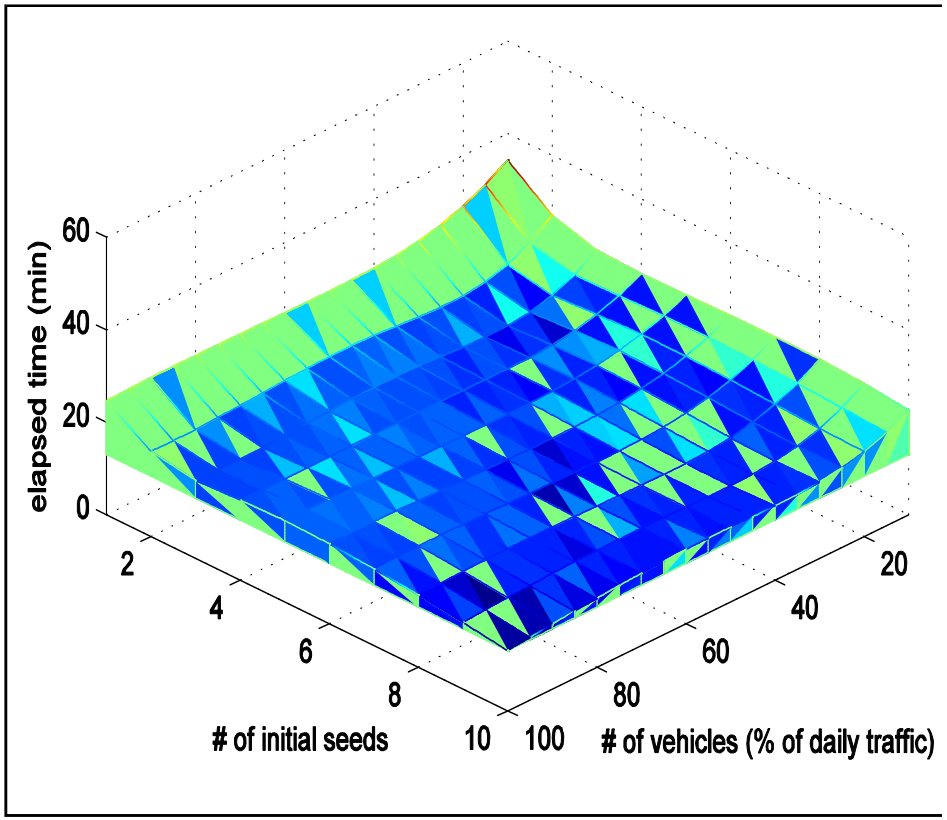
Counting convergence vs. complete process (until retrieving counting information), maximum elapsed time



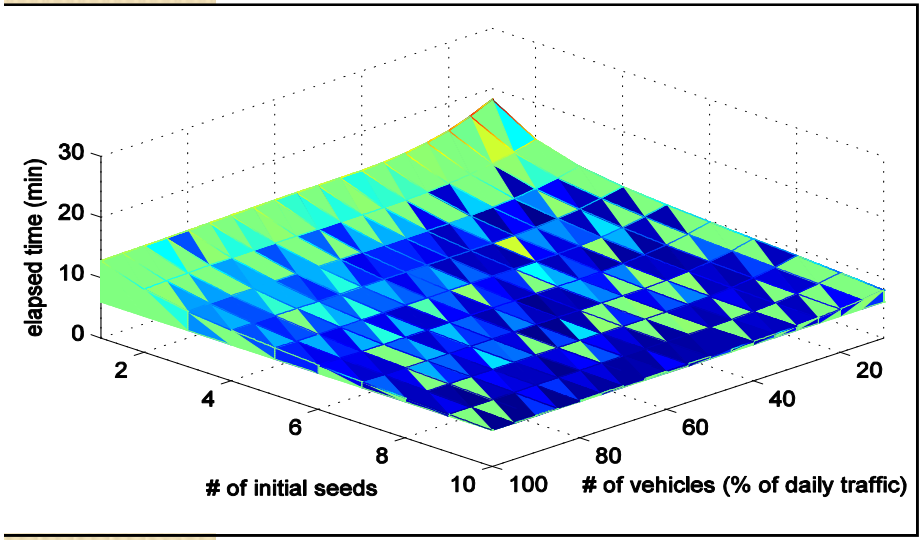


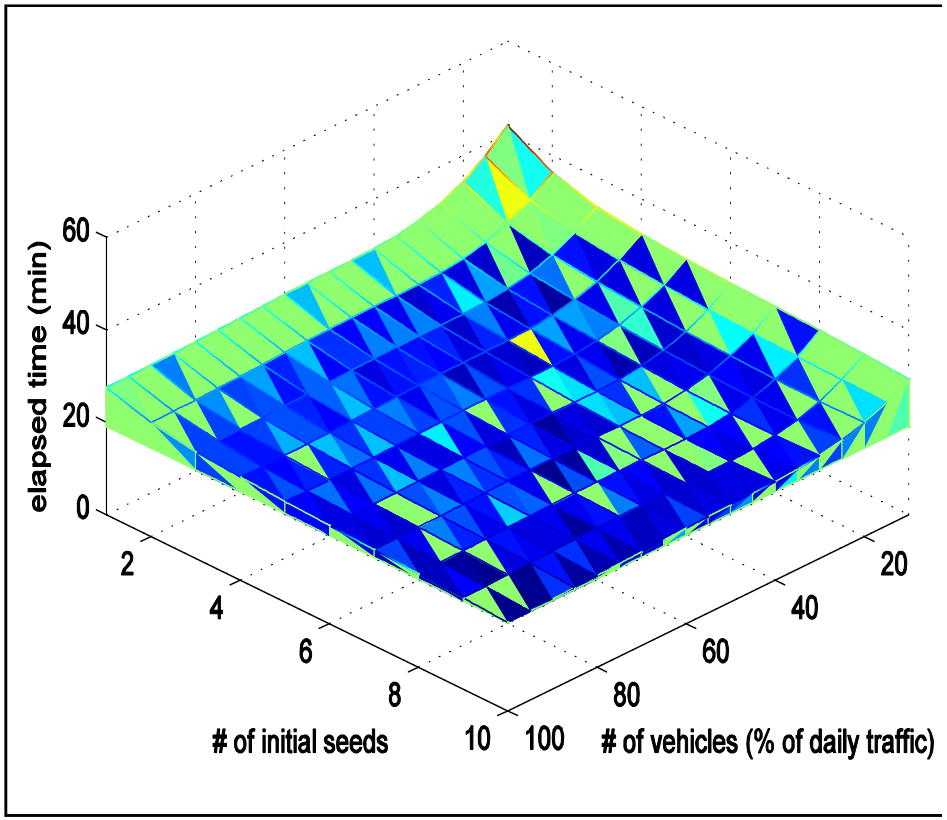
Counting convergence vs. complete process (until retrieving counting information), minimum elapsed time



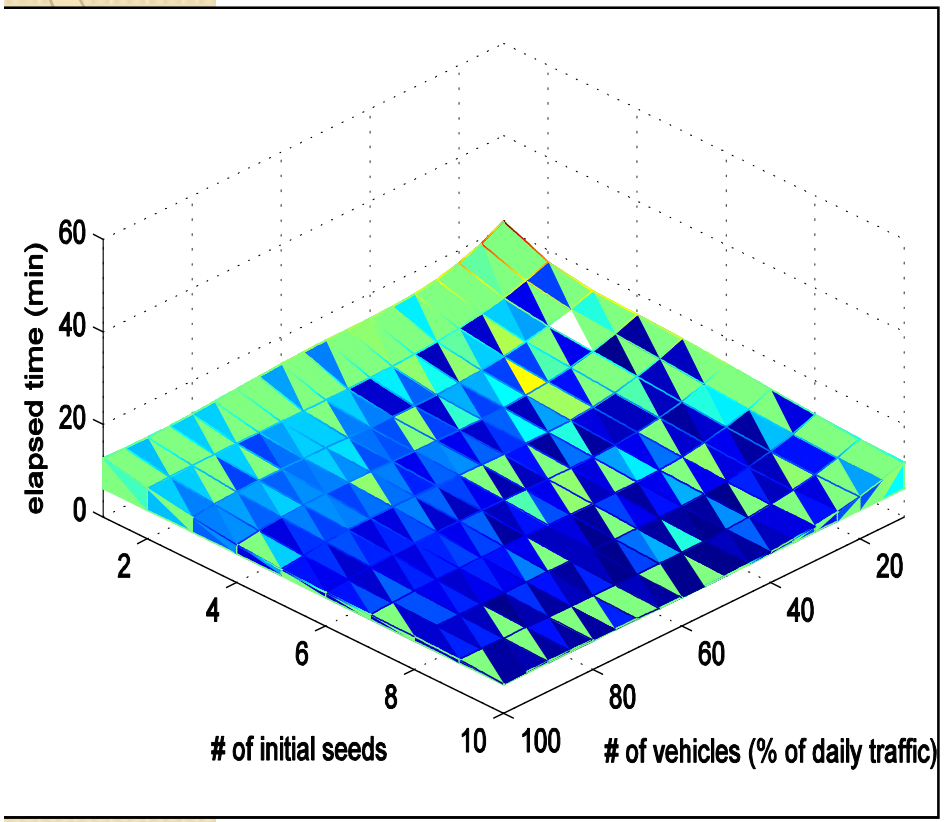


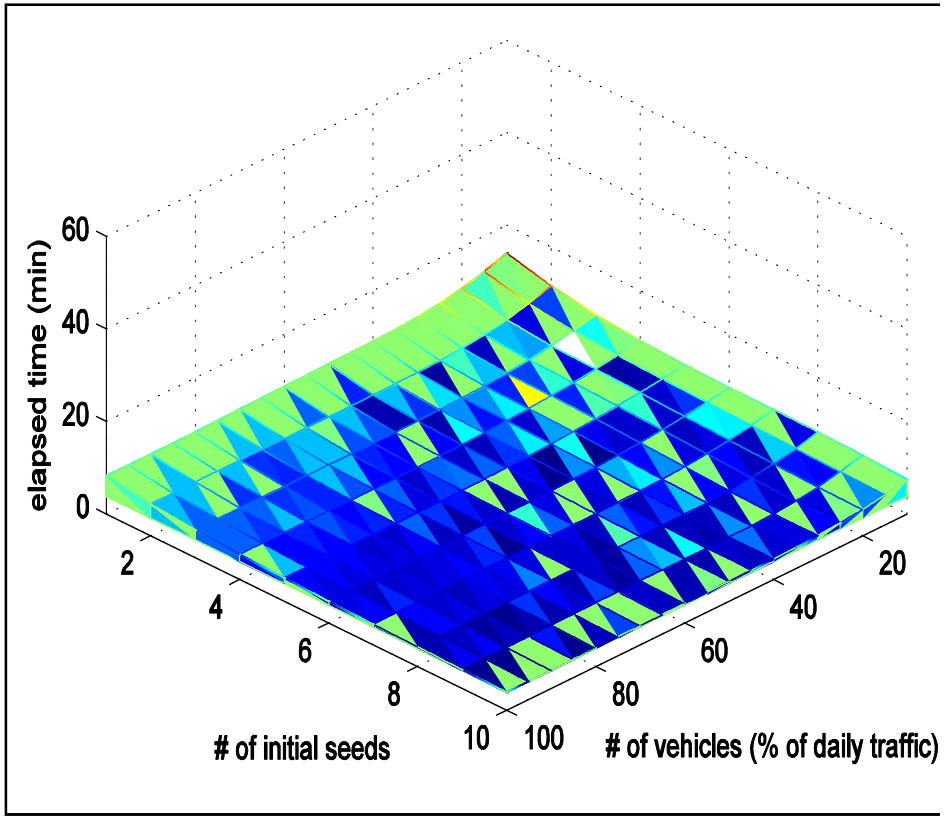
Counting convergence vs. complete process (until retrieving counting information), elapsed time on average





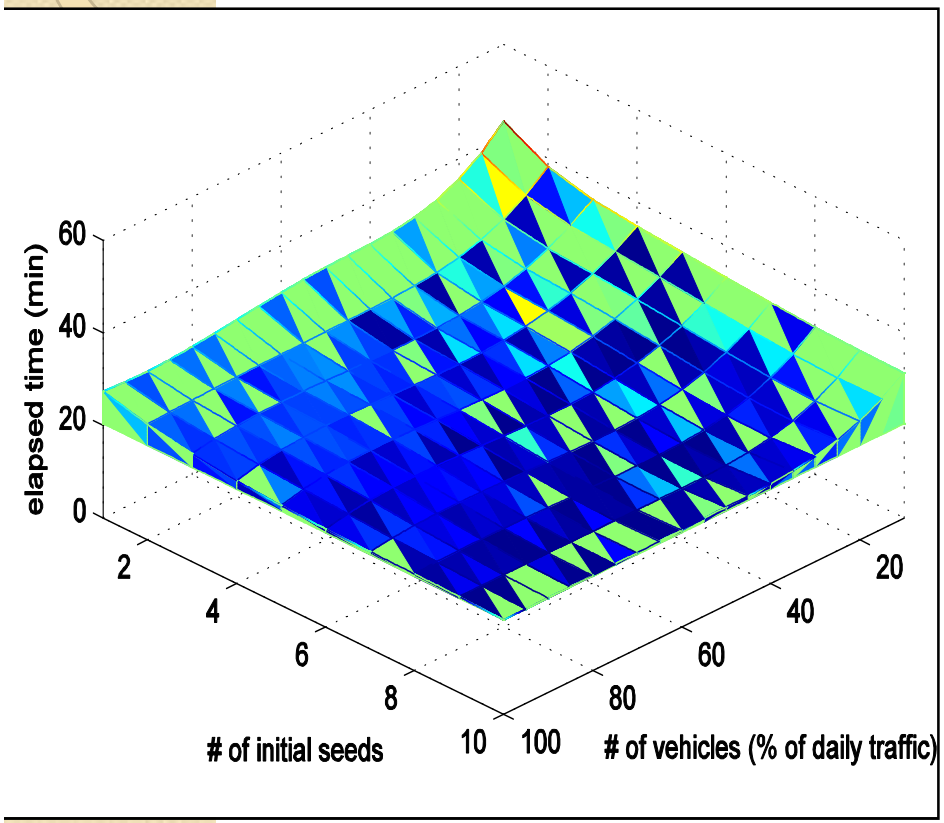
Counting convergence in open system, elapsed time on average

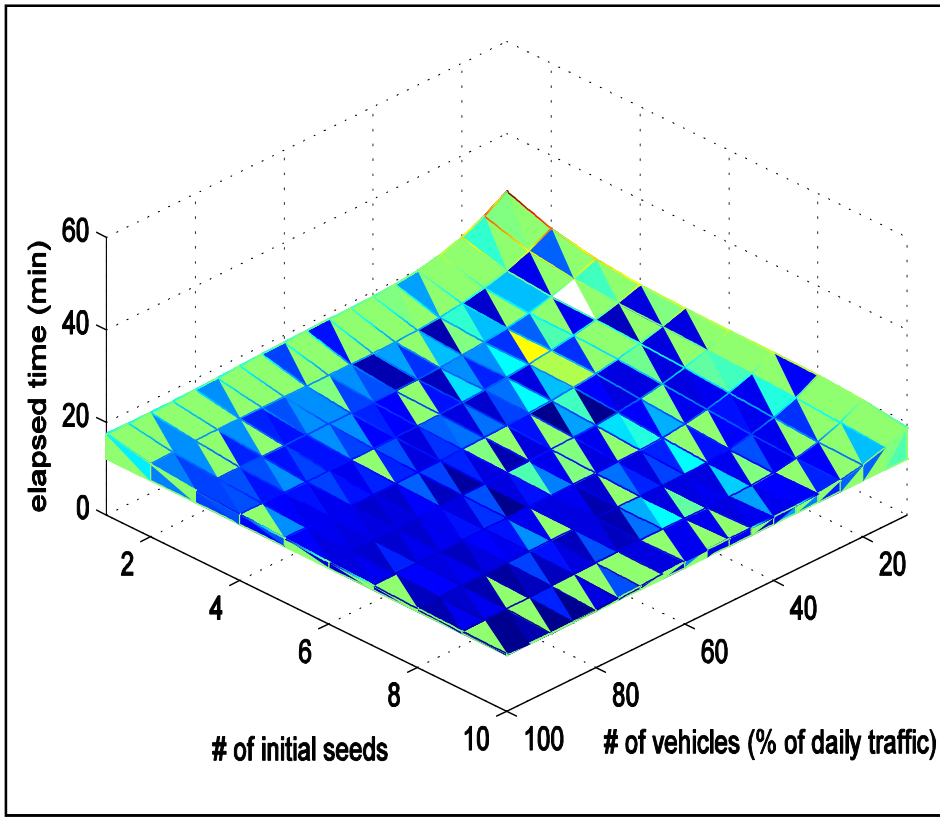




34~40% faster after a 66% speedup

Complete process in open system, elapsed time on average





34~40% faster after a 66% speedup

Summary (of experimental results)

- Counting with a fully distributed manner
- No escape, no double counting
- Scalable performance in both open and closed systems, in proportional to average vehicle speed
- No significant help from multiple seeds
- O(open) ~ O(closed)
- T(open) ~ T(closed) and T(open) > T(closed)
  - due to the delay for resuming the frontier wave at the boundary
- Accurate adjustment vs. dynamic road situations
- Correctness of the "complete status" in open system

Conclusion

- Precise counting with a fully distributed manner
- Dynamic adjustment via V2V communication, without extra infrastructure requirement
- Retrieving a global view with inconsistent local views
- Study of the impact of vehicle speed, and other factors
- A fundamental service for resource management in vehicle networks

Thank you!

- Questions and Comments