Distributed Dynamic Routing Using Network of Intelligent Intersections

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Distributed dynamic routing system development

- Provides single integrated and coherent picture of the network that is frequently and reliably updated
- Reduces congestion and maximizes capacity without worrying about drivers’ compliance and inertia
- Scalable, no need for costly infrastructure, and computationally less expensive
Outline of Presentation

• Motivation & Background

• End-to-End Dynamic Routing in Connected & Automated Vehicle Environment (E2ECAV)

• Case Study
  • Downtown Toronto Network

• Summary and Future Work
Motivation

- Annual cost to commuters in the Greater Toronto and Hamilton Area was $3.3 billion in 2006
- Estimated cost for 2031 will balloon to $7.8 billion (commuters) and $7.2 billion (economy)

[METROLINX]
Motivation

Problem

• **Congestion** (Inefficient use of roads)
  1. Local factors that are responsible for **local perturbations**
  2. Global factors impacting the **entire network**

Solution

• Distribute traffic optimally over the network using vehicle routing

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Background

Static Route Guidance
- Historical information
- Geographical locations

Dynamic Route Guidance (DRGS)
- Real time Traffic Info

Control Structure
- Distributed (V2I) + (I2I)
- Centralized

Role
- System Optimal (SO)
- User Optimal (UO)

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Background – DRGS

User Optimal Solution (e.g. Waze)

- Stable and fair from the perspective of drivers
- Potential of reducing travel time in the case of low to medium congestion

Drawbacks

- High congestion, high penetration rate and adverse condition
  ➢ Increase in travel time and increase in congestion

- Efficiency depends on the market penetration rate and the communication range of CAVs

Background – DRGS

System Optimal Solution

• 30% reduction in travel time under high congestion and adverse conditions

Drawbacks

• Unstable and unfair from drivers’ perspective
• Success depends on % compliance of the drivers

Zuurbier (2010); Wie et al (1995); Roughgarden & Tardos (2002); Boyce & Xiong (2004); Peeta & Mahmassani (1995); van den Bosch et al (2011)
Research Gaps

• Effects of individualistic and non-compliant behaviour of drivers

• V2V Solutions
  • No single integrated and coherent view of the network
  • Relies on MPR and range
Vehicle Routing Requirements

➢ Provide up to date and reliable real time traffic information
➢ Have single integrated and coherent view of the network
➢ Responsive to the changes in the network
➢ Maximize capacity & minimize travel time
➢ Scalable, and computationally less extensive

End-to-End Distributed Routing in Connected and Automated Vehicle Environment (E2ECAV) using Network of Intelligent Intersections
E2ECAV – Components

➢ The agents
  Agent Type 1: Connected and Automated Vehicles

  Agent Type 2: Infrastructure
    • Links
    • Intersections

➢ The agents’ environment
  • Road network
  • Communication network

➢ Interaction Rules
  • Defined by the city
1. Links store:
   a. # of vehicles on the link
   b. Vehicles’ speed

2. Compute average speed

3. $I^2$ estimates travel times for upstream links

4. $I^2$ communicates its adjacent upstream links’ travel times information to its neighbouring intersections

5. $I^2$ gradually builds full view of the network

6. $I^2$ from network impedance matrix creates dynamic on demand routing table

7. $I^2$ receives OD of vehicles and guides them to their destinations using dynamic routing table

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E2ECAV – Information Network Layer

Road Network Layer

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Case Study – Toronto Network

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Case Study – Toronto Network

Specifications

- **Study period:** 7:45am-8:00am
- **Dynamic 5 min OD Matrices** (Transportation Tomorrow Survey, 2011)
- **76 intersections, 223 links**
- **Three types of vehicles:** HDV, AV, CAV
- **Movement:** Intelligent Driver Model (IDM)

  - Same $a_{max}$ & $b_{max}$ for all three vehicle types
  - $T_{r,AV or CAV} = 2T_{r,HDV}$ and $s_{0_{AV or CAV}} = 2s_{0_{HDV}}$

- HDV & AV routed based on pre-trip dynamic shortest path
- CAV routed based on E2ECAV
Case Study – Goal

- Evaluating the performance of 100%E2ECAV and its impact on throughput/travel time in comparison to 100%HDV & 100%AV
Case Study – Travel Time (min) & VKT Analysis

- E2ECAV resulted in 40% decrease in travel time in comparison to HDV
- AV resulted in 31% decrease in travel time in comparison to HDV
Summary

• Dynamic distributed E2E routing based on the network of connected intelligent intersections and level 5 CAVs

• Reliable and up-to-date traffic information along with single integrated and coherent view of the network

• Responsive to the real time changes in the system

• With drivers no longer the decision makers full cooperation and coordination can be expected

• Distributes traffic in the network in such a way that maximizes capacity and minimizes travel time
Future Work

• Different queuing strategies and different classes of vehicles with different priority levels (e.g. emergency vehicles, street cars, etc.)

• Investigate the behavioral response of the drivers in CAV environment
  • Virtual Reality based experiments

• Comparison of E2ECAV with cooperative CAV using only V2V communication

• Shared and on-demand services
Acknowledgements

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THANK YOU!

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