Routing Autonomous Emergency Vehicles in Smart Cities Using Real Time Systems Analogy: A Conceptual Model

SUBASH HUMAGAIN

ROOPAK SINHA

rsinha@aut.ac.nz

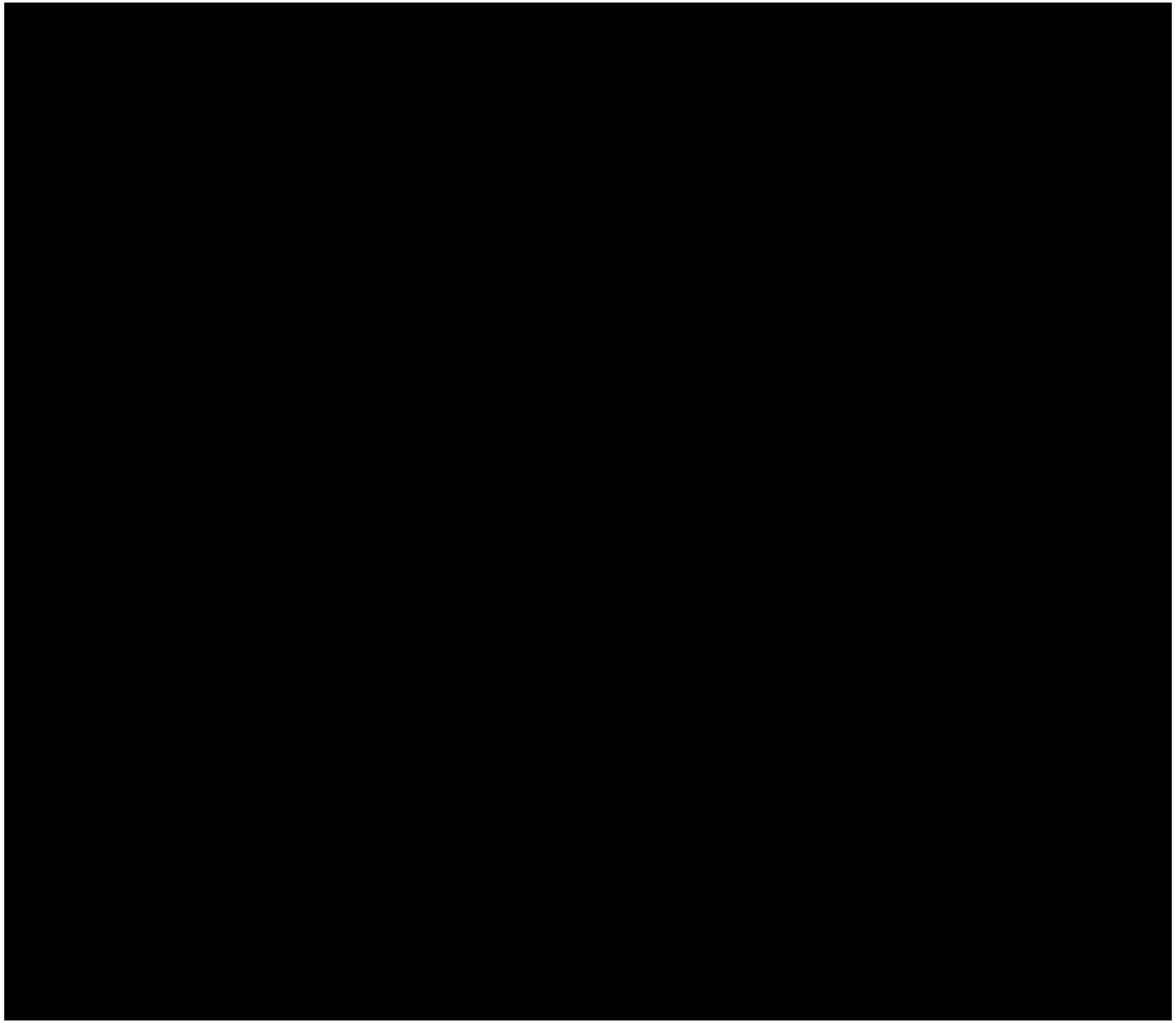
OVERVIEW

- **Problem: reduce** the travelling time of emergency vehicles (EVs).
- **Approach**:
  - A systematic literature review of existing techniques.
  - Develop new algorithms using analogical mapping between real-time systems (RTS) and EV routing.
- **Contribution**:
  - A conceptual model of autonomous EV routing in smart-cities (an ideal scenario).

EV ROUTING

In the USA alone, a 1-minute delay in EV response causes:

1. 1% increase in mortality.
2. $7B increase in healthcare expenses yearly (RapidSOS, 2015)



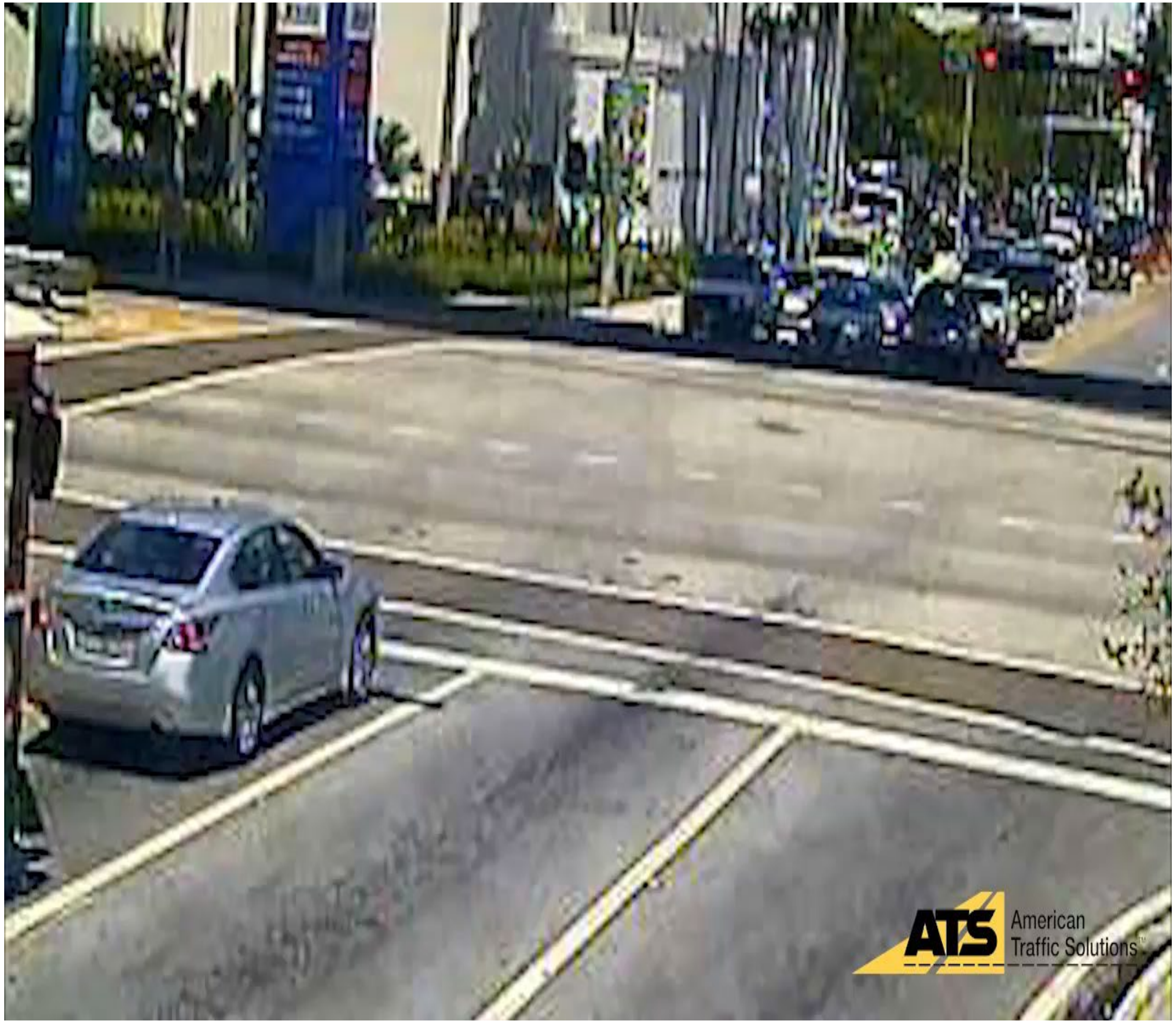
EV ROUTING

4500 accidents involving ambulances each year

3160 accidents involving fire vehicles

300 fatalities during police pursuit

(NHTSA, 2014)



Background

- Emergency services have target times to respond to different level of emergencies .
- For purple and red incidents, response time is:
  - NZ: 8 minutes for 50% of cases and 20 minutes for 95% of cases (St. John's, 2016).
  - UK and Canada: 75% of cases within 8 minutes (NHS England, 2015),
  - USA: 90% of cases within 8 minutes 59seconds (Pons & Markovchick, 2002),
  - Australia: 50% of cases within 10 minutes (Department of Health, 2015),
  - Hong Kong: 92% of cases within 12 minutes (J.Fitch, 2005).

Overall Approach

- Dynamic road-network parameters prevent EVs achieving desired response times (Gedawy,2013)
  - Congestion, Halts on road
  - Pedestrian flow, Queued vehicles
- These parameters are required for dynamic optimization and pre-emption
  - In smart cities, this data can be more easily accessed.
  - In autonomous vehicles, driver-behaviour can be more deterministic.

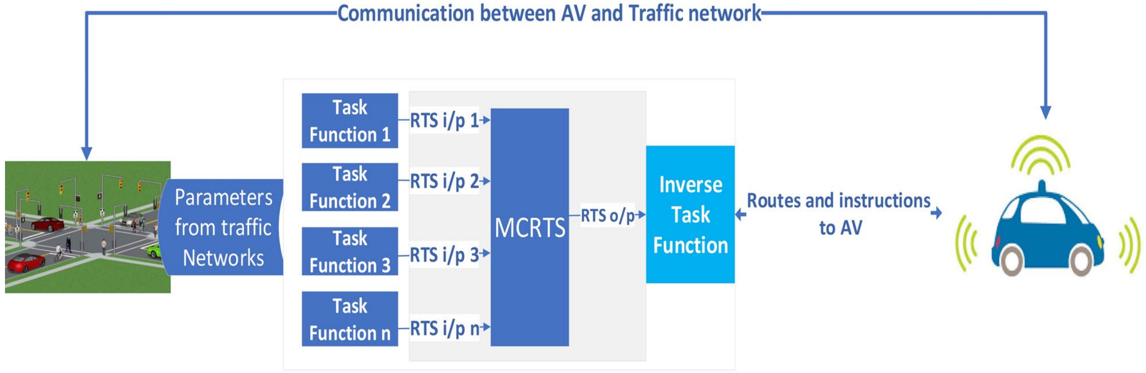
Proposal: A conceptual model of routing autonomous emergency vehicles (AEVs) in smart cities using mixed criticality real-time system (MCRTS) analogy.

Smart-Cities and AEVs: The Ideal Scenario

- Dynamic parameters are available in real-time: EVs can provide high assurance for meeting expected response times (Yaqoob,2017)
- Autonomous vehicles eliminate uncertainty due to driver behaviour (McAllister,2017)
- The system can coordinate actions like creating green wave, lane reservation, and informing other vehicles (Kokuti, 2017)
- Analogically mapping emergency levels to criticality levels in a mixed-criticality real-time system allows designing algorithms to cater to all emergency levels.

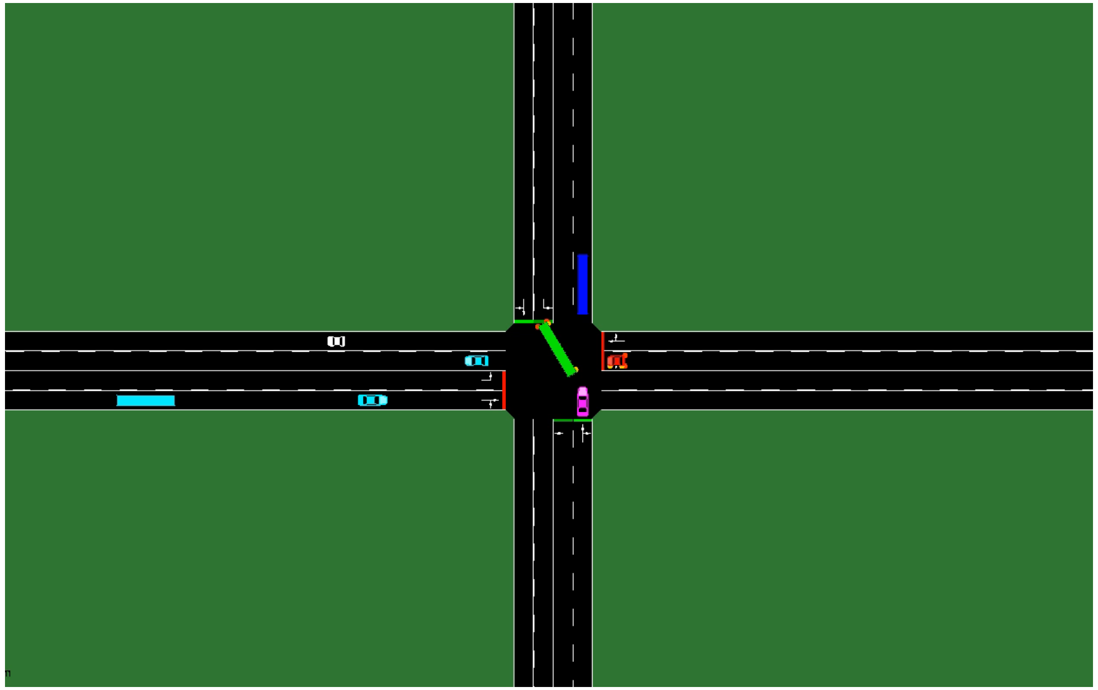
Analogical Mapping to MCRTS

Inputs	Outputs
Number of periodic, aperiodic or sporadic tasks Number of Pre-emptive and non-pre-emptive tasks Number of Fixed or dynamic priority tasks Number of Independent or dependent tasks Number of processors Number of reserved processor Release time, completion time deadlines, priority, precedence, constraints	Assigning task to processor Assign new deadline Queue task Alter priority Assign pre-emption etc.



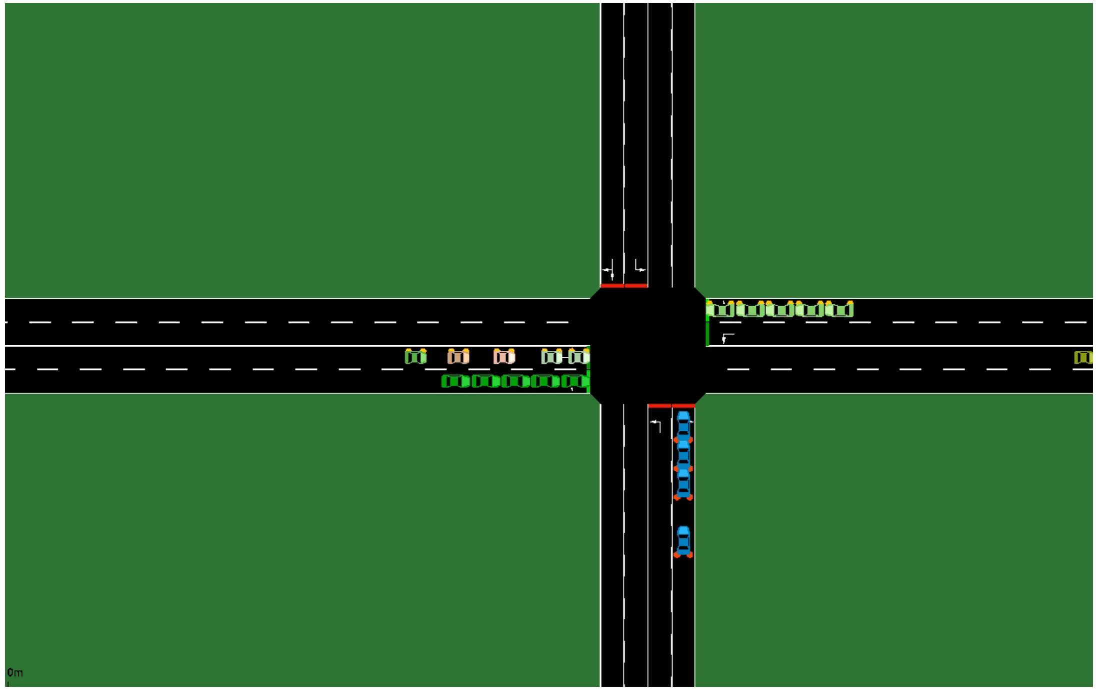
Case Study: Using Task Scheduling for Intersection Control

- Traffic intersection designed with random flow of traffic in SUMO.
- Vehicle types are mixed type and spawn randomly.
- Arrival time and departure time of each vehicle is randomised.
- Traffic intersection control is fixed time.



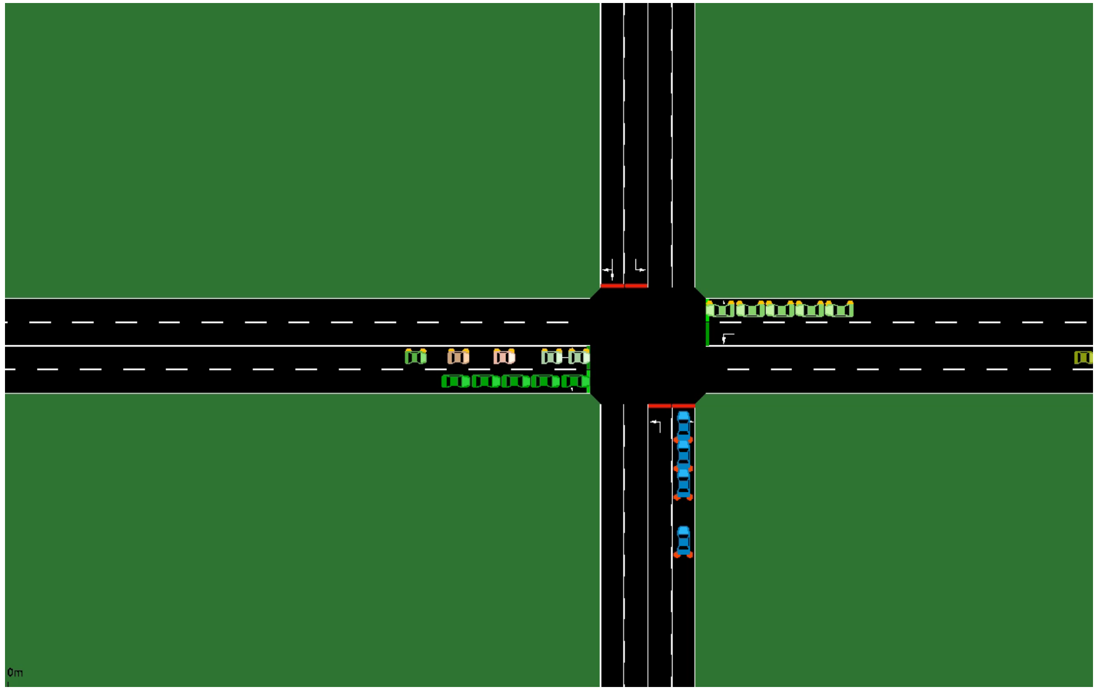
Case Study: Using Task Scheduling for Intersection Control

- Vehicles are grouped together to form a platoon.
    - Variable integer lengths.
    - Has a leader.
- Platoon leader negotiates with the traffic controller to set green-time that allows platoon enough time to pass by.
- Each vehicle can communicate with each other and traffic controller using V2X communications
- Implemented using OmNET++ and Veins.



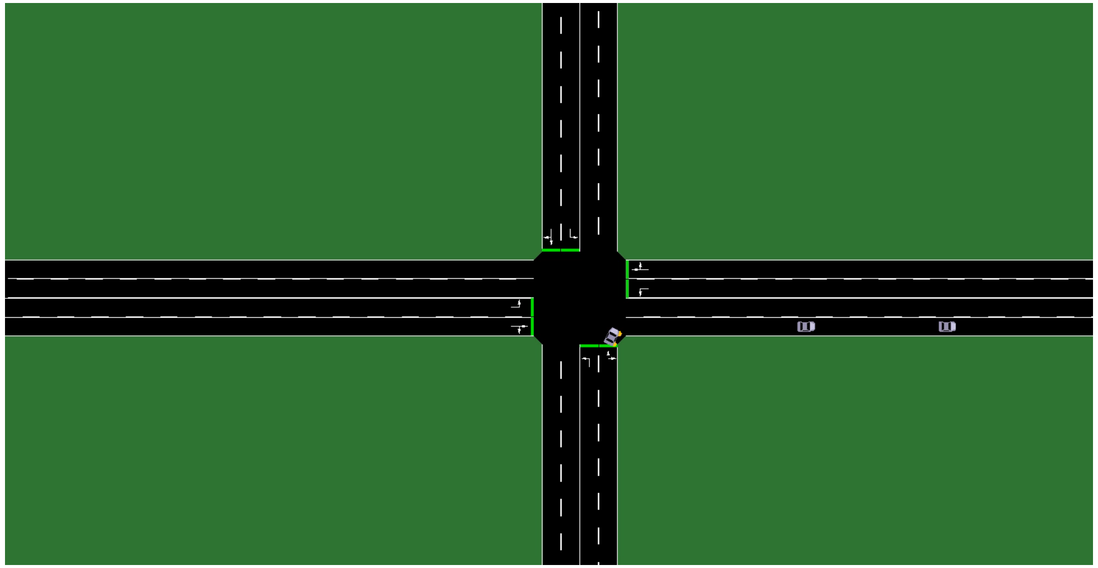
Case Study: Using Task Scheduling for Intersection Control

- Platoon containing an emergency vehicle uses pre-emption.
- A continuous green signal is provided until emergency vehicle crosses the intersection.



Extension: Routing EV through multiple connected intersections (WiP)

- A shortest path for EV is determined.
- Once a intersection processes an EV it communicates with next intersection in the EV’s path to request timely pre-emption.
- Multiple EVs negotiate their priority based on criticality level.
- Implementable as a virtual traffic light.



Experimental Results

Optimized Webster's Method		Variable quantum Round Robin Algorithm		Improvement
Throughput	Waiting Time	Throughput	Waiting Time	2.57% in throughput & 14.19% in waiting time
2757 pcu/hr	18.18 sec/veh	2828 pcu/hr	15.60 sec/veh	

Conclusions and Future Work

- The proposed system shows considerable reduction in EVs response time.
- An adaptive real-time traffic control system has improved throughput and waiting time.
- Next steps:
  - Complete experiments in calibrated real-life city traffic networks.
  - Further experiments and evaluations to justify our claims.
- Future Works:
  - How can dynamic parameters be made available in real-time?
  - Real-time cooperation between vehicles.

Thank you

rsinha@aut.ac.nz