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Coalition Game for Emergency Vehicles Re-routing in Smart Cities

Hayder M. Amer[a], Hayder A. A. Al-Kashoash[b], Andrew Kemp[c], Lyudmila Mihaylova[a] and Martin Mayfield[d]

[a] University of Sheffield, ACSE, UK
[b] Southern Technical University, Basra, Iraq
[c] University of Leeds, UK
[d] University of Sheffield, Civil Engineering, UK

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Outline

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2. The Proposed Game Coalition Framework
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   - Coalition game of emergency vehicles
3. Performance Validation and Evaluation
4. Conclusions and Future Work

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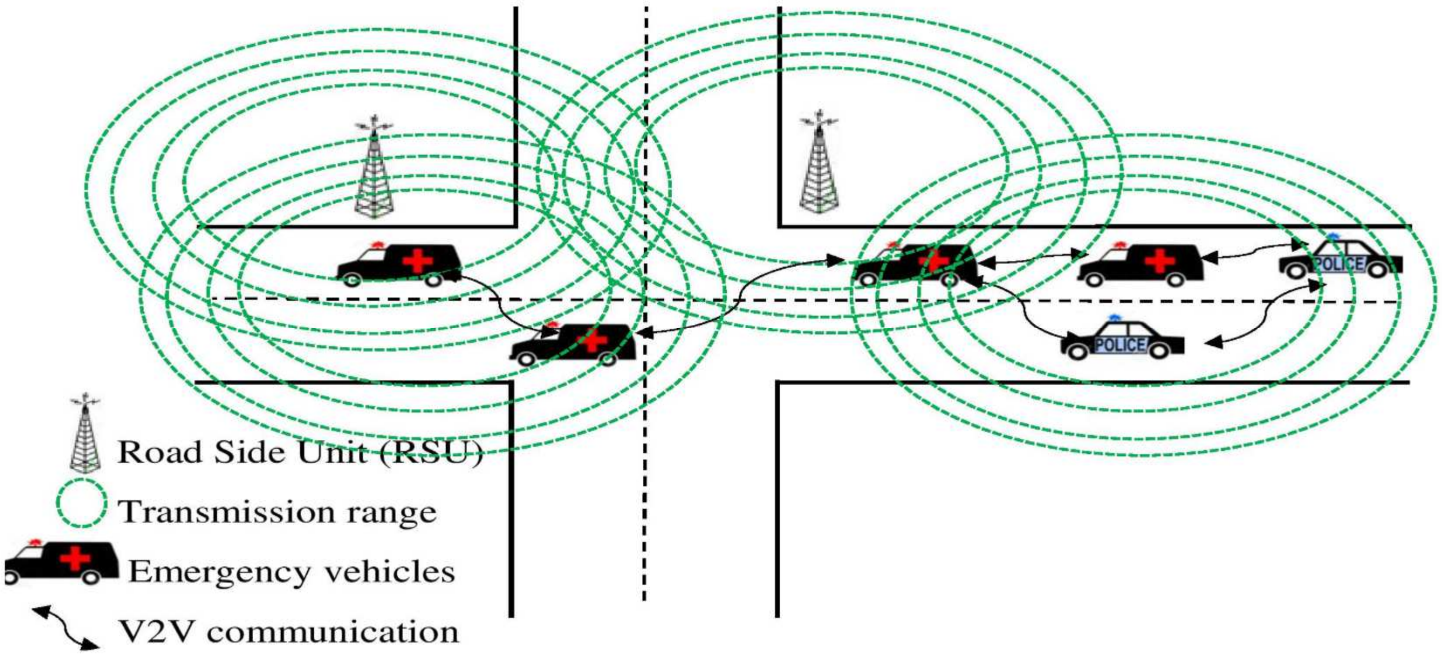
Introduction

- Impact of traffic congestion:
  - Increases travel journey
  - Increases accidents on roads
  - Increases road deaths
  - Increases fuel consumption and *CO*2 emissions.
- So, traffic congestion control mechanism is important in smart cities.
- VANETs include Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication systems.
- Both systems can be used to collect traffic information.

The Proposed Framework

- This system includes three phases are:
  - Data collection
  - Road network
  - *Coalition game of emergency vehicles*
- Each vehicle sends Road ID and average velocity using hello packets.



Road Network

- Road Network: road network can be modelled as a directed graph G = (N, E).

$$H = \begin{matrix} \\ H_1 \\ H_2 \\ \vdots \\ H_v \\ \\ \end{matrix} \begin{matrix} T_L & R_L & D_L \\ \left[\begin{matrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ \vdots & \vdots & \vdots \\ r_{v1} & r_{v2} & r_{v3} \\ w_1 & w_2 & w_3 \end{matrix}\right] \end{matrix}$$

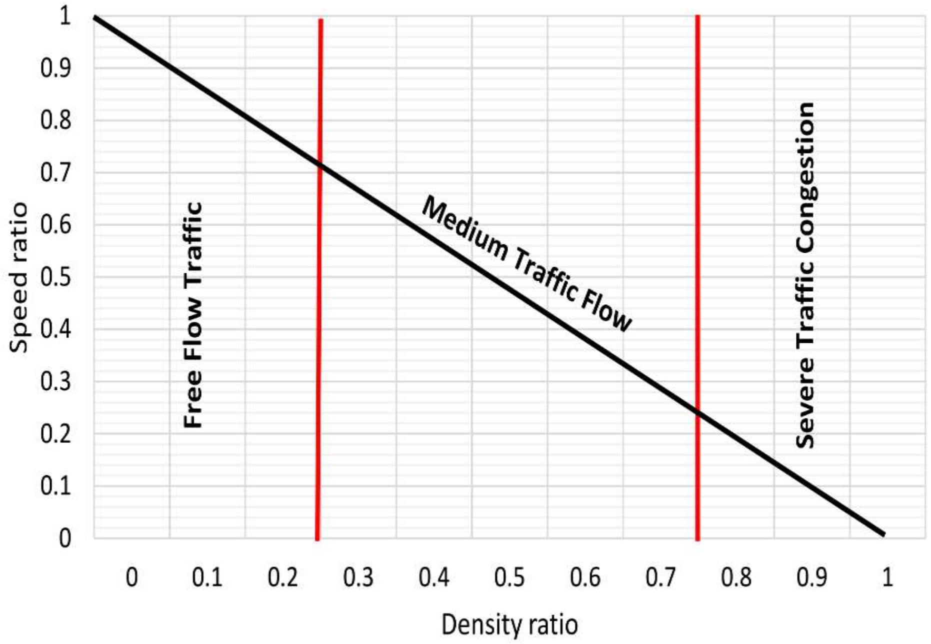
- The normalized road matrix has been obtained using the following equation:

$$r_{jk} = \frac{\max\limits_{\forall i}\{x_{jk}\} - x_{jk}}{\max\limits_{\forall i}\{x_{jk}\} - \min\limits_{\forall i}\{x_{jk}\}}.$$

$$r = \{r_{jk} | j = 1, \ldots, v; \quad k = 1, 2, 3\}$$

Road Network

- The speed ratio is defined to numerically represent the traffic state of a road as follows:



$$V_r = \frac{V_i}{V_f}.$$

Road Network

- Main parameters of the cost function:
  - Road travel time, road length, density of vehicles
- A linear relationship between speed and density (Greenshield’s model, [1])

The current traffic density: $$D_L = D_q(1 - V_r)$$

The maximum jam density: $$D_q = g\frac{L_i}{Avg_L}$$

Density ratio: $$D_r = \frac{D_L}{D_q}$$

Velocity ratio $$V_r = 1 - D_r$$

[1] M. A. Chowdhury, A. W. Sadek, Fundamentals of intelligent transportation systems planning, Artech House, U.S., 2003.

Road Network

- The cost function of the emergency vehicle:

$$f = \text{Min}\{w_1 T_L + w_2 R_L + w_3 D_L\}$$

$$T_L = \sum_{j=1}^{v} r_{j1}$$

$$R_L = \sum_{j=1}^{v} r_{j2}$$

$$D_L = \sum_{j=1}^{v} r_{j3}$$

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Coalition Game for Emergency Vehicles

- A normal form cooperative game is a couple (*N, U*) where:
  - *N* is a set of players.
  - *U* is a value function that assigns a real value to every coalition $C \in 2^N$.
- $EV = \{EV_1, EV_2, \ldots, EV_n\}$ represents number of players or emergency vehicles.
- Each route in $R = \{a_1, a_2, \ldots, a_m\}$ generated from PSO is considered as a coalition in the game and each *EV* in *N* will play a strategy *S* = *{join, not join}* that is *EV* prefer to join for a certain coalition or not.

Coalition Game of Emergency Vehicles

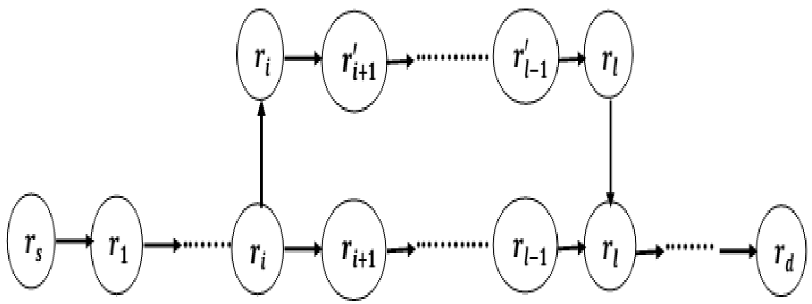
Algorithm 1 The particle swarm algorithm.

1: Initialize the particle array with some random solutions.
2: **Loop**
For each particle z with position p_z in S domain do
Estimate the fitness function f for each particle as in (7).
If $f(p_z) < f(pbest)$
$pbest = p_z$
where $pbest$ is the location of the best fitness of all visited location.
End If
If $f(pbest) < f(gbest)$
$gbest = pbest$
where $gbest$ is the best location or solution found so far.
End If
End For
3: Update particle velocity and position.
For each particle z in S do

$$vs = vs + e_1 rand()(pbest - p_z) + e_2 rand()(gbest - p_z) \tag{8}$$

$$p_z = p_z + vs \tag{9}$$

End For
Here, v is the particle velocity, p_z is the current solution. rand () is a random number between $(0, 1)$. e_1 and e_2 are learning factors. Usually $e_1 = e_2 = 1$.
4: $T = T + 1$ advanced iteration.
5: Exit the loop, if $T \geq T_{max}$.
6: **End**.



Coalition Game for Emergency Vehicles

- Communication among emergency vehicles and RSU is based on query and response messages.
- Each emergency vehicle send a query to request an optimal route or coalition from the RSU.
- RSU send a response messages that contain the optimal routes.
- Emergency vehicles send the coalition name to other vehicles to join this group or the second one.

Performance Evaluation

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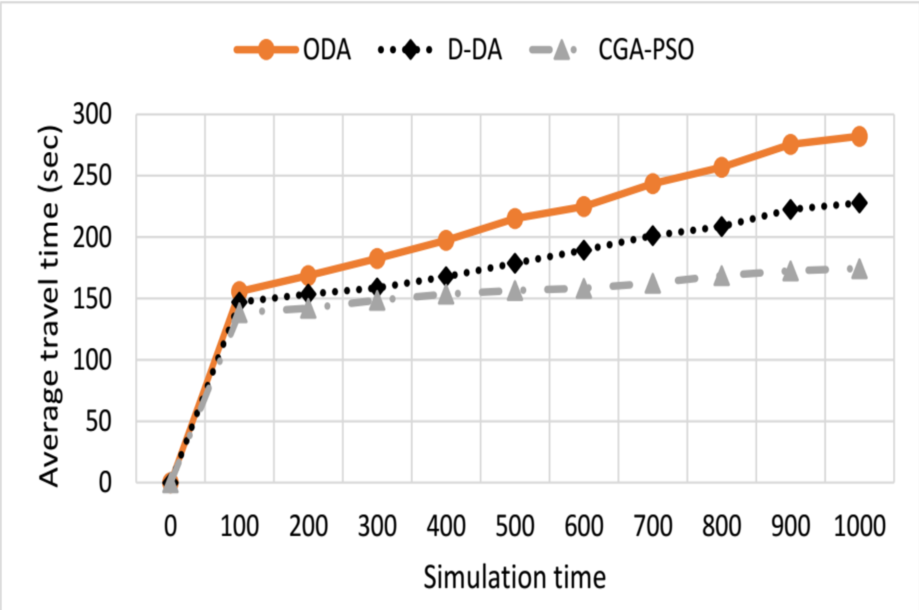
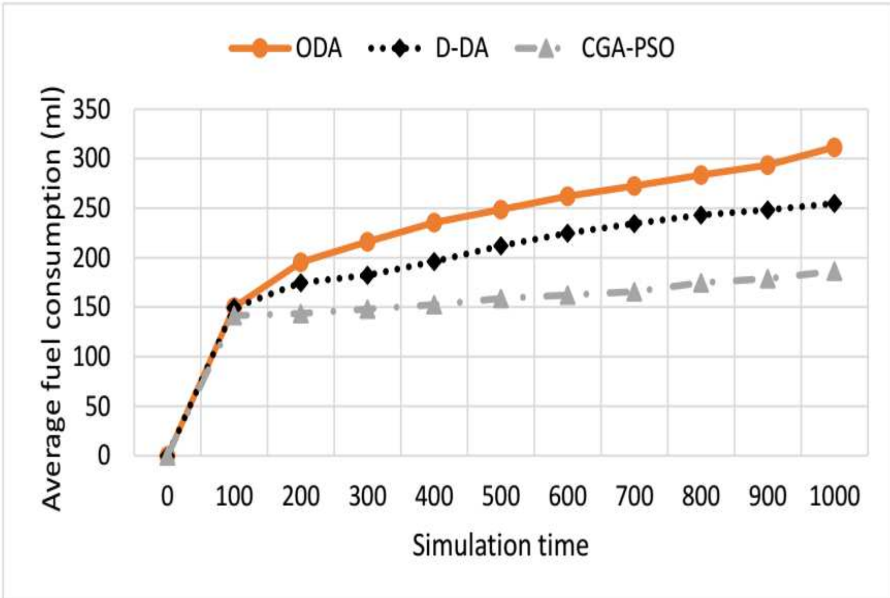
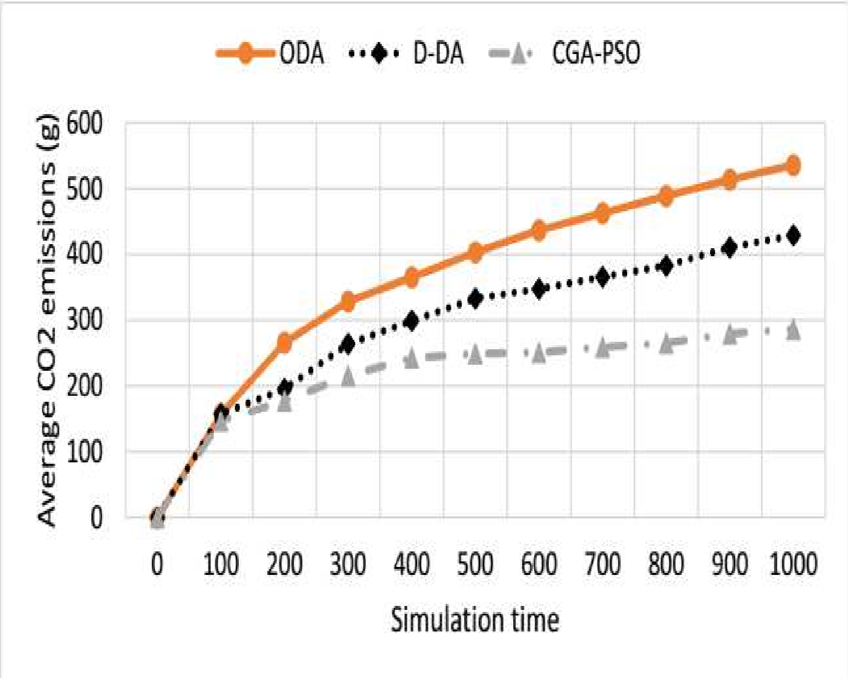
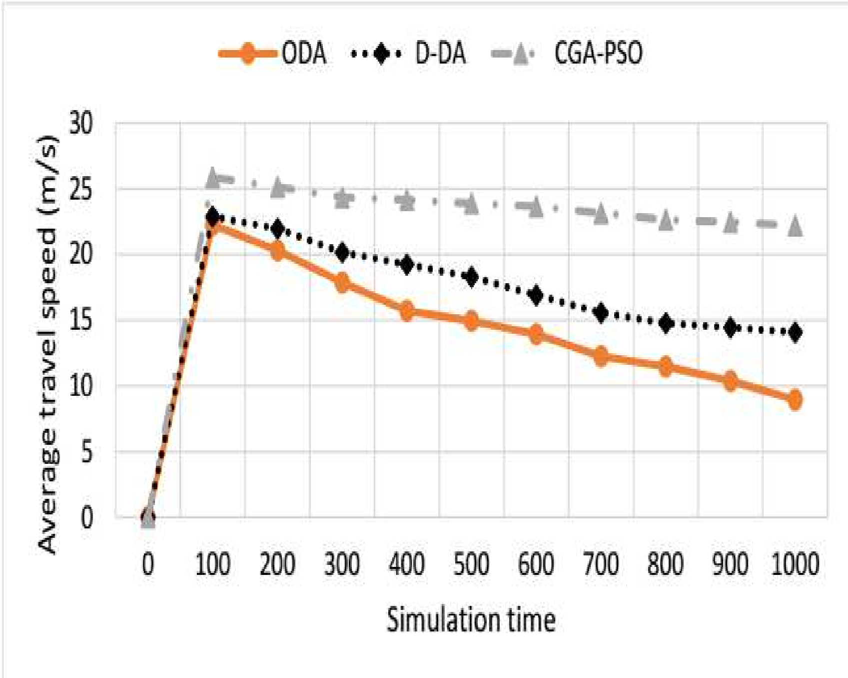
Performance Evaluation





Performance Evaluation





Conclusions and Future Work

- We propose a new dynamic approach called GA-PSO for the emergency vehicles routing.
- GA-PSO has been tested under traffic scenarios and compared with two other algorithms ODA and D-DA.
- GA-PSO has better performance in terms of:
  - Travel time.
  - Fuel consumption.
  - $CO2$ emissions.
  - Average travel speed.

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Thank you !