Coalition Game for Emergency Vehicles Re-routing in Smart Cities

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   - Coalition game of emergency vehicles
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Introduction

• Impact of traffic congestion:
  • Increases travel journey
  • Increases accidents on roads
  • Increases road deaths
  • Increases fuel consumption and CO2 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 $G = (N, E)$.

$$
\begin{align*}
& H_1 = \begin{bmatrix} r_{11} & r_{12} & r_{13} \\
& \vdots & \vdots & \vdots \\
& r_{v1} & r_{v2} & r_{v3} \\
& w_1 & w_2 & w_3 
\end{bmatrix} \\
& H = T_L \quad R_L \quad D_L \\
& H_v \\
\end{align*}
$$

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

$$
\begin{align*}
& r_{jk} = \frac{\max_i \{x_{jk}\} - x_{jk}}{\max_i \{x_{jk}\} - \min_i \{x_{jk}\}}. \\
& r = \{r_{jk} | j = 1, \ldots, v; \; k = 1, 2, 3\}
\end{align*}
$$
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

\[ V_r = 1 - D_r \]

Road Network

- The cost function of the emergency vehicle:

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

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

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

\[ D_L = \sum_{j=1}^{v} r_{j3} \]
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 the 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 \( f(p_z) < f(p_{best}) \)
      
      \( p_{best} = p_z \)

      where \( p_{best} \) is the location of the best fitness of all
      visited location.

      End If

      If \( f(p_{best}) < f(g_{best}) \)
      
      \( g_{best} = p_{best} \)

      where \( g_{best} \) 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

   \[
   v_z = v_z + e_1 \text{rand}() (p_{best} - p_z) +
   e_2 \text{rand}() (g_{best} - p_z) \tag{8}
   \]

   \[
   p_z = p_z + v_z \tag{9}
   \]

   End For

   Here, \( v \) is the particle velocity, \( p_z \) is the current solution.
   \( \text{rand}() \) 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

Birmingham New Street Train Station
Performance Evaluation
Performance Evaluation

![Graphs showing average CO2 emissions and average travel speed over simulation time for ODA, D-DA, and CGA-PSO.](image)
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.
Thank you!