VEHICULAR TRAFFIC FLOW MODELS
- AN OVERVIEW

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Outline

- Introduction
  - VANETs
  - Why we need to know traffic flow theories

- Traffic flow models
  - Microscopic
  - Macroscopic
  - Mesoscopic

- Summary
Introduction

- Vehicular ad hoc networks (VANETs)
  - Vehicles with communication capabilities.
  - Road side units (RSUs)
  - Dedicated short range communications (DSRC) channels.
- V2V / V2I communications.
- Safety and infotainment applications
Mobility is one of the major issues in VANETs.

- Nodes move with high speeds.
- Dependent on drivers behaviour and interactions with other vehicles.
- Susceptible for variable traffic density from time-to-time and from point-to-point on the same roads.

Vehicles movement is not completely random.

What is the right mobility model?
Study the VANET structure: vehicular traffic.

Traffic flow models — civil engineering literature.

Very rich literature.

The proposed traffic flow models are categorized according to the level of details they model into:

- Microscopic – Mesoscopic - Macroscopic
Microscopic level

- Details: vehicle’s behaviour and its interaction with leading vehicle(s) is individually modelled.
  - Car following models "keeping a safe distance ahead".
  - Pipe’s rule[1] "A good rule for following another vehicle at a safe distance is to allow yourself at least the length of a car between you and the vehicle ahead for every ten miles an hour of speed at which you are travelling“

Microscopic- cont.

- Forbe’s Theory\textsuperscript{[1]} Reaction time
- GM Model\textsuperscript{[1]} response=func(Sensitivity ($\theta$), stimuli)
  \[ a_i(t + \Delta t) = \theta(v_{i+1}(t) - v_i(t)) \]
- Multi-Anticipative\textsuperscript{[2]} interaction with N nodes ahead
- Limitations of car-following models\textsuperscript{[3]} vehicle not always in a following mode
- Cellular Automata (CA) models \textsuperscript{[4]}

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  \begin{tabular}{ccc}
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  \end{tabular}
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- CA-Markov Models \textsuperscript{[5]}

Details: aggregate behaviour (flow)

This level is important for deciding traffic flow state. (Average)

Density-speed-flow relations $D = \frac{F}{V}$

Density disruptions [6]

## Macroscopic level-cont.

<table>
<thead>
<tr>
<th>Density (veh/ml/lane)</th>
<th>Level of Service</th>
<th>Flow conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-12</td>
<td>A</td>
<td>Free-flow</td>
</tr>
<tr>
<td>12-20</td>
<td>B</td>
<td>Reasonable free-flow</td>
</tr>
<tr>
<td>20-30</td>
<td>C</td>
<td>Stable</td>
</tr>
<tr>
<td>30-42</td>
<td>D</td>
<td>Borders on unstable</td>
</tr>
<tr>
<td>42-67</td>
<td>E</td>
<td>Extremely unstable flow</td>
</tr>
<tr>
<td>67-100</td>
<td>F</td>
<td>Forced or breakdown</td>
</tr>
<tr>
<td>&gt;100</td>
<td></td>
<td>Incident situation</td>
</tr>
</tbody>
</table>

Uncongested flow conditions

Near-capacity flow conditions

Congested flow conditions

Mesoscopic level

- Details: Does not trace individual vehicles, but models behaviour of individuals.
- Time headway distributions
- Vehicles enter the highway according to a renewal process
- The time headways (inter-arrival times of vehicles) are i.i.d.
Mesoscopic level- cont.

- Time headway:
  - low traffic flow conditions (exponential distribution)
    \[ f_T(t) = \lambda e^{-\lambda t}, \quad t \geq 0 \]
  - High traffic flow conditions (normal distribution)
    \[ f_T(t) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(t-\mu)^2}{2\sigma^2}}, \quad t \geq \alpha \]
    \[ \mu = \frac{1}{\lambda}, = \frac{1}{F} \quad \text{suggested:} \quad \sigma = \frac{\mu-\alpha}{2} \]

Mesoscopic level–cont.

- Intermediate traffic flow conditions
- Composite models
  - A combination of normal distribution and shifted exponential. Very hard to tune.
- General distribution – Pearson Type III \((\lambda, k, \alpha)\)
  - \(f_T(t) = \frac{\lambda^k}{\Gamma(k)} (t - \alpha)^{k-1} e^{-\lambda(t-\alpha)} \quad : t > \alpha\)
  - \(k = \frac{(\mu-\alpha)^2}{\sigma^2}\)
  - \(\lambda = \frac{\mu-\alpha}{\sigma^2}\)
Distance headways are more important to VANETs
- Low traffic density $\sim$ exponential (constant velocity)
- High traffic density $\sim$ Normal

[7] proposes that the use of exponential distribution for both distance and time headway for any traffic density.

[8] shows that log-normal distribution (or more generally $\Gamma$ distribution) fits the pdf of the time headways. The empirical pdfs of distance headways for different traffic flow conditions is also shown (not exponential)


We went over some of the vehicular traffic flow models in literature.

Different models reveal different levels of details of the behaviour of vehicles (Microscopic, macroscopic and mesoscopic).

According to empirical data fitting, different headway distribution is suggested for different traffic flow state.

Although exponential distance headway distribution is widely used in VANET literature, it is not valid for high and intermediate traffic flow conditions.

The choice of vehicular traffic flow model is important for VANET analysis.
Questions...