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Implementing Clustering for Vehicular Ad-hoc Networks in ns-3

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Outline

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Motivation

Motivation (1/2)

- Vehicular Ad-hoc networks consist of the following types of communication
  - Short-range communication between vehicles (V2V)
  - Communication based on using preexisting network infrastructure such as Road-Side Units (RSUs) for longer communication range (V2I)
- VANET applications
  - Safety
  - Traffic Management
  - Infotainment

Motivation (2/2)

- WAVE protocol available in the latest versions of NS-3. However:
  - Congestion and thus communication failure may occur when having large number of devices cooperating in this band
  - Clustering schemes might be a solution to the network congestion problem by reducing data volumes exchanged. However, the absence of a clustering mechanism in the simulator is the motivation for our work

So, we implemented a new type of application that uses a v2v clustering scheme to group vehicles into a number of clusters based on their mobility

Related Work

Related Work

- Mobility based clustering schemes are classified into:
  - Direction based clustering schemes
    - DMAC algorithm
  - Non-Direction based clustering schemes
    - Basagni's Distributed algorithm
- One hop schemes
  - Affinity Propagation algorithm
- Multihop schemes
  - Fast Randomized algorithm

Traditional clustering algorithms for ad hoc networks are not suitable for vehicular ad hoc networks, due to the high mobility of the nodes

Implementation

Control Application Model (1/2)

- Extends NS-3 built-in application model
- Control v2v application supports:
  - Exchange cluster information and node status
  - Exchange specific clustering messages
  - Cooperative Collision Warning
    - Send either Point-to-point or Broadcast
    - Receive Cooperative Collision Warnings
  - Gather statistics related to cluster

Control Application Model (2/2)

- Finite State Machine(FSM) with four different states:
  - CLUSTER_INITIALIZATION
  - CLUSTER_HEAD_ELECTION
  - CLUSTER_FORMATION
  - CLUSTER_UPDATE
- V2v maintains information for neighboring vehicles:
  - ID
  - Cluster ID
  - Status (Standalone/CM/CH)
  - Mobility (Position, Velocity, Direction)

Header Messages Model

- Custom header messages extend NS-3 built-in header class
- Four different types of messages
  - V2vClusterInfoHeader
    - Broadcast periodic update messages
  - V2vInitiateClusterHeader
    - Start cluster formation algorithm
  - V2vFormClusterHeader
    - Announce cluster head role
  - V2vIncidentEventHeader
    - Report an incident to the cluster

Clustering Algorithm

- In general, each vehicle
  - periodically broadcasts information messages
  - Categorize its neighbors as stable and non-stable according to their velocity vectors → only stable neighbors may form clusters
- Clustering mechanism comprises the following processes
  - Cluster Formation
  - Cluster Maintenance

Clustering Algorithm – Cluster Formation

- Starts when the COV sends a message containing a temporary cluster id.
- Only faster stable neighbors react to this message:
  - Setting the temporary cluster id received from COV
  - Calculating their suitability to become Cluster Head (Suitability Check)
- Cluster Head (CH) announces the new cluster Id
  - Cluster Members (CM) set their new cluster id
  - Standalone vehicles continue through the same process

Clustering Algorithm – Cluster Maintenance

- Cluster Maintenance supports:
  - Vehicle joins to a cluster
    - Select most suitable cluster according to RT (Remaining Time)
  - Vehicle leaves a cluster
    - Select most suitable cluster according to RT, if any
    - Set current status to Standalone, if no cluster in range
  - Merge of two Cluster Heads
    - When two CH in range:
      - CH with less CMs becomes CM of the other CH
      - CM of the old CH also attempts to join the new CH
      - If new CH is not in range, then vehicles select other cluster
      - If no cluster in range, vehicles turn to Standalone state

Cooperative Collision Warning

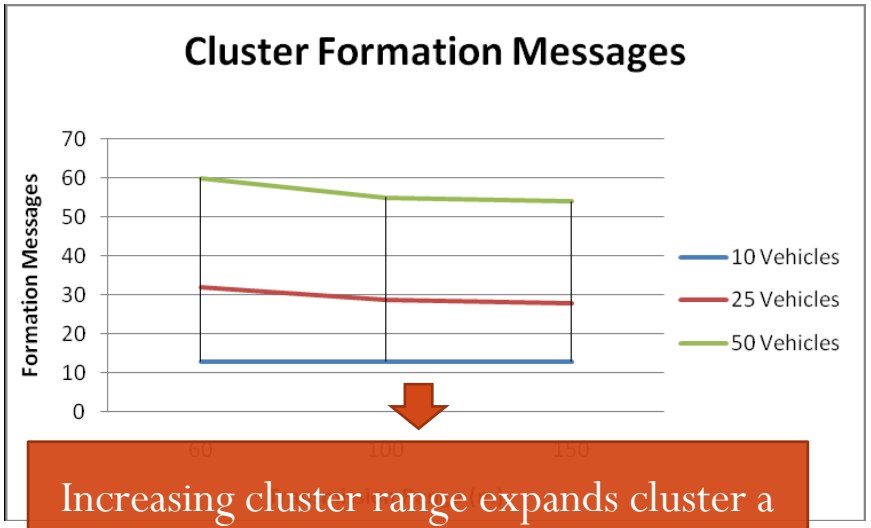
- Control Application generates safety messages randomly during the simulation time using uniform random variable
- Currently the application supports 2 types of messages:
  - Notification messages
  - Emergency messages
- Three different cases for safety message propagation:
  - Standalone vehicle just broadcasts the message
  - CH broadcasts the message to the cluster
  - CM sends the message to the CH (via point-to-point link) and CH broadcasts the event to the whole cluster

Worst Case Scenario

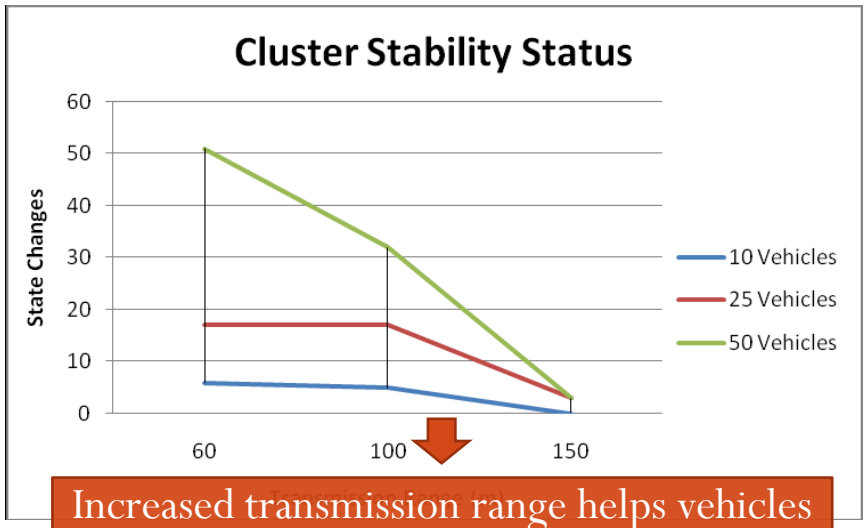
Evaluation

Cluster Evaluation

- No comparison available with other algorithms in NS-3
- Evaluation of our implementation by calculating:
  - Number of messages during formation process
  - Number of state changes of vehicles



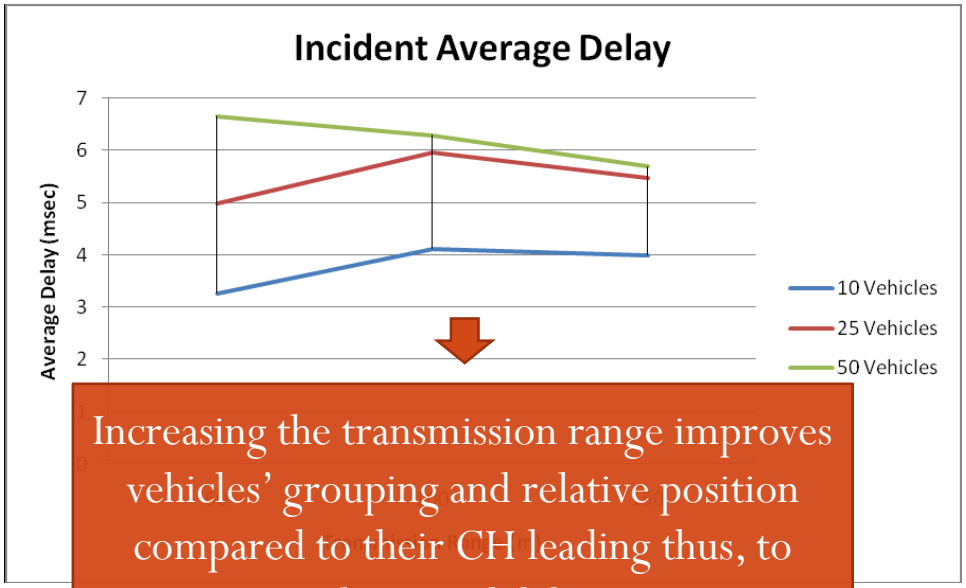
Increasing cluster range expands cluster a bigger area and thus, the formation messages are reduced



Increased transmission range helps vehicles to find suitable neighbors with good Remaining Time and thus, reduced number of maintenance messages

Cooperative Collision Warning Delay

- For the mean delay calculation we included only the worst case scenario
  - CM ➡ CH ➡ Cluster
  - The aggregation of the time is done using the timestamp field included in the header messages



Conclusions and Future Work

- Conclusions
  - New application model
  - First clustering algorithm implementation
  - New header messages implementation
  - Code available at https://gitlab.scanlab.gr/lkatsikas/v2v.git
- Future Plans
  - Generalize the current API to support Mobility based Clustering schemes
  - Implement a couple of new algorithms
  - Develop a more realistic mobility model for VANETs using SUMO traffic simulator

Questions and Answers

"Questions are guaranteed in life; answers aren't"

Thank you