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Clustering in Vehicular Networks

Seminararbeit im Fach Informatik

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Clustering in Vehicular Networks

Seminararbeit im Fach Informatik

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Distributed Embedded Systems
(CCS Labs)

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Abgabe der Arbeit:	**27. Januar 2018**

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(Gaurav Kumar Singh)
Paderborn, 27. Januar 2018

Abstract

This thesis captures an overview of ideas, techniques, results and future possibilities of clustering in vehicular networks. Clustering is a technique to group nodes based on a selected criteria which defines certain level of similarities among the nodes. Grouping the nodes together in such a way helps define or design a set of functionalities applicable only to the group and can be applied to the smaller sub-set. In a Vehicular Ad Hoc Network (VANET) environment clustering presents possibilities to group vehicles based on a parameter of interest and help to reduce the network traffic, achieve better network throughput, effective information dissemination.

The thesis presents a set of parameter and respective methodologies based on them for VANETs as a comparative study. First chapter presents the motivation behind the clustering and outlines the basic set of problems which is presented by vehicular Networks which the researches are trying to address. The second chapter describes the methodologies grouping them based on the main parameters used for clustering. The third chapter introduces the evaluation techniques used to evaluate the methods along with some important metrics used to compare the effectiveness of the algorithms. The fourth chapter captures a comparative study based on the results, highlighting benefits and drawbacks of different approaches based on simulation results. Finally the thesis captures some ideas which will give an overview of the future research work on the topic.

Contents

Chapter 1

Introduction

Along with the advancement in wireless networking in the past two decades, there has been a lot of research targeted towards developing techniques to minimize the network overhead and achieve effectiveness within the system. A special class of wireless network, Wireless Ad Hoc Network (WANET), which allowed nodes to communicate with each other without the need of special infrastructure such as bridges and routers was developed. WANET lead to use of wireless communication for special applications with needs of distributed control. Shortly use of Mobile Ad Hoc Network (MANET) increased which allowed continuos movement of the nodes. This was followed by use of wireless networking among vehicles to create Vehicular Ad Hoc Network (VANET) which allows communication of various parameters among vehicular focussed towards application for safety and cooperative driving. The use of wireless networks in various domains has lead to a lot of research focussed towards improvements and optimization which are often valid for all domains.

Clustering in wireless networks involves grouping nodes together which are geographically close to each other based on a certain set of parameters. Parameter selection for clustering depends mostly on the type of application which would use the clustered network. In VANETs clustering of vehicles into groups provides a basis for limiting the networking overhead and interference by efficiently defining the target nodes fr communication and designing filters to limit the traffic. Due to the possibility of selecting huge range of parameters, numerous solutions have been proposed which target various scenarios in the VANETs. [1] and [2] presents a detailed overview of research work in this field in past years. In the following sections we would look at some of the important terminologies and parameters to create a general overview of clustering in VANET and help us to discuss and understand the methodologies better.

1.1 Terminologies

In this section we look at some of the common terminologies used widely across the algorithms on clustering for VANETs.

- **Cluster Member (CM):** All the nodes which are become part of the cluster and participate in the communication within the cluster.
- **Cluster Head (CH):** Each cluster is supposed to elect one of the CM to act as the CH based on some rules. Its possible for any CM to be elected as the CH but some of the algorithms may apply special requirements for a CM to be elected to ensure stability of the cluster. The responsibilities of a CH may vary but in general its responsible for the maintenance of the cluster (addition and removal of nodes) and communication with the external nodes (other CHs and Road Side Unit (RSU)s).
- **`HELLO` Message:** Also referred as `DISCOVER`, is the first message sent by a vehicle to identify the presence of existing cluster. This is mostly a broadcast frame.
- **`INVITE` Message:** This is transmitted by a CH or a CM in respond to a received `HELLO` message if the requesting vehicle is found fit to join the cluster.

Figure 1.1 shows a typical cluster organization with one CH and multiple CMs.

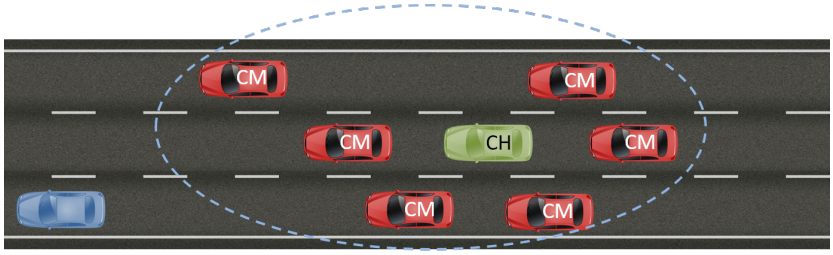


Figure 1.1 – Typical VANET cluster

Chapter 2

Clustering methodologies

In order to achieve a robust and effective communication in the high mobility environment, VANET applications use various parameters to cluster the nodes into meaningful sub-groups based on the applications requirement. This leads to a wide range of clustering methodologies which define applications specific algorithms useful for respective application or a generic algorithm with possibility to handle different requirements. In this chapter we discuss some of the common parameters used individually or in combination with each other to define thresholds for vehicles to join cluster and cluster head selection along with some methodologies which use them for clustering.

2.1 Clustering Parameters

Parameters play an important role to build stable cluster effectively which can be used to perform the application specific communication with minimal overhead. Some of the common parameters which are used by the algorithms to form basis for threshold calculation are summarized in Table 2.1.

Parameter	Description
Vehicular mobility	This is the most common parameter used in the algorithms. Mobility of the vehicles are measured in terms of relative velocity and average velocity over time of the vehicle
Direction of the travel	In many cases information to shared between vehicles only has relevance if the vehicles share the same path and direction. This is knowledge is used by the algorithms by forming trajectory tables or assigning Road IDs to compare directions and route

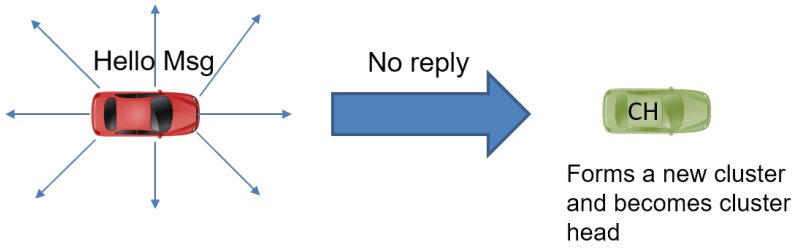
Table 2.1 – Common clustering parameters

Parameter	Description
Destination	Used by application which give importance to route taken by the vehicles to provide longer stable cluster
Density	Mostly used to differentiate sparse and dense networks and define different communication model to ensure reliable communication in both scenarios
Unique ID	Simplest clustering parameter. Commonly used to identify and cluster vehicles requiring 1 hop reliable communication
Location	Used with application requiring location based information such as intersection support and congestion avoidance

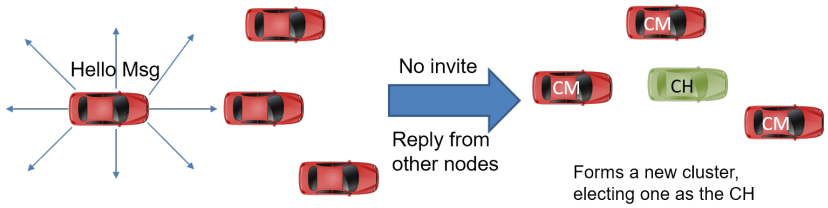
Table 2.1 – Common clustering parameters contd...

2.2 Typical clustering Operations

To group vehicles togethers there are two main set of operations used by the clustering algorithms. First is the cluster creation operations as shown in Figure 2.1.



(a) Cluster creation with single vehicle



(b) Cluster creation with multiple vehicles

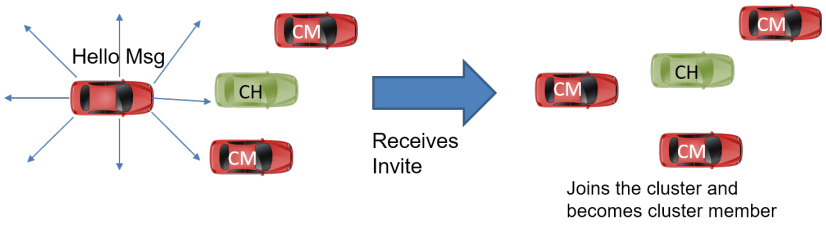
Figure 2.1 – Cluster creation operations

As the name suggest these operations are used to create a new cluster after verifying the fitness of the participants. Figure 2.1a shows a case where there is no

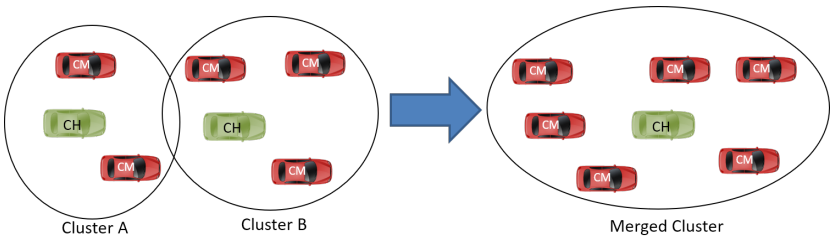
vehicle around. The vehicle first sends the HELLO messages to discover presence of other cluster and after a certain timeout identifies that there is no one around and starts a new cluster becoming the new CH. The second operation depicted in Figure 2.1b is used when there are vehicles in the vicnicity which have not yet formed any cluster. In this case the the vehicles discover each other via HELLO messages and form a cluster followed by an election of the CH.

The second set of operations are used for cluster maintenance shown in Figure 2.2. Cluster joining operations shown in Figure 2.2a is used to add new members to the cluster. The request to join is initiated by the vehicle by sending the HELLO message. When the CH receives this message, it verifies if the vehicle is fit to join the cluster and then invites it using INVITE message. Cluster merging happens when two CH come in contact with each other as shown in Figure 2.2b. At this point the CHs decide to merge the clusters if the current state of the two cluster is similar in terms of the cluster parameters. After merging one of the existing CH becomes the new CH of the merged cluster and the other CH becomes a CM.

It should be noted that the actual implementation of these operations may change from one methodology to another depending upon the parameter and the uses case for the clustering.



(a) Cluster joining



(b) Cluster merging

Figure 2.2 – Cluster maintenance operations

2.3 Methodologies

This sections would present some of the methodologies which are popular and used as the basis for several algorithms designed for clustering is VANET.

2.3.1 Clustering using vehicular mobility

Vehicular mobility is one of the common and vastly used methodology for clustering. Relative velocity which can be used to differentiate the vehicles into different subgroups is used as one of the main parameters in such algorithms. The vehicle mobility is the main element affecting the network topology which the algorithms use to estimate dynamicity of the network and improve stability. Clustering algorithms presented in [3]–[5] use relative velocity as the main parameter to define the cluster joining and cluster head selection metrics.

2.3.2 Clustering using direction and destination

It has been identified that vehicles which travel in same direction or to same destination are supposed to be benefitted most if they share information to each other. This makes the direction of travel and destination based clustering another important parameters used for clustering. This methodology requires the vehicles to be equipped with Global Positioning System (GPS) devices to get accurate location information. There can be variation based on the estimation and comparison of the routes of the vehicles. The methodology presented in [6] uses trajectory tables to store position information which is then shared and compared by the vehicles to check the direction and route of travel whereas methodology presented in [7] calculates the direction at intersection points based on the turn the vehicles are going to take. The solution proposed in [8] uses lane based information to decide the direction and cluster the vehicles.

2.3.3 Clustering using vehicular density

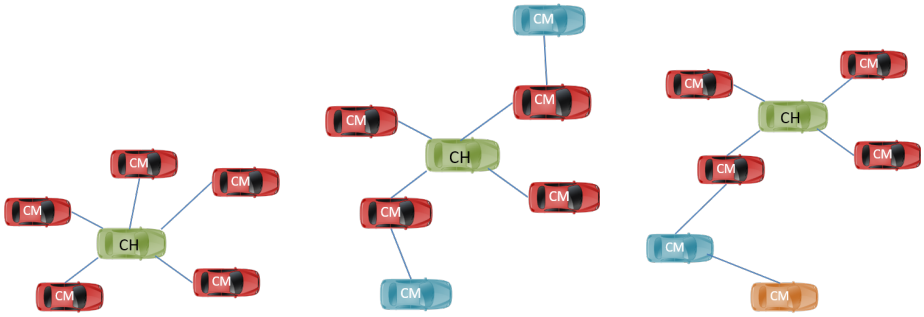
Density of the vehicles is changed based on the environment considered. This is often utilized by the clustering algorithm as a important parameter to define different communication methodologies for dense network in city vs sparse network on highways. Aim of such algorithms is to reduce network congestion in cities by avoiding unnecessary flooding and provide long range network coverage on highways using long range communication. [9] discusses one such algorithm which uses density based clustering to define different communication model based on connectivity and link quality estimates.

2.3.4 Hybrid clustering

Some application may require use of more than one parameter to make decision. Clustering algorithms defined for such application are complex and use multiple parameters in combination to each other. The clustering scheme proposed in [5] uses a combination of location, vehicular velocity and destination information to build up clusters which can adapt with changes in any of the parameters. Such methods are always complex and require a lot of communication between the vehicles to share real-time information.

2.3.5 Multi-hop clustering

The methodologies summarized till now in this section relies on one hop communication i.e. direct communication between the CH and the CM. The one hop based communication clustered face the problem of frequent handoffs between the clusters for members with high mobility. Multi-hop clustering methods try to address this issue by including N-hop members to the cluster. As shown in 2.3b and 2.3c, the multi-hop members communicate to the CH via the intermediate members and can be located a maximum of N-hop distance away from the CH. In a multi-hop clustering methodology, the `HELLO` messages contain additionally the number of current hops and are re-broadcasted by a node after adding themselves as a intermediate node. This forms the basis for identifying routes to the N-hop nodes after clustering. The clustering schemes based on multi-hop are described in [10] and [11].



(a) 1 Hop **(b)** 2 Hop **(c)** 3 Hop

Figure 2.3 – Multi-hop clustering

Chapter 3

Evaluation and analysis techniques

<General simulation steps for evaluation>

3.1 Important metrics for evaluation

3.2 Analysis of

Chapter 4

Conclusion

- summarize again what your paper did, but now emphasize more the results, and comparisons
- write conclusions that can be drawn from the results found and the discussion presented in the paper
- future work (be very brief, explain what, but not much how, do not speculate about results or impact)
- recommended length: one page.

List of Abbreviations

CH	Cluster Head
CM	Cluster Member
GPS	Global Positioning System
MANET	Mobile Ad Hoc Network
RSU	Road Side Unit
VANET	Vehicular Ad Hoc Network
WANET	Wireless Ad Hoc Network

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