Computers and Electrical Engineering 52 (2016) 82–97

Contents lists available at ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

Learning Automata-assisted Predictive Clustering approach for Vehicular Cyber-Physical System ☆

Rasmeet Singh Bali, Neeraj Kumar*

Department of Computer Science and Engineering, Thapar University, Patiala, Punjab, India

A R T I C L E I N F O

Article history:
Received 24 May 2015
Revised 4 September 2015
Accepted 9 September 2015
Available online 14 November 2015

Keywords:
Vehicular Adhoc Cyber-Physical Systems
Predictive Clustering
Learning Automata
Stochastic environment
Reward
Penalty

A B S T R A C T

Vehicular Cyber-Physical Systems (VCPS) are the most popular systems of the modern era due to their abilities to disseminate the safety related information to the moving vehicles on time. For efficient data dissemination, vehicles form a cluster with other vehicles in VCPS environment. But, due to high velocity and constant topological changes, cluster maintenance is one of the most difficult tasks to be performed in this environment. To address this issue, in this paper, we propose a novel Learning Automata (LA)-based hybrid clustering scheme for vehicles in VCPS environment. We have improved our existing solution *Energy Efficient Predictive Clustering (EEPC) approach*, by incorporating the future mobility prediction computed by LA stationed on the vehicles. For this purpose, a Predictive Clustering Algorithm using Learning Automata (PCALA) is proposed. Extensive simulations are performed to evaluate the performance of the proposed scheme with respect to various metrics. Results obtained confirm the effectiveness of the proposed scheme in comparison to the existing EEPC scheme.

1. Introduction

The latest advancements in wireless communication technologies are the key enabler for making the life of people easier and comfortable. In the modern era, with the evolution of Internet of Things (IoT), a large collection of objects/devices are interconnected with one another for data sharing, and information dissemination. In IoT, vehicles can be viewed as intelligent objects which are capable of taking intelligent decisions. The existing wireless technology integrated with vehicular environment improve user safety, driving conditions, and comfort of the end users. Wireless networks integrated with vehicular environment are characterized by highly dynamic nature that affects the performance of various routing and data dissemination solutions in VCPS environment. The unknown time varying characteristics impact signal strength, spectrum allocation, and the movement patterns of vehicles. The variations in these parameters generate the need to design efficient protocols for clustering and data dissemination in VCPS environment.

Vehicular Ad hoc Networks (VANETs) have several characteristics such as mobile nature of vehicles, unlimited battery power and storage, delay in transmitting messages and predictable movement of vehicles that differentiate them from contemporary ad hoc networks. Vehicles communicate with neighboring vehicles for information exchange in a Vehicle-to-Vehicle (V2V) manner. Also, when vehicles communicate through a fixed equipment next to road called as Road Side Unit (RSU), then it is called as Vehicle-to-Roadside unit (V2R) communication [1]. Apart from this, On Board Unit (OBU) is also included in vehicles which is a device mounted on-board vehicle and is used for exchanging information with RSU's.

☆ Reviews processed and recommended for publication to the Editor-in-Chief by Guest Editor Dr. J. Kim.
* Corresponding author. Tel.: +91 8872540189; fax: +91 175 223456.
E-mail addresses: rasmeetsbali@gmail.com (R.S. Bali), neeraj.kumar@thapar.edu, nehra04@yahoo.co.in, nehra04@gmail.com (N. Kumar).

http://dx.doi.org/10.1016/j.compeleceng.2015.09.007
0045-7906/

Communication between vehicles allows sharing of different types of information for applications related to safety, user convenience, entertainment, and multimedia sharing. However, safety and passenger convenience are the two most important VANET applications [2,3]. In some cases, communication in vehicular environment tends to slow down due to congestion which temporarily disrupts the network efficiency as a large number of vehicles generate data and share it with other vehicles. To minimize this problem that mainly occurs due to flooding and causes inefficient message broadcast, several clustering algorithms for VANETs environment have been designed in literature. Vehicles form clusters among themselves for information sharing and data dissemination. Each cluster in the network has at least one Cluster Head (CH) selected by other Cluster Nodes (CN's). The clustering algorithms provide improvements in VANETs characteristics such as efficiency, stability, reducing transmission overhead, simplified routing and efficient usage of the network resources.

The cluster formation process in VANETs specifically addresses the requirement of creating a hierarchical structure that improves network efficiency. Although VANETs can function without a cluster also, but the use of clustering provides an efficient usage of network resources and it increases data dissemination efficiency. Current solutions to this problem are primarily based on vehicles characteristics and network performance parameters such as vehicle speed, density and distance to the final destination. But, these existing solutions fail to predict the future mobility of the vehicles which can be used to improve the overall performance of any solution designed for VCPS environment. The main contribution of this work is to present a Learning Automata (LA)-based solution to the clustering problem for creating clusters based on prediction of future positions of vehicles to improve cluster stability which in turn, provides an efficient vehicular environment.

1.1. Motivation

To improve road safety and user convenience, a number of solutions using vehicular technology have been proposed in the literature. But, these solutions are not sufficient to get real-time interaction with the environment for achieving satisfactory data dissemination. In this direction, clustering of vehicles has received a lot of attention with an aim to obtain optimal performance of the network with respect to parameters such as high throughput, and reduced delay. However, constrained mobility patterns, high density along with high speed make clustering a challenging task. Hence, there is a requirement of prediction of the position of vehicles by estimating their future mobility. Accurate prediction also assists in making clusters more stable which ultimately improves the network performance. Thus, there is a need of a clustering scheme based on accurate future mobility prediction. Moreover, LA have been used in wide range of application to get a real-time interaction with the environment using which efficient algorithms for monitoring the states of vehicles can be designed. We have also motivated by our previous solutions [5–7,16–20], where we have applied LA in various engineering applications. The performance of these solutions are found satisfactory in comparison to the other existing solutions in the literature. Thus, motivated from these factors, we propose a clustering scheme which improves the prediction accuracy of existing EEPC clustering scheme [4]. Distributed LA are used in the proposed scheme for improving the performance of the VCPS.

1.2. Contributions

In this paper, the results of Predictive Clustering Algorithm [4] are extended by observing the inherent shortcoming of current scheme. Specifically, we emphasize on efficiency and stability of clustering schemes by predicting the future positions of vehicles. Furthermore whereas, existing schemes for clustering in VANETs were focused on divergent vehicular characteristics for cluster formation, we propose an enhanced predictive clustering scheme. The main contributions of this work are as follows.

- A new LA-based CH election method is proposed to handle a wide range of vehicular movements which provides stability to different clusters.
- A new LA-based prediction technique is introduced for improving the efficiency of message dissemination and overall network performance.
- A centralized cloud-based backbone selection method is incorporated into the vehicular network to optimize the cluster stability.

1.3. Organization

The rest of the paper is structured as follows. In Section 2, we briefly review the literature on clustering algorithms in VANETs and Learning Automata. Section 3 describes the system design and different steps of proposed Predictive Clustering Algorithm using Learning Automata (PCALA). In Section 4, we provide a detailed description of our proposed predictive clustering scheme. The performance of proposed PCALA is evaluated using extensive simulations in Section 5. Finally, the paper is concluded in Section 6.

2. Literature review

This section is subdivided in two parts-clustering-based VANETs, and LA-based proposals. The key proposals relevant to each subsection are discussed in the following sections.