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# Learning Automata-based Opportunistic Data Aggregation and Forwarding scheme for alert generation in Vehicular Ad Hoc Networks

Neeraj Kumar [a], Naveen Chilamkurti [b,*], Joel J.P.C. Rodrigues [c]

[a] Department of Computer Science and Engineering, Thapar University, Patiala, Punjab, India
[b] Department of Computer Science and Computer Engineering, LaTrobe University, Melbourne, Australia
[c] Instituto de Telecomunicações, University of Beira Interior, Rua Marques D'Avila e Bolama, Covilhã, Portugal

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ABSTRACT

Due to the highly mobile and continuously changing topology, the major problem in Vehicular Ad Hoc Networks (VANETs) is how and where the collected information is to be transmitted. An intelligent approach can adaptively selects the next hop for data forwarding and aggregation from the other nodes in the networks. But due to high velocity and constant topological changes, it is a challenging task to meet address the above issues. To address these issues, we proposed a Learning Automata-based Opportunistic Data Aggregation and Forwarding (LAODAF) scheme for alert generation in VANETs. Learning automata (LA) operate separately which are deployed to the nearest Road Side Units (RSUs) to collect and forward the data from respective regions along with alert generation. Once data is aggregated, LA adaptively selects the destination for data transfer, based on the newly defined metric known as Opportunistic Aggregation and Forwarding (OAF). LA predicts the mobility of the vehicle and adaptively selects the path for forwarding, based on the value of OAF. Moreover, it updates its action probability vector and learning rate based on the values of OAF. This will reduce network congestion and the load on the network as it is aggregated and forwarded only when required. An algorithm for opportunistic data aggregation and forwarding is also proposed. The proposed strategy is evaluated using various metrics such as a number of successful transmissions, connectivity, link breakage rate, traffic density, packet reception ratio, and delay. The results obtained show that the proposed scheme is more effective for opportunistic Data Aggregation and Forwarding in VANETs.


## 1. Introduction

The advancements in wireless technology and embedded systems have led to the development of next generation Intelligent Transport Systems (ITS). The most common networks used in ITS are Vehicular Ad Hoc Networks (VANETs). VANETs have many application domains to enhance the safety of the driver and passengers on the road. Vehicles/nodes share information with each other that can be helpful in making an adaptive decision. Vehicles can communicate with each other, which is called vehicle-to-vehicle (V2V), or they can communicate with the infrastructure which is called vehicle-to-infrastructure (V2I). Most of the modern vehicles have information on board about the outside parameters, such as the density of the traffic, a map of the places to be visited/has visited, pollution quantity, duration of traffic lights on the next intersection etc., which can be used by drivers to make adaptive decisions about the selection of an appropriate route and to reduce the pollution on the road. The passengers on board can use various types of resources provided by the infrastructure via the Internet, which is known as Internet based Vehicular Ad Hoc networks (IVANETs). VANETs are traditionally different from Mobile Ad Hoc Networks (MANETs) due to the provision of valuable features such as well-defined routes, mobility patterns and information on the environment in which they are operating [1–3].

Although VANETs can be used in many applications, there are still many challenges yet to be resolved in these networks which need to be addressed. The biggest challenge in VANETs is the continuous topological changes due to the high mobility of the nodes. Moreover, interference from neighboring vehicles, disconnection of the nodes in some regions of the network and limited communication range are other factors which severely affect the performance of wireless networks.

As discussed above, data is collected by vehicles with sophisticated devices from different locations across dense urban or sparse regions. But due to the high mobility of the nodes, data aggregation is a challenging task in VANETs. Moreover, the aggregated data needs to be transferred to other nodes so that it can reach the final destination. But each collected piece of data does not need to be sent at once to all the nodes as this will create an overload on the network, causing performance degradation. Hence, there is a

* Corresponding author.
*E-mail addresses:* nehra04@yahoo.co.in (N. Kumar), n.chilamkurti@latrobe.edu.au (N. Chilamkurti), joeljr@ieee.org (J.J.P.C. Rodrigues).

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need for an intelligent approach which takes care of incoming traffic requests and transfers them according to the network conditions such as load on the nodes, resource availability etc.

For data aggregation and forwarding in VANETs, many proposals have used broadcasting and multicasting mechanisms from the source node [4–7]. In these proposals, authors have constructed the minimum spanning tree to broadcast the data. Most recently, Ruiz et al. [8] proposed an information dissemination mechanism based upon tree topology, proposing a decentralized broadcasting algorithm for continuous topological changes in VANETs. Moreover, a tree topology construction algorithm is also proposed by the authors. In addition to these approaches, researchers have also used multipath routing schemes to mitigate the frequent disconnection problem in highly dynamic networks. Ad Hoc on demand Multipath Distance Vector (AoMDV) [9] is one such protocol which uses this technique. In this scheme, if one of the paths fails for some reason, then another path may be taken as an alternative to complete the route.

From the above discussion, it is clear that there is a need for an efficient mechanism for opportunistic data aggregation and forwarding for highly dynamic VANETs. The vehicles in VANETs should have built-in intelligence mechanisms to adapt to the network conditions. They should have the capability to make the best decision about when and where the data aggregation and forwarding technique should be applied [10]. This is necessary as during high mobility scenarios, vehicles need to communicate with each other to share information. Vehicles which are equipped with intelligence mechanisms can be used in a wide range of applications in both dense urban and sparse regions, e.g., to generate alarms for safety operations, military applications etc.

Hence, to address these issues, we propose a new Learning Automata-based Opportunistic Data Aggregation and Forwarding (LAODAF) scheme for VANETs. Learning Automata (LA) operate separately in each vehicle in which it is deployed and collects data in its respective region as the vehicle moves from one place to another. LA adaptively selects the destination for data transfer, based on the newly defined metric by considering various factor such as load, available resources etc. The moving vehicles share information with each other LAs. Each action taken by an LA is either rewarded or penalized by the environment in which it is operating. Based on the input provided by the environment the future course of action is decided, i.e., in which direction the LA will take its action.

The main contributions of the paper are as follows:

1. A new LA-based opportunistic data aggregation and forwarding scheme has been proposed
2. A metric OAF has been proposed which is used by the LA for forwarding the collected data at respective nodes in the network
3. Mobility of the nodes is predicted, based on their current position which is used by the automaton to make the decision to forward the data or buffer the data opportunistically

The rest of the paper is organized as follows. Section 2 describes the most relevant related work in this area. Section 3 provides an overview of the LA approach. Section 4 describes the problem statement. Section 5 describes the proposed approach. In this section, the description about the proposed algorithm is also provided. The simulation environment with results and discussions are described in Section 6. Section 7 provides the conclusions and future work.

## 2. Related work

Over the years, VANETs have emerged as a new technology which can be used in a wide area of applications with an ultimate goal to provide maximum safety to the user and the passengers on board. However, VANETs present a number of challenges to researchers in this domain such as constant topological changes and variable density. To address these challenges, Ruiz et al. [8] proposed a new mechanism for information dissemination in VANETs, using tree topology, that is, a decentralized algorithm for the construction of tree topology in VANETs. Li et al. [11] used a directional antenna approach for broadcasting in VANETs. Tonguz et al. [12,13] proposed a broadcasting algorithm for topology maintenance with respect to the traffic patterns generated both from urban and sparse regions. Bai et al. [14] presented a multi-hop broadcasting mechanism for various types of safety message dissemination in VANETs. Slavik et al. [15] proposed a stochastic scheme for broadcasting in VANETs. These authors also proposed security architecture for secure data dissemination using the proposed algorithm. Mylonas et al. [16] proposed a speed adaptive probabilistic forwarding scheme and considered various parameters such as speed and delivery delay for the vehicles in dense urban regions. Huang et al. [17] proposed an opportunistic scheme for generating a collision warning in VANETs.

As VANETs can be used in a wide range of applications in the future, researchers are working to design new protocols which are capable of providing various services such as mobile marketing, mobile multimedia and social networking. For all such applications, there is a need to upgrade on-board hardware [18]. Moreover, there is a need for powerful sensor nodes capable of sensing the environment in which they are operating so that they can collect data from the environment and disseminate this as per the requirements [19,20]. Most recently, Pau et al. [21] outlined the various challenges and opportunities in vehicular sensing networks. The authors proposed an architecture for VANETs which can be used for pollution control in dense urban regions and can also be used in designing the next generation ITS. Recent studies have shown that pollution control is a serious problem in dense urban regions, which can be controlled by using intelligent computational techniques [22,23]. Giordano et al. [24] proposed a realistic urban propagation model for data dissemination in VANETs.

Schwartz et al. [25] presented a directional dissemination protocol for vehicular networks. The authors presented a novel mechanism to overcome the broadcast storm problem in dense regions using the store and forward technique. Borsetti et al. [26] presented an application level framework for information dissemination in VANETs where vehicles can share the application level role with each other by using the mobility patterns of vehicles. Li et al. [27] presented an opportunistic event-driven broadcasting scheme for loss links in VANETs. An opportunistic protocol was proposed by the authors, which is capable of maintaining a high packet reception ratio and multi-hop message transmissions. Moreno et al. [28] presented contention-based opportunistic data dissemination in VANETs. Moreno et al. [29] presented vehicle-to-vehicle communication for safety critical applications. Moreno et al. [30] proposed a contention-based packet forwarding scheme for VANETs. In these schemes, the contention period is considered and the distant node is opportunistically selected for transmission. Vinel et al. [31] provide a detailed analysis of trustworthy broadcasting in VANETs Campolo et al. [32] described the broadcast packet loss in vehicular networks.

Computation intelligence techniques can also be applied to solve many real time problems in wireless networks. In this regard, researchers have found that LAs can be very useful in many applications [33–39] as it is an optimization approach in which an action is taken by LA by using its own knowledge and then using this knowledge to adapt to the situation [31–37].