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# Bayesian Coalition Game for Contention-Aware Reliable Data Forwarding in Vehicular Mobile Cloud

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## HIGHLIGHTS

- A Bayesian Coalition game-based reliable data transmission is proposed for vehicular cloud.
- Learning Automata (LA) are assumed to be the players in the game.
- For each action taken by the players in the game, they may get a reward or a penalty based upon which all the future actions to be taken are decided.
- The results obtained are convincing as compared to other approaches of its category.

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## ABSTRACT

The exponential growth in the demands of users to access various resources during mobility has led to the popularity of Vehicular Mobile Cloud. Vehicular users may access various resources on road from the cloud which acts as a service provider for them. Most of the existing proposals on vehicular cloud use unicast sender-based data forwarding, which results in an overall performance degradation with respect to the metrics such as packet delivery ratio, end-to-end delay, and reliable data transmission. Most of the applications for vehicular cloud have tight upper bounds with respect to reliable transmission. In view of the above, in this paper, we formulate the problem of reliable data forwarding as a Bayesian Coalition Game (BCG) using Learning Automata concepts. Learning Automata (LA) are assumed as the players in the game stationed on the vehicles. For taking adaptive decisions about reliable data forwarding, each player observes the moves of the other players in the game. For this purpose, a coalition game is formulated among the players of the game for taking adaptive decisions. For each action taken by a player in the game, it gets a reward or a penalty from the environment, and accordingly, it updates its action probability vector. An adaptive *Learning Automata based Contention Aware Data Forwarding (LACADF)* is also proposed. The proposed scheme is evaluated in different network scenarios with respect to parameters such as message overhead, throughput, and delay by varying the density and mobility of the vehicles. The results obtained show that the proposed scheme is better than the other conventional schemes with respect to the above metrics.



## 1. Introduction

In the past few decades, there has been growing interests of the research communities in the area of *Vehicular Cloud (VCloud)* due to their use in various domains such as Intelligent Transport Systems (ITS), Urban Surveillance Systems, safety and security in community networks, and emergency applications. Many researchers across the globe are working to design new solutions to provide facilities to the users on-board their vehicles to make use of them in case of emergency situations such as collision on the road, traffic block, safety alarms for fire, and theft. For all of these applications, the broadcasting of message is to be done efficiently with minimum contention of available resources [1,2]. In the current paper, we use the concepts of both vehicular networks and cloud for

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accessing the resources such as infrastructure, platform and computation.[1]

There are two types of communications that exist among vehicles using the services provided by the cloud: *Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I).* V2V communication is peer-to-peer (P2P), in which all the vehicles collaborate with one another for sharing valuable information based on the traffic conditions on the road and these information are provided from the cloud for further action. If the vehicles work in collaboration with one another for information sharing, then efficient solutions can be designed for reliable data delivery to its final destination [3–6]. On the other hand, vehicles take advantage of the existing infrastructure, deployed alongside the road for information dissemination from one end of the road to another. In the latter case, the whole information is passed to the centralized controller for further distribution among the nodes/vehicles. As the vehicles have limited computation and storage capabilities, services of cloud can be used for storage and retrieval of the data. There are number of objects such as sensors, vehicles, and smart gadgets which share the resources and application among themselves in such type of environment called Internet of Things (IOT), which has attracted a lot of attention from the research community in recent times [7].

As the information is passed among the vehicles using broadcasting, acknowledgment of the sent message is required to increase the reliability of the message. But the existing solutions do not take into account this acknowledgment because of the poor signal strength of the wireless channels. In this direction, repetition-based broadcasting mechanism has been used [1] to enhance the reliability of message transmission. A sender broadcasts a message so that all the nodes in its area can also have chance to get the message back, but repetition should be below a threshold value, so as to reduce the congestion in the network.

All the critical applications discussed above have requirements for reliable transmission, minimum end-to-end delay, and scalability [8]. Reliable transmission concerns the ratio of the number of packets received to the total number of packets sent from the source. End-to-end delay concerns the occurrence of delay in transmission of information from one end to another and scalability concerns the overhead occurrence during the transmission [8]. Due to the high mobility and fast changing topology, it is a challenging task to control all these three issues [9–12].

Control broadcasting and multicasting mechanisms are two most common techniques used for information dissemination among vehicles in most of the critical applications in VCloud. The messages generated from one source are transmitted to a group of recipients [13–16]. To meet the goals of reliability and scalability, and to minimize the goal of end-to-end delay, a minimum spanning tree-based approach for broadcasting has been used in these proposals. Ruiz et al. [17] proposed an information dissemination mechanism using the tree topology. A decentralized broadcasting algorithm for continuous topological changes for vehicles has been proposed by them. But none of the existing solutions have considered the collaborative approach for data dissemination, so that information can be sent from a source to destination in a collaborative manner, i.e., the information passage should be in such a manner that all the nodes share and collaborate with the other nodes for performing the task of data dissemination. Moreover, the nodes that possess computational intelligence power also adapt to the situation and dynamically select the best path for data dissemination. From the above discussion, it is clear that although there exist many proposals addressing the issues of routing, security, QoS in VCloud, these solutions are not adequate to address the issues such as providing QoS in presence of high velocity and varying density of the vehicles on the road. Moreover, as vehicles are considered as intelligent machines, these are capable of providing data dissemination and communication among themselves using machine-to-machine (M2M) communication which is one of the most efficient ways of communication. As we have assumed that Learning Automata (LA) are deployed on the vehicles, M2M communication among these vehicles provide better data dissemination in comparison to the existing approaches in literature.

Based on the synthesis of the existing literature, in this paper, we propose a new algorithm named *Learning Automata-based Contention Aware Data Forwarding (LACADF)* for critical applications in the VCloud. LA are assumed to be deployed on the vehicles in such a manner that each automaton shares the information with one another in a collaborative manner, and passes the same to the other automaton. The prime advantage of using LA is that they are self-adaptive and self-configured in nature and have the ability to learn. Even though, initially it takes time for learning, but the performance of LA improve in due course as they take actions. Based on the feedback received from the environment, the subsequent actions are decided and executed. The performance of the proposed solution is evaluated with respect to various metrics.

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 LA. Section 4 describes the system model and problem formulation. Section 5 describes the proposed approach. The simulation environment with results and discussions are described in Section 6. Section 7 presents the conclusions and future work.

## 2. Related work

With the advancements in wireless technology, vehicular networks in general, vehicular ad hoc networks (VANETs) in particular have emerged as a new technology for providing seamless services to the end users. There are various challenges in these networks that need to be addressed by the research community. As nodes in VANETs are highly mobile, topology management is one of the key issues. Moreover, the data transfer to the suitable node without any delay with minimum resource consumption is also an issue that needs special attention. Many research proposals on the above issues are described as follows.

Yoo et al. [1] proposed a cooperative diversity scheme for reliable broadcasting. It ensures minimum number of broadcasting repetitions movements with poor signal strength. The authors have suggested the use of virtual antenna array for gain at the receiver. The proposed scheme was evaluated in different network conditions, where results obtained show the superior performance of the designed scheme. Scaglione et al. [18] proposed the construction of large array for cooperative diversity in which large number of nodes send information simultaneously from the source in a collaborative manner. By using this strategy, large amount of energy consumption is saved by the receiver. As energy is one the most valuable resources in the network, this proposal can be used in upcoming technologies such as vehicles-to-grid (V2G) for efficient power distribution. Hong et al. [19] proposed a mechanism for the optimal energy consumption in cooperative broadcasting. Authors have used a periodic broadcast in which transmission occurs only when there is a requirement of the same which results in a considerable reduction in energy consumption.

Mergen et al. [20] proposed a technique for minimum energy consumption in cooperative broadcasting. The authors have suggested that the nodes whose contribution in cooperative forwarding is less can be neglected from broadcasting. The authors have made use of signal-to-noise ratio (SNR) for setting up the threshold to remove the nodes participation in broadcasting. The

[1] The preliminary version of this paper has been presented at 11th IEEE International Conference on e-Business Engineering (ICEBE 2013), Coventry University, Coventry, UK, 11–13 September 2013.