Computer Engineering and Intelligent Systems
ISSN 2222-1719 (Paper) ISSN 2222-2863 (Online)
Vol.5, No.9, 2014 www.iiste.org

Cluster Based Neighbor Coverage Relaying (CBNCR)-A Novel Broadcasting Mechanism for Dissemination of Data in VANETs

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Abstract
VANETs are emerging technology that provides road safety, traffic efficiency convenience and comfort to both drivers and passengers. Vehicular Ad hoc Network (VANET) is a subset of Mobile Ad Hoc Networks. In VANETs vehicles are equipped with embedded sensors and wireless communication capabilities providing powerful and potential applications on safety, efficiency and public collaboration while on the road. A Vehicular Sensing Network (VSN) is a type of Wireless Sensor Network (WSN) which performs traffic routing and distributed surveillance. Data dissemination in VSN is used to communicate with neighboring vehicles which requires broadcasting of data to all vehicles in the network. Usually the problem with the broadcasting is redundancy, collision and contention. To improve the reliability of message communication the aforementioned problems are to be minimized. In this paper, we propose Cluster Based Neighbor Coverage Relaying mechanism to efficiently broadcast the data to all nearby vehicles in the network. The architecture combines the features of both Cluster Based Broadcasting and Multi-hop Relaying mechanisms. The targeted approach provides an optimal solution in delivering data over VANETs.
Keywords: VANET, Broadcasting, Summary Harvesting, Data dissemination, Cluster based broadcasting, Multi-hop relaying, Cluster Based Neighbor Coverage Relaying (CBNCR).

1. Introduction

A VANET is a self organized network with vehicles that performs short range communication. VANET architecture [1] is basically a combination of an On Board Unit (OBU) and more Application Units (AUs). An OBU is a device with communication capabilities placed in the vehicle. An AU is a device executing applications by using OBU's communication capabilities. The Ad hoc network includes vehicles equipped with on board units and stationary units placed along the road. The basic role of VANET is to improve vehicle to vehicle communication in terms of road safety and traffic efficiency.

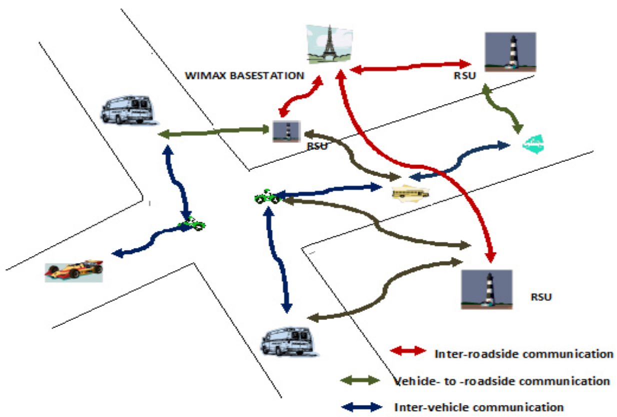

Figure 1:VANET Architecture

Figure 1 shows the sample of VANET Architecture.

VANET architecture enables communication among nearby vehicles and between roadside equipments. The three possibilities of communication [1] are:-

i. *Vehicle-to-Vehicle ad hoc network (V2V):* It provides Vehicle-to-Vehicle communication. It uses multi-hop multicast/broadcast to transmit traffic related information to a group of vehicles and is mainly employed for safety, security and data dissemination applications.

ii. *Vehicle-to-Infrastructure network (V2I):* This configuration allows a vehicle to communicate with the roadside infrastructure mainly for information and data gathering applications.

iii. *Hybrid architecture:* It combines both Vehicle-to-Vehicle ad hoc network (V2V) and Vehicle-to-Infrastructure network (V2I).

The different types of communication discussed above use message multicast/broadcast of data from a given source vehicle to all vehicles located in its neighborhood. In all the above types of communication, the key concern is to transmit data over the VANET efficiently. In doing so, due to mobility characteristic of the vehicular node, communication links may fail. To establish reliable communication across the nodes, it is proposed to combine the Cluster based broadcasting with the Multi hop relaying to transmit the messages to the farthest nodes efficiently. In this paper, proposed work is organized in three stages. First, Cluster based broadcasting is discussed. Secondly, Multi hop relaying is discussed. Finally, a refined *Cluster Based Neighbor Coverage Relaying* architecture is discussed by combining the aforesaid two techniques of broadcasting.

2. Previous Work

VANET has envisioned being useful in road safety and many commercial applications. Broadcasting is a mechanism which transmits message from source vehicle to all neighboring vehicles in the network. There are mainly two categories of data dissemination. Push based data dissemination, where the messages can be efficiently delivered from moving vehicles or fixed stations to other vehicles. Pull based data dissemination, where a vehicle can extract information about other vehicles in the network.

2.1 Summary Harvesting

Along with data dissemination, [3] Uichin Lee *et al*. discussed the procedure of "Summary Harvesting" for tracing missing information as below:

The RSU broadcasts a harvest request message to all vehicles in its vicinity. Each neighboring vehicle prepares a list of missing packets to RSU. The RSU sends back an acknowledgement to all vehicles, and the neighboring vehicles update their list of missing packets.

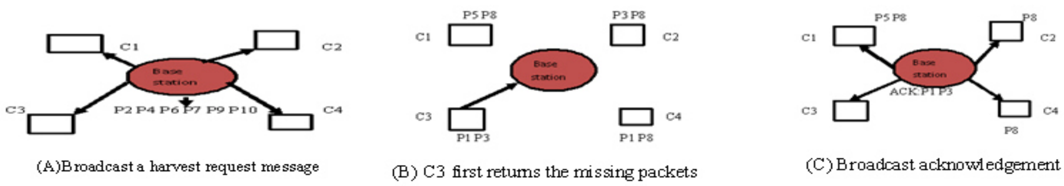

Figure 2:Summary Harvesting

Figure 2 shows the procedure of Summary Harvesting

The base station prepares a list of packets as an harvest request message and broadcasts it to all its neighbouring vehicles in the network. The vehicles determine the missing packets and one of the vehicles responds to the base station with those missing packets.The base station sends back an acknowledgement to all vehicles and the vehicles update their list of packets by removing the missing packets. Hence both Data dissemination and Summary Harvesting requires broadcasting data to all vehicles in the network.

2.2 Broadcasting Scenario

When traffic density is high the wireless medium is shared by several numbers of vehicles for the same safety broadcast message [4]. As broadcasting over VANETs use store and forward mechanism to disseminate data, there is a chance of redundancy, contention and packet collision. This is exemplified in the following diagram Figure 3.

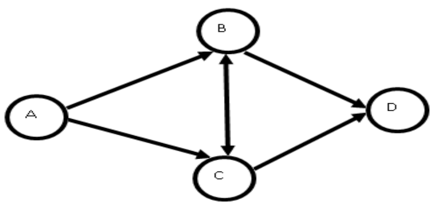

Figure 3:A simple scenario of Broadcasting

In Figure 3, a simple network scenario is considered to discuss the issues of broadcasting. Node A is within the transmission range of nodes B and C and hence redundancy occurs when same message from nodes B and C are received by A. Also nodes B and C may require the broadcast medium at the same time which may result in medium contention. If nodes B and C perform broadcasting at same time, packet collision may take place.

The broadcasting techniques used for VANET should satisfy the requirements such as Scalability, Effectiveness, Efficiency, Dissemination delay, Delay-tolerant dissemination, Robustness [5].The two broadcasting mechanisms Cluster Based Broadcasting and Multi-hop relaying techniques used by proposed *Cluster Based Neighbor Coverage Relaying* architecture are discussed below.

3. Cluster Based Broadcasting (CBB)

Cluster-based solutions provide less propagation delay and high delivery ratio [6]. In CBB [7], the transmission range is partitioned into number of clusters and a vehicle within the cluster is selected as cluster head. The cluster head is responsible for efficiently rebroadcasting messages. Vehicles with in a cluster can communicate with each other but cannot interact with vehicles in other clusters.

Every cluster can have three types of nodes: Cluster head, Gateway and ordinary node. The Cluster-head is a vehicle which can transmit to every other vehicle in the same cluster. Ordinary nodes are normal vehicles in a cluster. The Gateway node belongs to more than one cluster. The gateway node after receiving a message rebroadcasts it to cluster head of next cluster which will take care of retransmission of message.

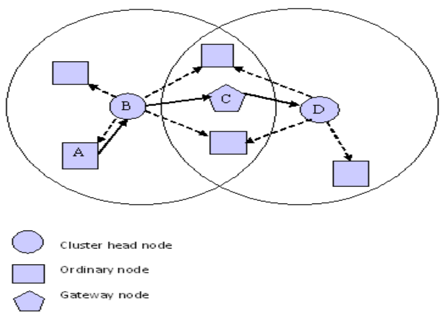

Figure 4:Cluster Based Broadcasting technique

In Figure 4, the solid line represents transmission of message among the source/forwarder vehicles that are allowed to broadcast. The dashed line represents transmission of message from cluster head and gateway nodes to ordinary nodes.

Nodes B and D are cluster head nodes. An ordinary node A broadcasts the message to a cluster head node B of its cluster. The node B in turn rebroadcasts the same message to all other vehicles in its cluster. In that process the gateway node C receives the message from B. Node C can transmit the message to the cluster head node of its consecutive cluster i.e. D. Node D receives the message and rebroadcasts it to all its neighboring nodes. The proposed approach of CBB performs broadcasting in a VANET by placing a limit on number of vehicles to be message forwarders. Here a number of clusters are formed dynamically and a vehicle from each cluster is selected as a cluster head. Initially one of the forwarder vehicles starts the broadcasting process. Once the forwarder broadcasts the message to its cluster head, it then becomes the next message forwarder.

Formation of clusters and Cluster head selection [8] is the important aspect of Cluster based broadcasting which is shown in Figure 5.

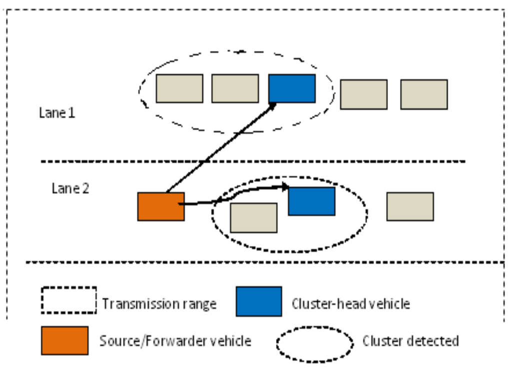

Figure 5:Cluster formation and Cluster head selection

3.1 Cluster Formation

Initially the source/forwarder vehicle willing to broadcast transmits a request-to-broadcast control message to all its nearby vehicles in the transmission range. The source vehicle then gathers the id and distance of its nearby vehicles and calculates the inter-vehicle distances among its nearby vehicles. The source vehicle also fixes a minimum distance value as threshold value. If the distance between each pair of vehicles is less than the threshold value, that pair of vehicles are considered to be in the same cluster. If the inter-vehicle distance between the vehicles exceeds the threshold value, then they belong to next cluster within the transmission range. The number of clusters formed depends on the threshold value. If the threshold value is higher, then more number of vehicles is placed in each cluster. If the selected threshold value is 0, then each vehicle belongs to a 1-size cluster.

3.2 Cluster Head Selection

After forming multiple clusters the source vehicle selects the vehicle which is farthest from source and nearest to destination is selected as a cluster head. The source vehicle transmits the message to cluster head which in turn becomes the message source and broadcasts the message to all its neighboring vehicles within the same cluster. Hence Cluster Based Broadcasting may decrease redundant broadcasts, contention and collisions that affect inter-vehicle communication.

4. Multi-hop Relaying

Multi-hop relaying [7] is a broadcast technique in which the source vehicle selects all its nearby vehicles as relay vehicles to complete the broadcast. The performance parameters considered for performance evaluation of broadcasting are Reliability, Overhead and Speed of data dissemination [9]. Multi-hop relaying broadcast reduces the number of redundant transmissions by selecting only a small number of relay vehicles as message forwarders [10]. This method is based on a “broadcast set cover” that contains minimum subset of nearby vehicles of a given vehicle which will cover all two-hop neighbors of that vehicle. Relay vehicles of source vehicle are one-hop neighbors that cover all two-hop neighbors of that vehicle. Once the source vehicle transmits the message to its relay vehicles, they in turn transmit to all two-hop neighbors of source vehicle.

The procedure of Multi-hop relaying is as follows:

1. Find all two-hop neighbors reachable from a single one-hop neighbor.
2. Assign all one-hop neighbors of source vehicle as multi-hop relay vehicles.
3. The “broadcast set” is determined which contains two-hop neighbors that receive the message from the current multi-hop relay vehicles.
4. The source vehicle transmits the message to all its relay vehicles which in turn broadcasts them to “broadcast set “of vehicles.
5. The remaining one-hop neighbors who are not relay vehicles determines the two-hop neighbors covered by them which are not in “broadcast set”.
6. Repeat from step 3 until all two-hop neighbors are covered.

The broadcasting technique can be applied for several vehicles in a network by considering multiple hops from the source vehicle.

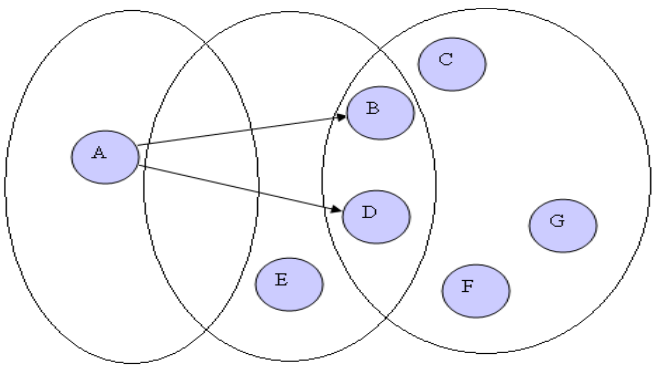

Figure 6:Multi-hop relaying broadcast

In the above diagram Figure 6, node A is the source vehicle which initiates the broadcast. Nodes B, D and E are one-hop neighbors and nodes C, G and F are two-hop neighbors of node A. Nodes B and D are selected as relay vehicles. Node C is covered by B and nodes F and G are covered by D. Node E is not selected as a relay vehicle because its two-hop neighbor F is already covered by D. Hence Multi-hop relaying reduces redundant transmissions and collisions with the help of relay vehicles.

5. Cluster Based Neighbor Coverage Relaying (CBNCR)

To enhance broadcasting *Cluster Based Neighbor Coverage Relaying* mechanism is proposed. *Cluster Based Neighbor Coverage Relaying* combines Cluster Based Broadcasting and Multi-hop Relaying to mitigate redundancy, collision and contention in broadcasting. In this architecture, to reduce link failures and to provide reliable communication across the network the transmission range of the network is divided into number of dynamic clusters and a vehicle from each cluster is selected as a cluster head. The cluster head is responsible for broadcasting a message to all vehicles in its cluster and to the cluster heads of other clusters. The clusters are formed based on the inter-vehicle distance between the vehicles. After a cluster is formed the vehicle which is farthest from source and nearest to destination is selected as cluster head. The cluster head then transmits the message to all its neighboring vehicles in the cluster. It also broadcasts the message to the remaining cluster heads in the network based on Multi-hop relaying broadcast technique.

The cluster head can also be termed as representative vehicle in a cluster. The source/forwarder vehicle initiates the broadcast and transmits the data to its neighboring cluster head. The cluster head determines its entire two-hop neighbor representatives which are reachable from one-hop neighbor cluster heads and assigns all one-hop neighbor representatives to the list of relay vehicles. The broadcast message is transmitted from cluster head to all vehicles in the cluster and to the relay vehicles (one-hop neighbors). Each relay vehicle then forwards the message to the vehicles in its cluster and to the two-hop neighbor representative vehicles. The process is continued until every vehicle in the network receives the broadcast message.

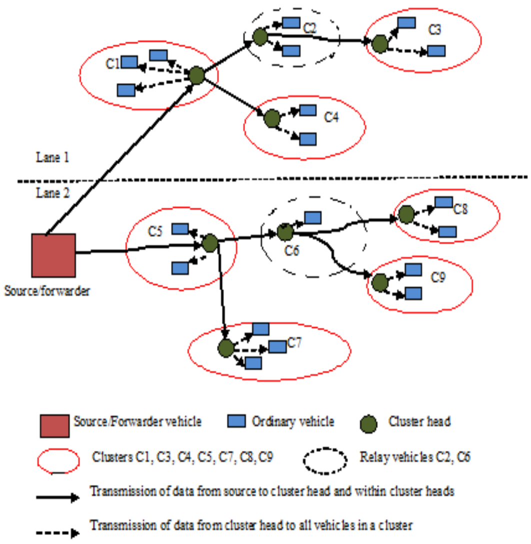

Figure 7:Cluster Based Neighbor Coverage Relaying mechanism

Figure 7 gives a view of *Cluster Based Neighbor Coverage Relaying* mechanism. The clusters C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8, and C_9 are formed dynamically by calculating the inter-vehicular distance of the vehicles in the network. After forming the clusters a vehicle from each cluster is selected as a cluster head which is farthest from source and nearest to the destination. The source/forwarder vehicle starts the broadcast process and transmits the message to its neighboring cluster heads in both lane1 and lane2. The cluster heads which received the message from the source, determines its entire two-hop neighbor cluster heads reachable from their one-hop neighbor cluster heads. The one-hop neighbor cluster heads used for data transmission are called as relay vehicles.

In the above figure the cluster head from the cluster C_2 is made as a relay vehicle because using it the initial cluster head from cluster C_1 can transmit the message to its two-hop neighbor cluster heads. Hence C_1's cluster head transmits the message to all the vehicles in its own cluster as well as to the relay vehicle i.e. C_2's cluster head. The C_2's cluster head in turn rebroadcasts the same message to its own vehicles and to the cluster head of the cluster C_3.The cluster head of C_1 in turn broadcasts the message to the cluster head of C_4 which is not a relay vehicle so that the message is broadcasted to all the vehicles in lane1. The same procedure is repeated in lane2 also. In lane2, cluster head of C_5 transmits the message to C_6's cluster head which is a relay vehicle. The cluster head of C_6 in turn broadcasts the message to the vehicles in its cluster and to the two-hop neighbor cluster heads of C_8 and C_9. C_7's cluster head which is not a relay vehicle also gets the message from the initial cluster head.

6. Results and Discussion

A comparative analysis of different broadcasting techniques is given below in Table 1:

Table 1:Comparison of different broadcasting techniques

Broadcasting technique	**Reliability**	**Performance**	**Congestion**	**Rebroadcast**	**Collision**	**Contention**
Flooding	Depends on traffic	Moderate	Very high	redundant	Severe	Very high
Cluster based broadcasting	High	High	Average	Efficient	Low	Very low
Multi-hop relaying	Moderate	Moderate	Moderate	controlled	moderate	Moderate

As the proposed architecture *Cluster Based Neighbor Coverage Relaying* combines the features of both Cluster Based Broadcasting and Multi-hop relaying, it efficiently reduces redundant broadcasts. It also makes collision and contention very low. The performance of the architecture is very high as it improves message reliability. Performance comparison of the broadcasting mechanisms flooding and the *Cluster Based Neighbor Coverage Relaying* (CBNCR) is evaluated using R console in terms of Average Throughput, Packet Delivery Ratio, Reliability Ratio and Total delay.

6.1 Average Throughput

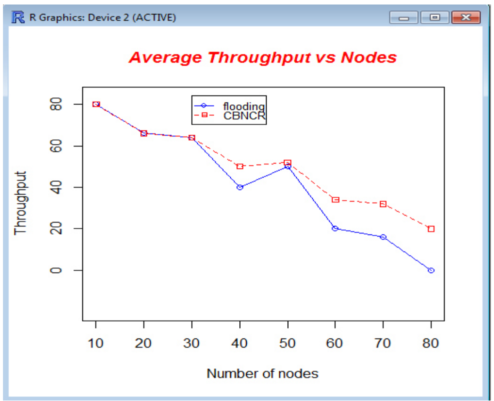

Figure 8:R-graph for Average Throughput versus Nodes

Figure 8 shows the R-graph between flooding and *Cluster Based Neighbor Coverage Relaying* (CBNCR). In this graph X-axis denotes the number of nodes and Y-axis denotes the throughput. Blue line indicates flooding and Red line indicates CBNCR. This graph indicates that throughput is nearly same for both techniques for nodes in the range from 10 to 50. From 50 to 80 nodes CBNCR performs better in comparison to flooding.

6.2 Packet Delivery Ratio

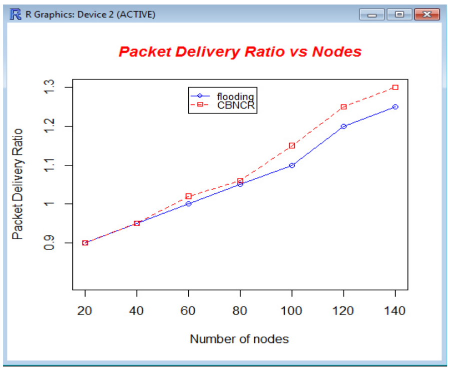

Figure 9:R-graph for Packet Delivery Ratio versus Nodes

Figure 9 shows the R-graph between the broadcasting mechanisms flooding and CBNCR. In this graph the X-axis represents number of nodes and Y-axis represents Packet Delivery Ratio. Red line is for CBNCR and Blue line is for flooding. From the graph, it is analyzed that both the mechanisms perform same till 60 nodes. Beyond 80 nodes the performance of CBNCR improves significantly.

6.3 Reliability Ratio

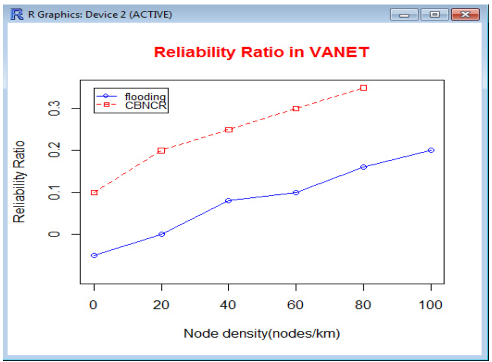

Figure 10 :R-graph for Reliability ratio versus Node density

Figure 10 shows the R-graph between the broadcasting mechanisms flooding and CBNCR. In this graph the X-axis represents number of nodes per km and Y-axis represents Reliability Ratio. Red line is for CBNCR and Blue line is for flooding. From the graph, it is analyzed that the reliability of CBNCR mechanism is higher than flooding in which the reliability depends on traffic.

6.4 Total Delay

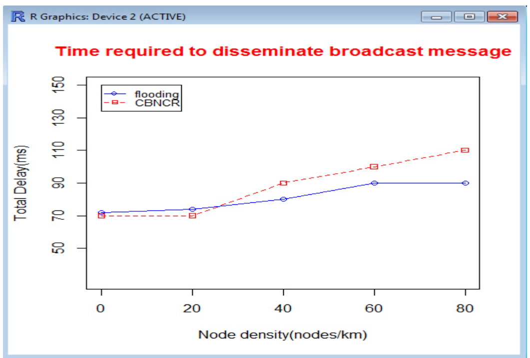

Figure 11 :R-graph for Total Delay versus Node density

Figure 11 shows the R-graph between flooding and *Cluster Based Neighbor Coverage Relaying* (CBNCR). In this graph X-axis denotes the Node density i.e. number of nodes per km and Y-axis denotes the Total delay (ms). Blue line indicates flooding and Red line indicates CBNCR. This graph indicates that the time delay is nearly same for both techniques for nodes in the range up to 40. Beyond that the total delay of CBNCR slightly increases in comparison to flooding.

7. Conclusions

The proposed *Cluster Based Neighbor Coverage Relaying* architecture enhances the performance of broadcasting by increasing message reliability and reducing redundancy, contention and collision. Cluster based broadcasting saves the network resources during data transmission and provides high performance. Multi-hop relaying is an efficient broadcast technique in which every node in the network should maintain the knowledge of one-hop or possibly two-hop neighbors. In Multi hop relaying neighborhood information is maintained in routing table to monitor the time variant mobile network. This work can be extended to designing of efficient broadcast techniques considering link failures that can be operated on mobile networks.

Acknowledgment

First and foremost I offer my sincere gratitude to my Principal Dr. T. K. Ramakrishna Rao, Vice-principal R. Srinivas, M.Tech (Ph.D) and to my Head of the Department Mr. G. Sanjeev Rao, M.Tech (Ph.D) for their valuable help and support. My thanks go in particular to Miss N. Suryakala with whom I started this work and many rounds of discussion with her helped me a lot. I would also like to thank my well wisher Miss D. Prasanna Lakshmi working in TCS, for her encouragement in completing my work.

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