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A GATEWAY SELECTION ALGORITHM IN A HYBRID CLUSTERED VANET - LTE ADVANCED NETWORK

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***Abstract*— In this work, we propose a cooperative traffic transmission algorithm in a joint VANET - LTE Advanced hybrid network architecture that elects a gateway to connect the source vehicle to the LTE Advanced infrastructure under the scope of Vehicle to Infrastructure (V2I) communications. The originality of the proposed Fuzzy QoS-balancing Gateway Selection (FQGwS) algorithm is the consideration of QoS traffic classes constraints for electing the gateway. Our algorithm is a multi criterion and QoS based scheme optimized by performing the fuzzy logic for making the decision over the appropriate gateway. Criteria are related to the Cluster Head and gateway candidates Received Signal Strength, load and the vehicle to vehicle Link Connectivity Duration. Moreover, results show the efficiency of FQGwS algorithm as it adapts its gateway selection decision to cluster density and to relative velocity of source node.**

***Index Terms* — (Vehicular ad hoc networks (VANETs) Fuzzy, QoS-balancing Gateway Selection Algorithm (FQGwS) algorithm clustered mobile ad hoc architecture).**

I. Introduction

IEEE 802.11-based Vehicular Ad hoc (VANET) networks have been widespread due to their relevant attractive features such as self-organization and the decentralized administration. Although VANET networks are considered to be a subset

of MANETs networks, they have some advantages over these later. Typically VANET nodes do not have battery limitations and benefit from more processing power and storage space. The great potential of this technology has been acknowledged with the establishment of ambitious research programs on vehicular communication systems worldwide, such as European Safety framework, numerous United States V2V and V2I projects, and the Japanese Smart way and Advanced Safety Vehicle programs.

In fact, future vehicles are expected to be equipped with high efficiency computing systems and multiple wireless communication interfaces, the running vehicles will have communication capabilities and they estimate that by 2027 almost 100% of the vehicles will be equipped with On Board Units (OBUs). OBUs are devices that provide communications among neighboring vehicles, i.e. Vehicle to Vehicle (V2V) or between vehicles and nearby fixed equipments (called also Road Side Units (RSU)), i.e. Vehicle to Infrastructure (V2I) communications [1]. Thus, Intelligent Transportation Systems (ITS) attract not only research community but also the automotive industry. Recently, they focus their efforts to grow vehicular communication and networking into maturity by moving it from research field into real implementation, aiming to provide not only more safety in the transportation systems but also other high quality of service (QoS) based services and applications for their customers.

Obviously, VANET networks have to overcome some issues and challenges related to their specific characteristics, such as the very dynamic network topology related to vehicles high velocity, to ensure acceptable Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications. Most of the

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solutions proposed to handle these issues are based on the creation of dynamic clusters to self-organize the vehicular network where the dynamic clustering formation can be either in a decentralized or centralized way. Clustering is to group the nodes into homogeneous sets named clusters. Each cluster has one Cluster Head (CH) elected from the cluster members' that controls flows and signaling inside the cluster especially for V2I communications. Typically, the members of one cluster have some common characteristics, e.g. near coordinates, velocities, same direction, etc.

In this paper, we focus not only on safety critical and convenience services delivered on highways via V2I architecture but also on other QoS classes delivering real time, streaming or best effort services. An efficient algorithm based on a QoS-balancing scheme will be proposed.

Vanet Clustering

As in a classical MANET network, VANET nodes have dynamic connectivity and self organizing features. However, with the increasing of the number of nodes, where each node handles its own decentralized routing and neighborhood connectivity maintenance tasks, serious scalability and hidden terminal problems may occur. The most common solution adopted for this problem is the clustering.

The main challenge for a VANET clustering algorithm is to maintain cluster stability for the longest period otherwise the performance will be degraded due to the frequent re-clustering operations. Besides, clustering in VANETs requires selecting a Cluster Head (CH) to be responsible for coordinating the members of the cluster. This process is carried out by each node belonging to the cluster by broadcasting its information to all other neighboring nodes.

A similar approach; where clusters are formed based on vehicles position in the road. However, proposed algorithm is very limited as it does not address the cluster maintenance and CH election. Another position based clustering algorithm that performs hierarchical and geographical data collection and dissemination. The cluster formation in this algorithm is Its performances are affected by the mandatory availability of an infrastructure. Moreover, it generates high overheads for V2V and V2I communications.

1.1. Existing System

IEEE 802.11-based Vehicular Ad hoc (VANET) networks have been widespread due to their relevant attractive features such as self-organization and the decentralized administration. A VANET is composed of three components: onboard units (OBUs) equipped in moving vehicles, fixed roadside units (RSUs), and a central trust authority (TA). The OBUs are the wireless units fitted in the vehicles such as cars to enable the wireless communication feature. The Road-Side-Units (RSUs) are used as access points for Vehicles as the moving vehicle can deliver or access the messages, Internet...etc., The Trusted Authority (TA) authenticates each and every vehicular node using digitally signed Certificates. But the main challenge in VANET is to ensure the QoS. Due to factors such as the very dynamic network topology related to vehicles high velocity, to ensure acceptable Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications. Most of the solutions proposed to handle these issues are based on the creation of dynamic clusters to self-organize the vehicular network where the dynamic clustering formation can be either in a decentralized or centralized way. But these methods are not well suited for these high-speed networks as the vehicular nodes are moving in inconsistent speed.

II. RELATED WORKS

For a non-clustered ad hoc networks, in reference [16], authors proposed an algorithm for gateway selection based on choosing the mobile node with shortest hops from source node. One single metric that combines physical hops and, virtual hops relative to congestion and contention levels, is used. This algorithm has got one limitation which is the use of the NAV timer to compute virtual hops for contention measurements which is not an easy parameter to evaluate concretely. In [17], authors discuss the issues associated with the selection of mobile gateways in an integrated MANET-UMTS heterogeneous network. They use simple additive weighting techniques to select an adequate gateway based on residual energy, UMTS signal strength and mobility speed of the gateway candidates. In [18], metrics used to select the gateway for interconnecting the MANET with the infrastructured network are remaining energy, mobility, and number of hops based on a simple additive weighting method. Node with the highest weight will be selected as a gateway. These three metrics are not enough to select the optimal gateway as the link from the gateway to the infrastructure is not considered. In clustered networks, clustering algorithms are used in VANETs to ensure stability and increase link lifetime between vehicles belonging to the same cluster. There are basic clustering and CH election techniques that were proposed in literature such as highest degree [19] and lowest Id [20] algorithms which are not effectively efficient as they may generate frequent re-clustering. In [6], as cluster formation is based on direction of vehicles, the first vehicle moving in that direction will be elected as CH. Using this method, vehicles with high relative speed will generate frequent CH reselection which causes additional overhead in the cluster. In [21] authors propose to elect one CH in each segment of a road based on geographical information collection which are provided by the infrastructure. This algorithm fails to address cluster stability and cluster maintenance. In reference [22], the cluster head is elected based an additive metric of three criteria: network connectivity level (based on the maximum number of vehicles that are directly connected to considered vehicle and on the vehicles on the same traffic flow) and average distance and velocity levels. Authors considers urban scenarios characterized by several lanes and intersection architecture, e.g. going straight through or turning left or right. Gathering information over the roads' topology and flows intersections requires accurate positioning systems which is not always achieved. Moreover, the high dynamicity of the vehicular nodes and the random drivers' reactivity causes limits to this approach. In reference [10], authors elects the cluster head based on relative velocity. The relative velocity is computed using a ratio of received signal strength of two successive HELLO messages. The CH is then the node with the lowest relative velocity variance. This is an interesting approach for electing the CH, however, there is more accurate schemes for computing relative velocity than the HELLO messages based approach. In [11], after handling hierarchical clustering technique, authors propose to elect the CH as the slave node that received three synchronous messages. This method does not consider vehicles' movement dynamicity and causes huge amount of overhead to the messages exchange for the hierarchical cluster maintenance. In [7], the cluster head is designed as the vehicular node that is in the middle of the cluster, at equal distance from the border nodes. A source vehicle will then select one of the elected CH as gateway to the infrastructure.

III.PROPOSED SYSTEM

To the best of our knowledge, there is no proposed algorithm for gateway selection to infrastructure in a clustered VANET architecture that considers traffic class priority. In this paper, a cooperative traffic transmission algorithm in a joint VANET - LTE Advanced hybrid network architecture that elects a gateway to connect the VANET source vehicle to the LTE Advanced infrastructure under the scope of V2I communications. LTE Advanced standard might be widely adapted by numerous operators as the next generation of their cellular networks. We propose then a multi-criteria and QoS related attributes approach used

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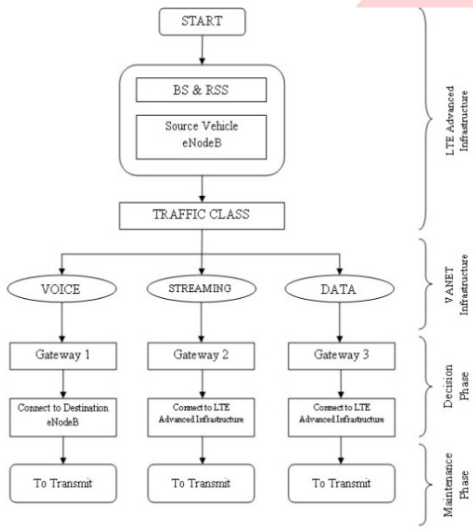
to make a decision of the appropriate gateway for source vehicle to the LTE Advanced infrastructure. The originality of our algorithm is the consideration of QoS traffic classes constraints for electing the gateway.

Flow Diagram



IV SYSTEM MODELING

The system model is based on a hybrid network architecture that consists of two systems: 1).An LTE Advanced infrastructure and 2).A VANET network. The architecture comprises IEEE 802.11p based VANET vehicles and LTE Advanced eNodeBs interconnected through X2 interface and connected via S1 interface to core network, i.e. Evolved Packet Core (EPC).

We assume that all vehicles are equipped with OBUs that contain an IEEE 802.11p interface. (IEEE 802.11p is an approved amendment to the IEEE 802.11 standard to add wireless access in vehicular environments (WAVE)). Each vehicle uses its VANET interface to communicate with its neighboring vehicles based on IEEE 802.11p standard. IEEE 802.11p inter-vehicle communications are possible even if vehicles are inside eNodeB coverage. The OBU could also contain an LTE interface to communicate directly with the infrastructure. Simultaneous two interfaces communications do not cause harmful interferences as they lie on distinct non-overlapping channels in two different spectrum regions.

Fuzzy QoS-Balancing Gateway Selection Decision

An efficient gateway selection algorithm has to take aware of the QoS features of traffic to be transmitted to the infrastructure. We designed a QoS-

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balancing gateway selection algorithm (QGwS) in a VANET - LTE Advanced hybrid network where the decision over the gateway depends on the traffic to be transmitted to the infrastructure. It is an adaptive multi-criteria multi-attribute gateway selection decision algorithm. The fuzzy logic has two objectives:

1).First, it develops computational methods that can perform reasoning and problem solving tasks that require human intelligence,

2). Second it explores an effective trade-off between precision and the cost in developing an approximate model of a complex system.

Fuzzy inference system is a computing framework based on the concepts of fuzzy set theory, fuzzy if-then rules, and fuzzy reasoning. It is known as the process that draws conclusions from a set of facts using a collection of rules.

INPUT PARAMETERS

FQGwS algorithm input parameters are divided into two categories:

1).Attributes

2).Criteria

1). Attributes:

In this paper, we consider only one attribute which is the type of traffic to be transmitted by a source vehicle to the infrastructure. We define three classes of traffic: Class 1, Class 2 and Class 3. As the source vehicle is a VANET node, generated traffic types are governed by IEEE 802.11p standard. On the other side, the infrastructure is an LTE Advanced cellular network. Thus, to achieve systems' compatibility, a mapping between IEEE 802.11p access categories and LTE Advanced priority classes, using the QoS Class Identifier (QCI) is done.

The mapping is performed based of QoS constraints (packets average delay budget and packets loss) of VANET and LTE Advanced standards. Traffic mapping is define only three QoS category classes because for first deployments, a majority of 4G operators will likely start with three basic service classes containing *voice, and best effort data classes*. Class 1 traffic as Voice traffic, Class 2 as Streaming and Class 3 as Data traffic.

ITS protocols are designed for the *5.850- to 5.925-GHz* band, divided into one central control channel (CCH) and six service channels (SCHs) where CCH is dedicated to the transmission of traffic safety messages,

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whereas SCHs are dedicated to the transfer of various application data.

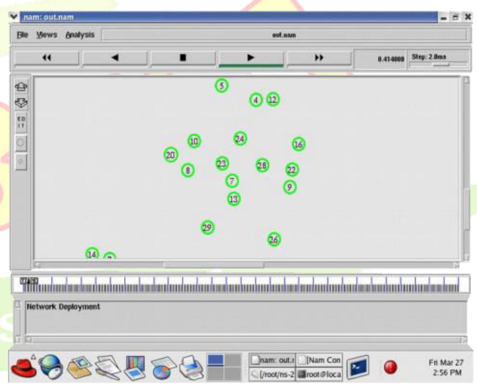
Inside the *class 1 traffics, safety and alerts services have priority* over other conversational voice or live streaming services. Our work considers traffic priority class for choosing the adequate gateway to the infrastructure under V2I context.

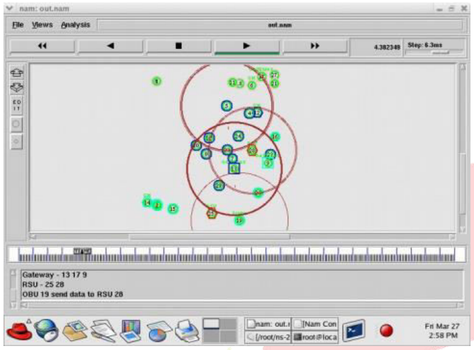
2).Criteria

Criteria are input parameters that are either measured or received by the source vehicle from neighboring vehicles: Source Vehicle to LTE Advanced Infrastructure Link Connectivity Strength (Source2I LCS) CH to LTE Advanced Infrastructure Link Connectivity Strength (CH2I LCS).Load of the CH. Source Vehicle to CH Link Connectivity Duration (Source2CHLCD).Gateway candidate to LTE Advanced Infrastructure Link Connectivity Strength (GwC2I LCS). Load of the Gateway candidate. Source Vehicle to gateway candidate Link Connectivity Duration (**Source2GwCD**)

V. SIMULATION RESULTS

The proposed system is implemented in NS2 stands for Network Simulator Version 2. It is an open-source event-driven simulator designed specifically for research in computer communication networks.





VI.CONCLUSION

This paper presented an original algorithm based on a fuzzy logic modelization for gateway selection from a VANET network to the LTE Advanced infrastructure. The complexity study of the algorithm shows that FQGwS algorithm presents linear complexity. This new approach has been compared to the standard deterministic approaches that use the CH as a default gateway. Simulation results show that an efficient CH election algorithm is important to ensure good performances and that our protocol performs better results in terms of delay and packet loss than the deterministic approach.

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