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Advances on Network Protocols and Algorithms for Vehicular Ad Hoc Networks

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Abstract

Vehicular Ad Hoc Networks (VANETs) have become an emerging area of wireless ad hoc networks in the last years. They facilitate ubiquitous connectivity between vehicles through Vehicle-to-Vehicle (V2V) or Vehicle-to-Roadside (V2R) and Roadside-to-Vehicle (R2V) communications. VANETs aim to improve the safety of passengers and traffic flow, reduce pollution to the environment and enable in-vehicle entertainment applications. They have a large number of research challenging issues in both communication and data management aspects. This special issue is focused on collecting recent advances on network protocols and algorithms for vehicular ad hoc networks, which aims at presenting innovative and significant research on the design, implementation, usage, and evaluation of vehicular ad hoc networks. We are deeply grateful for receiving many excellent submissions to this special issue. The review and revision processes for all papers were carried out in a rigorous and thorough manner. Accepted papers fall into various important areas including routing, route prediction and vehicular mobility, audio and video streaming, VANET Topology formation techniques, handover techniques, Path and channel loss, Medium Access Control Protocols and Security.

Keywords: Network Protocols, Network Algorithms, Vehicular Ad Hoc Networks.

1. Introduction

Vehicular Ad Hoc Network (VANET) is an emerging area of wireless ad hoc networks that facilitates ubiquitous connectivity between smart vehicles through Vehicle-to-Vehicle (V2V) or Vehicle-to-Roadside (V2R) and Roadside-to-Vehicle (R2V) communications. This emerging field of technology aims to improve safety of passengers and traffic flow, reduces pollution to the environment and enables in-vehicle entertainment applications. The safety-related applications could reduce accidents by providing drivers with traffic information such as collision avoidances, traffic flow alarms and road surface conditions. Moreover, the passengers could exploit an available infrastructure in order to connect to the internet for infomobility and entertainment applications [1].

The increasing necessity of this network is an impetus for leading car manufacturers, research communities and governments to increase their efforts toward creating a standardized platform for vehicular communications. However, VANET's unique characteristics and special requirements excite new challenges to the research community. To address these challenges in both safety- and comfort-oriented applications, there is a pressing need to develop new protocols and algorithms for channel characterization and modeling, Medium Access Control (MAC), obstacle modeling, adaptive geographical routing to sparse and dense traffic conditions.

This special issue aimed to theme innovative research achievements in the field of vehicular networks and communications. We were seeking original, innovative and unpublished papers related to radio obstacle modeling in urban vehicular environments [2], VANET routing protocols [3] (such as efficient geographical routing [4], delay-aware routing protocols [5], delay tolerant routing protocols [6], routing

protocol using movement trends [7], etc.), adaptive beaconing protocols [8], mobility management and handovers [9], network size [10], transmission power adaptation systems [11], Quality of Service [12], security and privacy issues [13], efficient packet forwarding optimization[14], modeling and simulation [15], etc. We also welcomed other typical VANET topics such as channel characterization, congestion control and resource management, medium access protocols and channel assignments, mobility models, message dissemination for safety-related applications, cooperative vehicular communications, test-beds, case studies, experimental systems and real evaluations. Our purpose was also to include new VANET topics such as Inter-domain Proxy Mobile IPv6 in VANETs [16], Vehicular Cloud Computing [17] and security in Vehicular Clouds [18].

We received 77 submissions and only the best 12 papers have been accepted, which means an acceptance ratio of 15.58%. We give many thanks to the reviewers for their time revising and providing useful comments to the authors and to the authors for their patience when some steps have been delayed because of the amount of received papers.

We have classified the accepted papers in the following list of topics:

1) Path and channel loss
2) Topology formation
3) Vehicle route prediction and vehicular mobility
4) Medium Access Control
5) Handover
6) Routing
7) Audio and video streaming
8) Security

From a communication layer point of view, we can group them as it is provided in figure 1. We have split the architecture in 4 layers, where three of them are horizontal layers, while one of them (security) is vertical.

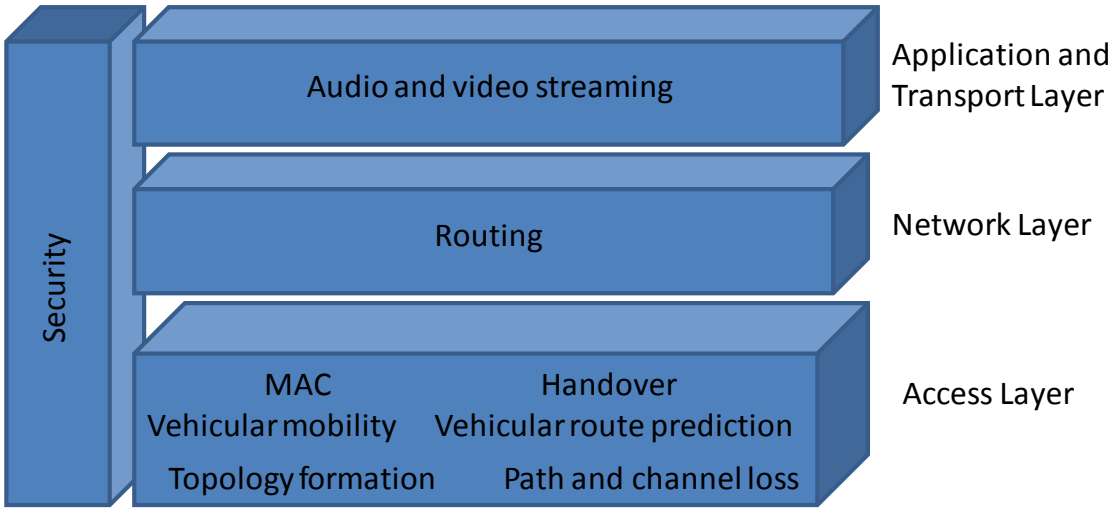

Figure 1. Papers topics grouped in Layers

The number of papers accepted for each layer is shown in table 1. We can see that the highest number of accepted papers belongs to the access layer.

Table 1. Number of papers accepted in each layer.

Layer	**Number of Papers**
Access	6
Network	3
Application and Transport	2
Security	1

The rest of the paper is structured as follows. Section 2 shows the accepted papers focused on access layer issues. Accepted papers focused on network layer are shown in section 3. Section 4 present the papers accepted which are focused on application and transport layer. Accepted papers focused on security are included in section 5. Finally, section 6 presents our conclusions.

2. Access Layer

This section includes the accepted papers focused on path and channel loss,

2.1 Path and channel loss

In [19], H. Fernández et al. analyze the path loss, in terms of the Transmitter-Receiver separation distance and fading statistics, in two different urban environments, with different road traffic densities and propagation characteristics, and in an expressway environment. Based on a narrowband channel measurement campaign carried out at 5.9 GHz, they present a vehicular path loss characterization and propose a simplified propagation model, which is suitable for VANETs simulators to evaluate and analyze the performance of safety and non-safety applications under realistic propagation conditions. The proposed path loss model has a linear relationship between the path loss and the logarithmic of the Tx-Rx separation distance. They evaluated the packet error rate (PER) and the maximum achievable Tx-Rx separation distance for a PER threshold level of 10% according to the digital short-range communications (DSRC) specifications.

2.2 VANET Topology formation

In [20], Y. Allouche and M. Segal present a self-organizing cluster-based topology to serve as the infrastructure for an efficient and reliable beacon dissemination process. This process provides a real-time, broad and coordinated map under the challenging VANET conditions. Moreover, they propose the Distributed Construct Underlying Topology (D-CUT) algorithm tailed specifically to provide an optimized topology for such beacon dissemination process. In order to achieve this goal, the network is partitioned into clusters of adjacent vehicles. Each cluster contains a designated vehicle that acts as the cluster head, connected by one-hop intra-cluster links to its cluster members. The second level of the topology connects adjacent cluster heads by multi-hop, inter-cluster links. The system integrates contention-free medium access control (MAC) protocols. Moreover, it aims to reduce the interference by geographically optimizing the topology, and, in this way, allows the execution of extensive but reliable inter-cluster bandwidth reuse. They evaluated the performance of the D-CUT algorithm under realistic road conditions. Their simulation results support their theoretical findings with respect to logarithmic initial convergence time under realistic traffic scenarios.

2.3. Vehicle route prediction and Vehicular mobility

In [21], A. F. Merah et al. design and implement 5 communication schemes for depicting the road segments in which vehicles traverse through during their trips in a specific geographic area, as sequential patterns. These traces are compiled into a database of historical sequential patterns traversed by vehicles and make use of data mining techniques in order to build travel profiles for vehicles that may be tracked in a real-time fashion. They classified them in two categories: Based on Road Side Unit scheme, which periodically queries the vehicles to send their traversed paths to their neighbors and based on Vehicle schemes, where vehicles initiate the sending of their traversed paths according to a certain criteria. They simulated an on-road infrastructure environment to collect vehicular paths, by using the time-ordered objects, and extracted frequent paths through data mining. Then, they measured and analyzed the probability of these frequent paths in order to evaluate the effectiveness and efficiency of the proposed schemes. The schemes proposed in this paper provide different methods of collecting this information, and the communication overhead cost of each one has been evaluated to identify their advantages and/or shortcomings.

Daqiang et al. investigate in [22] the data collected from around 4,000 taxi traces of the Shanghai Grid project. Authors found that the tail distribution of inter-contact time follows the power law, and both node spatial distribution and inter-contact time distribution decay at least as the power law. They use these data

to propose an efficient model for detecting vehicle mobility in hot roads, which can generate synthetic traces that captures Vehicles' spatial and temporal features. The model takes the network topology, the selection of origin and destination, and the rules of movement into account to generate more realistic vehicular traces for the measurement of vehicular services and applications VANETs.

2.4. Medium Access Control

In order to address the issue of designing an efficient MAC protocol, in [23] the authors proposed a novel Multichannel QoS Cognitive MAC (MQOG) for vehicular communications. In the proposed algorithm, channel sensing is performed prior any data transmission and packets are always sent on the good quality wireless channel to mitigate high interference and multipath problems. Moreover, this protocol ensures QoS by granting safety messages higher priority of accessing the medium over data messages. Those features make the proposed protocol more suitable for VANETS than other existing protocols. However since MQOG has some limitations in terms of fair medium access, the authors modified it by adding MoByToP, a MAC Layer enhancement scheme. MoByToP includes mobility characteristics, QoS and transmit data rate and integrates them into the MAC to mitigate VANET challenges. It uses beacon information to calculate LOP (Link Out of Range Prediction) and then uses it to circumvent link failure. Moreover, it ensures QoS by granting safety messages higher priority of reserving the medium over data messages. In addition, MoByToP adjusts the frame burst based on the RSS (Received Signal Strength) to create a fair effective sharing of resources and hence enhancing the system’s overall throughput. Those features combined make EMQOG (Enhanced MQOG) very suitable for VANETs. To evaluate the performance of MQOG and EMQOG, implementation was done in OMNet++ 4.1 and our results showed an improvement in throughput.

2.5. Handover

S. Reñé et al. proposed in [24] a TCP-aware handover architecture based on IEEE 802.21 MIH standard to feedback information to the TCP transport layer about the network situation of the RSUs at the moment of the handover. The feedback information to the transport layer provides the ability to adapt the congestion window to the new network parameters to speed up the convergence time of the congestion control algorithm to the characteristics of the new link. The proposed architecture has been designed for 802.11 networks and can deal with layer 2 and layer 3 handovers. VSPLIT has been implemented and tested in the NS-3 simulator. The authors include the some of the most interesting performance evaluation results, which show a good performance of our proposal for the intended scenario.

3. Network Layer

The accepted papers that belong to this layer are focused on routing techniques.

B. Blanco et al. proposed in [25] an intelligent routing algorithm called GARI, which adapts its operation based on the high mobility and changing characteristics of vehicular city environments. The nodes sense the network locally and collect information to feed the cognitive module which selects the best routing strategy. Their proposed algorithm performs the decision process locally without extra protocol overhead, without the need of additional protocol message dissemination or convergence mechanism, but the benefit is perceived globally with the general improvement of the network performance. This first approach to global adaptiveness has made use of linear discriminant analysis with successful results.

J. Kim et al. propose in [26] a novel routing protocol for cognitive radio vehicular networks, called Spectrum-Aware BEaconless geographical routing (SABE). The main idea in SABE is that the routing decision, as well as the resource allocation strategy, are made by the receivers on a per-packet and per-hop basis. A packet carrier vehicle broadcasts a forward request packet, and includes in it its available resources and location. Receivers calculate a link weight with consideration of their and source’s available resources and locations. Then, a timer to reply to the request is set depending on the link weight. The receiver with the highest link weight replies first, establishing itself as the relay node. Simulation

results show that our protocol increases the end-to-end network throughput by up to 250% and decreases the end-to-end delay by up to 400% compared with other geographical routing protocols.

In [27], João A. F. F. Dias et al present a comprehensive study about the influence of cooperative nodes in the performance of vehicular delay tolerant networks when deployed in a rural environment. The authors proposed two levels of cooperation for VDTNs, considering buffer space and connection-time sharing. Finally, they conducted several studies to evaluate the impact of cooperation on the performance of VDTNs using five routing protocols, each one with single characteristics (First Contact, Epidemic, Spray and Wait, PRoPHET, and GeoSpray). Simulation results show that GeoSpray protocol performs better than the rest of the studied routing protocols. It is also concluded that cooperation between nodes improves the overall bundle delivery probability, leading to a better performance of VDTN networks.

4. Application and Transport Layer

The papers accepted in this layer are focused on audio and video streaming.

In the paper [28], Ali S. Sadiq et al. propose an Intelligent Network Selection (INS) scheme to make vertical handover decisions in VANETs using V2I communications. They used three parameters (Faded Signal-to-Noise Ratio, Residual Channel Capacity, and Connection Life Time) to develop a maximization scoring function that collectes data from each network candidate during the selection process to efficiently rank available wireless network candidates. The proposed INS scheme effectively decreases the delay associated with the handover process, End-to-End delays for VoIP and Video applications, packet loss ratios. Simulation results show how that the proposed INS scheme outperform existing approaches in terms of decreasing the probability of the link connection breakdown and unnecessary handovers. Moreover, it increases the efficiency of the network selection processes in comparison existing ones.

The paper in reference [29], presented by S. Machado et al., proposes a structured peer to peer (P2P) network designed for the distribution of live-content, with low bandwidth consumption in VANETs. It allows a peer to schedule consecutive video chunks, requesting parts of the media transmission to other peers, by means of a scheduling algorithm to a set of peers based on P2P paradigm. The transmitting peer may be placed in a road-side-unit or in a special car that patrols the area. Vehicles create a P2P network with the aim of achieving the maximum number of vehicles within a minimum delay. Each peer shares its buffer content and issues a set of requests to other peers for unreceived video chunks. Simulation show that under stable conditions of the network, the system can ensure certain quality of service parameters as the worst case chunk delay, the buffer size needed and the maximum number of peers that can be connected to the network.

5. Security

This section includes the accepted papers focused on security.

An efficient algorithm for modeling the node compromise attack in VANET is proposed by Chi Lin et al. in [30] to enhance the attacking efficiency of the node compromise attack in VANET by developing a general attack model based on the connected dominating set for modeling the node compromise. In the deployed VANET, the authors established a connected dominating set as network backbone. After that, an efficient algorithm is proposed to model node capture attack; a centralized and a distributed attack are developed for the purpose of destroying the connected dominating set of the network. In this paper, simulations are conducted and the results reveal that the proposed scheme enhances the attacking efficiency in different mobility models and different applications, which is suitable for modeling the node compromise attack in VANET.

6. Conclusion

We have observed in this special issue that it has increased the interest in the researchers on starting new research lines related with network protocols and algorithms for VANETS. We have classified the papers accepted in this special issue into 3 horizontal layers (Access, Network and Transport and Application layer) and 1 vertical layer (security). The layer where we have more accepted papers have been the access layer. This has happened because it includes more topics than the rest. We can state that there are appearing new research lines which will benefit the Vehicular technology and we hope to see them implemented in vehicles in a very near future.

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