# Performance Analysis of Real-Time Multimedia Transmission in 802.11p based Multihop Hybrid Vehicular Networks

**H. Venkataraman,**
Performance Eng. Lab.
School of Electronic Eng.
Dublin City University
+353-1-7006401
hrishikesh@eeng.dcu.ie

**A. d'Ussel, T. Corre**
Performance Eng. Lab.
School of Electronic Eng.
Dublin City University
+353-1-7007643
adrien.dussel@gmail.com

**C.H. Muntean**
National e-Learning Lab.
School of Informatics
National College of Ireland
+353-1-4498623
cmuntean@ncirl.ie

**G.-M. Muntean**
Performance Eng. Lab.
School of Electronic Eng.
Dublin City University
+353-1-7007648
munteang@eeng.dcu.ie

## ABSTRACT

Real-time multimedia communications over vehicular *ad-hoc* networks (VANET) will play an extremely significant role in the next generation intelligent transport systems. In recent years, there has been an upsurge of interest in the quality-oriented adaptive multimedia delivery, including over VANET. In this paper, a hybrid IEEE 802.11p-based multihop network communication solution is presented, which makes use of both infrastructure and ad-hoc modes in order to deliver quality-oriented real-time multimedia content to high-speed vehicles. Simulation-based testing shows how multimedia delivery to vehicles when using the multihop hybrid mechanism achieves significantly higher throughput in comparison to the case when the infrastructure mode is employed and the vehicles communicate directly with the base station. This result is obtained while the average delay and packet loss in the two cases are similar.

## Categories and Subject Descriptors

C.2.1 [**Computer Systems Organization**]: Network Architecture and Design – *Network topology.*

## General Terms

Performance

## Keywords

802.11p, infrastructure, ad-hoc, multihop, multimedia transmission, vehicular wireless networks.

## 1. INTRODUCTION

Over the last decade, there has been significant work on intelligent transportation systems with special focus on vehicular safety. Recently, the interest has shifted towards supporting additional services, including multimedia applications. In this context, significant research performed on real-time multimedia delivery over high-speed vehicular networks [1] showed that in order to support high quality advanced real-time rich media services, it is necessary to support high data rate, low loss rate and good connectivity.



This paper proposes a hybrid design which integrates multihop communications into high-speed vehicular networks resulting into one of the most promising architectural solutions to meet the next generation demand of multimedia transmissions in outdoor wireless networks. In such an architecture, the base station (BS) (directly connected to a server) communicates with the end-users in multiple hops, through intermediate vehicles which act as mobile relay nodes [2]. The combination of vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communications which results in a multihop hybrid vehicular wireless network is considered in this paper as the underlying model for next generation high-speed vehicular networks. This hybrid solution aims to increase the throughput and avoid the frequent handovers experienced by V2V communications and at the same time, minimize the infrastructure investments required to support V2I communications. Additionally shorter data transmission distances in each hop results in lower transmit power for each transmitter and therefore in power saving.

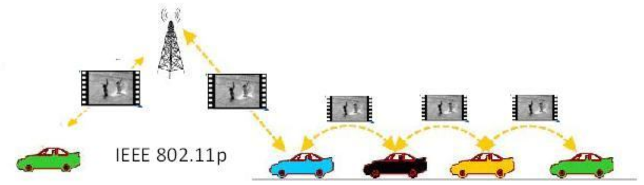


**Figure 1 Multimedia Delivery in Vehicular Wireless Networks**

Fig. 1 shows a generic illustration of multimedia transmissions in a vehicular wireless network. Multimedia data is transmitted from the server via BS to the vehicles either directly (in case of the infrastructure mode) or in multihop fashion. In the context of real-time multimedia streaming and video-on-demand in vehicular networks, there are two significant challenges [3]. The first challenge is the transmission of high quality video (and audio) in dynamically changing wireless network conditions affected by issues such as congestion, contention and mobility. The second challenge is to minimize the transmission delay and loss.

In this paper, a state-of-the-art feedback-based quality oriented adaptive scheme (QOAS) is considered for high quality multimedia transmission in the multihop hybrid vehicular wireless networks. In order to analyze the potential benefits, QOAS is employed to deliver multimedia over both multihop hybrid and infrastructure architectures. Different routing protocols are used in turn: including DSDV and AODV and different vehicular speeds are considered. The performance is analyzed in terms of the throughout, delay, loss rate and jitter.

The paper is organized as follows. Section two presents the motivation and related works, section three describes system architecture including the IEEE 802.11p-based multihop hybrid vehicular wireless communication solution and section four the different routing protocols employed. Testing setup and results are presented in section five and the conclusion is drawn in the last section.

## 2. MOTIVATION AND RELATED WORKS

The vehicular wireless networks are significantly different from the wireless *ad-hoc* networks that are implemented and deployed for the infrastructure-less environments. Firstly, the vehicles have far greater energy/power supply than normal mobile devices, as often energy can be derived from the vehicle itself. Secondly, given the size of the vehicle, a large number of sensors can be fitted onto the vehicles. This is particularly significant in case of having an intelligent transportation system with safety, security, communication, infotainment and other services deployed. Thirdly, the vehicles usually travel at high speeds and thereby have great difficulty in consistently maintaining vehicle-to-vehicle connectivity. Finally, unless there is a heavy investment in upgrading the current infrastructure, the vehicles are most often few hops away from BS or access points (AP). However, in order to have fixed access points to cover all roads at short distance one from another, huge and expensive investment is required, which is practically impossible. Hence, there is a need to design and develop novel methods to enable vehicular wireless network-support for the above requirements.

The IEEE 802.11p standard has been recently proposed for dedicated short range communication (DSRC) in high-speed vehicular wireless environments [5]. DSRC operates in the 5.9 GHz range [6] and supports speeds up to 120 mph, with a nominal transmission range of 300 m (up to 1000 m) and default data rate of 6Mbps (up to 27 Mbps). This will enable operations related to the improvement of traffic flow, highway safety, and other Intelligent Transport System (ITS) applications in a variety of environments called DSRC/WAVE (Wireless Access in a Vehicular Environment). For fast access, WAVE does not allow IEEE 802.11 active scanning, authentication and association. Instead, it uses specific beacons containing all the relevant information about the Base Station System and associated applications.

In case of real-time multimedia transmissions in vehicular wireless network, the unpredictability and the constantly varying nature of the wireless channel along with the high-speed of the vehicles require novel solutions to be proposed to address these issues such as the feedback-based adaptive mechanism for efficient multimedia delivery QOAS [7]. An adaptive prioritization mechanism, QPAMS has been recently proposed for hierarchical wireless networks [8] and obtained very good results when tested in two-hop WiMAX-based cellular networks [9]. Recently, significant work has been done on the design and benefit of the relay nodes for transmitting information from the mobile nodes to the server in a multihop network framework, specifically in the vehicular domain [10, 11]. However, to the best knowledge of the authors, there is no work done that investigates the throughput and other quality-of-service (QoS) parameters in multihop hybrid vehicular networks.

## 3. SYSTEM ARCHITECTURE

### 3.1 Network Model

The scenario considered for the deployment of the vehicular wireless network is a semi-urban environment where there is good road connectivity and the traffic is neither dense, nor sparse. The vehicles are assumed to move at a minimum velocity of 40 km/h, speed which could increase up to 100 km/h. In both the infrastructure and the multihop hybrid modes, CBR multimedia is considered as application traffic which makes use of UDP. Packet size is set to 1400 bytes. A random waypoint mobility model is considered in the network design.

An OFDM based physical layer is considered in the system design. There are 52 subcarriers of which 48 are data subcarriers and 4 are pilot subcarriers. The operating frequency band is 5.9 GHz. There are 6 channels each with 10 MHz bandwidth. Of these, the central channel is reserved for safety messages and the remaining 6 channels are used for multimedia transmissions. The WAVE-based MAC design is similar to the IEEE 802.11e Enhanced Distributed Channel Access (EDCA) Quality of Service (QoS) extension. Therefore, application messages are categorized into 4 different access categories (ACs), where AC0 has the lowest and AC3 the highest priority. Within the MAC layer a packet queue exists for each AC. During the selection of a packet for transmission, the four ACs content internally. The selected packet then contends for the channel externally using its selected contention parameters.

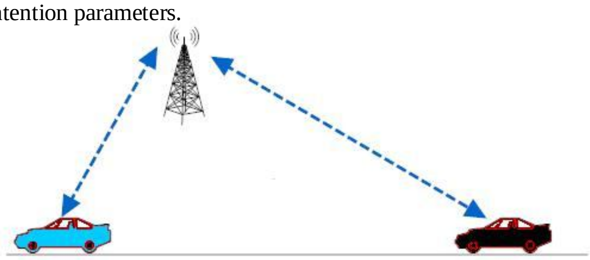

**Figure 2 Vehicle to Infrastructure Communication**

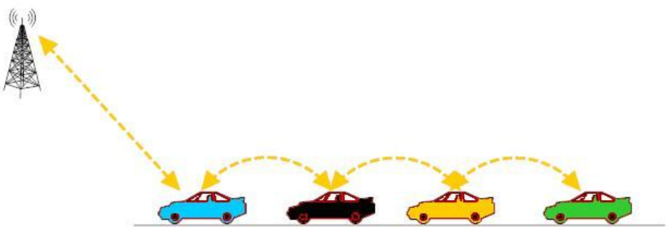

**Figure 3 Multihop Hybrid Communication**

Fig. 2 shows an infrastructure mode communication wherein the vehicles always communicate directly with the BS/server. In this case, the transmission range of communication between vehicle and the server is around 1 km. The distance between the servers is also 1 km. In contrast, Fig. 3 shows a multihop hybrid communication mode, wherein the moving vehicles communicate either with the server or with other vehicles in their vicinity. The servers are placed 5 km apart from each other. A constant speed of 50 km/h is considered for the vehicles. The transmission range of a single hop is around 1 km. Hence, the uplink mode, a vehicle that is more than a kilometer away from BS sends its data to another vehicle which in-turn retransmits it either to another vehicle or to the nearest BS/server. Given the transmission range (1 km) and the distance between the two servers (5 km), the maximum number of hops between the vehicle and the infrastructure is three hops.

## 3.2 Adaptive Multimedia Streaming

In order to support high quality multimedia streaming in wireless networks, a client-server feedback-based approach is employed. In particular the principle of QOAS, as state-of-the-art adaptive multimedia streaming scheme, is employed [7]. It involves the client monitoring quality of service transmission-related parameters, estimating user perceived quality [12] and sending feedback to the server which adjusts video transmission rate. This is based on the fact that random losses have a greater impact on the perceived quality than a controlled reduction in quality. The primary aim of integrating quality-oriented multimedia delivery adaptivity with the IEEE 802.11p standard is to maintain high end-user perceived quality in two difficult conditions: first, when the vehicles are moving at high speed, and second, when there is a quick handover between different relay nodes and sender.

# 4. ROUTING PROTOCOLS

There are different routing protocols available in the literature [13]. However, not all protocols offer the best performance under different conditions. Hence, in order to assess the multihop hybrid vehicular wireless network impact on the performance of multimedia delivery, different modes and good routing protocols are considered in this paper.

**1. Infrastructure Mode**: The infrastructure mode (no ad-hoc or NOAH) is a wireless communication mode which requires the presence of a BS and all data exchanged by nodes travels through BS. This mode can effectively be used in high-speed vehicular wireless networks, if the aim is to send/receive data to/from vehicles via the base station. In case of multihop networks though, NOAH cannot be used.

**2. Destination Sequence Distance Vector (DSDV):** The DSDV routing protocol, originally proposed for mobile ad-hoc networks (MANET), is based on the Distributed Bellman-Ford algorithm. The reason for considering DSDV for vehicular networks is that each route is tagged with a sequence number indicating how old the route is. Each node manages its own sequence number by assigning it a higher value at regular intervals. When a route update with a higher sequence number is received by a node, the old route is replaced with the new one. Stale routes are deleted. The main drawback of DSDV is that it requires regular updates of the routing tables, which use up battery power and importantly, a small amount of bandwidth even when the network is idle. In addition, whenever the topology of the network changes, a new sequence number is necessary before the network re-converges, making DSDV not suitable for highly dynamic networks.

**3. Ad-hoc On Demand Distance Vector (AODV):** The AODV routing algorithm is a reactive routing protocol. It is based on an on-demand algorithm capable of both unicast and multicast transmissions. There is no routing overhead when there is no data packet to be sent. The reason for its selection for vehicular networks is that, the protocol maintains the routes only while needed by the sources. When a vehicle wants to send a packet, the route discovery process broadcasts a Route Request message to discover the destination node. Route Request messages are flooded up to a predetermined hop count: the maximum time-to-live value. If the destination receives Route Request, it replies with a Route Reply. The number of hops of the route discovery process is determined by the predetermined maximum TTL value. The tradeoff between the scope of route discovery and overhead of flooding routing messages is critical for the AODV performance. AODV+ protocol is an upgraded form of AODV that is used in scenarios when multihop *ad-hoc* relay and the backhaul connection coexist.

# 5. SIMULATION SETUP

In order to analyze the effect wireless delivery has on multimedia traffic, a vehicular wireless network with 100 vehicles (nodes) is considered in the simulation model. During the initial simulation, the speed of the vehicles is assumed to be constant at 40 km/h. Depending on the mode of communication, the vehicles communicate with the infrastructure directly or over multiple hops.

In the simulations, the number of hops is minimized by selecting the farthest car within the source transmission range as the relay vehicle which forwards the message. To this aim, each car that has received the message emits a jamming signal with a duration that is directly proportional to the distance between the considered car and the message source. The car with the longest jamming signal is the farthest car from the source and becomes the next forwarder.

The network is simulated using Network Simulator version 2.33 (NS2). The length of all NS-2 simulations is 300 s. Since NS2 does not accurately simulate the high-speed vehicular networks, the Marco-Furie patch for IEEE 802.11 has been deployed, which has an in-built Nakagami propagation model. In order to simulate the adaptive transmission of multimedia packets, a quality-oriented adaptive multimedia delivery scheme was modeled in NS2 to deploy the additive increase-multiplicative decrease principle. All the vehicles in the network request multimedia traffic. In order to support multimedia traffic, the video streams are modeled using Transform Expand Sample (TES) and then encoded using MPEG4. Multimedia data adaptation is performed between five different data rates: 0.75 Mbps (high), 0.6 Mbps (upper medium), 0.45 Mbps (medium), 0.3 Mbps (lower medium) and 0.15 Mbps (low data rate). The video delivery begins with the lowest available data rate. If no drop of packets happens during transmission, the data rate increases in steps towards the maximum rate. However, if loss occurs, the data rate decreases.

## 6. RESULTS

### 6.1 Throughput Analysis

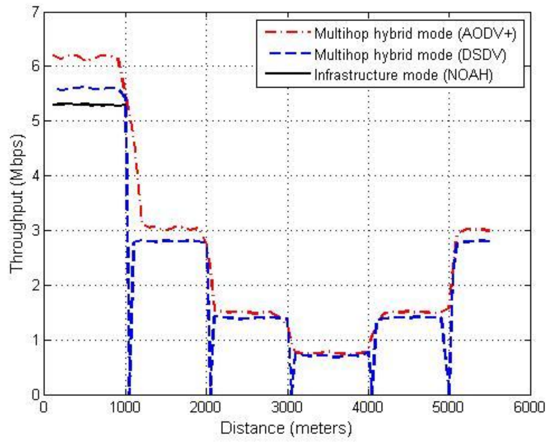


**Figure 4 Throughput comparison of three different vehicular networks scenario**

Fig. 4 shows the throughput results of the multihop hybrid vehicular wireless network communication mechanism when all the vehicles are moving at a constant speed of 40 km/h. Separate results are presented when AODV+ and DSDV routing protocols are employed. It can be observed that for both AODV+ and DSDV, with the addition of one relay after every 1000 m, the throughput decreases by a factor of two. This is due to the fact that with the addition of a relay, it takes twice the normal time to transport a packet to the final destination. At the same time, with the addition of a third relay (at 3000m), the throughout decreases by a factor of three. This is because there are many packets stored in each router queue. These packets will be transmitted every time the channel is accessed and found to be idle. Hence, this particular amount of throughput is added to the overall packet transmission, decreasing the throughput per vehicle.

It can also be observed that, the average throughput of the network is higher when AODV+ protocol is used than when DSDV is employed. This is because for the DSDV protocol, every time the vehicle moves from one relay to another, there is a finite connectivity drop corresponding to a finite distance (usually 50 m) wherein there is no connection between the vehicle and the server. In the AODV+, this effect does not occur. \\%This can be seen in Fig. A wherein the throughput drops to zero for DSDV at every 1000m. This is due to the fact that DSDV is a proactive protocol. Hence, in case of a change in the dynamics, there is a break in the continuity for a small period.

Significantly, it can be observed from Fig. 4 that up to 1000 m, the throughput obtained when the multihop hybrid mechanism is used with both DSDV and AODV+ is significantly superior to the pure infrastructure mode. This is a significant result, indicating that irrespective of the routing protocol, the usage of the multihop hybrid vehicular wireless communication scheme is beneficial in terms of throughput.

### 6.2 Loss and Delay Analysis

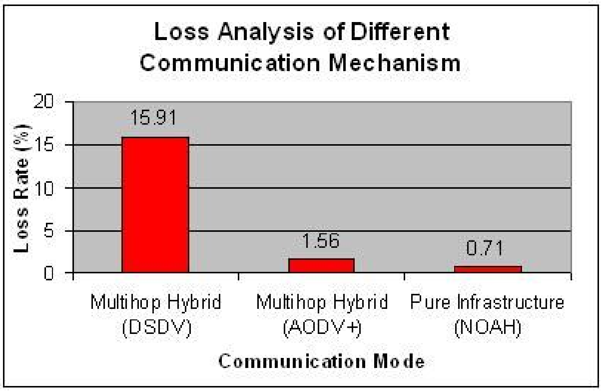


**Figure 5 Packet loss for multihop-hybrid and infrastructure-based vehicular networks**

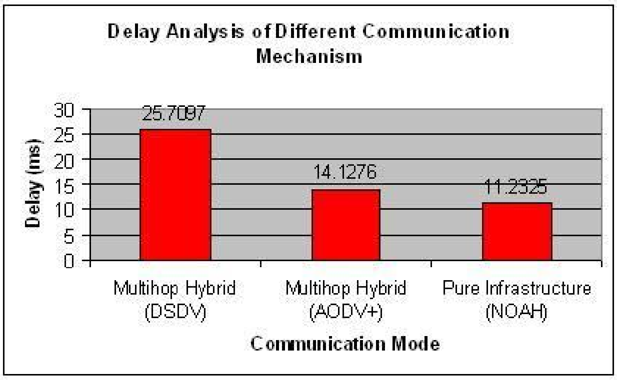


**Figure 6 End-to-end delay for multihop-hybrid and infrastructure-based vehicular networks**

Fig. 5 and Fig. 6 show loss and delay results when the multihop hybrid mechanism and the infrastructure mode are employed when all the vehicles are moving at a constant speed of 40 km/h. In order to have a fair comparison, 60,000 packets were transmitted between the server and the moving vehicle in both cases. In case of the multihop hybrid mode, a total of 9550 packets were dropped (by the nodes communicating with the server in up to 3 hops) in case of DSDV resulting in a loss of 15.91\%; whereas in case of AODV+ only 940 packets were dropped over the same period, resulting in a loss of 1.56\%. This can be explained by the fact that DSDV being a reactive protocol, loses more packets due to the long latency between rerouting of traffic through the relays. In the equivalent infrastructure mode, there was a drop of 430 packets, resulting in a loss of 0.71\%. %It can be observed from Fig. 5 that even with using the multihop hybrid mode, the packet loss is in the same range as that of the infrastructure mode.

In a similar result, Fig. 6 shows that the overall delay in case of multihop hybrid networks when DSDV is employed is 25.71 ms, whereas that in case of AODV+ is 14.13 ms, i.e., 1.82 times less than that of DSDV. The delay in case of the equivalent single-hop infrastructure-based network is 11.23 ms; i.e. less than DSDV-based multihop hybrid network with more than a factor of two, but less than AODV+ by 20\%. These results show that by using efficient routing protocols like AODV+, the delay and the loss of the multihop hybrid vehicular network can be significantly reduced, while having an overall throughput higher than the infrastructure-based solution.

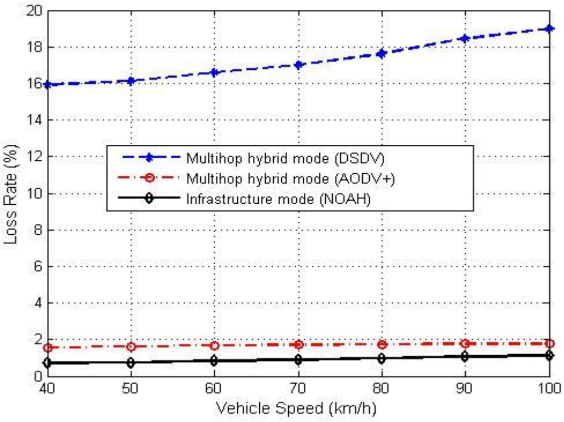


**Figure 7 Loss analysis of different communication mechanism under different speed**

In order to compare the effects of mobility, the speed of all the vehicles in the network was increased from 40 km/h to 100 km/h and the loss rate was observed. Fig. 7 shows the loss rate for different mechanisms under different speeds. A significant point to be noted is that for the DSDV protocol, the loss rate of the multihop hybrid mechanism increases exponentially with an increase in the speed of the vehicles. However, in case of AODV+, the loss remains almost constant. This is a significant result and it shows the feasibility of using AODV+ for next generation multihop hybrid mechanism for real-time multimedia based applications in vehicular wireless networks.

## 7. CONCLUSION

This paper investigates the benefits of using a multihop hybrid solution for high quality multimedia streaming in IEEE 802.11p-based vehicular wireless networks. The average throughput when using the multihop hybrid mechanism with both AODV+ and DSDV routing protocols is significantly superior to that when an infrastructure-based single-hop vehicular wireless communication was considered. In addition, the average loss rate and delay of the multihop hybrid solution when AODV+ protocol is used was superior to that obtained with the DSDV protocol, but in the same range with that when the infrastructure-based single-hop approach was employed. Importantly, with the increase in the speed of the vehicles, the loss rate of AODV+ based multihop hybrid solution remains almost constant unlike other methods where the loss rate increases with the increase in the speed of the vehicles. This very significant result paves the way for further research in proposing new solutions and redesigning existing routing protocols such as AODV+ to consider multihop hybrid communications. This would enable high quality multimedia delivery in high speed vehicular wireless networks without any additional investment in deploying new infrastructure.

## 8. ACKNOWLEDGEMENTS


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