# Generalized Comparative Study between Vehicular AdHoc and Mobile WiMAX Networks

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**Abstract:** The paper compares two of the most based wireless technologies: mobile WiMAX based on IEEE 802.16e standard and the 5.9 GHz technology based on the IEEE 802.11p standard. The paper investigates, through simulation, the potential and limitations of both technologies as a communication media for Vehicular AdHoc Networks VANETs. The performance of the two systems is evaluated for different vehicle speeds behaviors, traffic data rates, and network deployments.

**Keywords:** ITS, ITT, IEEE 802.11p, 5.9 GHz technology, IEEE 802.16e, mobile WiMAX, V2I, simulation, VANETs.

## 1. Introduction

Thousands of injuries and hundreds of fatalities are reported daily worldwide due to traffic accidents [1]. In an attempt to reduce these terrifying numbers, government agencies and the private sector are responding by introducing Intelligent Transportation Technologies ITT to the existing transportation system. Vehicular AdHoc Networks VANETs and WiMAX are emerging as the preferred network design for ITS technologies. In VANETS, vehicles employ wireless communication to form AdHoc networks which are envisioned to accommodate the new generation of cooperative road safety applications. A major challenge in such an application is the design of an efficient broadcast scheme which will facilitate the fast and reliable dissemination of the early warning message to the approaching vehicles. A straightforward solution is flooding [2], IEEE 802.11p based technology has been developed for the specific context of vehicular networks.

In particular, it is expected to be particularly suitable for medium range and delay-sensitive road safety applications. Mobile WiMAX; on the other hand, offers a promising alternative because of its potential to offer medium to long range connectivity, full support of mobility, and high data rates with moderate delay. Our main work is to show the possibility of having different communication technologies for vehicular communication yields to the necessity to understand which is the most suitable in every specific context.

Indeed, since in the near future vehicles will be equipped with different access technologies, knowing the capabilities message delivery delays caused by increased contention, in areas with high vehicle densities. The paper refers to the proposed scheme as Speed Adaptive Probabilistic Flooding SAPF.

## 2. Vehicle AdHoc Network VS. WIMAX

### 2.1 Vehicle AdHoc 802.11e standard

IEEE 802.11p is an approved amendment to the IEEE 802.11 standard to add Wireless Access in Vehicular Environments WAVE. It defines enhancements to 802.11 required to support Intelligent Transportation Systems ITS applications. This includes data exchange between high-speed vehicles and between the vehicles and the roadside infrastructure in the licensed ITS band of 5.9 GHz (5.85-5.925 GHz). IEEE 1609 is a higher layer standard on which IEEE 802.11p is based [3]. 802.11p will be used as the ground work for Dedicated Short Range Communications DSRC, a U.S. Department of Transportation project based on the International Standard Organization ISO, Communications Air-interface, Long and Medium range CALM. Architecture standard looking at vehicle-based communication networks, particularly for applications such as toll collection, vehicle safety services, and commerce transactions via cars. The ultimate vision is a nationwide network that enables communications between vehicles and roadside access points or other vehicles [4]. From that perspective, many phases of the basic 802.11 communication protocol at MAC layer have been eliminated or shortened. Indeed, unlike 802.11, 802.11p allows stations to communicate in Offset Codebook Mode OCB mode [5] i.e. outside the context of a Basic Service Set BSS, thus avoiding the latency caused by the association phase. Moreover, there is no need to scan the channel since the OCB communication occurs in a frequency band dedicated to ITS use. Also, when exchanging frames in OCB mode, the MAC layer authentication services are not used. Yet, it is still possible to have secured communications provided by applications outside the MAC layer. At the physical layer, the amendment concerns mainly the spectrum allocation.

Vehicular communications are performed in the 5 GHz range, where one channel is dedicated to control and the others to ITS services. In order to reduce the effects of Doppler spread, the use of 10 MHz channels has been adopted instead of the usual 20 MHz used by 802.11a. Consequently, all Orthogonal frequency-division multiplexing OFDM timing parameters are doubled e.g. the guard interval, the OFDM symbol duration, etc. and the data rates are halved (vary from 3 to 27 Mbps instead of 6 to 54 Mbps).

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TABLE I 802.11p VS 802.16e

| | 802.11p | 802.16e |
|---|---|---|
| Frequency | 5.470 – 5.925 GHz | 10-66 GHz |
| Channel BW | 10 MHz | Depends on PHY profile (3.5,5,8,10 MHz etc) |
| QoS support | 4 classes of QoS | 5 classes of QoS |
| Security Support | No Authentication prior to data exchange instead each packet is used for authentication by certificate based digital signature | Data encapsulation protocol with a set of cryptographic suites and PKM protocol to synchronize keying data between BS and MS |
| Media Access Technique | CSMA/CA No scanning .No association | TDMA,FDD and TDD |
| Usage | Network dedicated to vehicles ITS Stations | Could be used by residences, companies , personal devices, … etc. |
| Other support features | | Support MIMO |

## 2.2 WIMAX 802.16e Standard

The IEEE 802.16 - 2004 standard defines the air interface for fixed Broadband Wireless Access BWA systems in the frequency ranges10-66 GHz – where Line Of Sight LOS is required –and sub range 11 GHz- where non-LOS NLOS is possible. The IEEE 802.16e - 2005 amendment updates and expands IEEE 802.16 Standard -2004 to support subscriber stations moving at vehicular speeds and thereby specifies a system for combined fixed and mobile broadband wireless access.

## 3. System Design and Settings

For our simulations, the paper has used the network simulator OPNET Modeler 14.5 which is the commercialized version of OPNET Technologies Inc. The Advanced Wireless Library proposed by OPNET Modeler14.5 integrates a simulation model for mobile WiMAX with the support of several features such as Physical Orthogonal Frequency-Division Multiple Access PHY OFDMA, Point-to-multipoint communication PMP and Time Division Duplex TDD modes, AMC capability, QoS scheduling services, etc. Nevertheless, the simulator does not include an 802.11p model. Therefore, the paper have first implemented the necessary changes to existing 802.11a PHY and 802.11a MAC models in order to adapt them to 802.11p specifications. Note that the paper has adapted the power of the transmitter and the minimum sensitivity of the receiver to what has been specified in [6-17].

The other simulator used is VISSIM that is microscopic multi-modal traffic flow simulation software. It is developed by PTV Planung Transport Verkehr AG in Karlsruhe, Germany. The name is derived from "Verkehr In Städten - SIMulationsmodell" (German for "Traffic in cities - simulation model"). VISSIM was started in 1992 and is today a global market leader.The chosen test site is a five lane highway which spans a distance of 2Km. The paper conducted a number of experiments to reflect different scenarios. Our objective has been to examine the behavior of the performance metrics of Total delay, Throughput, Media Access Delay and Load; as the paper change the rebroadcast probability, the vehicle density and the velocity pattern. To generate scenarios with different vehicle densities the paper considered different rate of vehicles entering the chosen test site. The paper considered the following penetration rates: 10 vehicles, 25 vehicles, 45 vehicles and 56 vehicles. The duration of each experiment is 100 seconds. All values obtained are averages over 10 simulation experiments. The chosen site distance is short in order to eliminate the need of rebroadcasting of the emergency message from each node; that to avoid the rebroadcast flooding for 802.11p Adhoc system.

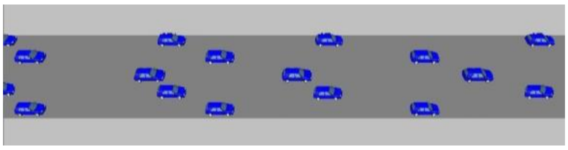

**Figure 1** Snapshot of vehicles velocity variations

The network is confined within a 500m x 2 km area, where each vehicle has a constant transmission range of 2.2 km. The latter is ensured by setting the Transmission Power equal to 100 mW. Each vehicle uses 802.11a MAC layer protocol and operates in AdHoc mode. The vehicles are configured to operate in Random mode with no ACK/CTS/RTS mechanisms. The TTL value is set to 0.5 sec.

Our study is divided in three parts. During the first part the paper compare the connectivity of the two infrastructure technologies in order to determine the Throughput, Load and Delay. In the second part, the paper establish the VANET AdHoc network on a highway segment varying the speed of the vehicle with normal speed pattern of 19.45 as mean and 8.33 as variance. After analyzing the performance of WiMAX, the performance of VANET networks is investigated by replacing the single BS with the number of RSUs necessary to cover the same segment and removing the RSUs at AdHoc system with applying parameters in table II. Finally, the third part, Impact of changing the vehicles traffic with normal velocity on the performance of VANET 802.11p.

TABLE II: Simulation Parameter

| | 802.16e | 802.11p infrastructure | 802.11p AdHoc |
|---|---|---|---|
| Frequency | 3.5 GHz | 5.9 GHz | 5.9 GHz |
| BS Tx Power | 100 mW | 100 mW | ------ |
| BS Antenna gain | 15dBi | 3dBi | ---- |
| Data Rate | --- | 12 Mbps | 11 Mbps |

## 4. Results and Discussions

In this section; the paper discusses the procedures of the simulation and the obtained results regarding the three perspectives of the comparison. All the simulation experiments were conducted using an integrated platform


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combining two simulators, VISSIM, a traffic simulator, and OPNET Modeler, a network simulator. The following scenarios shows the procedures followed.

### 4.1 *Scenario I:* Impact of changing the speed and velocity on the performance of WIMAX and WLAN Infrastructure

This scenario shows that changing of speed velocity has different effects on the Backoff, Delay and throughput Fig.2. The varying of speed has a slightly effect on Backoff of the WLAN which is varying between 37 and 43 slots. That considered a slight effect in comparison with the Backoff of the VANET described in the next scenario.

delay and throughput are not affected by the changing in velocity as the coverage area and the power of signal are sufficient to prevent the effecting of the varying allowing the data to reach each Mobile Station MS, however the results shows that the performance of the WIMAX has a better performance than infrastructure WLAN 802.11p in both Delay and throughput. Figure 2

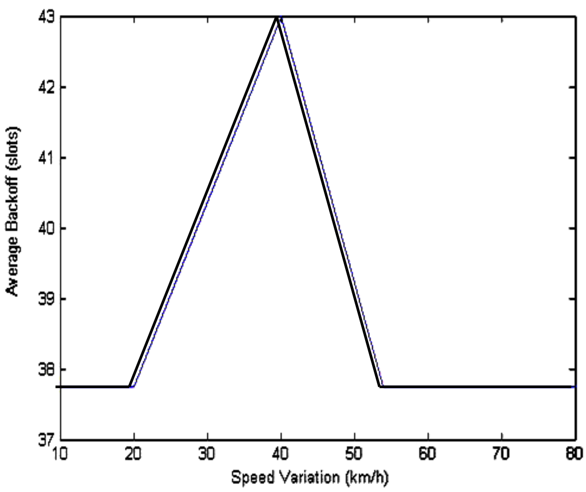


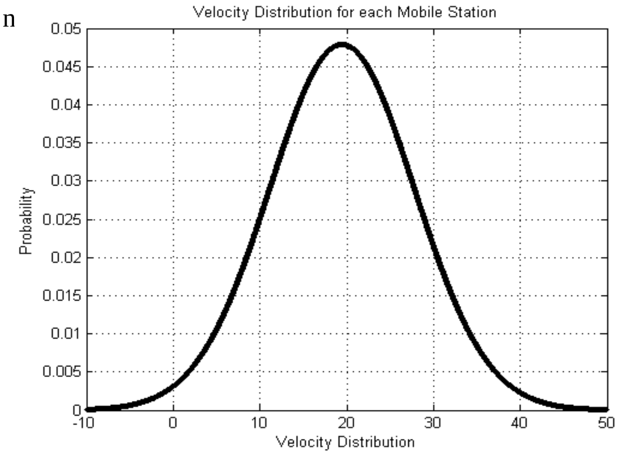

**Figure 2** Backoff Variations for WLAN 802.11p

### 4.2 *Scenario II:* Impact of changing the speed and velocity on the performance of VANET 802.11p

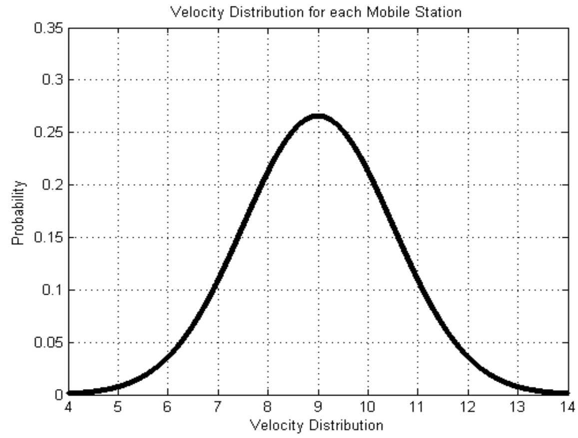
In this scenario, the simulation changes the speed pattern and the velocity changes in order to describe the variation of speed on Delay, Throughput, Backoff and Media Access Delay MAD in order to simulate the normal variation of traffic in test site.

The topology of the simulation model used in our study is based on a section of the San-Stefano Sea Road in Alexandria. The chosen test site is a five lane road with 2000 m long. The objective of this scenario is to describe the performance due to the variation of the speed pattern and velocity as described in Figure.3 a) and b) the velocity pattern is a normal distribution with velocity variation between 20 to 100 km/h. the velocity changes between 9±1.5 m/s, 19.45±8.3 m/s, constant speed of 11 and 27 m/s. These changes allow showing the effect of variations on the performance.

Using the predefined velocity on VANET (802.11p) with 10 vehicles traffic in the simulation period of 100 sec, the performance study shows that in general speed increase affects the delay that increase due to the increase of the speed for normal velocity which is the opposite with the constant speed variation. The maximum increase in total delay for normal distribution in is due to the high traffic rate after 72 sec of simulation Figure 4. Throughput which is increased by the decrease of the speed. maximized with the n




a) Velocity variations with mean 19 and variance 8.3




b) Velocity variations with mean 9 and variance 1.5

**Figure 3** Velocity Normal Variations

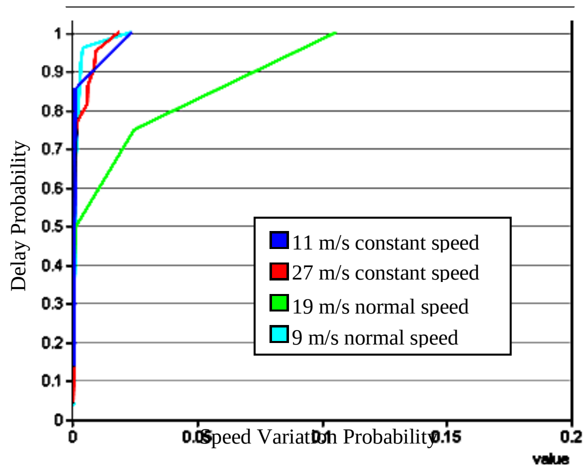



**Figure 4** Delay due to Velocity variations

## 5. CONCLUSION

The current research is a generalized comparative study between Vehicular AdHoc and Mobile WiMAX Networks. The simulation results reveal on one side the great competitiveness of mobile WiMAX technology in the context of V2I communications. In particular, this technology, offers, not only large radio coverage and high data rates, but also reasonable and even very low delays. On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the other side, the 802.11p technology is better suited to low traffic loads, where it offers very short latencies even at high vehicle speed. The obtained results can be considered as a first step for the definition of an efficient common radio resource management module for vehicular networks. Results could further be used as pre-defined criteria for radio access technology selection for ITS applications. Future work will focus on extending this study to the urban environment. A broad analysis of the performance of the two technologies will be used to develop new algorithms for smart selection of the optimal radio access technology based on the applications requirements, the channel load, and the user's preferences.

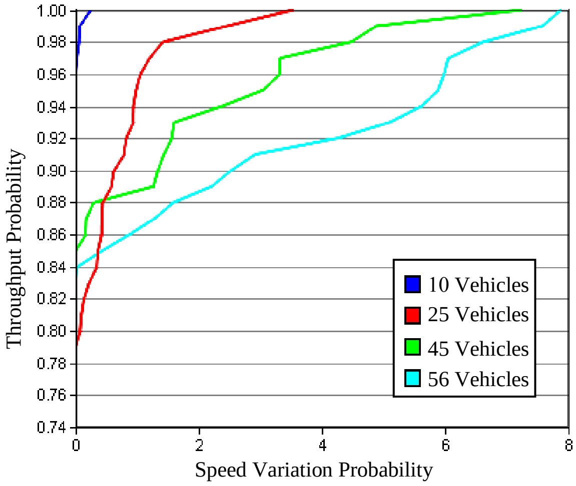


**Figure 5** Throughput due to Vehicles variations

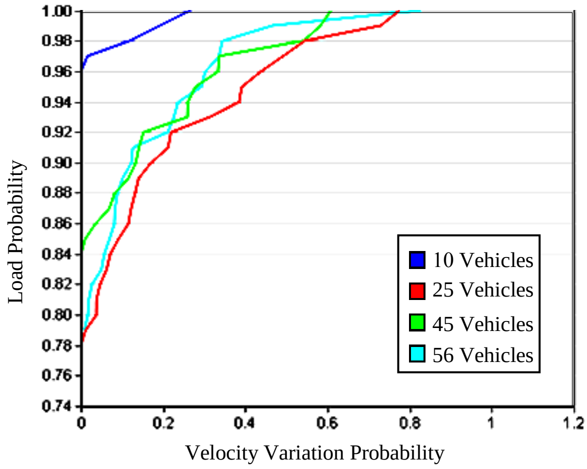


**Figure 6** Load Probabilities Due to Velocity

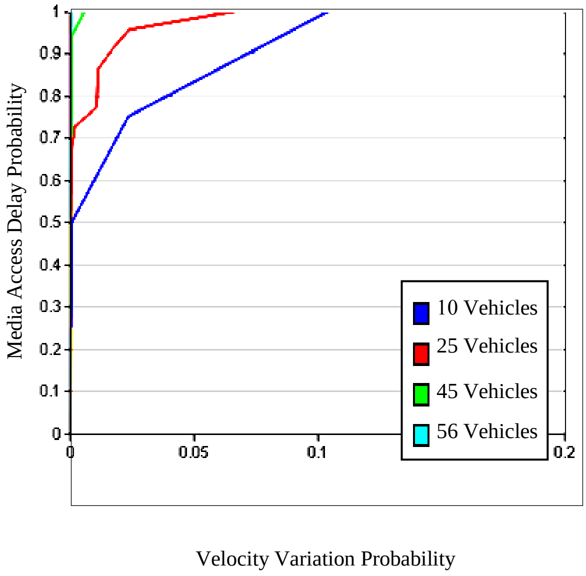


**Figure 7** MAD probability due to velocity

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