Performance Evaluation of 802.11p and WiMAX over Resource Data and Penetration Rate Changes

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Abstract: 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 studied and compared. The potential and limitations of both technologies as a communication media for Vehicle to infrastructure Networks V2I are simulated. The obtained results show the performance of the two systems evaluated for different Vehicle Penetration Rate VPR, Source Data Rate SDR, and network deployments.

Keywords: ITS, ITT, IEEE 802.11p, 5.9 GHz technology, IEEE 802.16e, mobile WiMAX, V2I, simulation, VPR, I2V.

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. 802.11p networks and WiMAX are emerging as the preferred network design for ITS technologies. In Vehicle to infrastructure Networks V2I, vehicles employ wireless communication to form infrastructure. A major challenge in such an application is the design of an efficient broadcast scheme which will facilitate the fast and reliable dissemination data to the approaching vehicles; IEEE 802.11p based technology has been developed for the specific context of vehicular networks.

In particular, it is expected to be low latency communication with vehicles, gateway to the internet and extend connectivity and distributing time-critical data. 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. Data dissemination among vehicles depends on the type of assumed network architecture.

Received 6/16, Reviewed 6/30

2. Vehicle infrastructure Network

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). A higher layer standard on which IEEE 802.11p is based is IEEE 1609 [3]. IEEE 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 this 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]. For example: 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.

Push-based and Pull-based approaches are considered for V2I (or I2V) data dissemination. In the push-based approach, the roadside unit broadcast the data to all vehicles which are in its range. The disadvantage is that everybody may not be interested to the same data. It is suitable for applications supporting local and public-interest data such as data related to unexpected events or accidents causing congestion and safety hazards. It also generates low contentions and collisions during packet propagation. In Pull-based approach vehicles are enabled to query information about specific targets and responses are routed toward them. It is useful for acquiring individual specific data. It generates a lot of cross traffics including contentions and collisions during packet propagation [6]. In the push-based approach, data is disseminated to anyone and it is suitable for specific data which is in the interest of anyone. In the pull-based approach, the network entities are able to query the required information and this approach is suitable for unspecific data propagation. In pull based approach generated cross traffic can cause interference and collisions among propagating data packets. It is noted that periodically pouring data on the road is necessary since vehicles receiving the data may move away quickly, and vehicles coming later still need the data

2.1 WIMAX 802.16e Standard

The IEEE 802.16 standard is a wireless broadband access standard that includes two main specifications: IEEE 802.16-2004 [7] for fixed wireless access scenarios and IEEE 802.16e [8], which include mobility support. One of the novelties introduced by the standard is the native support for Quality of Service QoS. To enable such support, the standard specifies different scheduling services that are optimized for different kinds of applications. The IEEE 802.16 QoS model includes service flows that characterize the traffic transported in different connections. In fact a significant difference of IEEE 802.16 from other IEEE 802 standards is that connections between the Subscriber Station SS, or Mobile Station MS in mobile environments, and the Base Station BS are identified by connection identifiers and not by MAC addresses. WiMAX is based on the IEEE 802.16 standards and on the ETSI HiperMAN [9] standards. WiMAX complements the specification of IEEE 802.16 standards by defining a complete network architecture that includes the access and connectivity segments. The access service network includes the MS, the BS and the gateway responsible for the network access. The connectivity service network includes functionalities related with IP services, such as Authentication, Accounting, and Authorization AAA and IP Multimedia Services IMS, among others. The WiMAX network reference model [10, 11] also takes into account support for mobility.

3. System Design and Settings

For our simulations, the researchers use 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 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 [12-20].

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 is to examine the behavior of the performance metrics of Total delay, Throughput, Media Access Delay and Load. The researcher changes the velocity, the vehicle penetration rate VPR and Source Data Rate SDR. To generate scenarios with different vehicle densities the paper considered different rate of vehicles entering the chosen test site. The paper considered the following VPR rates: 926 Vehicles/h, 1543 Vehicles/h, 2057 Vehicles/h, 4114 Vehicles/h and 5142 Vehicles/h. The duration of each experiment is 35 seconds. All values obtained are averaged over 10 simulation experiments. The chosen site distance is 500m which is considered short compared with coverage area 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.

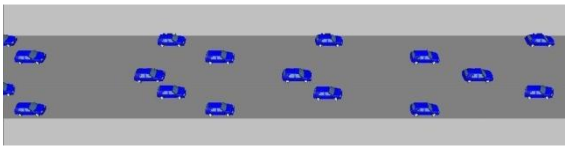

Figure 1 Snapshot illustrate Vehicles Penetration Rate

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 into two scenarios. During these scenarios the paper compares the performance of the two infrastructure technologies in order to determine backoff, Throughput, and Delay with different velocities, VPR and SDR. After analyzing the performance of WiMAX, the performance of 802.11p 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 I.

TABLE I: Simulation Parameter

	802.16e	802.11p infrastructure
Frequency	3.5 GHz	5.9 GHz
BS Tx Power	100 mW	100 mW
BS Antenna gain	15dBi	3dBi

4. Results and Discussions

Simulations produced a numerous results that will be discussed and extract a useful conclusions regarding the performance of the networks. 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 combining two simulators, VISSIM, a traffic simulator, and OPNET Modeler, a network simulator. The following scenarios will show the procedures taken in order to investigate the changes into the performance.

4.1 802.11p infrastructure network

In this part paper discusses different scenarios in order to show impact of changing velocity and data rate over the performance of the infrastructure network

***Scenario I:* Impact of velocity change over performance**

In this scenario, performance of the 802.11p is evaluated according to changes in velocity and vehicle traffic while keeping the data rate constant. The results show that value of backoff is increasing due to the increase in the velocity while increasing in the vehicle traffic passing the test site has the same effect. Figure 2.

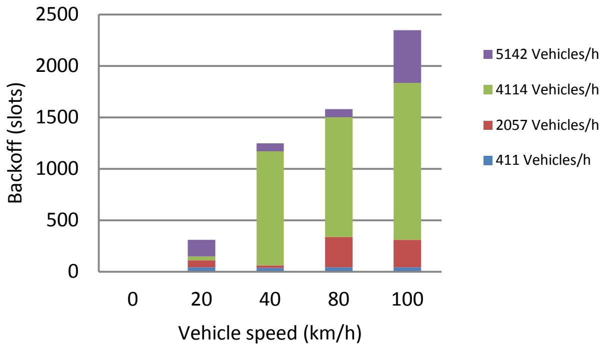

Figure 2 Impact of velocity changes over 802.11p

***Scenario II:* Impact of source data rate changes over performance**

Results of this scenario produce a complete view about the effect of varying source data rate and vehicle traffic over the performance of 802.11p infrastructure network. For low data rates (less than 100 kbps) backoff increases with the increase of the data rate. Results reveal that Vehicles Penetration Rate VPR has a considerable effect over backoff, as magnitude of backoff is affected by VPR than data rate. With high data rate (over 100 kbps): generally; increasing of the penetration rate increases the backoff value. After 1Mbps backoff tends to saturate. Figures 3 and Figure 4 illustrates low and high data rate effects.

On the other hand, changing source data rate has a different effect over throughput and delay. Increasing source data rate decreases throughput and delay respectively. Heading toward high frequency delay and throughput tends to saturate for low VPR values (less than 2075 vehicles/h) at high source data rate. Vehicles velocity is considered constant during the simulation with 80km/h speed, as shown in Figure 5 and Figure 6.

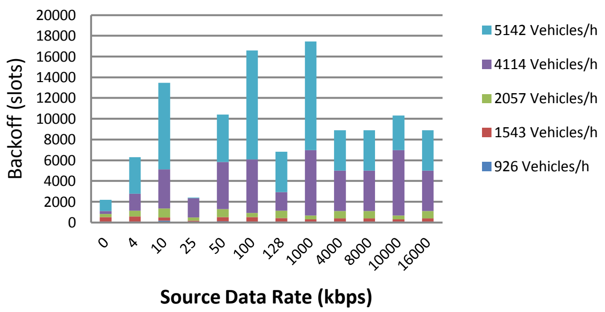

Figure 3 Impact of Low data rate over backoff

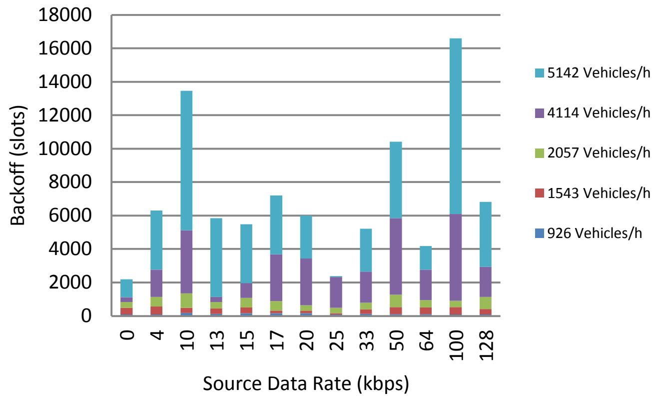

Figure 4 Impact of High data rate over backoff

Results indicate that at all penetration rates the delay exhibits a monotonically increasing pattern. This is also expected as higher contention causes collisions which delay message delivery.

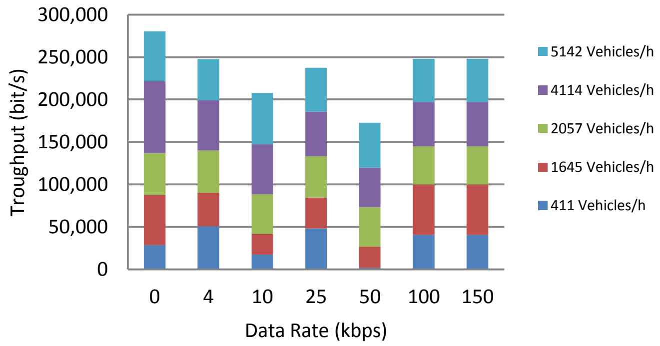

Figure 5 Varying of data rate over throughput

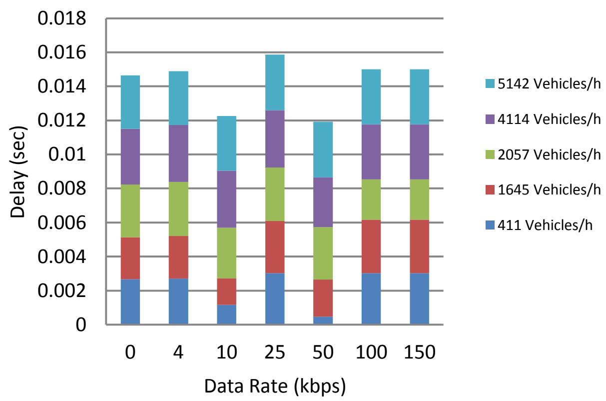

Figure 6 Varying of data rate effect over delay

Considering the effect of changing vehicles velocity, results are considered for different speed conditions at 20km/h, 40km/h and 80 km/h and average values are collected for different VPR; as shown in Figure 7. Similar behavior at all velocities is observed with the number of backoffs tends to saturate as source data rate is increased. Increasing of the source data rate has a greater effect than increasing of the vehicle speed over the backoff

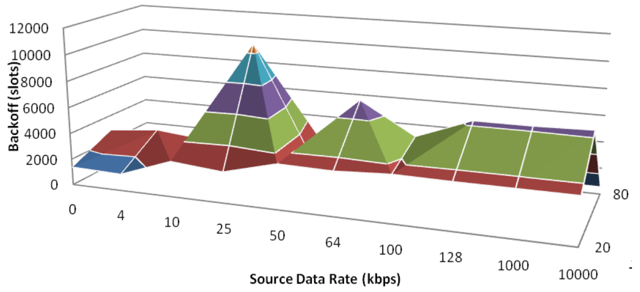

Figure 7 Average backoff against Velocity and SDR

4.2 WiMAX 802.16e infrastructure network

Changing of source data rate has insignificant effect over the WiMAX. As throughput and delay do not affected by the increase of the data rate; meanwhile, increase of the penetration rate of the vehicles has an effect over the delay. Increasing of penetration rate increases the delay till cell reach maximum capacity of the network then decrease towards saturation while increasing of the traffic, as shown into Figures 8 and 9

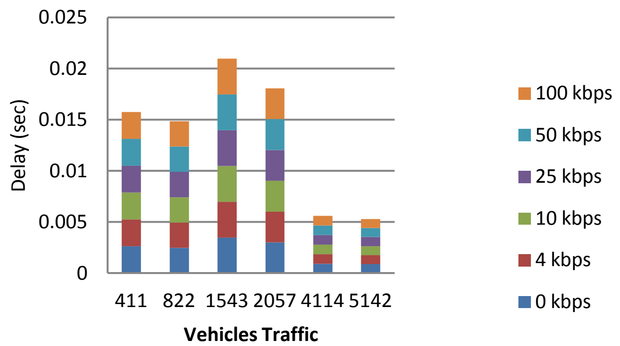

Figure 8 Vehicle penetration rate effect over delay

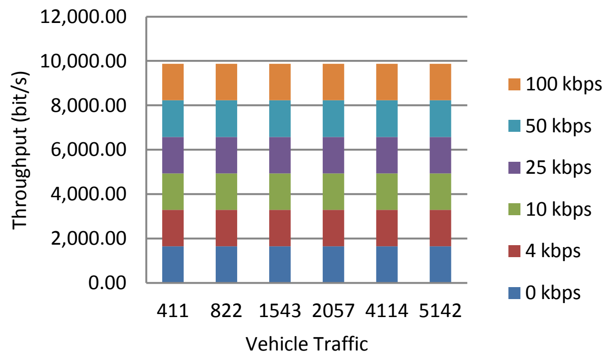

Figure 9 Increasing of VPR over throughput

Generally, increasing of Vehicles Penetration Rate VPR increases delay for the 802.11p infrastructure network, while decreasing the delay for WiMAX. At the same time throughput increases for 802.11p infrastructure, while remains constant for WiMAX. For increasing of the data rate, results show that 802.11p has a better performance than WiMAX for throughput; meanwhile 802.11p has a higher delay than WiMAX.

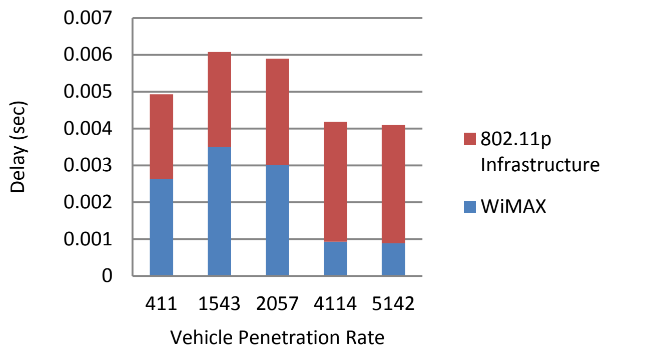

Figure 10 Average delay with vehicle penetration rate

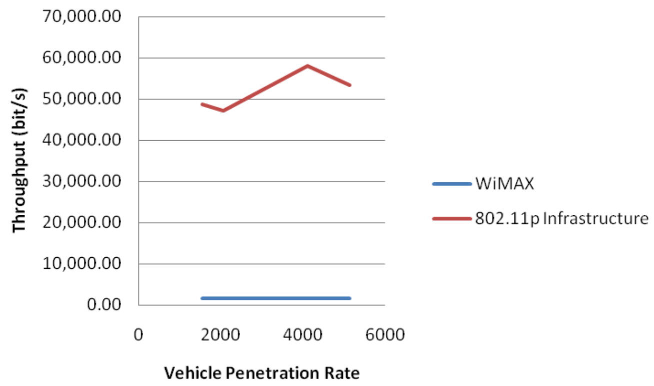

Figure 11 Average throughput vehicle penetration rate

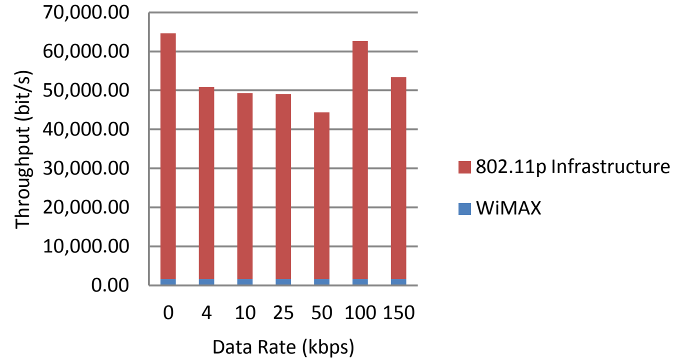

Figure 12 Average throughput with source data rate

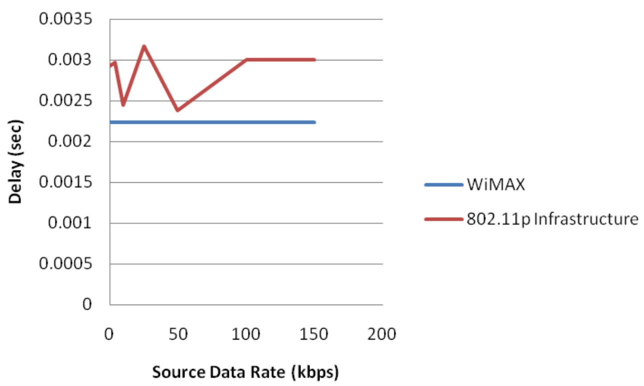

Figure 13 Average delay with source data rate

5. Conclusion

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 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.

Finally, IEEE 802.11p shows a better performance over the varying of source data rate, velocity and VPR. Results indicate that with the higher performance over WiMAX; 802.11p has a higher delay ratio due to collisions related to VPR and velocity variations.

Clearly, there are still lots of empirical work lying ahead. Moreover, researchers plan to validate and contrast the results in the lab with those obtained using practical results.

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