Performance Analysis of Hybrid WiMAX/DSRC Scenarios for Vehicular Communication Environment

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***Abstract*—Internet becomes a vital and important service being integrated in the current scenarios of competing technologies, therefore there is a need for higher speed broadband access. Emergence and evolutions of technologies from the first generation to 4G LTE then to the promising 5G and WiMAX . For achieving high data rates and services to multiple users, WiMAX is one of the competing technology, which was introduced by the Institute of Electrical and Electronic Engineers (IEEE) designated for fixed wireless and mobile wireless applications and Dedicated Short Range Communication (DSRC) is another technology which is a trend in the vehicular network in the current situations employed in the Intelligent Transportation System in the United States which supports high speed data rates. In this paper, the authors considered a hybrid scenario and compared the communication link taken place in the DSRC-to-DSRC traditional system with the hybrid DSRC-WiMAX system communication link namely DSRC-to-Fixed WiMAX and Mobile WiMAX-to-Fixed WiMAX, with evaluation of performance by considering certain parameters simulated in MATLAB.**

I. Introduction

Wireless Communications is growing leaps and bounds in the competing area of emerging technologies. In order to overcome the demerits of a stand-alone technology, a concept of consolidation of two technologies comes into the picture. Worldwide Interoperability of Microwave Access (WiMAX) intends to blanket a wide area thereby, support efficiently a large number of users [1].WiMAX is of two flavours, IEEE 802.16d 2004[6] which is Fixed WiMAX based on Orthogonal Frequency Division Multiplexing (OFDM) with 256 FFT sizes. The current revision of WiMAX is the IEEE 802.16e -2009 [9] i.e., Mobile WiMAX, which operates at frequencies of 2 to 11 GHz for Non- Line of sight applications and based on Orthogonal Frequency Division Multiple Access and varying FFT sizes of 128,512,1024 and 2048. The IEEE 802.11p - 2010 [10] which is Dedicated Short Range Communication (DSRC) on the other hand is used for point to point communication or between vehicles to vehicles within the range of 1Km (1000M) distance and it also serves high-speed broadband Internet without significant roadside infrastructure. DSRC is based on Orthogonal Frequency Division Multiplexing (OFDM) with 64 FFT size.
The authors in [3] have proposed combined physical layer OFDM approach between DSRC and WiMAX for efficient vehicular communication taking into account different modulation schemes namely, QPSK and 16 QAM modulation techniques by taking 10MHz bandwidth to converge the 64 FFT subcarrier and 256 FFT subcarrier and combine these two existing technologies (IEEE 802.11p and IEEE 802.11d)[2].

II. Existing Vehicular Scenarios

DSRC is the only standard used for Vehicle-to-Vehicle (V2V) collision avoidance systems and is a supplement to cellular wireless communications by offering very high data transfer rates in situations where latency needs to be minimized in the communication connection and in situations where small zones needs to communicate. It is also known as Wireless Access in Vehicular Environments (WAVE), with IEEE 802.11p standard. The existing DSRC applications are the Electronic Toll Collection(ETC), traveler's alert, travel time delay and measurement as well as warning information. Another technology is WiMAX, which offers wide area connectivity of vehicles and intends to broadcast or communicates a large area that serves a large number of users in addition with the capability of high-speed network. Therefore Mobile WiMAXs weakness is witnessed if there are numerous higher connections that wants to communicate [8]. By converging with other technology such as Dedicated Short-Range Communications (DSRC), DSRC can communicate and relatively reduce WiMAX connections. Mobile WiMAX can cover the range between 2Km 5 Km and Fixed WiMAX can communicate more than 10Km distance up to 50 Km.
Continuous Air interface Long and Medium range (CALM) is another technology which offers uninterrupted communications between a vehicle and the infrastructure

using a diversity of communication media, including cellular, 5 GHz, 63 GHz and infra-red links.
Presently, the European Countries are incorporating DSRC technology in Intelligent Transport Systems[11]. Intelligent infrastructures have enhanced and are used in many applications such as safety systems, crash preventions, road weather management, traffic incident management, electronic payment and pricing etc.

Mobile WiMAX is based on OFDMA and Fixed WiMAX is based on OFDM both these digital modulations are similar, but their main differences lies in their FFT sizes where the number of data carriers differs therefore, for sending of data or information from Fixed WiMAX to mobile WiMAX and vice-versa, the frame structure has been explored. The frames are composed into downlink and uplink subframes. A downlink subframe is separated from an uplink subframe by a Transmit Time Gap (TTG), and the gap between the uplink subframe and the subsequent downlink subframe is called Receive Time Gap(RTG) as shown in Figure 1 and Figure 2.

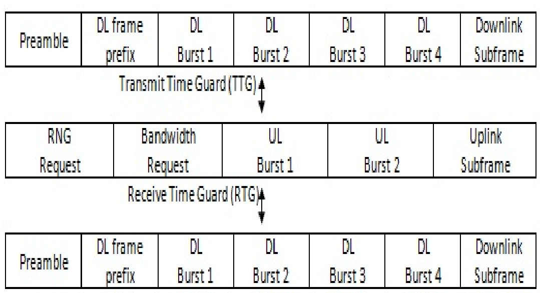

Fig. 1. Frame Structure of Fixed WiMAX (OFDM)

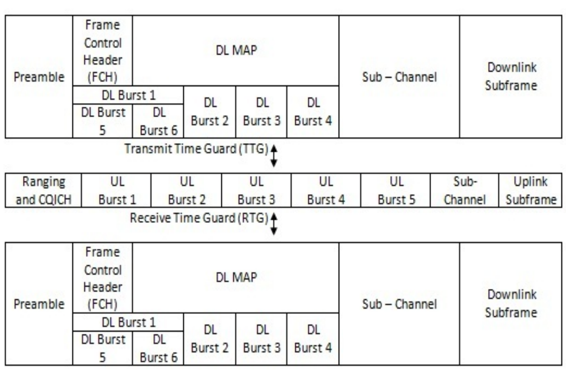

Fig. 2. Frame Structure of Mobile WiMAX(OFDMA)

III. Proposed Scenario For Hybrid Vehicular Communication Approach

The proposed Hybrid Architecture of DSRC and WiMAX communication, which satisfies the condition of Downlink and Uplink scenario between Fixed WiMAX and Mobile WiMAX is shown in Figure 3.

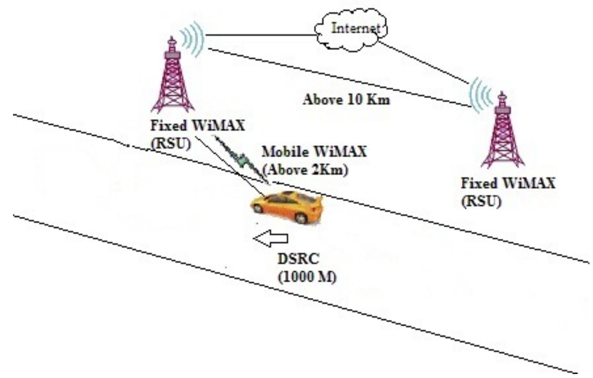

Fig. 3. DSRC to DSRC, DSRC to Fixed WiMAX Mobile WiMAX to Fixed WiMAX infrastructure

Figure 3 depicts the scenario where we have a vehicle having both DSRC and Mobile WiMAX transceivers, whereby no other vehicle is present. As the Vehicle can travel using DSRC range so it will not be able to communicate using DSRC if it is not in the proximity of Base Station, in this case since no other vehicle is present on the road only Mobile WiMAX will be used.

The following are the steps for calculating the efficiency of the WiMAX/DSRC system.
Step I: The first step is to calculate the total number of data carriers (N_{DC}) in the downlink directions and uplink directions. As in OFDM, multiple accesses are achieved by assigning a subset of subcarriers for each individual user [**?**] therefore in the downlink we define a cluster which consists of 48 subcarriers spread over one symbol.Over one symbol, this represents 48 data carriers and 4 pilot symbols.
48 + 4 pilot symbol= 52 carriers.

Using a 10MHz channel as an example,(N_{DC}) can be calculated as follows:

IV. Downlink and Uplink Scenario Between Fixed WiMAX and Mobile WiMAX

A. *Mobile WiMAX (OFDMA) to FIXED WiMAX (OFDM) Uplink- 1024 FFT to 256 FFT*

This scenario is for the uplink where nodes are sparse and in cases where nodes move out from densely populated areas. By considering 1024 FFT size of Mobile WiMAX OFDMA, subchannelization comes into the picture to establish the uplink communication between mobile WiMAX and Fixed WiMAX. The Uplink subframe can supports only Partial Usage of Sub-Channels (PUSC) and Adaptive Modulation and Coding (AMC) subchannelization. A preamble is non-existing in the uplink scenario. It is a collection of regions for bandwidth request, frequency ranging, CQICH and uplink burst.
Here, PUSC slot contans 1 subchannel * 3 symbols, and AMC has 2 Subchannel * 3 symbols.

$$N_{DC} foruplink = \frac{35sc * 8dc/tile * 6tiles/sym}{3sym/tile} \quad (1)$$

$= 560$ datacarriers/symbol

where, '*sc*' indicates subchannels, '*dc*' indicates datacarriers and '*sym*' is for symbol(s).

B. Fixed WiMAX (OFDM) to Mobile WiMAX (OFDMA) Downlink- 256 FFT to 1024 FFT

This scenario is for the downlink where the BS consists of fixed WiMAX and the Subscriber Station or Mobile WiMAX 802.16d does not support the Partial Usage of Subchannels (PUSC) or Full Usage of Subchannels (FUSC) channel allocations [5], therefore for the 10MHz channel bandwidth for transmission of the OFDM packet from 256 FFT to 1024 FFT, we consider 16 QAM Modulation scheme particularly to increase periodic ranging between 1024 FFT size to 256 FFT size. Therefore, 16QAM = FFT $*1/4$ bits per symbol; 1024 FFT$*1/4$ bits per symbol = 256 FFT.

$$N_{DC} fordownlink = \frac{16sc/sym * 48dc/clust * 2clust/sc}{2sym/clust} \quad (2)$$

$= 768$ datacarriers/symbol

where, '*clust*' indicates cluster.

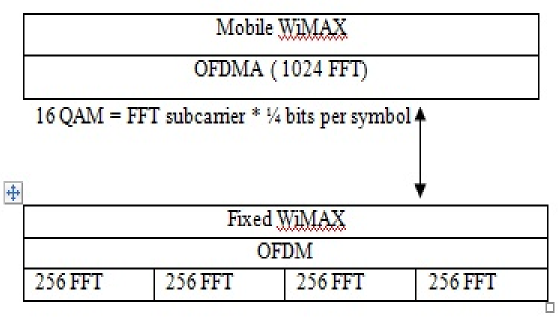

Fig. 4. Uplink and Downlink Scenario by Subchannelization

Step II: Modulation and Coding Rate:- A block is a basic unit of data transmission which consists of total 48 number of data carriers being carried over either two (for downlink) or three/four (for uplink) symbols. Physical mode (m) indicates the selected combination of the modulation and code rate. Coded channel Block size indicates the overall bits that will be encoded in a block. Uncoded channel Block size denotes the number of user data bits that will be encoded in the block and defined in the following:-

$$M_C = N_{DC} * C_R * log_2 M \quad (3)$$

Where,N_{DC} denotes the total number of data carriers per channel.
C_R denotes the code-rate.
M denotes the number of constellation points in the digital modulation scheme used.

Step III: The efficiency of the system can be defined by the ratio of the MAC data transmitted over the air interface to the total data transmitted.

$$Efficiency\, \eta = \frac{T_{net/MAC}}{T_{PHY/symbol}} \quad (4)$$

$$T_{net/MAC} = \frac{Payload}{T_{frame}} \quad (5)$$

$$T_{PHY/symbol} = \frac{N_{DC} * C_R * log_2 M}{T_{symbol}} \quad (6)$$

Where, Payload is the overall number of bits transmitted.
T_{frame} is the frame duration which is 5 ms for DSRC.
T_{symbol} is the symbol duration

Physical transmission rate is described as follows:-

$$T_{PHY/sym} = \frac{[(N_{symDL})(N_{DLDC} * C_R * log_2 M)]}{(N_{symDL} + N_{symUL})T_{sym}} \quad (7)$$

Where, N_{symDL} is the total number symbol dedicated to the downlink.
N_{symUL} is the total symbols dedicated to the uplink.
N_{DLDC} is denoted for the number of data subcarriers in the downlink.
N_{ULDC} is for the number of data subcarriers in the uplink.

Step IV: Payload calculations and the total slots available for transmission of data are carried out in detailed in this step whereby considering particular scenarios as mentioned further. Here, the scenario for transmissions in downlink direction i.e., from Fixed WiMAX(256 FFT) to DSRC(64 FFT) is considered.

$$N_{SlotsDL} = [(N_{symbolsDl} - 1) * N_{DLSC}] \quad (8)$$

Here, we remove one symbol to provide a rationale for the preamble.

And, considering just for the fourth scenario from Mobile WiMAX(512 FFT) to Fixed WiMAX (256 FFT)for the uplink, we can calculate the number of slots as follows:

$$N_{SlotsUL} = [(N_{symbolsUl}/3) * N_{ULSC}] \quad (9)$$

Where,
N_{DLSC} is the Number of channels dedicated for downlink.
N_{ULSC} is the Number of channels dedicated for uplink.

Number of total slots available for user data i.e., payload is defined as,

$$N_{payload} = N_{slots} - \sum overhead \quad (10)$$

If we are considering Mobile WiMAX then the overhead of the system takes the form of the preamble, the frame control header (FCH), the DL_MAP, the UL_MAP on the downlink and contention channels for Ranging, bandwidth request, and fast response on the uplink. One symbol is for the preamble which allow for synchronization of all the clients. Calculation of payload for downlink and uplink are as follows:-

$N_{DL\_payload} = N_{slotsDL} - N_{FCH} - N_{DLmap} - N_{ULmap} - N_{DCD} - N_{UCD}$

$N_{UL\_payload} = N_{slotsUL} - N_{Ranging} - N_{CQICH} - N_{ACK} - N_{padding}$
Where, N_{CQICH} is the channel quality information.

Step V: The length of the DL_MAP and UL_MAP messages in bytes is defined as:-

$L_{DLMAP} = N_{CRC+Header} + L_{DL\_MapHeader} + L_{PHY\_SYNC} + N_{DL\_MAP\_IE} + L_{Padding}$

DL_MAP and UL_MAP are dependent on the number of connections. Each MAP consists of a standard MAC header and terminates with a CRC of 10 bytes. Each message has the standard UL_MAP and DL_MAP with an Information Element (IE) for each connection.
$L_{DL\_MAP} = 80 + 72 + 32 + \eta_c * 60 + 4$
$= 188 + \eta_c * 60$

Similarly the length for the UL_MAP,
$L_{ULMAP} = N_{CRC+Header} + L_{UL\_MapHeader} + N_{UL\_MAP_IE} + L_{Padding}$
$L_{ULMAP} = 80 + 64 + \eta_c * 48 = 144 + \eta_c * 48$
Where, η_c is the total number of active bi-directional connections in the system.
The upload map is modulated using QPSK and the download map is modulated using 16QAM. OFDM is tolerant to multi path interference. A high peak data rate can be achieved by using higher order modulations, such as 16 QAM and 64 QAM, which improve the spectral efficiency of the system [1].

$$N_{DLMAP} = \frac{L_{DLMAP}}{QPSK} \quad (11)$$

$$N_{ULMAP} = \frac{L_{ULMAP}}{16QAM} \quad (12)$$

Genetic MAC header consists of 6 bytes, therefore 6 bytes accounts for ranging, and 6 bytes accounts for channel quality information(CQICH) requests.
If the transmission rate is high, the unused allocations will leads to lost of the bandwidth, which ultimately leads to overhead of the system,

$$N_{Padding} = \eta_c * Unused\, allocations \quad (13)$$

MAC data bit rate in the downlink directions and uplink directions are calculated as follows,
$N_{DL\_Payload} = N_{slotsDL} - [(\frac{6+188+\eta_c*60+144+\eta_c*48}{QPSK}) + N_{Padding}]$
And,

$$N_{ULPayload} = N_{slotsUL} - (6 + 6 + N_{Padding}) \quad (14)$$

Where, $N_{Ranging}$ =6 and N_{CQICH} =6 Therfore, calculation for transmission rate of MAC data is,

$$T_{net/MAC} = \frac{(N_{DLPayload} + N_{ULPayload}) * M_C)}{T_{frame}} \quad (15)$$

Where, $N_{DLPayload}$ and $N_{ULPayload}$ can be referred from equation (14).

V. Simulation Results

Here in this paper, we are taking into consideration the uplink and downlink scenarios where communication is between Mobile WiMAX to Fixed WiMAX (Uplink) and Fixed WiMAX to Mobile WiMAX (downlink).
In this paper BER is calculated to determine the error performance based on distance between transmitter and receiver radios.
Bit Error rate can be defined simply as the percentage of total number of errors to the total number of bits transmitted [12]. The symbols are transmitted and the Bit Error Rate (BER) performance versus Signal to Noise Ratio (SNR) value from the received signals is simulated.
The parameters considered in this paper for computing the performance is by calculating the Bit Error Rate(BER) under 16QAM with 0.125 guard time interval for uplink whereby communication with FFT sizes 1024- 256 and QPSK modulation with 0.25 guard time interval for downlink technique with FFT sizes 256-1024 for a typical SNR value of 12 dB which is almost 0 is observed.
Figure 5 are the parameters setup values of the system which are given as input to the system where communication takes place between a transmitter and a receiver which may be mobile or fixed.In Figure 5 , the value of M varies, M=1024 is for the uplink scenario and when M=256 communication is from the Base Station to the Mobile Station which is the downlink scenario.

```
% Initialization
    M  = 1024;              % Number of subchannels
    Guard_Interval = M/8;% Guard interval length
    q  = 4;                % Modulation level
    nloop = 100;            % Number of iteration
    SNR= 0:15;             % signal to noise ratio vector in dB
    Rate0= zeros(1, length(SNR)); % initializing bit error rate
```

Fig. 5. Parameters Initialization

Figure 6 depicts the BER with respect to uplink and downlink communication Fixed WiMAX and Mobile WiMAX.

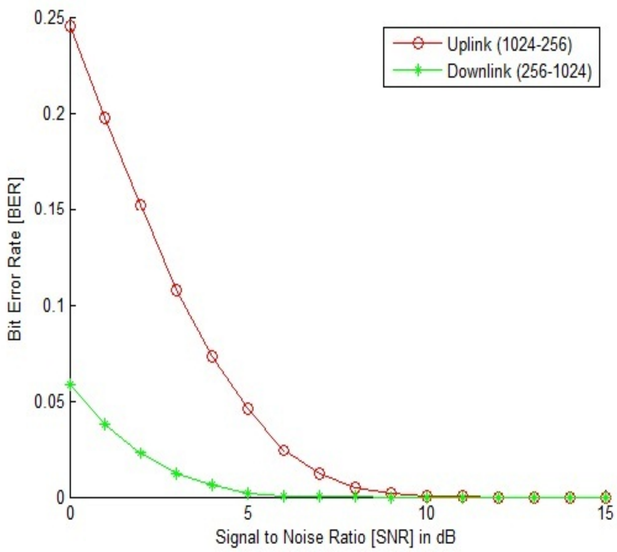

Fig. 6. Bit Error Rate(BER)

VI. Conclusion

In conclusion, efficiency of vehicular communication has been explored theoretically by deriving the number of data carriers for the uplink and downlink respectively . Authors have derived the efficiency of the system by sub channels allocation, with the formation of clusters as well as concentration on the number of symbols which are 2 for downlink and 3 for uplink. As fixed WiMAX and DSRC have common OFDM in the PHY layer, therefore transmission between Fixed WiMAX and Mobile WiMAX is considered taking into account the varying FFT sizes and number of data carriers, the MAC data transmitted has been finally calculated. Authors also compute the performance of the proposed combined system by calculating the Bit Error Rate vs Signal to Noise Ratio (SNR) is calculated at the end of the simulation for both the scenarios.

References

[1] Ramjee Prasad, Fernando J. Velez, "WiMAX Networks: Techno Economic Vision and Challenges ",ISBN 978-90-481-8752-2, Springer, 2010.

[2] Md. Ashraful Islam , Md. Zahid Hasan, Riaz Uddin Mondal, "Performance Evaluation of Wimax Physical Layer under Adaptive Modulation Techniques and Communication Channels", *(IJCSIS) International Journal of Computer Science and Information Security*, Vol. 5, No.1, 2009.

[3] D. Kandar, V. Dhilip kumar, P.Chyne, "An Adaptive Broadcasting Scenario for Intelligent Transportation System", *TCIFES CLRI,Chennai*, 2015

[4] IEEE P802.16-2004/Cor1/D3 Corrigendum to IEEE Standard for Local and Metropolitan Area NetworksPart 16: Air Interface for Fixed Broadband Wireless Access Systems, IEEE, New York, 2005.

[5] K.Daniel Wong, "Fundamental of wireless Communication Engineering Technologie", Wiley Series on Information and Communication Technology, *Wiley Publisher*, ISBN : 978-111-812-1092, pp:568, 2011.

[6] IEEE. Standard 802.16-2004, Part 16: Air interface for fixed broadband wireless access systems, June 2004

[7] WiMAX Forum. WiMAX Forum Mobile System Profile. 200607.

[8] NC Doyle, N Jaber, KE Tepe, "New combined WiMAX/DSRC infrastructure design for efficient vehicular networking" , *EURASIP Journal on Wireless Communications and Networking*, Springer Open Access 2012.

[9] IEEE Std. 802.16-2009 IEEE Standard for Local and metropolitan area networks Part 16, Air Interface for Broadband Wireless Access Systems. WG802.16 - Broadband Wireless Access Working Group, 2009, pp. pp. C1pp. C2004. doi:10.1109/IEEESTD.2009.5062485

[10] IEEE Std. 802.11p-2010 IEEE Standard for Information technology Telecommunications and information exchange between systems Local and metropolitan area networks Specific requirements Part 11, Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 6: Wireless Access in Vehicular Environments, WG802.11 Wireless LAN Working Group, 2010, pp. pp. 1pp. 51. doi:10.1109/IEEESTD.2010.5514475.

[11] Yunxin (Jeff) Li, "An Overview of the DSRC/WAVE Technology", Quality, Reliability, Security and Robustness in Heterogeneous Networks, Volume 74 of the series Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering pp 544-558, Springer, 2011.

[12] Shubhangi R. Chaudhary, "Performance of WiMAX/ IEEE 802.16 with Different Modulation and Coding", Information Technology and Mobile Communication,Volume 147 of the series Communications in Computer and Information Science pp 440-444, Springer 2011.

[13] B.SivaKumar Reddy, Lakshmi, "Improvement in the Performance of WiMAX with Channel Equalizers and Space Time Block Coding Techniques Using Simulink", Wireless Pers Commun DOI 10.1007/s11277-015-2768-5, Springer Science+Business Media New York 2015.