# Uplink Communication between WiMAX and IEEE 802.11P using subchannelization

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***Abstract - In this paper an integrated architecture of Vehicular standards and Mobile standards for Efficient Intelligent Transportation system is proposed. By combining these two technologies many research challenges has been adopted to establish a communication between different standards. In this paper, we considered the hybrid scenario of Uplink and Downlink between IEEE 802.11p and IEEE 802.16d systems. We addressed the problem of sub channelization by establishing communication between different subcarriers. Authors provide an analytical result based on the Modulation schemes as well as AMC (Adaptive and Modulation Coding). The simulation results are provided to evaluate the performance of efficiency of payload, coverage range and data capacity with different modulation schemes and sub channelization.***

***Keywords: DSRC, WiMAX, 64FFT, 256 FFT, AMC.***

## I. INTRODUCTION

The Fixed Environment of Cellular standard i.e., IEEE 802.16d (Fixed WiMAX) connection establishment is based on physical layer components such as Orthogonal Frequency Division Multiplexing(OFDM) and Medium access control (MAC) for providing communication to vehicular standards such as IEEE 802.11p (Dedicated short range communication) also called as DSRC. However, in some high speed and longer range dynamic environment signals may not be transmitted or received using DSRC technology. The solution to overcome this drawback of DSRC is by incorporating Fixed WiMAX with DSRC to convey the frequency signal in multiuser DSRC environment for ITS.

## II. OVERVIEW OF ITSS

Intelligent Transportation System (ITS) are being deployed in various VANET research challenges such as inter vehicle communication for safety application in high mobility dynamic environment and establishing communication between different networks for longer range communication(i.e., DSRC to WiMAX). Each vehicle takes on different realm equipped with VANETs standards such as DSRC, WAVE, CALM or IEEE 802.16e (Mobile WiMAX) also acted as On-Board Unit (OBU). These standards are employed to communicate between vehicle to vehicle (V – to – V)[17] [19]. In a realistic situation vehicles require to communicate with Road Side Infrastructure Unit (RSU) with the use of possible configuration parameters and communication protocol to deliver the information or communication between the OBU's and RSU's.

### A. VANETs Standards

The standard IEEE 802.11 p was considered for DSRC and WAVE architecture which provides a short to medium range communication service in high speed data transfers with low latency communication between vehicle to vehicle (V-2-V) and vehicle to Roadside Infrastructure(V-2-I) as well as it is deployed in the various safety applications such as Navigation system, Automatic Toll Collection, Traffic Management etc. In 1999, the US Federal Communication Commission allocated 5.850 - 5.925 GHz Radio frequency band at 75MHz spectrum [8]. DSRC is organized into 10MHz band which consists of seven channels out of which six channels are reserved for service channels used for non safety communications and the remaining one channel is reserved for control channel used for safety [12] [13]. DSRC are installed in vehicles and acts as OBU for gathering the sensor's information from vehicle and transmit the gathered information to other vehicle within the range of 1000 Meters (1KM) [6][7].

### B. WiMAX standards

The WiMAX (Worldwide Interoperability for Microwave Access) is a wireless broadband access standard. The IEEE 802.16-2004 standard comprises of the static and dynamic environment i.e., Fixed WiMAX (IEEE 802.16d) and Mobile WiMAX (IEEE 802.16e). WiMAX governs the air interface dependent on physical layer OFDM. In Fixed WiMAX the OFDM consist of 256 FFT with subcarrier frequencies at 3 – 10 MHz channel Bandwidth with data capacity up to 3.5 to 5.8 GHz frequency band. Therefore Fixed WiMAX offers wide coverage range up to 30 Miles (around 50 KM) and also act as a Road side Infrastructure. In Mobile WiMAX physical layer contains of the Orthogonal Frequency Division Multiple Access (OFDMA) and it supports multi carrier FDMA and it supports both Frequency and Time domain duplexing (i.e., it depicts the time and frequency domain allocated to the subcarriers into various user slot and transmitting signal to multiple OFDM). [10][14]. The physical layer of dynamic WiMAX supports 128, 512 and 1024 FFT subcarriers at 2 - 11 GHz radio frequency band for Non Line of sight (NLOS) applications and operates on the RF band from 2.3GHz to 3.5 GHz [16]. It also supports point to multipoint communication using MAC layer and it covers up to the range of 3 – 10 Miles (5 – 15 KM) whereby it can act as an RSU or an OBU.

## C. *Limitation of standalone Technologies:*

By utilizing the existing Technologies such as VANET (DSRC) and Cellular standards (WiMAX) to construct a new combined architecture framework for providing an efficient vehicular communication, modulation schemes and sub-channelization is one of the major issues to combine the different wireless communication standards. In 2013, Nicholas Doyle have proposed the combined architecture of DSRC and Mobile WiMAX by evaluating the payload calculation between DSRC physical layer OFDM and Mobile WiMAX OFDMA by using clustering and PUSC and FUSC sub-channelization. By evaluation of the performance of combined architecture it will increase the throughput as well as decrease the control overhead [1] [15][18].

# III. Proposed Mechanism (possibilities of Convergence between DSRC and Fixed WiMAX)

In this paper, we proposed a new combined scenario by establishing communication between DSRC and Fixed WiMAX for longer range communication. By considering the existing scenario of the combined architecture of Mobile WiMAX and DSRC, payload can be calculated, and communication using 1024 FFT and 64 FFT subcarrier by using Partial Usage and Full Usage of Sub Channels (PUSC and FUSC) sub-channelization can be carried out [9].

Fixed Wimax does not support the PUSC and FUSC sub-channelization scheme in 256 FFT subcarriers [11]. So we brought into picture AMC sub-channelization to evaluate the system efficiency by influencing the existing mathematical model for solving the efficiency issue by utilizing Fixed WiMAX and DSRC, thereby providing longer range communication with high bandwidth and low latency [20]. The proposed scenario will aims for better efficiency as well as to increase the coverage range and data capacity and it helps an establish communication to the huge number of users using the Modulation scheme such as 16 QAM.

## A. *Subchannelization of IEEE 802.16d*

IEEE 802.16d (Fixed WiMAX) standard define two modes of sub-channelization are Adjacent and Distributed (Diversity) Sub-channelization mode.

In Distributed sub-channelization mode, the sub-channels are summarized with distributed subcarriers over all the available channel bandwidth [4], and it further divided into two modes: Partial usage and Full UsageFUSC (Full Usage of Sub-Channels) mode and PUSC (Partial Usage of Sub-Channels) mode

- In FUSC mode, subcarriers are dedicated to a full usage of the total formatted sub-channels in one cell
- In PUSC mode, subcarriers are dedicated to partial usage of the total formatted sub-channels, and it can be splits into sector/cell.

In Adjacent Sub-channelization mode, adjacent subcarriers are used to form sub-channels and it can rapidly assign a modulation and coding combination per sub-channel.

Adjacent sub-channelization is also further divided into two modes: AMC (Adaptive and Modulation Coding) mode and Adjacent PUSC mode

AMC mode is strongly suggested as it increases the spectral efficiency of the system. In Fixed WiMAX, Physical layer OFDM requires 256 FFT subcarriers and DSRC OFDM requires 64 FFT subcarrier and supports up to 10 MHZ channel Bandwidth.

Therefore, with the parameters already available, in the implementation part the following formula is adapted for calculating the Inverse Fast Fourier Transform

$$\text{N-IFFT: } X(t) = \sum NJ\text{-}1\ X(j)\ .\ e\ j2\pi fjt$$

The Supported Size in IEEE 802.16d is given as,

[256 FFT; 192 + 8 + 56]

Where, 192 data subcarriers are for data transmission, 8 pilot subcarriers for synchronization and estimation purposes and the remaining 56 Null Subcarriers are for guard bands and DC carriers.

In DSRC, the supported size is,

[64FFT ; 48 + 4 + 12]

Where, 48 data subcarriers are for data transmission, 4 pilot subcarriers for synchronization and estimation purposes and remaining 12 Null subcarriers for guard bands and DC carriers.

While establishing the communication between DSRC and Fixed WiMAX (64 FFT to 256 FFT) sub-channelization and modulation schemes are necessary. Sub-channelization is used for grouping of subcarriers into different permutations such as distributed subcarrier (PUSC and FUSC) and Adjacent Subcarrier (AMC). Many radio communications systems nowadays use the dynamic adaptive modulation techniques such as (BPSK, QPSK, 8PSK, 16QAM, 32QAM, 64QAM). They sense the channel conditions and adapt the modulation scheme to obtain the highest data rate for the given conditions. As signal to noise ratios decrease, errors will increase along with re-sends of the data, thereby slowing throughput.

Figure 1 shows the combined architecture scenario with DSRC radio vehicles as OBU's and Fixed WiMAX towers as Base Stations or RSU's.

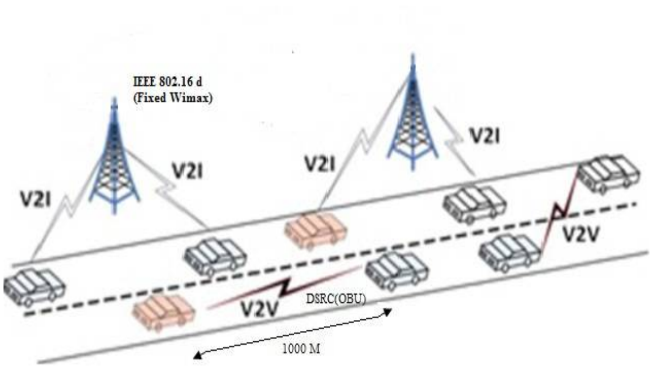


Figure 1: DSRC – Fixed WiMAX Architecture

## B. *Downlink Scenario*

The modulation schemes for Downlink Scenario i.e., Fixed WiMAX to DSRC is given in Table 1

**Fixed WiMAX to DSRC (256 FFT to 64 FFT)**

| Modulation | Bits Per symbol | Symbol Rate |
|---|---|---|
| BPSK | 1 | 1* bit rate |
| 16 QAM | 4 | ¼ bit rate |

Table 1: Modulation schemes for WIMAX - DSRC

While establishing the communication between same standards (Example: DSRC to DSRC) the physical layer OFDM requires 64 FFT for modulation as well as demodulation for one OFDM symbol.

Therefore, BPSK requires 1 bit per OFDM symbol (i.e. 1 * Bit rate = 1* 64 FFT subcarrier)

Table 2: Parameter table for 256 FFT OFDM AMC carrier allocations

| Parameters | Values |
|---|---|
| Number of Subcarriers | 256 FFT |
| Number of Data subCarriers | 192 |
| Number of Data Carriers per subchannel | 48 |
| Number of Bins per second | 4 |
| Number of Bands | 6 |
| Number of Used Subcarriers | 217 |
| Number of Pilot Subcarriers | 24 |
| Number of DC subcarriers | 1 |
| Number of Guard Subcarriers, Left | 20 |
| Number of Guard Subcarriers, Right | 19 |

In DSRC-OFDM, the subcarrier frequency spacing Δf is given as,

(Δf =BW/Nfft=10MHz/64= 156.25 KHz )

Where, Tg is the guard time (Tg=8μs).

For the downlink scenario, 10 MHz system Bandwidth is required with 5.8GHz Radio frequency, and the Number of Subcarriers (Δf) is 256FFT and 16QAM Modulation Scheme is used i.e. 16QAM Modulation Scheme is used for modulation and demodulation of the signals from Fixed WiMAX to DSRC.

Therefore, Δf * Symbol rate = 256 FFT * ¼ = 64 FFT

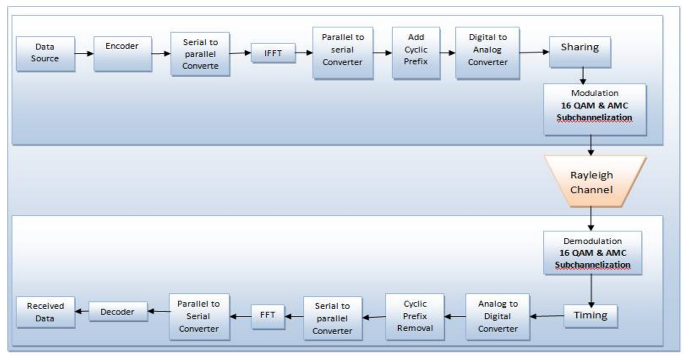


Figure 2: Block Diagram for WIMAX DSRC system at 16QAM and AMC sub-channelization

## C. *Uplink Scenario - DSRC (64 FFT) to Fixed WiMAX (256 FFT)*

IEEE 802.16d does not support Partial Usage of Sub-channels (PUSC) or Full Usage of Sub-channels (FUSC) channel allocations. [5]. so we have considered AMC sub-channelization for the uplink scenario. Figure 2 depicts the block diagram for WiMAX DSRC system using 16 QAM and AMC sub-channelization. Figure 3 shows how the subcarriers are spaced using the AMC sub-channelization and modulated data carriers using 16QAM modulation technique.

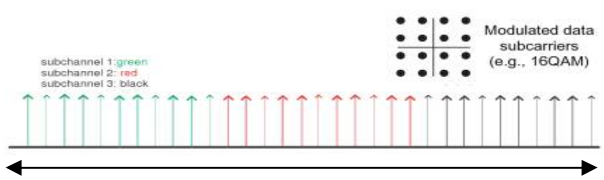


Figure 3: AMC subchannelization in 256 FFT subcarriers

## D. *AMC OFDM symbol*

Table 2. Depicts the Parameters for 256 FFT OFDM AMC carrier allocations are mentioned in Table 2.

The value of pilot subcarrier index is

9k+3M+1 for K=0,1,…. 23

Where, M= [symbol index] mod 3.

Therefore symbol of index 0 is the first AMC data symbol in the downlink or uplink. There are four types of AMC sub-channels which are different in the collection of 6 bins in a band. In the first type(default type), the available bins in a band are enumerated by starting from the lowest bin in the first symbol to the last bin in the symbol and then going to the lowest bin in the next symbol and so on. A sub-channel consists of 6 consecutive bins in this enumeration. In the other types, the shapes of an AMC sub-channel are shown in figure 3. In all the types, the index of the sub-channels in a band is increased along bins and then symbols.

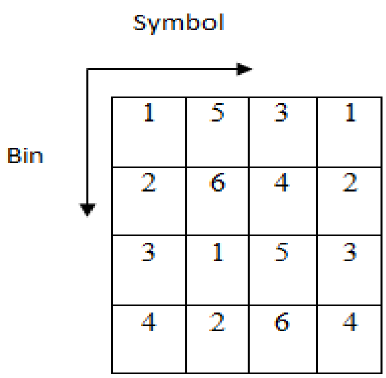


Figure 4 : AMC Default Type

In the above figure 4 we depict the default type of AMC sub-channelization.

### *E. Payload Calculation using Sub-channelization (AMC)*

AMC uses adjacent subcarriers to build a sub-channel for establishing a communication for 256 FFT subcarriers into 64 FFT subcarrier. This Sub-channelization consists of 6 contiguous bins within the same band. Each bin contains 6 consecutive symbols. For 256 FFT subcarriers r4 bins per second are needed, so it supports AMC by default. In AMC permutation, there are 9 adjacent subcarriers, 8 data subcarriers + 1 pilot subcarrier to form 1 Bin. [2].

In Figure 4, we depict 6 bands in 256 FFT AMC type, out of which 4 bins can be processed every symbol time. In the Uplink and Downlink Scenario of Fixed WiMAX and DSRC 16 QAM Modulation scheme is used to establish communication from 256FFT to 64 FFT subcarriers (i.e. 256 * ¼ symbol rate = 64 FFT). While in the Uplink, AMC sub-channelization is based on segmentation of subchannelization and is dependent on time (n, n+1, n+2..etc). Therefore, AMC requires 1 subchannel * (1, 2 or 3 OFDM symbols) for calculating Payload, and to examine the data capacity, range and as well as spectral efficiency.

The number of data carriers (NDC) for Uplink and Downlink is given as follows

$$NDC = \frac{48 \text{ subchannels} * 8 \text{ datacarriers / Bin} * 2 \text{ Bins/symbol}}{1\text{Bin/tile}}$$

[NDC= 768 Data Subcarriers].

## IV. Simulation Parameters (Fixed WiMAX and DSRC)

The Parameter table for finding the data capacity of uplink and downlink scenario between fixed wimax and DSRC Using AMC sub-channelization with 16 QAM modulation scheme with 10MHz bandwidth is mentioned below in Table 3. [2] [3].

| Parameter | DL AMC | UL AMC |
|---|---|---|
| System Channel Bandwidth | 10 MHz | |
| FFT Size(N) | 1024 | |
| Null Subcarriers | 159 | |
| Pilot Subcarriers | 96 | |
| Data Subcarriers | 768 | |
| Used Subcarriers | 865 | |
| Number of Subchannels | 48 | |
| Subcarrier Spacing | 10.94 KHz | |
| Sampling Frequency | 11.2 MHz | |
| Cyclic Prefix Length | ¼ FFt Size = 22.8 | |
| Modulation Scheme | 16 QAM<br>Code rate ½. 2/3 , ¾, 5/6 | 16 QAM<br>½ ,2/3 , 5/6 |

Table 3: AMC sub-channelization Parameters

The graph below describes uplink and downlink communication data capacity of AMC sub-channelization at 10 MHz Bandwidth. The X-Axis denoted number of users can achieve the signal from WiMAX and the Y-Axis denotes the data rates in kbps.

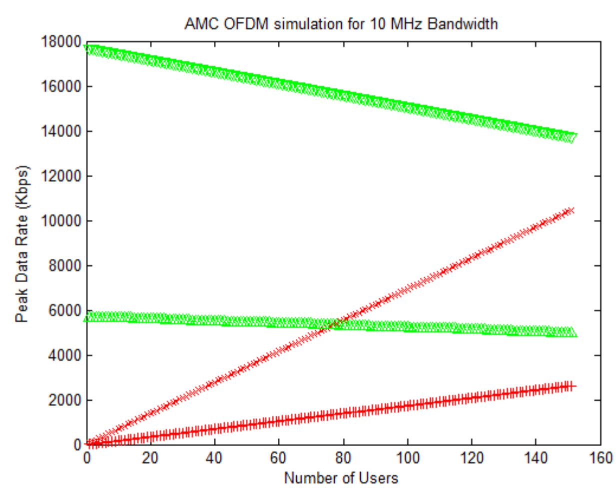


Figure 5: AMC OFDM simulation for 10 MHz Bandwidth

In this plot, the red line indicates Minimum Demand of data rates to establish communication to users. It initializes the data signal so the data rates starts from 0 and ends with

10467.9 Kbps in downlink scenario. For uplink concept, it will ends with 2616.98 Kbps. The Green line indicates the available bandwidth of uplink and downlink scenario at AMC sub-channelization.

In downlink concept, the peak rate starts from 17680 Kbps and ends with 13724.4 Kbps available bandwidth. In the uplink scenario, it starts from 5671.5 Kbps and ends with 4973.5 Kbps. By evaluating these downlink and uplink communication between DSRC and Fixed WiMAX, we can achieve data capacity and we can also handle communication for 151 subscribers simultaneously.

## V. Conclusion

Authors have proposed an uplink and downlink scenario for Fixed WiMAX and DSRC by using 16QAM modulation scheme and AMC Sub-channelization technique to establish communication between Fixed WiMAX and DSRC i.e., 256 FFT to 64 FFT subcarriers in 10 MHZ channel Bandwidth as well as 5.8 GHz Radio frequency. Using AMC Sub-channelization, we may observe some loss of frequency diversity, however, we observe an increase in the system capacity and throughput because a sub-channel is allocated to the user at any given time with the highest signal to Noise ratio as well as capacity in the sub-channels.

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