Effect of Sensing Time on Performance of OFDM Based Opportunistic Cognitive Radio

P. Ravinder Kumar, Archena, Subhash S Kulkarni, Sandeep.V.M

Abstract: - The increased demand on wireless communications results in spectrum congestion that cannot be solved by the static spectrum allocation. In this regard, we propose Cognitive Radio (CR) with Orthogonal Frequency Division Multiplexing (OFDM) technology. OFDM increases the data rate and CR improves the spectrum utilization opportunistically, which is usually underutilized, to the unlicensed users called cognitive users.

Keywords: Birth rate, Death rate, Efficiency, Sensing time, Transmission loss, Transmission interference.

I. INTRODUCTION

Communication is an exchange of data either analog or digital between the devices. Analog signal varies with respect to time and digital will be in binary which has proved better and possess more advantages. Digital communication has source encoder and the channel encoder which converts analog to digital and encodes it with suitable modulation technique like ASK, FSK, PSK, QPSK and QAM. This encoding is necessary to reduce the bandwidth of the binary data which is infinite. The samples with N bits needs N-time slots for ASK, FSK, PSK schemes N/2, N/3, N/M time slots for QPSK, QAM and M-ary PSK respectively. For better resolution higher value of N is preferred. The complexity in implementation of these schemes increases exponentially and as we try to reduce number of time slots and thus overrides the benefits gained through using the time slots for transmission. This makes these schemes highly distracting. The need of the hour is to transmit N bits in a single time slot and yet to keep the complexity under control. In this direction OFDM comes to our rescue. The main concept of OFDM is to split the band into N orthogonal sub carriers and use each subcarrier to contain one bit of information and there by allow one to transmit all N bits of information in a single time slot making it to be the most efficient technique in broadband wireless communication. In wireless communication the fixed frequency bands are allocated to different applications which are called as static spectrum allocation method. The number of users utilizing the spectrum is increased due to the attractive services provided by it, which leads to the spectrum congestion and spectrum scarcity that cannot be solved by the fixed spectrum allocation.

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In order to better utilize the licensed spectrum the CR technology is coined to satisfy the users desire by accessing the spectrum which is underutilized by sensing the spectrum periodically and offers the spectrum opportunistically to the unlicensed users called secondary users or cognitive users [5] [6]. The arrangement of this paper is as follows. The section 2 deals with our model in which we present the working the OFDM transmitter and Cognitive radio where as in section 3 we discuss the parameters on which the complete function of our work and the methods employed in performing the function is explained in section4. The proof for section 4 and is revealed in section 5 results and discussions. Finally we conclude this paper in section 6.

II. OUR MODEL

A. OFDM Transmitter and OFDM Receiver

The first part transmitter side of OFDM system consists of creating N orthogonal subcarriers in a band. This is the main theme of Inverse Fast Fourier Transform (IFFT). Where in the coefficients of orthogonal signals are fed as inputs and the output is a complex signal that is a scaled sum of the orthogonal signals. This inspired us to use the readily available IFFT block as OFDM generator [8]. Here the N bits of the input data are fed to IFFT that in turn produces complex signal Literature suggests that the IFFT implementation has undergone many challenging revolutions and today we have fast, efficient, implementation with respect to speed, space and power requirements. This allows implementing OFDM scheme at least cost. The baseband OFDM signal hence produced is further amplitude modulated to the required band and then transmitted.

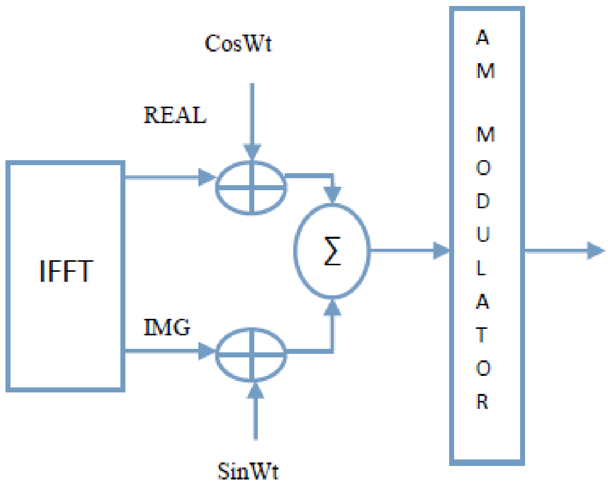

Fig. 1. OFDM Transmitter

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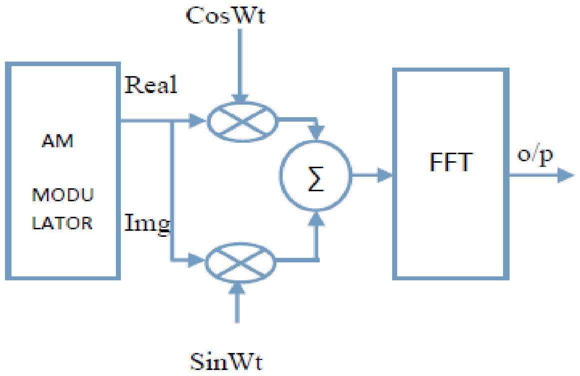

Fig. 2. OFDM Receiver

B. Cognitive Radio

The demand over wireless communication is increased rapidly. In OFDM we increase the data rate but we cannot solve the problem of the spectrum inefficiency, as the competition among the users in accessing the spectrum creates the spectrum congestion and spectrum scarcity, leads to the spectrum under utilization, which cannot be solved by the static spectrum allocation. In order to reuse the available spectrum more efficiently the proposed solution is the Cognitive Radio Technology which access the spectrum opportunistically. The main function of the CR is the spectrum sensing to avoid the interference by the secondary users (SU) to the Primary users (PU) which are licensed users, where CR users are called as secondary users which are unlicensed users. The three methods to increase the sensing accuracy which depends on transmitter detection are Matched Filter Detection, Energy Detection, and Feature Detection. Out of these the energy detection method is used to sense the channel in a Time period (T) which takes (t_s) seconds to know whether the PU is utilizing the channel or not. Depending on the received signal energy compared with the preset threshold we come to know whether the PU is present or not. If the energy of the received signal is less than the threshold it shows the channel is Free (i.e., PU OFF state) then the SU sends its data by using OFDM technique in ($T-t_s$) seconds, or else it awaits for the next time period to sense, if the energy of the received signal is more than the threshold it shows the channel is Busy which shows that the PU is utilizing the channel (i.e., PU ON state). The primary ON and OFF states are known as Birth rate (β) and Death rate (α). While sensing when the SU detect the PU where actually the PU is not present gives False-Alarm i.e., the channel is shown as busy where actually the channel is free. In this case the SU has the opportunity to send the data, but because of the False Alarm it lost the opportunity by this we calculate the Transmission Loss (TL). While sensing if the SU detect the channel as free where actually the PU is present i.e., the channel is shown as free where the channel is busy, because of this Missed Detection, the SU starts sending its data which leads to interference, by this Missed detection we calculate the Transmission Interference (TI). Finally we calculate the efficiency. The above process can be repeated for different time periods (T), sensing time (t_s) with various birthrates and death rates.

III. PERFORMANCE EVALUATION

This paper deals with OFDM and Cognitive Radio. The performance of OFDM is evaluated depending on the Bit Error Rate (BER) in the received data. We can improve this BER by increasing the Signal to Noise Ratio(S/N).

Bit Error Rate It is the fraction of number of error bits to total number of bits transmitted. Cognitive Radio performance is revealed by the parameters TI, TL, efficiency (η).

Transmission Interference It is the ratio of the Number of Missed detection States to Total number of Time periods.

Transmission Loss It is the fraction of the Number of False-Alarm states to the Total number of Time periods.

Efficiency It is calculated by the total number of Time periods that the SU takes to transmit N bits of data.

IV. IMPLEMENTATION

The main theme of this paper is to increase the data rate and the spectrum efficiency by avoiding the interference. To implement this we use OFDM and cognitive radio technologies. By using OFDM we send N number of data in Single time period which is possible by its orthogonality property between the subcarriers and reduces the ISI [4]. In cognitive radio the three methods to improve spectrum efficiency are Matched filter detection, Energy detection, Feature detection. Out of these we use energy detection method where as in Matched filter detection cognitive radio sensing is applicable to limited PU bands. In order to operate for higher PU bands the complexity in the circuitry increases and by this we cannot detect the information of the transmitted signal [2] [3]. By Feature detection it requires longer processing time to identify the modulation types of the Primary signals which increases the computational complexity. In energy detection method depending on the received signal energy after sensing detects the status of the PU [1] [7]. By this we can avoid the interference.

V. RESULTS AND DISCUSSIONS

A. OFDM Results

Table-1: Shows the Input and Output data with total Errors

S.NO	Input Data	Output Data Without Errors	Output Data With Errors
1	1	1	1
2	1	1	0
3	0	0	0
4	1	1	1
5	1	1	1
6	0	0	0
7	0	0	0
8	1	1	0
9	1	1	1
10	1	1	1

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11	0	0	0
12	1	1	1
13	1	1	0
14	0	0	0
15	1	1	1
16	0	0	0
Total Errors		**0**	**3**

In the below Figs the pink bars represent the input and black bars represent the output data.

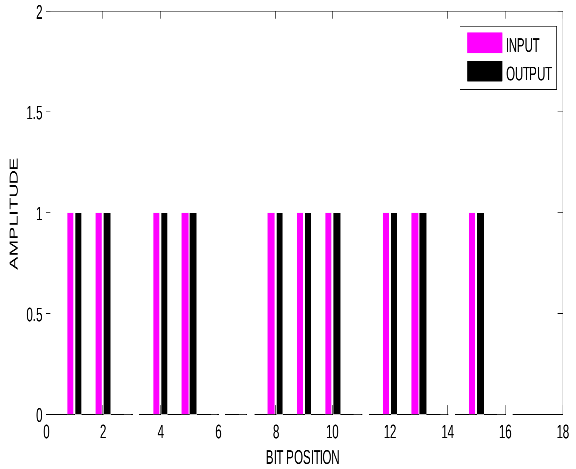

Fig. 3. Input and output response with no errors

Fig 3 above shows the data transmitted and received data where the number of errors occurred are zero.

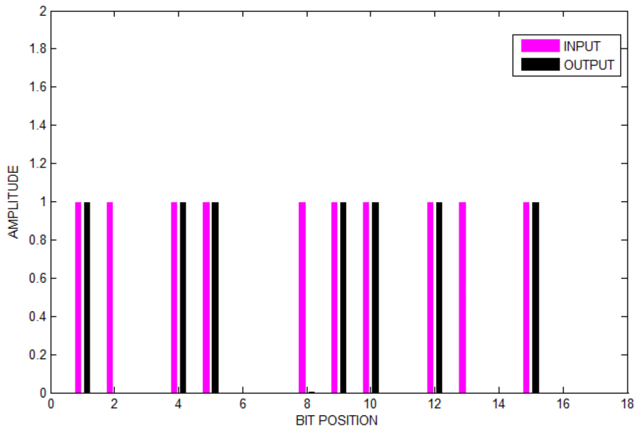

Fig .4. Input and output response with errors in received data

Fig 4 shows the data transmitted and received where errors are occurred. The total number of errors can be identified by performing XOR operation on input and output data, which is shown in Table 1. The table 2 below gives the percentage of errors for various execution cycles. It shows that various times of transmitting the data results in less percentage error i.e., the received will be more efficient.

Table- 2: Percentage Error After Execution

Execution Cycles	Percentage Errors (%)
1	25
5	26.25
10	28
25	32
50	38.5
100	44.6
300	42.5
500	47.5
1000	48.2

BER can be reduced with increase in the signal to noise ratio which is clearly seen from the table 3 and the graph shown in Fig 5.

Table -3: S/N ratio v/s percentage error.

S/N Ratio	% Error
5	18.75
10	12.5
20	6.25
30	0
35	0

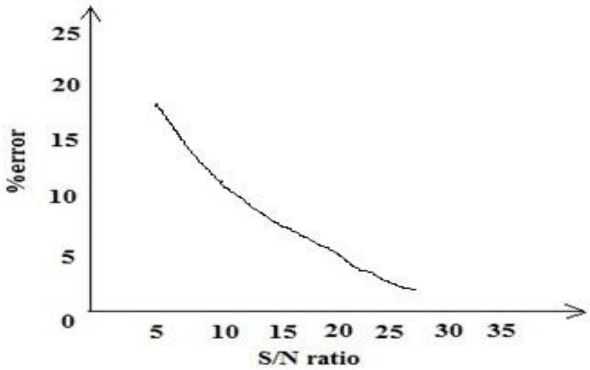

Fig 5. Graphical representation of SNR v/s percentage error

B. Cognitive Radio

The experiment is conducted for single time period (T=9), various sensing times (t_s=1, 2, 3) and birthrate and death rate (β=1, α=1).which gives the status of the PU. Death rate gives the primary OFF where the SU transmits the data. Birth rate gives the primary ON state. Due to false-alarm and missed detection we calculate TI and TL and efficiency (η) for this we create a secondary occupancy channel which includes busy and free states depending on the threshold level. This all is done to transmit N number of SU data through the primary channel. Table 4 shows the intended results of Transmission loss for various t_s and single T. In case of increase in sensing time there will be a chance to occur false alarm in maximum amounts and at the same time there will be decrease in transmission time to send the data. Thus the SU losses the opportunity which leads in increase in the Transmission loss for various t_s values. This is clearly seen from the Fig 6.

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Table-4: Transmission loss for single Time Period and various t_s.

Transmission Loss						
	t_s =1	t_s =2	t_s =3	t_s =4	t_s =5	t_s =6
T=9	7.16	7.48	9.11	8.66	9.38	8.92

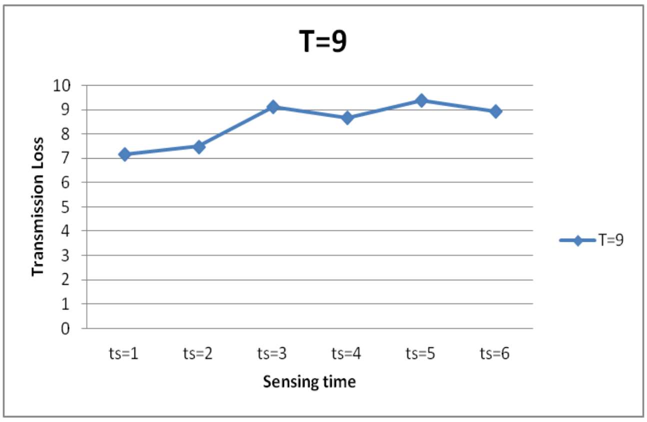

Fig 6. The effect of ts on Transmission Loss for single Time period value

Table 5 shows the intended results for Transmission interference for various t_s and single T. As the sensing time increases the transmission time decreases but the interference of SU with the PU is reduced which can be observed clearly from the Fig 7.

Table -5: Transmission Interference for various t_s and single T

Transmission Interference						
	t_s =1	t_s =2	t_s =3	t_s =4	t_s =5	t_s =6
T=9	5.88	3.32	3.38	1.79	0.78	0.11

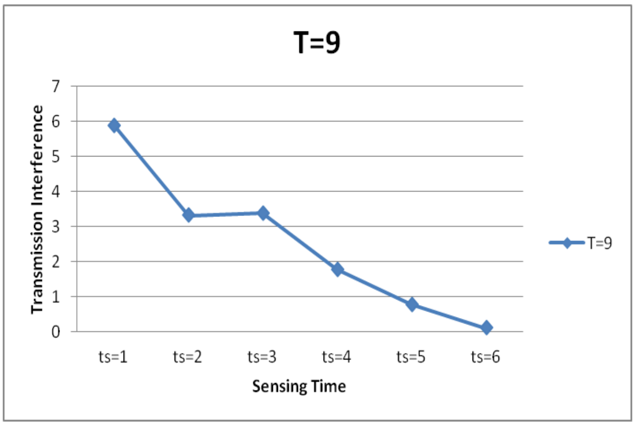

Fig. 7. The effect of t_s on Transmission interference for single T value

Table 6 It shows the effect of ts on efficiency, observation time and the transmission time which influence the spectrum efficiency. Due to the increase in sensing time (t_s) the transmission time (T) gets decreased, where transmission of data gets decreased which effects the efficiency of the SU. This can be observed clearly from the Fig 8.

Table -6 : Efficiency for various t_s and single Time period T

Efficiency(η)						
	t_s =1	t_s =2	t_s =3	t_s =4	t_s =5	t_s =6
T=9	9.56	4.82	4.63	2.81	2.5	2.5

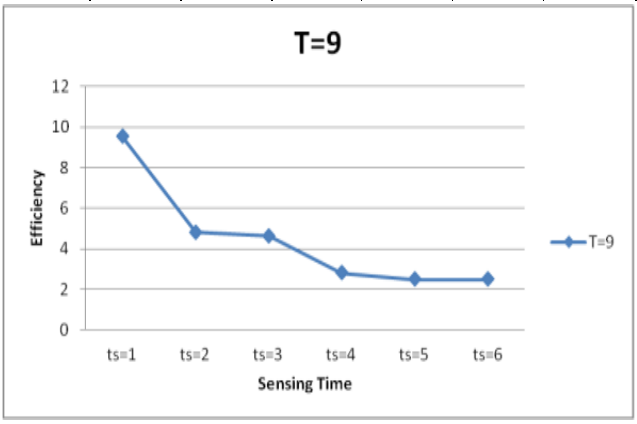

Fig .8 . The effect of t_s on efficiency for single T

VI. CONCLUSION

Orthogonal frequency division multiplexing provides high data rates where it sends orthogonal signals through the channel which is done easily by using IFFT and FFT by reducing the complexity and thereby increasing the computational speed. This thesis would extend in further better utilization of bandwidth. The development can be made by implementing error correcting mechanism and also an error free transmission. Cognitive Radio is a promising technology which enables spectrum sensing for opportunistic spectrum usage. The use of spectrum sensing gives the satisfactory results in terms of efficient use of available spectrum and avoiding the interference to the primary users. In this project the optimization method was applied to point to point cognitive radio link in which the efficiency is maximized depending on single T and various t_s. This can be done for various values of T, t_s and Birth rate (β) and Death rate (α) and calculate TI, TL, efficiency. This can be extended by applying the optimization method to multichannel or multi user system by providing some additional methods.

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