

# Joint Beamforming and Channel Selection for Multicast IEEE 802.11n WLANs

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*Abstract*—Multicast transmission over WLANs is becoming a popular application. IEEE 802.11n technology is developed due to the ever increasing demand for higher data rate and Quality of Service (QoS). However, there is an unmanaged and rapid growth of wireless devices in unlicensed frequency bands. WLANs experience significant interference from near-by environment which lead to significant performance degradation. The impetus of the present study is to describe a novel distributed algorithm that will allow interfering Access Points (APs) to select appropriately the channel band that will experience minimal interference. Therefore, a fair share of available spectrum is achieved. We investigate the IEEE 802.11n WLAN where a large number of clients attempt the same high bit rate from the single AP. We formulate the problem of transmit beamforming to a multicast group and minimize total emitted power adopting a QoS criterion.

## I. INTRODUCTION

Multicast is the method of a communication network that it allows transmission and routing of a single application message to multiple recipients at different locations using minimum network resources. Multicast communication has been developed in the Internet environment for fixed users using wired links. At the same time, the use of WLAN for data communication is well established due to the low cost of WLAN devices

and the fact that most portable terminals like laptops or mobiles phones include a WLAN modem as standard. Many emerging mobile applications-including group-oriented mobile commerce, on line gaming, distribution of television content, distance education-require multicast support. However, multimedia communication is very different from data communication. The wireless delivery of such multimedia content requires high throughput and low end-to-end latency for quality viewing. Because of radio bandwidth limitation, point to point communication cannot be accommodated with each remote user for a large number of remote terminals. Multicast transmission must be used at the physical layer. In this scenario, the streams are transmitted only once and scheduler doesn't duplicate the emitted data.. This efficient method supposes that the Channel State Information (CSI) passes to network layer (cross layer design). We schedule and transmit only to users during good channel condition with dynamic rate adaptation. WLANs based on IEEE 802.11 have become increasingly popular. IEEE 802.11n widens the scope of WLANs and enables the transmission of low latency streaming media. Higher physical layer data rates and improved MAC efficiency is the goal for the next generation IEEE 802.11n standard [1]. MAC layer must provide a throughput of 100 Mbits/s which mean that the transfer rate over air

will be 200 Mbits/s [2]. The use of simple and robust Carrier Sense Multiple Access with Collisions Avoidance (CSMA/CA) for medium access has contributed to the success of IEEE 802.11. Contention overhead increases with augmenting the number of stations accessing the medium. The physical throughput is limited from MAC layer. Increasing physical layer data rate will result in even lower MAC efficiency. Multicast overcomes these inefficiencies by minimize excessive contention. Finally, IEEE 802.11n improves preamble overheads at data and control frame transmission as well as interframe spacing.

The unlicensed band offers growing interest because the licensed spectrum is expensive. The most popular frequency band is the 2.4 GHz Industrial, Scientific and Medical (ISM) band, where a rapid growth in the number of users as well as new technologies is observed. The range of ISM band is from 2.4 to 2.4835 GHz. Also, 5.2 GHz Unlicensed National Information Infrastructure (UNII) band has spectacular market success under WiFi. This band covers the following frequencies: 5.15-5.35 GHz and 5.725-5.825 GHz. In the unlicensed band, all systems operate independently and so mutual interference is inevitable. The end-terminal is not sufficient able to separate the interesting signal from the others signals in the vicinity. Therefore, throughput and cell range will decline. Due to low cost, WLANs are growing exponentially. Such density leads to high degree of interference. Other source of interference in ISM band is microwave ovens, cordless phones, Bluetooth and Home RF. The UNII band is overlapped from the C band of military radar. Because the number of carrier frequencies available is limited, the radio transceivers must be capable of

adapting to the changing environment and communicate even with other sources in the neighbourhood.

In the multicast scenario, we have the problem of heterogeneity among receivers since each user have different channel conditions. In order to increase data rate and range without any increase in transmit power, multiple antennas at the receivers is proposed. A WLAN span a small geographic area, typically a single building or a cluster. A transmission from one AP is receiving by all the users of the network. Therefore, in a rich scattering environment, a single multicast group is implemented. Different schemes are introduced for multicast, which make use of the request to send (RTS) and clear to send (CTS) hand shaking to eliminate hidden-station problem [3-4]. In [5] the maximum theoretical throughput in MAC layer would be increased up to 85 per cent for any number of stations when not using RTS/CTS. Clearly, the channel busy status in CSMA protocol can be caused by neighbouring APs transmitting simultaneously. In order to eliminate contention periods and collisions, frequency allocation method is proposed. We analyse a new frequency allocation technique for keeping interference to an acceptable level, taking into account that there is no coordination among APs. In unicast schemes, the destination station will send back an Acknowledgment (ACK) if the packet has been received without error. For multicasting, IEEE 802.11 does not support a reliable handshaking. If we guarantee a minimum SINR for all receivers, we achieve reliable data exchange. With these ideas in mind, we design a downlink multicast transmit beamforming minimizing the total transmit power and thus leakage in vicinity, subject to providing at

least a prescribed received SINR to each intended receiver. From the set of fixed number of available channels using by APs and users, we select the channel that gives the minimum transmit power after beamforming optimization. The key feature of the proposed algorithm is that allows multiple interfering multicast IEEE 802.11n WLANs to select their operating frequency and forming their beams in a way that interference is minimized. APs are able to assess the radio environment and adjust their configuration appropriately. In addition, the low efficiency of Power Amplifier(PA) for OFDM system results high linearity and par consequence spectrally efficient modulation which lead to even less adjacent channel interference.

The paper is organized as follows. The next section analyzes multicast optimization without interference. In section III, we present our self-configure algorithm. In section IV, we evaluate simulation results. We conclude in section V.

## II. OPTIMIZATION WITHOUT INTERFERENCE

On purpose to keep cost down and ease backward compatibility, it is proposed the reuse of legacy technologies such as Orthogonal Frequency Division Multiplexing (OFDM) and Quadrature Amplitude Modulation (M-QAM). The standard supports 20 MHz bandwidth where the spectrum is limited and 40 MHz with two adjacent spectral channels. In IEEE 802.11a/g standard, a high data rate digital signal is converted to 48 orthogonal overlapping sub-channels. Each sub-channel occupies 312,5 KHz and is not individually filtered. In addition to the 48 data channels, there are 4 pilot tone channels and one null in the center of the band. The signal bandwidth is 16.6 MHz. Therefore, from the available sub-band of 20 MHz, only 75 per cent is used for data. PHY layer

multicasting has been study from prior works for a frequency flat channel [6-7]. In this section, our design is developed for an OFDM system, using multiple antennas at the receiver as in IEEE 802.11n.

### A. Optimization Sub-carriers

When high-speed data is transmitted, OFDM is used to combat frequency selective fading channel. It is a multi-carrier transmission technique, which divides the available spectrum into many sub-carriers, each one being modulated by a low data rate. The transmit signal propagates via different paths caused by reflections of the radio waves from the surround. This is called multipath propagation. Each of the multipath components has different relative propagation delays and attenuations which, when summing up in the receiver, results in filtering type of effect on the received signal where different frequencies of the modulated waveform are experiencing different attenuations and phase changes. This is termed frequency –selective fading. Coherence bandwidth is the range of frequencies over which the channel considered flat, meaning that all frequency components experience similar behavior. When bandwidth of transmit signal is smaller than coherence bandwidth the channel possesses a constant gain and linear phase response. Frequency selective fading channel is usually modeled as the sum of several flat fading channels with different delays. Antenna arrays form beams to detect or emit signals at directions of interesting paths (spatial filter). Adaptive beamforming to different sub-channels, only the gain of the antennas weights are changed according to attenuation factor. Beamforming acts in spatial domain, where spatial beams are formed . Par consequence, we minimize total transmit power

subject to providing at least a prescribed SINR at each receiver, for the sub-channel with minimum gain. Simultaneously this power guarantees the above constraints for all others sub-carriers with greater gain.

Let's study a system with a single AP and K receivers. We indicate with  $I_{SC}$  the set of indexes corresponding to the subcarriers. Consider a MIMO system with  $M_t$  Tx antennas and  $M_r$  Rx antennas. Denoting  $H_k(n)$  an  $M_r \times M_t$  matrix whose entry  $(i, j)$  is the complex flat-fading coefficient at subcarrier  $n \in I_{SC}$  between the  $j$ th transmit antenna and  $i$ th receive antenna for user  $k$ . From basic properties of linear algebra, every matrix  $H_k(n)$  can be factorized by its singular value decomposition (SVD)

$$H_k(n) = U_k(n)D_k(n)V_k^H(n) \quad (1)$$

where  $D_k(n)$  is an  $M_r \times M_t$  matrix with only non zero elements given by  $D_k(n)[i, i] = \sqrt{\lambda_{ki}(n)}$ .  $i = 1, 2, \dots, q_k(n)$  with  $q_k(n) = \min(M_t, M_r)$  the rank of  $H_k(n)$  correspond to the number of spatial degrees of freedom. The SVD is an appropriate way of diagonalizing the matrix  $H_k(n)$ , which lead to a number of parallel channels (eigen modes). The power gain of  $i$ th mode is  $\lambda_{ki}(n)$ . The columns  $u_{ki}(n)$  and  $v_{ki}(n)$  are the optimum weights at the Rx and Tx antennas for  $i$ th eigen mode [8]. If we apply optimum weights at the transmitter and at the receiver, then received power at user  $k$  is

$$P_k(n) = |U_k^H(n)H_k(n)V_k(n)|^2$$

$$P_k(n) = \sum_{i=1}^{q_k(n)} D_k^2(n)[i, i] \quad (2)$$

The subcarrier  $n_{min}(k)$ , which corresponds to weakest gain at each user  $k$ , is taken from

$$n_{min}(k) = \arg \min_{n \in I_{SC}} \sum_{i=1}^{q_k(n)} D_k^2(n)[i, i] \quad (3)$$

$$\forall k \in \{1, 2, \dots, K\}$$

Therefore, each user is characterized from a subchannel  $\nu_k = n_{min}(k)$  with  $\nu_k \in \{1, 2, \dots, N\}$ . Finally, we define the set  $I_{min} = \{\nu_1, \nu_2, \dots, \nu_k, \dots, \nu_K\}$ .

### B. Receiver antenna arrays

The separability of the MIMO channel relies on the presence of rich multipath which needs to make the channel spatially selective. Under these conditions, it's possible to transmit  $\min(M_t, M_r)$  independent data streams simultaneously over the eigenmodes of a matrix channel  $H$ . Clearly, the rank of  $H$  is always both less than the number of Tx antennas and less than the number of Rx antennas. The columns of  $V_k$  are used as Tx weight vectors and the rows of  $U_k^H$  as Rx vectors. This strategy is referred as Eigenvector Steering (ES)[9]. In order to receive scattering energy from all reflected paths and consequently achieve higher reception diversity gain, we apply to our design the rows of  $U^H(\nu_k)$  as weights at each  $i$  element of the received array with  $i=1, 2, \dots, M_r$ . Reference training sequences are transmitted from AP in 4 pilot tones to estimate the channel matrix  $H_k(n)$ . The location of pilot carriers is :  $l=-21, -7, 7, 21$ . User  $k$  measures subchannel matrix  $H(\nu_k)$  and send it to AP through MIMO channel Measurement frame defined in 802.11n [1].

### C. Downlink Beamforming Optimization

Basic OFDM philosophy is the low cost. Discrete Fourier Transform (DFT) replaces the banks of sinusoidal generators and par consequence

the implementation complexity of modem is reduced. The sub-carriers are not individually filtering nor amplifying. Therefore, the beamformer must multiply by the same complex weights all sub-channels. We treat the problem by transforming the frequency selective channel into a frequency flat channel describing propagation loss and phase shift by  $H(\nu_k)$  with  $\nu_k \in I_{\min}$ . We have assumed that channel impulse response changes at a rate much slower than the transmitted baseband signal. If Rx matrix is  $U(\nu_k)$ ,  $v$   $N_t \times 1$  is the applying beamforming weight vector to  $M_t$  antenna elements then the received power is

$$P(\nu_k) = |U^H(\nu_k)H(\nu_k)v|^2 \quad (4)$$

If the noise is zero mean with variance  $\sigma_k^2$  then noise power is  $\sigma_k^2 \|U(\nu_k)\|^2$ . Given  $U(\nu_k)$ , the pose problem is to generate an optimal downlink beamforming at AP, minimizing at the same time the total transmitted power and guarantying prescribed SNR constraint  $\gamma$  for all users.

$$\begin{aligned} \text{Q} \quad & \min \|v\|_2^2 \\ \text{s.t.} \quad & \frac{|U^H(\nu_k)H(\nu_k)v|^2}{\sigma_k^2 \|U(\nu_k)\|^2} \geq \gamma \\ & \|U(\nu_k)\|^2 = 1 \\ & \forall k \in \{1, 2, \dots, K\} \\ & \forall \nu_k \in I_{\min} \end{aligned}$$

This problem was found NP-hard for general channel vector [6]. In the general case, the constraint  $\text{rank}V = 1$  is not convex. Ignore the associated non convex constraint, the original problem is relaxed to a suitable Semi Definite Programming (SDP) problem. We introduce  $K$  real “slack” variables  $s_k$  and we underline the fact that

the terms in denominator of linear inequalities are all non-negative; we take the relaxation problem R.

$$\begin{aligned} \text{R} \quad & \min \text{trace}(V) \\ \text{s.t.} \quad & \text{trace}(R(\nu_k)V) - s_k = \gamma\sigma_k^2 \\ & V_g \geq 0 \\ & V_g = V_g^H \\ & s_k \geq 0 \\ & \forall k \in \{1, 2, \dots, K\} \\ & \forall \nu_k \in I_{\min} \end{aligned}$$

Problem R can be efficiently solved by any SDP solver, such as SeDuMi [10], based on interior point methods. The relaxed problem R provides only lower bounds on the optimal solution. Our solution  $V_{\text{opt}}$  is not rank-one in general. A randomization procedure (mentioned as rand C in [6]) is employed to generate candidate beamforming  $v$ . The computation cost is negligible. At the beginning SVD is used in  $V_{\text{opt}} = U\Sigma U^H$ . We put  $v = U\Sigma^{1/2}w_g$ , where  $w_g$  is a Gaussian variable with  $w_g \sim N(0, 1)$  to insure that  $E[vv^H] = V_{\text{opt}}$ . From computing feasible points, the vector with minimum  $\|v\|_2^2$  is chosen.

### III. CHANNEL BAND SELECTION

Each WLAN standard defines a set C of fixed number of available channels, using by APs and users.

$$C = \{1, 2, \dots, F\}$$

According to IEEE 802.11a, the available spectrum into UNII band is 300MHz. Thus, 4 indoor, 4 outdoor and 4 indoor or outdoor channels with bandwidth 20MHz is defined. At IEEE 802.11g standard, the available bandwidth is 83.5 MHz in ISM band and 3 indoor or outdoor channels are used [11]. So, for ISM band goes  $F=3$  and for UNII

goes  $F=8$ . Consider a geographical area where there is a set  $A$  of available APs. AP  $a \in A$  has to select an operating frequency channel  $f_a \in C$ . We introduce the interference factor or I-factor, denoted by  $I(f_a, f_b)$  which is defined in [12].  $f_b \in C$  is the interference frequency channel of neighboring AP  $b \in A$ . I-factor can translate as the normalized fraction of power which is transmitted at channel  $f_b$  and is captured from the receiver that works at channel  $f_a$ . In [12], it is showed how we calculate the I-factor; we measure the SINR at receiver with operating frequency  $f_a$  when the transmitting frequency  $f_{TX}$  is  $f_a$  and  $f_b$ .

$$I(f_a, f_b) = \frac{\text{SINR}(f_{TX} = f_b)}{\text{SINR}(f_{TX} = f_a)}$$

If  $P_k(f_b)$  is the interfering power at channel  $f_b$ , measured from user  $k$  when AP  $a$  is silent,

$$\begin{aligned} \text{Int} \quad & \min \|v_a\|_2^2 \\ \text{s.t.} \quad & \frac{|U^H(\nu_k)H(\nu_k)v_a|^2}{\sigma_k^2 \|U(\nu_k)\|^2 + \sum_{f_b} |U^H(\nu_k)H_k(f_b)v_b|^2 I(f_a, f_b)} \geq \gamma \\ & \|U(\nu_k)\|^2 = 1 \\ & \forall k \in \{1, 2, \dots, K\} \quad \forall \nu_k \in I_{\min} \\ & \forall \nu_k \in \{\nu_1, \nu_2, \dots, \nu_K\} \quad \forall f_b \in \{1, 2, \dots, F\} \end{aligned}$$

Equation (3), which finds sub-carrier,  $\nu_{\min}(k)$  is modified as

$$n_{\min}(k) = \arg \min_{n \in I_{SC}} \frac{\sum_{i=1}^{q_k(n)} D_k^2(n)[i, i]}{\sigma_k^2 + \sum_{f_b} |U^H(n)H_k(f_b)u_b|^2 I(f_a, f_b)} \quad (6)$$

$$\forall k \in \{1, 2, \dots, K\}$$

$$\forall f_b \in \{1, 2, \dots, F\}$$

Let's  $P_{TX} = \|v_a\|_2^2$  is the transmitted power of AP  $a$ , computing from problem Int. Our proposed solution focuses on selection a channel  $f_a$  that

$$P_k(f_b) = |U^H(\nu_k)H_k(f_b)v_b|^2 \quad (5)$$

$v_b$  is the  $N_t \times 1$  beamforming weight vector applied to AP  $b$ . In practice, the power  $P_k(f_b)$  is calculated using Dynamic Frequency Selection (DFS) technology. As aforementioned, we estimate the channel  $f_b$  by inserting pilot symbols with known modulation at equal spaced locations in frequency domain. Each user scans for listening every channel at the four pilot tones and measures the Received Signal Strength Index (RSSI). In order to estimate  $P_k(f_b)$ , we average the RSSI of the four pilot tones. These measurements -channel frequency  $f_b$  and interference power  $P_k(f_b)$  - in the vicinity are reported from user  $k$  to AP  $a$ . According to what has been described, problem Q is reformulated as

minimize  $P_{TX}(f_a)$  for all possible operating channels.

$$f_c = \arg \min_{\{f_a \in C\}} P_{TX}(f_a)$$

When the number of users  $K$  is too big, received interference for a few users is strong and/or SINR targets are too high, problem Int can easily become infeasible. In this situation, we remove the user  $k$  with minimum  $\nu_k = n_{\min}(k)$  computing from equation (6).

## IV. PERFORMANCE EVALUATION

### A. Method of evaluation

For validation reasons, we apply the proposed algorithm in a configuration with  $F=4$  channel reuse in 5GHz spectrum. Specifically, the settings correspond to a network that consists of 5 cells non overlapping as in fig. 1. Each cell is represented by a circle radius  $R$  and served by an AP at the centre of the cell. The distance between two AP is  $D=2R+d$ . One possible assignment of four channels to APs is:  $AP_2$  to channel 1,  $AP_3$  to channel 2,  $AP_4$  to channel 3 and  $AP_5$  to channel 4. The channels of neighbouring APs are separated by gaps of 3,2 and 1 intervening channels. Our proposed technique in section III enables self-configuration of channel assignment to AP1 based on measurement of channel conditions in the wireless environment. The goal is to minimize the impact between neighbouring APs on users' performance of AP1 by choosing one of four channels. PHY layer modes in 20 MHz channel width with different coding and modulation schemes are present in table 1 [1]. For bandwidth  $BW=20$  MHz, the noise at the input of receiver is  $N(\text{dBm})=10\log(KT)+10\log BW=-174+73=-101$ .  $K$  is the Boltzmann's constant and  $T=290^\circ$  K is the absolute room temperature. If receiver noise figure is  $NF=6\text{dB}$ , total noise floor is  $N_{\text{floor}}=-101+6=-95$  dBm. Minimum sensitivity for each mode requires minimum SINR equal to  $\text{SINR}(\text{dB})=\text{Sensitivity}(\text{dBm})-N_{\text{floor}}(\text{dBm})$  and is presented in table 2. Consequently, the received SINR constraint are set to  $\gamma=15\text{dB}$  and the additive power noise  $\sigma_k^2=-95\text{dBm}$ . At set-up of fig. 2, the interference signal is an OFDM signal, unsynchronized with regard to reference signal. In table 1, adjacent channel rejection is measured by

setting the desired signal 3dB above the sensitivity of each mode and raising the power interfering signal until 1% Packet Error Rate (PER) is cause for a payload 4095 bytes. Calculations in section III are related to minimum SINR equal to 15 dB. Therefore,

$$I(f_a, f_b) = \begin{cases} 0\text{dB} & \text{for co-channel} \\ -16\text{dB} & \text{for adjacent channel} \\ -32\text{dB} & \text{for other cases} \end{cases}$$

It's important to remark that in IEEE 802.11a, the outer 12 sub-carriers are zeroed in order to reduce adjacent channel interference. Received power and interference power in (4) and (5) is normalized in relation to transmit power. Therefore, it must be multiply by transmitting power of AP equal in our case to 500 mW. Cell radius is consider equal to  $R=100\text{m}$  and distance  $d=2R=200\text{m}$ . The system simulation is implemented within MATLAB environment. APs consist of  $M_t=4$  transmit antenna elements and users of  $M_r=4$ . Antenna array is Uniform Linear Array (ULA) with distance between elements equal to  $\lambda/2$ . IEEE 802.11n channel model B in NLOS conditions is used to simulate channel matrices [13]. Implementation is available from L. Schumacher [14]. Multicast beamforming example is consider for  $AP_1$  to  $AP_5$  with  $K=16$  downlink users for each cell. Due to approximation of numerical results, we realize 100 Monte Carlo runs for different locations of users in the cell of  $AP_1$ . For the interference cells 2 to 5, a constant location is taken. At each location, 107 interpolated samples are collected for a time varying channel due to Doppler effect. If we take the speed of moving scattering environment equal to  $v_o=1.2\text{Km/h}$ , maximum Doppler shift is  $f_m=v_o f/c = 208\text{Hz}$ . Coherence time due to Doppler spread is

$T_c \approx 1/f_m = 40808 \mu\text{s}$ , that is, 1000 times slower than the transmitted OFDM symbol. At each run, 1000 Gaussian randomization samples to solve random C problem are generated.

### B. Simulation results

In our analysis, contention periods and collisions within the MAC operation are eliminated. Fig. 3 shows the average transmitted power in Watt as function of active users for channels 1 to 6. In our network deployment, we remark that the calculated power for channel 1, 2 and 4 exceeds the maximum value of 500mW and par consequence, these channels does not be accepted from 8 to 16 active users. If our standard supports  $F=4$  channels, our algorithm gives for channel 3 average power approximately equal to 0.5W for 12 and 16 active users. If the number of available channels defined by standard is  $F=6$ , then channel 5 or 6 is assigned to  $AP_1$ . Fig. 4 depicts variation in time of transmitted power, calculating for optimum channel 3. In our simulation, we consider that maximum instantaneous power is 2W. The range of emitted power is between 0.4 and 0.7W. Our solution can contribute to reduce non-linearity effect and facilitate the design of RF power amplifier. Let's remember that M-QAM is a linear modulation. Fig. 5 presents the throughput per user when channel 3 with transmitted power 500mW is selected. In this study,  $SNR_k(n)$  for user  $k$  at sub-carrier  $n$  follows Gaussian distribution with mean value computing from simulation for flat frequency channel and standard deviation 3 dB as in [15]. Fig. 6 shows the number of rejected users, when the optimization algorithm for our configuration can not find a feasible solution.

## V. CONCLUSION

In this paper, we have investigated the efficiency of a self-configure algorithm that can be deployed in a multicast IEEE 802.11n AP. The proposed algorithm use local measurement from all interfering WLANs in order to AP selects a channel. We simulate a scenario with strong interference environment. We experience advantages in power efficiency of the power amplifier and bit rate. These advances are related to the use of unlicensed spectrum and multimedia applications.

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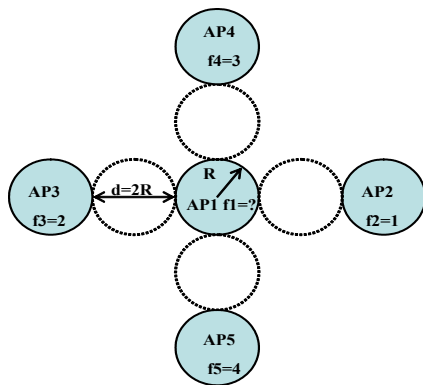


Figure 1 Deployment of a configuration

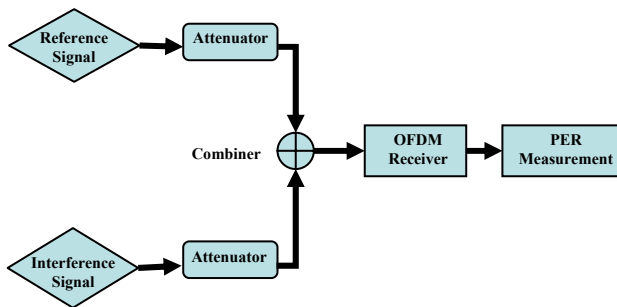


Figure 2 Set-up appointed for adjacent channel rejection

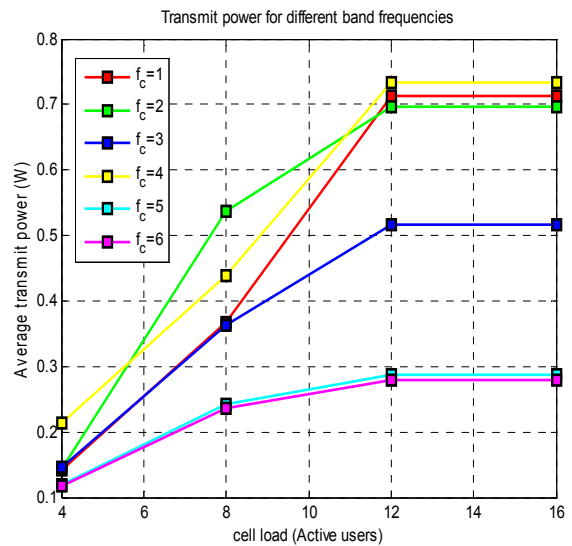


Figure 3 Calculated transmitted power for 6 channels vs number of active users

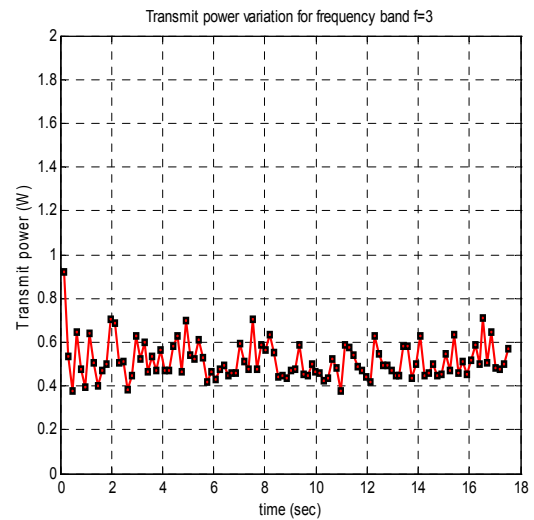


Figure 4 Variation of transmitted power in time

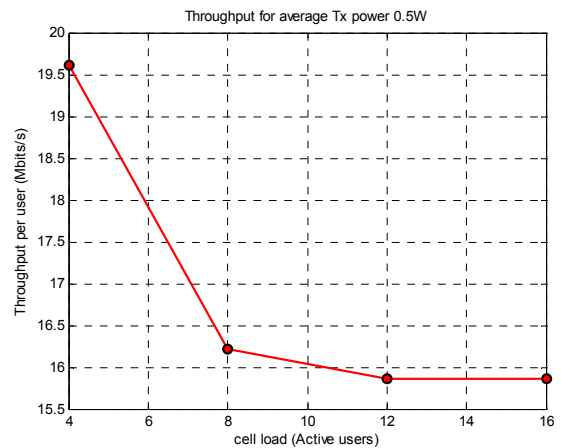


Figure 5 Throughput vs cell load

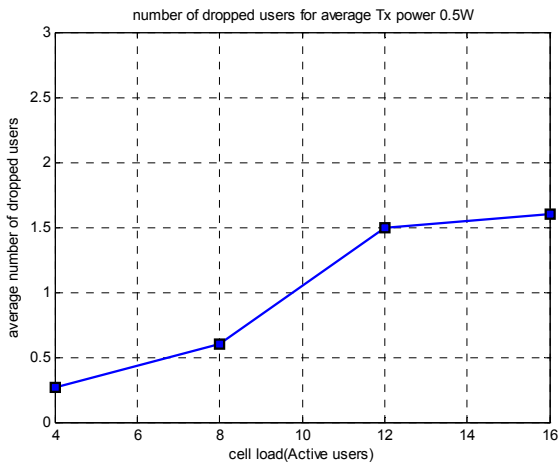


Figure 6 Number of dropped users vs cell loa

TABLE II MINIMUM SINR

Mode	Minimum SNR(dB)
1	15
2	18
3	20
4	23
5	27
6	31
7	32
8	33

TABLE I MODE-DEPENDENT PARAMETERS

Mode	Modulation	Coding rate	Coded bits per sub-carrier	Adjacent channel rejection (dB)	Non adjacent channel rejection (dB)	Minimum sensitivity (dBm)
1	BPSK	1/2	1	16	32	-80
2	QPSK	1/2	2	13	29	-77
3	QPSK	3/4	2	11	27	-75
4	16-QAM	1/2	4	8	24	-72
5	16-QAM	3/4	4	4	20	-68
6	64-QAM	2/3	6	0	16	-64
7	64-QAM	3/4	6	-1	15	-63
8	64-QAM	5/6	6	-2	14	-62