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Modeling and Analysis of Co-Channel Interference for IEEE 802.11 Wireless Local Area Network

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Abstract: With emerging network technologies, internet is used to provide backbone support for communication with each other. In this highly dynamic wireless environment Co-channel interference (CCI) create a constraint in terms of congestion. To maintain quality of service (QoS) in IEEE 802.11, WLAN performance analysis of CCI is necessary. In this paper, we present an analytical model for performance evaluations of the CCI effect in multi access point (AP) WLAN. The AP regions are overlapped to produce CCI effect which forces the network for retransmission of lost data results in congestion in the network. Various performance measures of the proposed scheme such as response time, queue length, probability of loss etc with respect to CCI factor is determined. Computational aspects of the proposed model in terms of graphs are presented.

Keywords: WLAN, CCI, AP, QoS.

I. INTRODUCTION

The upgradation of technology in WLAN makes it possible for deployment of hand held devices in every sector of life. Starting from personal, home, working, office, business and education etc., every sector need to access working of wireless devices through internet. To receive signal devices working in collaboration with wireless network through Access Points (AP). It may happen nearby AP have signal conflict among them due to interference in IEEE802.11WLAN, called as Co-channel interference (CCI) as shown in figure 1. Use of widely accepted collisions avoidance technique like CSMA/CA (carrier sense multiple access with collision avoidance) able to CCI when multiple wireless node share same signal zone. But for a multiple wireless AP areas (dense WLAN) there is a high amount CCI generated through APs and client stations [1]. Due to CCI the performance and QoS (Quality of service) of the network is destroyed. To improve the performance, it need to study the QoS parameters and need to reduce CCI. In IEEE 802.11 WLAN, sometimes channel with other interfering communication transmit data successfully as transmission power exceeds joint interference power. There is a threshold factor called signal-to-interference noise ratio (SINR), which is widely accepted factor for CCI management.

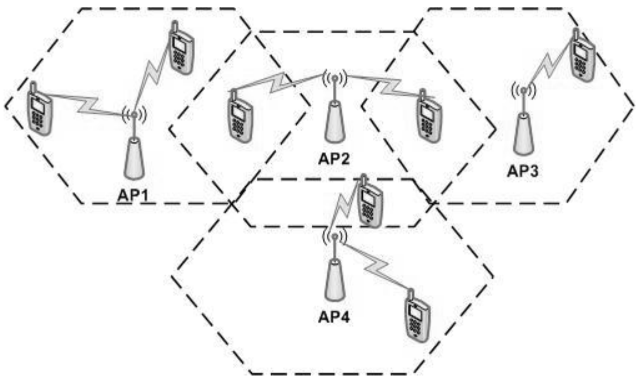

Fig.1. WLAN with multiple AP and devices with CCI

Queuing theory plays an important role in modeling network problem involving congestion. Data packets arrive to certain network device and form a queue. When there is queue, service point and departure process, queuing theory takes its existence [2]. In a WLAN data packets arriving to access points, served and transmitted. If it suffers with CCI, it is allowed to retransmit with the fresh arrival of the data. As a result it causes a huge congestion in the network. Hence it needs to study the performance factors in terms of CCI using queuing theory with all possible channels of a single AP and other surrounding public networks. In this paper we use a M/M/C/N queuing model approach to model our proposed model for IEEE 802.11 WLAN model with CCI.

The rest of the paper is organized as follows. Literature review is given in Section II. We discuss proposed model and methodology description Section III. The performance measures given in section IV. Numerical results in the form of graphs are presented in Section V. Finally section VI concludes the paper.

II. LITERATURE REVIEW

In a wireless LAN Co-channel interference is one of the important factors which affect performance of the network. This happens due to increase reuse of frequency in widely spread wireless system. This happens due to increase reuse of frequency in widely spread wireless system.

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Therefore, reducing co-channel interference is a focused issue in current years. The effect of Co-channel interference in WLAN and the process to minimize it through cognitive radio approach is studied [3].
Here, the interference on data throughput is calculated in a multiple access point environment and minimized by adjusting transmission power.
Geographical division of cells in to more numbers increase the efficiency of frequency reuse but use of seven cell cluster pattern is not sufficient to reduce co-channel interference. By increasing the reuse pattern of frequency, reduce number of channels per cell. Hence, one of the solution to use the same seven cell cluster but with directional antennas with different angle [4].

Channel assignment scheme is a method to overcome Co-channel interference in IEEE802.11 WLAN. An adaptive channel assignment method proposed for uncoordinated environment of access points [5]. During WLAN planning, frequency management based on signal to interference plus noise ratio (SINR) can reduce interference of channels. To compute SINR multiple signals can be taken in to consideration is a proposed approach to reduce co-channel interference [6]. The performance analysis of cooperative diversity network due to Co-channel interference is studied with amplify-and-forward (AF) relaying. Here, SINR is calculated at destination with tight upper bound and probability distribution function is used for determining the effective SINR for co-channel interference [7].

In paper [8] authors proposed a network model and interference model for multiple AP co-channel deployment. Here the channel allocation problem is converted to a time slot problem to mitigate co-channel interference. A vertex coloring algorithm is also used for improving the channel allocation process and the result is established by simulation. Cell sectoring is a method used for reduction of co-channel interference in a wireless cellular network. By increasing number of sector in 120 degree opening per sector reduces the interfering nodes. the model is simulated using Matlab simulation and result is established [9]. Co-channel reduction for multiple input and output system with channel fading is proposed in [10]. In this paper authors used a adaptive variation of diversity scheme by which the power of signal is reduced. it is concluded that for adaptive interference power, the system performance degrades due to dominant interferers. In [11] the performance of AP, Co-channel interference and adjacent channel interference based on IEEE 802.11g is explained. Simulation is done for performance calculation for a dense wireless network. The performance analysis of the WLAN for Co-channel interference with error correcting code is presented in [12]. The bit error rate for cellular network is used access co-channel interference and simulated to get the performance measures. Most of the papers listed above used simulation method to establish the performance measures for CCI. We proposed a mathematical model with CCI and establish the performance indices using queueing theory approach.

III. MODEL DESCRIPTION AND METHODOLOGY

In this section we have proposed a co-channel interference (CCI) model for an overlapped region of access points as shown in figure 1. Increased rate of wireless technologies facilitate the use of multiple devices in a small area (home network), which is a prime cause of CCI. In this proposed model access point regions in a IEEE 802.11 WLAN is considered, where the signal range is overlapped with each other producing a CCI effect. We analyzed the CCI based on queueing theoretic approach. The focus of the model is data packet transmission with CCI at MAC layer of WLANs. Figure 2 shows the state transition diagram using Markov Model for the proposed system with following assumptions.

- Data packets generated in the proposed WLAN model follow a Poisson process with a mean rate λ,
- Co-Channel interference comes with each arrival is η which is a probability factor varies between 0 to 1. For no CCI it is zero and for maximum CCI it is one,
- The packet service time is exponentially distributed with mean rate μ,
- There are C numbers of channels around the AP from public band to process the data packets,
- When arriving packets are more than C, the packets are queued in a buffer with finite size N,
- Hence, packets arriving to the system with CCI have a mean rate λ (1 + η).

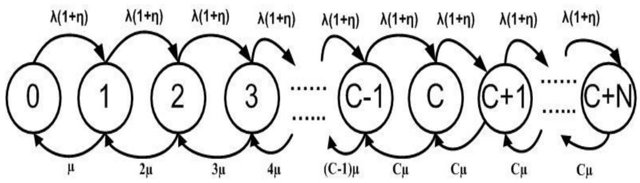

Fig. 2 State transition diagram

With all these above conditions, the state of the proposed model represents form no packets to N number of packets and CCI as η. Using probabilistic argument with respect to figure 2, we obtain the following balance equations:

$$\lambda(1+\eta)P_0 = \mu P_1 \quad (1)$$
$$(\lambda(1+\eta) + n\mu)P_n = \lambda(1+\eta)P_{n-1} + ((n+1)\mu)P_{n+1}, \quad 1 \le n \le c-1 \quad (2)$$
$$(\lambda(1+\eta) + c\mu)P_n = \lambda(1+\eta)P_{n-1} + c\mu P_{n+1} \quad c \le n \le N-1 \quad (3)$$
$$(\lambda(1+\eta))P_{N-1} = c\mu P_N \quad (4)$$

Here, P_n represents the steady state probability that the AP (Access Point) is in the state 'n'. Using birth-death process, the probability distribution P_n is found to be as follows:

$$P_j = \begin{cases} \frac{1}{c!}\left(\frac{\lambda(1+\eta)}{\mu}\right)^n P_0, & 1 \le n \le c, \\ \frac{1}{c!\,(c^{n-c})}\left(\frac{\lambda(1+\eta)}{\mu}\right)^n P_0, & c \le n \le N. \end{cases}$$

The normalizing condition results for the probability sum as:

$$P_0 + P_1 + P_2 + \ldots + P_n = 1$$

The expression for P_0 is obtained as:

$$P_0 = \left[1 + \sum_{n=1}^{c} \frac{1}{c!}\left(\frac{\lambda(1+\eta)}{\mu}\right)^n + \sum_{n=c}^{N} \frac{1}{c!\,(c^{n-c})}\left(\frac{\lambda(1+\eta)}{\mu}\right)^n\right]^{-1}$$

IV. PERFORMANCE MEASURES

By obtaining the state probabilities the following performance measures can be derived as follows:

Number of packets present in the AP for processing is represented as expected system size (Ls)

$$L_s = \sum_{n=1}^{N} \mathrm{nP_n}$$

Data packets enter in queue as AP is busy in sending other packets. The length of the queue is represented as expected queue size (L_q), which is maximum N in size.

$$L_q = \sum_{n=c}^{N} (\mathrm{n}-\mathrm{c})\mathrm{P_n}$$

The time elapsed by the data packets to enter in to service from the time it enter into the system is called expected waiting time in the system (W_s) and time spent in the queue till it got a channel for forwarding is expected waiting time in queue (W_q).

$$W_s = \frac{L_s}{\lambda(1+\eta)}$$

$$W_q = \frac{L_q}{\lambda(1+\eta)}$$

Mean number of data packets in the access point is denoted by 'A' and is derived as:

$$A = \sum_{n=1}^{N} \mathrm{nP_n}$$

Since the data packets entering to the access point is not lost but waiting in the buffer, hence mean response time can be calculated as $E_{[r]}$:

$$E_{[r]} = \frac{\sum_{n=1}^{N} \mathrm{nP_n}}{\sum_{n=0}^{N-1} \lambda(1+\eta)P_n}$$

Similarly, mean waiting time for data packets will be computed as $E_{[w]}$:

$$E_{[w]} = E_{[r]} - \frac{1}{\mu}$$

Due to CCI, large number of packets required to resend which uses more service time at access point. The utilization of AP can be calculated as:

$$U = \frac{\sum_{n=0}^{N-1} \lambda(1+\eta)P_n}{c\mu}$$

The probability that the AP is full with data is given by P_N. For this proposed system data packets are lost fatter buffer is full and the loss probability can be calculated as:

$$P_L = \lambda(1+\eta)P_n$$

V. RESULT AND DISCUSSION

In this section, the numerical results of the proposed model are presented to study the effect of CCI (η) with respect to various performance measures. The characteristics of a loss system when the CCI factor is fixed and allowed incoming traffic load increase is illustrated in Table I.

Table- I: Performance measures for the proposed model

η=0.2					
L_q	0.53643	2.51227	3.63865	4.14309	4.39258
W_q	0.41264	0.96625	0.93298	0.79674	0.67578
$E_{[r]}$	3.03281	3.47711	3.5886	3.70069	3.77382
U	0.5146	0.85668	0.96202	0.98808	0.9955
P_L	0.01037	0.17626	0.38331	0.52496	0.61711
η=0.7					
L_q	1.18222	3.30808	4.11627	4.43196	4.58677
W_q	0.69542	0.97296	0.80711	0.65175	0.53962
$E_{[r]}$	3.46178	3.53755	3.69357	3.78654	3.83974
U	0.6517	0.93758	0.98705	0.99632	0.99867
P_L	0.04161	0.3106	0.51614	0.6337	0.70627

The effect of CCI (η) on expected queue length (Lq) is represented in figure 3. It can be observed that with increased probability of CCI the queue length increases. Due to co-channel interference more number of data packets join with fresh arrival as repeat transmission for the interfered packets. This increases the queue length. Also we can observe that with increased arrival rate of fresh data packets the queue length increases due to accumulation of more data packets at the buffer. Hence, Arrival of fresh data packets is required to be lowered when CCI is more to achieve minimum queue length.

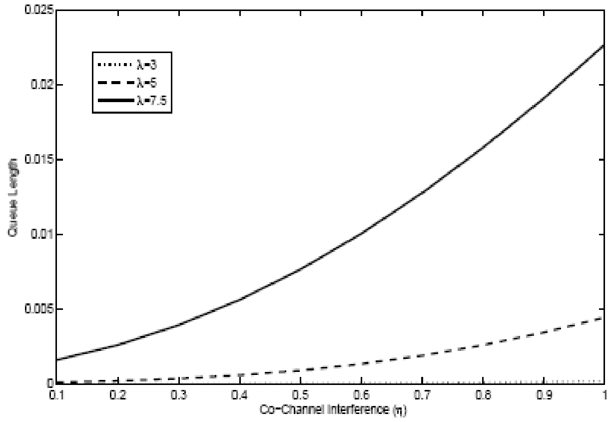

Fig. 3 Expected queue length (Lq) Vs Co-channel interference (η).

Figure 4 illustrates the effect of CCI on expected waiting time in the queue (Wq) for different arrival rate (λ). Upon increased probability of co-channel interference the waiting time for data packets in the buffer increases. When arrival rate for fresh data packets is lower (λ = 3), waiting time shows negligible effect as more number of CCI packets retransmitted using the available channels.

Hence, a tradeoff between arrival of fresh data packets and CCI keeps the waiting time lower in the queue.

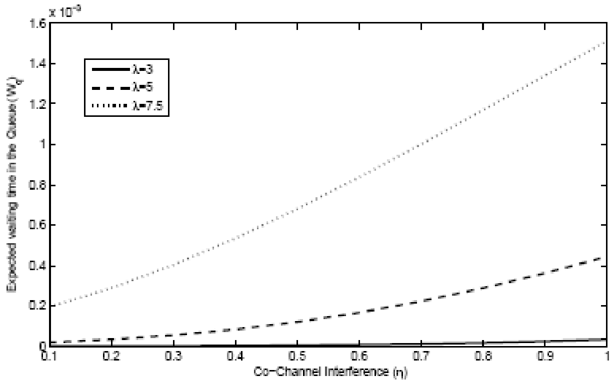

Fig. 4 Expected waiting time (Wq) Vs Co-channel interference (η).

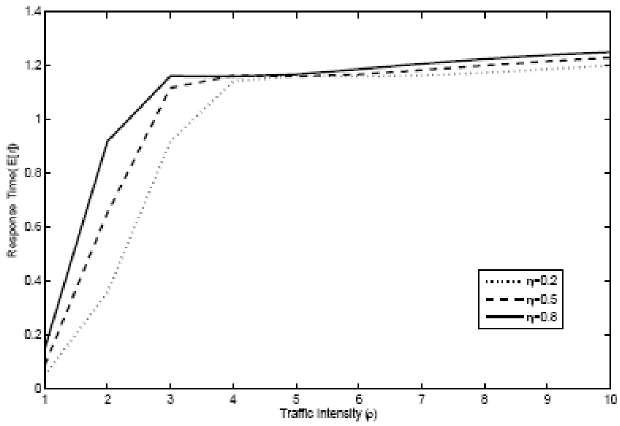

Fig.5 Response time Vs Traffic intensity (ρ).

Figure 5 demonstrates the behavior of response time with respect to traffic intensity (ρ) for different CCI values. It can be seen that increased traffic intensity increases the response time for all values of CCI. Response time is more for higher CCI but after a certain level ($\rho = 4.5$) of traffic intensity response time is almost equal for all level of interference (CCI). Hence, for a lower traffic intensity and higher CCI we get better response time.

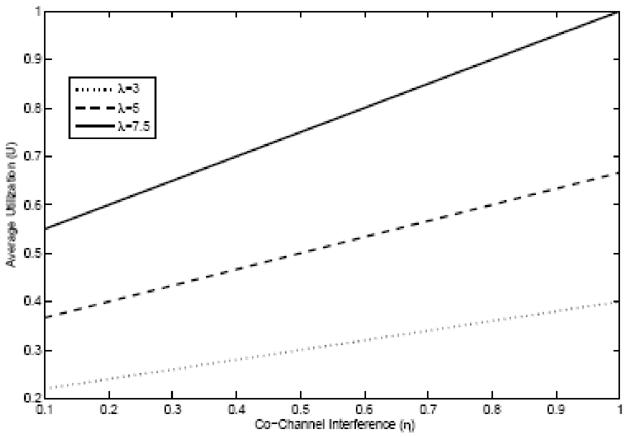

Fig. 6 Average utilization Vs Co-channel interference (η).

Figure 6 depicts the impact of CCI (η) on average utilization of the system for various arrival rates of fresh data packets (λ). We observed that average utilization increases with increased probability of CCI. Further for fixed value of arrival rate (λ), utilization increases when CCI increases. Increased arrival rate accepts more number of data packets and increased CCI forces more packets for retransmission of lost data, results in higher utilization. hence, we can set up an admissible value of fresh and CCI data packets to have maximum system utilization.

As traffic intensity (ρ) increases the impact of (ρ) on probability of loss for various CCI (η) is depicted in figure 7. It can be observed that as (ρ) increases the probability of loss increases monotonically. As channel size and buffer size is fixed, traffic loss happens when channels are occupied in full. In addition to this more value of CCI allows retransmission of lost data packets results loss of data packets. Hence, by varying the value of (ρ) and (η) better performance results can be achieved.

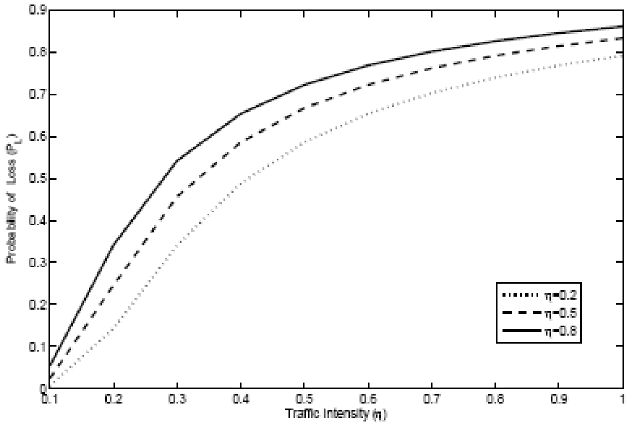

Fig.7 Probability of loss Vs Traffic intensity (ρ).

VI. CONCLUSION

In this paper, we have proposed and evaluated a Co-channel interference model for IEEE 802.11 WLAN. An analytical model based on queuing theoretic approach was developed and performance measures with respect to CCI(η) is derived. The QoS factor in terms of queue length, waiting time, response time, utilization and probability of loss is archived for CCI, and results are presented in terms of graphs. It is shown that the CCI can be reduced by making a tradeoff between fresh arrival rate (λ) and reduced retransmission of lost data (due to CCI).

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