Link Dependence Probabilities in IEEE 802.11 Infrastructure WLANs

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Abstract—**Interference management (RF management) remains one of the main challenges facing the design and deployment of large-scale WLAN. RF management involves the detection, estimation and control of power level, channel allocations and link schedules, to improve the performance of the wireless network. Among interfering links, one can find different types of dependencies. While some of these types can be predicted with relatively low overheads, observing and inferring other types can be a challenging task. In this paper, we ask the question — in WLANs, what is the probability of different types of pair-wise link dependencies? We answer this question by deriving analytical expressions for various types of link dependencies seen in IEEE 802.11 WLANs, numerically evaluating them, and comparing them against simulations.**

Index Terms—**RF Management, Pair-wise Link Dependencies, Infrastructure IEEE 802.11 WLANs**

I. Introduction and Related Work

In recent years, IEEE 802.11 based wireless local area networks (WLANs) have become an ubiquitous presence. Enterprises, residential areas, campuses and commercial hotspots make extensive use of IEEE 802.11 WLANs, to provide low-cost wire-free connectivity to end users. The popularity and commercial success of IEEE 802.11 WLANs continues to grow as reliable high speed variants are produced (for example IEEE 802.11e and IEEE 802.11n standards). The increase in the number of mobile devices, the need for high-bandwidth low-delay communications, and the continuing evolution towards quality-sensitive applications are pushing researchers and engineers alike, to design and implement improved media access control (MAC) for Wi-Fi.

Unlike the management of wired LAN, due to presence of several tunable parameters, such as power levels and multiple channel, wireless LAN management is more complex. Over the past decade, several researchers have studied the anomalies that plague WLAN deployments, and have proposed several WLAN performance management solutions [1], [2], [3], [4], [5]. Co-channel RF interference among wireless links can significantly impact the performance of WLANs [3], [4], [5]. While the default RTS/CTS mechanism in IEEE 802.11 provides a partial solution for the exposed and hidden node problems, it can bring down the throughput by as much as 50% [6]. Therefore, *RF management* remains one of the main challenges faced by modern day WLAN management solutions.

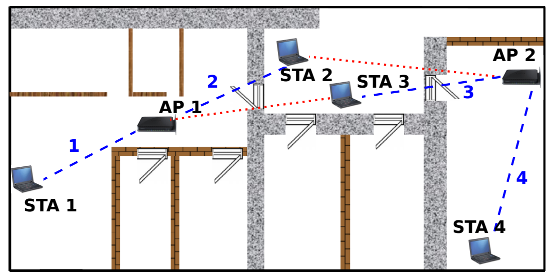

Fig. 1. A scenario with 2 IEEE 802.11 APs and 4 STAs. The dashed lines indicate STA-AP associations, while the dotted lines indicate STA-AP interference.

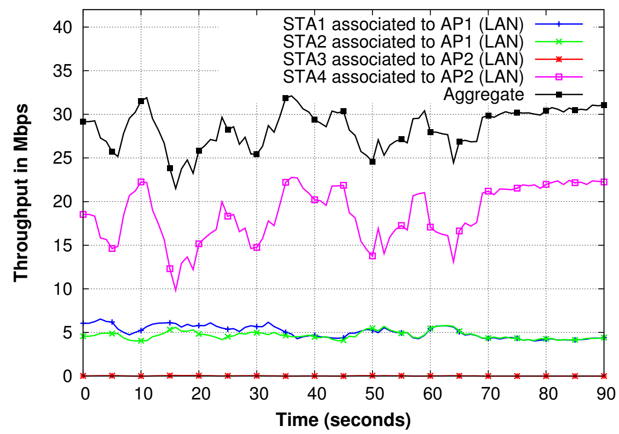

Fig. 2. 2 IEEE 802.11g APs and 4 STAs (experimental setup in Fig. 1): Individual and aggregate throughputs of the STAs.

To demonstrate the adverse effect of RF interference in multi-AP infrastructure WLANs, we perform an experiment on the scenario depicted in Fig. 1. In this experiment, there are four STAs associated with two co-channel IEEE 802.11g APs at a physical rate of $54\,Mbps$, and each STA is downloading a large file from a server on the local area network. Fig. 2 shows the throughputs obtained by the STAs and the aggregate throughput, for the duration of the experiment.

The throughputs obtained by the STAs in Fig. 2 indicates the behaviour of the default IEEE 802.11 DCF. In this scenario, each of the STAs, individually, can obtain a TCP throughput of about $22\,Mbps$. However, with the four STAs contending simultaneously, STA3 obtains a very low throughput (almost zero). STA1, STA2 and STA4 obtain highly variable throughputs of about $17\,Mbps$, $5\,Mbps$ and $5\,Mbps$, respectively. STA2 and STA3 obtain very low throughputs because these are the links "in-the-middle" (exposed nodes). Also, STA1 obtains a highly variable throughput, even though no other STAs interfere with it.

Given a set of wireless links, the link interference estimation problem is to predict whether (and by how much) their aggregate throughput will decrease when the links are active simultaneously, compared to their standalone throughputs [7]. A WLAN with n stations (STAs) can have $O(n)$ links. Even if we consider only testing for pairwise interference, we may potentially have to test $O(n^2)$ pairs. Such group testing requires artificial flows to be injected into the network. This can cause significant overhead; making it infeasible for use in large networks.

Interference detection has also been well-studied in the literature [3], [8], [9], [10]. In [8], [9], [10], the authors infer interference by observing the impact of multiple physical layer RF phenomena on the statistics of higher layer (e.g. NET/MAC layer). In [11], the authors have explored a trace-driven technique in which traces collected from real environment are replayed in a simulator, and the root-cause analysis is done on the simulation playback. In contrast, the authors in [7] propose a simple, empirical estimation methodology to predict pairwise interference that requires only $O(n)$ measurement experiments. Further, from these measurements, the authors construct a *dependence graph* to help them schedule conflict free links. A *dependence graph* is a directed graph representing dependencies of several objects on one another. Formally, the link dependence graph can be denoted by the graph $G(\mathcal{V}, \mathcal{E})$, where $\mathcal{V}$ denotes the set of STA-AP links in the network and $\mathcal{E}$ denotes the set of edges in graph G. For any two links $l_1, l_2 \in \mathcal{V}$, edge $(l_1, l_2) \in \mathcal{E}$ if and only if transmissions from either link interferes with the reception at the other.

Since dependent links interfere with one another, scheduling such links will lead to poor and unpredictable throughputs (see Fig 2). Therefore, it is extremely difficult to predict the performance if interfering links are scheduled. A way to tackle this issue is the classical approach of scheduling *maximal independent* sets of links. A subset of links $\mathcal{I} \subseteq \mathcal{V}$ in which no two links are dependent, and no other link can be added to the set $\mathcal{I}$ without resulting in a dependence is called a *maximal independent set*. It is often observed that predictable and high throughputs can be achieved if one can schedule maximal independent sets [5].

Among dependent links, one can find different types of dependencies [3]. While some types can be easily predicted, observing and inferring others types can be a arduous task. In this paper, we ask the question — in WLANs, what is the probability of different types of pair-wise link dependencies?. The remainder of the paper is organized as as follows. Section II discusses the system model. In Section III, we derive analytical expressions for various types of link dependencies. We compare the analytical expression with simulation results in Section IV. Finally, in Section V, we conclude the paper.

II. System Model

To ensure a desired rate (say atleast r_t Mbps) of association to stations (STAs) in a IEEE 802.11g infrastructure WLAN, we may have to deploy a dense layout of access points (APs), with significant overlaps among their coverage regions.

We consider a hexagonal micro-cellular layout of IEEE 802.11g with a cell radius of R_t and 3 non-overlapping channels (see Fig. 3). Since network architectures based on omni-directional antennas are quite common, we restrict our analysis to WLANs with omni-directional antennas. Let P_t denote the power level required at the receiver, to ensure a target rate of at least $r_t\,Mbps$.

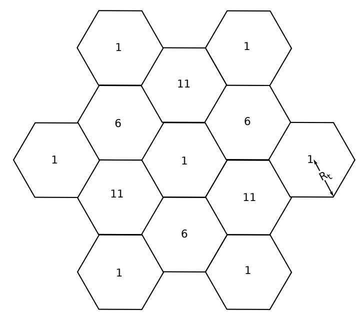

Fig. 3. Hexagonal micro-cellular layout of IEEE 802.11g with cell radius R_t and 3 non-overlapping channels.

Then, the cell radius R_t and the power level P_t are related as follows

$$P_t = S \cdot 10^{\frac{-\xi}{10}} \cdot \left(\frac{R_t}{R_0}\right)^{-\eta} \tag{1}$$

where S is the transmit power, R_0 is the "far field" *reference distance*, η is the path loss exponent and ξ is a Gaussian random variable with mean *zero* and variance σ^2. Let r_{min} be the minimum transmission rate possible. Let P_{min} and R_{min} be the power level and distance at which r_{min} is sustainable. Then, we have

$$P_{min} = S \cdot 10^{\frac{-\xi}{10}} \cdot \left(\frac{R_{min}}{R_0}\right)^{-\eta} \tag{2}$$

Dividing Equation (2) by Equation (1) and rearranging the terms, we obtain

$$R_{min} = R_t \cdot \left(\frac{P_t}{P_{min}}\right)^{1/\eta}$$

Let R_{cs} and R_i denote the carrier sensing and interference range of a wireless device (AP/STA), respectively. It is well known that network capacity is maximized in we have $R_i = R_{rs}$ [12]. Motivated by this, in this paper, we assume $R_i = R_{cs}$ i.e., any node within R_{cs} of a receiver can cause interference and nodes outside the R_{cs} cannot. Further, using the general observations in [13], we can write $R_{cs} = \alpha \cdot R_{min}$, where $\alpha = 2$ for the Energy Detection (ED) mode of carrier sensing, and $\alpha = 1$ for the Preamble Detection (PD) mode of carrier sensing. Thus, the interference region of a node is a disk of radius $R_{cs} = \alpha \cdot \gamma(\eta, P_t, P_{min}) \cdot R_t$ centred at the node itself, where $\gamma(\eta, P_t, P_{min}) = \left(\frac{P_t}{P_{min}}\right)^{1/\eta}$. For ease of analysis, we assume that the interference region is a regular hexagon circumscribing a disk of radius R_{cs}.

III. Dependence Probability

Given an association of stations with access points, we can think of each STA-AP association as a *link*. It is extremely difficult to predict the performance if interfering links are scheduled [5]. Since an access point (AP) can serve only one associated station (STA) at a time, stations associated with the same access point are considered *dependent* on each other. Since TCP provides reliable, ordered and error-checked data delivery between programs running on interconnected computers, TCP transfers constitutes a large fraction of the traffic generated by the STAs. Due to the existence of TCP transfers each end of a link has to serve as a transmitter and a receiver for any TCP connection on that link (due to TCP ACKs), as a consequence of this, link dependence in WLANs with TCP traffic is a symmetric relation.

In this section, we are primarily interested in computing the probabilities of various types of dependencies that can occur in the WLAN deployment scenario shown in Figure 3, in the presence of TCP transfers. Every STA associates with only one AP, hence link dependence can also be called *STA dependence*. Consider two stations S_1 and S_2. Let stations S_1 and S_2 be associated with access points A_1 and A_2, respectively. The APs are located at the centre of a hexagonal cell, and the STA associated with an AP can be located anywhere within the hexagonal cell to which the AP belongs to.

Consider a cell $j_0 \in \mathcal{N}$. Let D_j be the distance between the centres of cell j_0 and cell $j \in \mathcal{N}$. Here, $\mathcal{N}$ denotes the collection of cells deployed as in Figure 3. Consider a wireless device (AP/STA) located in cells j_0 and j, each. The maximum and minimum distances between these wireless devices is $D_j + 2R_t$ and $D_j - 2R_t$, respectively. Thus, if stations S_1 and S_2 belong to cells whose centres are atleast $R_i + 2R_t$ units apart, the stations will not depend on each other. Let

$$\mathcal{I} = \{j \in \mathcal{N} : \nu_j < \gamma(\eta, P_t, P_{min}) + 2\}$$

where $\nu_j = D_j/R_t$. Here, $\mathcal{I}$ represents the set of cells that can be the source for co-channel RF interference. Now, given that the links to STAs S_1 and S_2 interfere with each other i.e., AP A_1 is in cell j_0 and AP $A_2 \in \mathcal{I}$, we ask the question — what is the probability that the interference is of a specific type?

A. Type I dependency (Inter-STA Interference)

In this section, we are interested in interfering STAs that are associated with separate co-channel APs. In such scenarios, the STA experiences interference from a neighbouring STA while it is receiving data from its associated AP i.e., stations S_1 and S_2 are within the interference range of each other, the stations are also outside the interference range of the each others' access points, and the access points do not interfere with each other. This scenario is described in greater detail in [3]. In [3], the authors propose a test to detect inter-STA interference. In the worst case, each STA must perform such a test with every other STAs, causing the overhead of this interference test to be of the order $O(m^2)$, where m is the number of STAs in the deployment. Further, due to the dependence of inter-STA interference on the location of the STAs, in networks with mobile STAs, these tests have be performed at regular interval to accurately capture inter-STA link dependencies.

Let $p_j^{(1)}$ denote the *unconditional probability* that two stations have type I dependency. Let $\mathcal{H}((x,y),R)$ denote a regular hexagon of radius R centred at (x,y). Let the positions of the access points A_1 and A_2 be (x_1,y_1) and (x_2,y_2), respectively. Now, let us define the following

$$\begin{aligned}\Delta_1^j = \{&(x,y) \in \mathbb{R}^2 : (x,y) \in \mathcal{H}((x_1,y_1),R_t),\\ &(x,y) \notin \mathcal{H}((x_2,y_2),R_i), A_1 \in \text{cell } j_0 \text{ and } A_2 \in \text{cell } j\}\\ \Delta_2^j = \{&(x,y) \in \mathbb{R}^2 : (x,y) \in \mathcal{H}((x_2,y_2),R_t),\\ &(x,y) \notin \mathcal{H}((x_1,y_1),R_i), A_1 \in \text{cell } j_0 \text{ and } A_2 \in \text{cell } j\}\end{aligned}$$

i.e., $\Delta_1^j(\Delta_2^j)$ denotes the area outside the interference range of access point A_2 (A_1) and within the hexagonal cell of radius R_t centred at access point A_1 (A_2 resp.), when APs A_1 is in cell j_0 and A_2 is cell $j \in \mathcal{N}$. Let $p_1(x,y)$ and $p_2(x,y)$ denote the probability (density function) that STA S_1 and S_2 is located at (x,y), respectively. The stations are assumed to be uniformly distributed within the regular hexagonal cell with radius R_t, of their associated access points. Thus, we have

$$p_1(x,y) = \begin{cases} \frac{1}{3\sqrt{3}R_t^2/2} & \text{if } (x,y) \in \mathcal{H}((x_1,y_1),R_t) \\ 0 & \text{otherwise} \end{cases}$$

and

$$p_2(x,y) = \begin{cases} \frac{1}{3\sqrt{3}R_t^2/2} & \text{if } (x,y) \in \mathcal{H}((x_2,y_2),R_t) \\ 0 & \text{otherwise} \end{cases}$$

Now, we can compute the probability of type I dependency between stations S_1 and S_2 as

$$\begin{aligned} p_j^{(1)} = \int_{\mathbb{R}^2} \Big(&P[S_1 \text{ is at } (x,y)] \cdot \\ &P[S_2 \text{ interferes with } S_1 | S_2 \text{ is at } (x,y)] \Big)\, dx\, dy \end{aligned} \tag{3}$$

Since station S_2 also has a uniform distribution within its associated hexagonal cell, we have

$$P[S_2 \text{ interferes with } S_1 | S_2 \text{ is at } (x,y)] = \frac{Area(\mathcal{H}((x,y),R_i) \cap \Delta_2^j)}{3\sqrt{3}R_t^2/2}$$

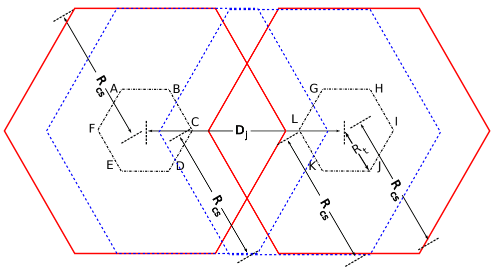

Fig. 4. ***Case 1:*** $D_j - 2R_t \leq R_i < D_j - R_t$. The red solid line denotes the interference range of the APs, the blue dashed line denotes the interference range of the STAs.

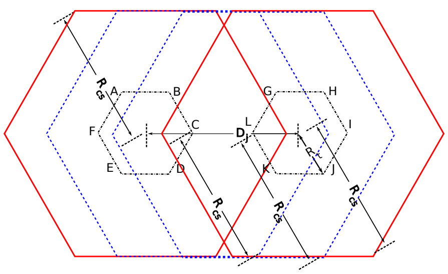

Fig. 5. ***Case 2:*** $D_j - R_t \leq R_i < D_j$. The red solid line denotes the interference range of the APs, the blue dashed line denotes the interference range of the STAs.

where $Area(\mathcal{X}), \mathcal{X} \subset \mathbb{R}^2$ denotes the area of the region in $\mathbb{R}^2$. Thus, integral (3) reduces to

$$p_j^{(1)} = \frac{4}{27R_t^4} \int_{\Delta_1^j} Area(\mathcal{H}((x,y),R_i) \cap \Delta_2^j)\, dx\, dy \qquad (4)$$

Case 1 (Fig. 4): $D_j - 2R_t \leq R_i < D_j - R_t$, or equivalently $\nu_j - 2 \leq \gamma(\eta, P_t, P_{min}) < \nu_j - 1$. In this scenario, we can rewrite integral (4) as

$$p_j^{(1)} = \frac{4}{27R_t^4} \int_{\Delta} Area(\mathcal{H}((x,y),R_i) \cap \mathcal{H}((x_2,y_2),R_t))\, dx\, dy \qquad (5)$$

where $\Delta = \mathcal{H}((x_1,y_1),R_t) \cap \mathcal{H}((x_2 - R_t, y_2), R_t)$. After some geometric constructions, integral (5) becomes

$$p_j^{(1)} = \frac{2}{9\sqrt{3}R_t^4} \int_0^{R_i+2R_t-D_j} \int_0^{R_i+2R_t-D_j} xy\, dx\, dy$$

$$= \frac{1}{18\sqrt{3}} \cdot \left(\frac{R_i - D_j + 2R_t}{R_t}\right)^4$$

Substituting for R_i and D_j in terms of R_t, we obtain

$$p_j^{(1)} = \frac{1}{18\sqrt{3}} \cdot (\gamma(\eta, P_t, P_{min}) + 2 - \nu_j)^4$$

Case 2 (Fig. 5): $D_j - R_t \leq R_i < D_j$, or equivalently $\nu_j - 1 \leq \gamma(\eta, P_t, P_{min}) < \nu_j$

For this case, we evaluate integral (4) by splitting Δ_1^j and $\mathcal{H}((x,y),R_i) \cap \Delta_2^j$ into non-overlapping area. After some inferences based on geometry and calculus, we get

$$p_j^{(1)} = \frac{1}{9\sqrt{3}} \cdot \left(1 - \left(\frac{R_i - D_j + R_t}{R_t}\right)^4 - \frac{1}{2} \cdot \left(\frac{D_j - R_i}{R_t}\right)^4\right)$$

$$+ \frac{1}{54} \cdot \left(\frac{R_i - D_j + R_t}{R_t}\right)^4$$

Substituting for R_i and D_j in terms of R_t, we obtain

$$p_j^{(1)} = \frac{1}{9\sqrt{3}} \cdot \Big(1 - (\gamma(\eta, P_t, P_{min}) + 1 - \nu_j)^4$$

$$- \frac{1}{2} \cdot (\nu_j - \gamma(\eta, P_t, P_{min}))^4\Big) + \frac{1}{54} \cdot (\gamma(\eta, P_t, P_{min}) + 1 - \nu_j)^4$$

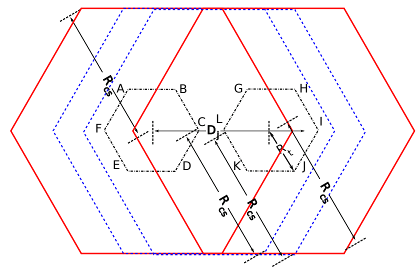

Fig. 6. ***Case 3:*** $D_j \leq R_i$. The red solid line denotes the interference range of the APs, the blue dashed line denotes the interference range of the STAs.

Case 3 (Fig. 6): $D_j \leq R_i$, or equivalently $\nu_j \leq \gamma(\eta, P_t, P_{min})$. In this case, the access points are within interference range of each other. Thus, in this scenario, it is impossible to have just *STA-STA* dependency between stations S_1 and S_2, and we have $p_j^{(1)} = 0$.

B. *Type II dependency (Inter-AP interference)*

If the interference range of one AP (say AP A_1) covers another AP (say A_2), then AP A_1 will suffer interference from transmissions of AP A_2. This is termed as *inter-AP* interference. The authors in [3] also propose a test for detecting inter-AP interference. Since each AP has to perform this test, the total number of tests required to detect inter-AP interference grows as $O(|\mathcal{N}|)$, where $|\mathcal{N}|$ is the number of APs in the deployment. Also, inter-AP interference are almost time invariant, and depend only on the location of the APs. They can be evaluated after deployment of the APs and stored for future reference.

In this section, we find the probability of type II dependency between two stations S_1 and S_2 i.e., APs A_1 and A_2 interfere with each other. Let $p_j^{(2)}$ denote the *unconditional probability* that two stations have type II dependency. The computation of type II dependence probability can be split into two simple cases as below.

Case 1 (Fig. 4 and Fig. 5): $D_j - 2R_t \leq R_i < D_j$, or equivalently $\nu_j - 2 \leq \gamma(\eta, P_t, P_{min}) < \nu_j$. In this case, the co-channel access points are out of each others interference range. Thus, $p_j^{(2)} = 0$

Case 2 (Fig. 6): $D_j \leq R_i$, or equivalently $\nu_j \leq \gamma(\eta, P_t, P_{min})$. In this case, the co-channel access points are within each others interference range. Thus, $p_j^{(2)} = 1$

C. *Type III dependency (Inter-Cell Interference)*

In this scenario, access points of stations S_1 and S_2 do not interfere with each other. Station S_2 is within the interference range of access point A_1 or station S_1 is within the interference range of access point A_2. Since the AP is hidden from the STA in such scenarios, packets sent by the hidden AP will be suppressed due to contention, and packets destined to the STAs associated to the hidden AP will collide with packets transmitted from the interfering STA. To detect such dependencies, the authors in [3] propose a test whose overhead grows as $O(m)$.

In this section, we find the probability of type III dependency between two stations S_1 and S_2. Let $p_j^{(3)}$ denote the *unconditional probability* that two stations have type III dependency.

Case 1: $D_j - 2R_t \leq R_i < D_j - R_t$, or equivalently $\nu_j - 2 \leq \gamma(\eta, P_t, P_{min}) < \nu_j - 1$. In this case, the interference region of the access points do not overlap. Therefore, in this case, type III dependency cannot occur i.e., $p_j^{(3)} = 0$

Case 2: $D_j - R_t \leq R_i < D_j$, or equivalently $\nu_j - 1 \leq \gamma(\eta, P_t, P_{min}) < \nu_j$. For this case, we have

$$p_j^{(3)} = 1 - P[\text{Access point } A_1 \text{ does not interfere with station } S_2 \text{ and access point } A_2 \text{ does not interfere with station } S_1]$$

By applying augments based on the geometry of the deployment, it can be shown that

$$\begin{aligned} p_j^{(3)} &= 1 - \left(1 - \frac{\sqrt{3} \cdot (R_i + R_t - D_j)^2/2}{3\sqrt{3}R_t^2/2}\right)^2 \\ &= 1 - \left(1 - \frac{1}{3} \cdot (\gamma(\eta, P_t, P_{min}) + 1 - \nu_j)^2\right)^2 \end{aligned}$$

Case 3: $D_j \leq R_i$, or equivalently $\nu_j \leq \gamma(\eta, P_t, P_{min})$. In this case, the access points interfere with each other. Thus, we do not have type III dependency i.e., $p_j^{(3)} = 0$

D. Final probability expression for each type of dependency

Let us define an indicator variable as follows:

$$I^j(S_2) = \begin{cases} 1 & \text{if station } S_2 \in \text{cell } j \\ 0 & \text{otherwise} \end{cases}$$

Let $E^{(i)}$ and $q^{(i)}$ denote the event and probability of type $i \in \{1, 2, 3\}$ dependency between stations S_1 and S_2 conditioned on the event that STA S_2 belongs to a cell in the set $\mathcal{I}$. Then, we have

$$\begin{aligned} q^{(i)} &= P[E^{(i)}|S_2 \in \mathcal{I}] = \sum_{j \in \mathcal{I}} P[E^{(i)}, I^j(S_2) = 1|S_2 \in \mathcal{I}] \\ &= \sum_{j \in \mathcal{I}} P[E^{(i)}|I^j(S_2) = 1] \cdot P[I^j(S_2) = 1|S_2 \in \mathcal{I}] \\ &\overset{(a)}{=} \frac{1}{|\mathcal{I}|} \cdot \sum_{j \in \mathcal{I}} p_j^{(i)} \end{aligned}$$

where equality (a) follows due to the assumption that STAs are uniformly distributed within the area of deployment.

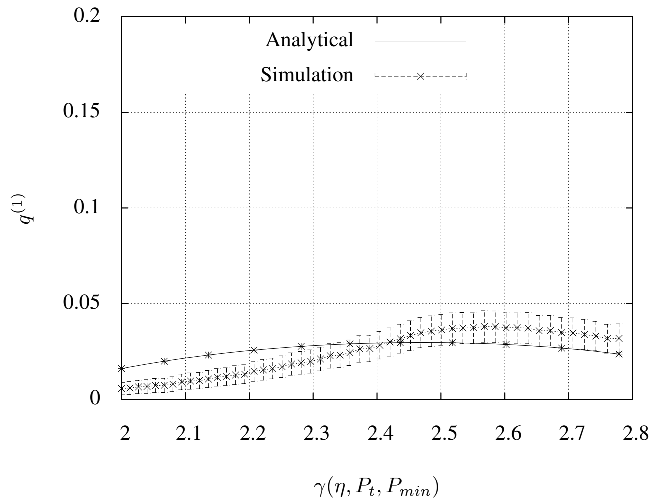

Fig. 7. Variation of $q^{(1)}$ as a function of $\gamma(\eta, P_t, P_{min})$, when P_t is varied from $-90\,dBm$ to $-80\,dBm$; confidence interval is 95% .

IV. Simulation and Numerical Validation

In this section, we compare analytical and simulated values of different types of link dependence probabilities. To compute the various probabilities, we perform Monte Carlo simulations with 100 cell Hexagonal micro-cellular layout (see Fig. 3) and 1000 STAs. An AP is placed at the centre of every cell in the hexagonal layout, and the 1000 STAs are uniformly distributed in the deployment area. We also relax the assumption of hexagonal regions by replacing every region with their corresponding inscribed circular counterparts. The number of simulation runs was 10^6. For the simulations, η and α where chosen as 3.5 and 1, respectively. The results of simulations are presented in Table I, Fig. 7 and Fig. 8.

TABLE I

Table showing the probability of various dependence against various values of r_t

r_t (P_t)		$q^{(1)}$	$q^{(2)}$	$q^{(3)}$
12 Mbps (-85 dbm)	Analysis	0.0236	0	0.182
	Simulation	0.0318	0	0.085
1 Mbps (-90 dbm)	Analysis	0.0160	0	0
	Simulation	0.0056	0	0

From Table I, we can see that the analytical and simulation values of conditional *type I link dependence* probability i.e., $q^{(1)}$ are close to each other. Whereas, the simulation values of conditional *type III link dependence* probability i.e., $q^{(3)}$ is upper bounded by its analytical counterpart. The same can be inferred from Fig. 7 and Fig. 8.

In the simulations, the interference region is a circular disk. However, for tractability, in analysis, we have assumed the interference region to be hexagonal. While the assumption of hexagonal regions resulted in closed form expressions for the probabilities, it leads to larger interference regions. Thus, the

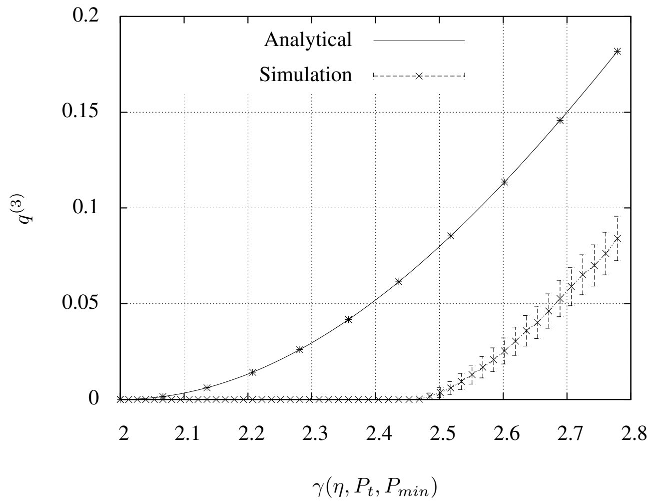

Fig. 8. Variation of $q^{(3)}$ as a function of $\gamma(\eta, P_t, P_{min})$, when P_t is varied from $-90\,dBm$ to $-80\,dBm$; confidence interval is 95%

analysis consistently overestimates the probability of *type III dependencies*.

V. Conclusion

RF management is one of the main challenges in WLAN management. RF management involves detecting, estimating and controlling the power level, allocating channel and scheduling links in the wireless network. Among dependent links, one can find different types of dependencies. Inferring STA-STA dependencies contributes a substantial amount of overhead (grows as $O(m^2)$). Also, due to the mobile nature of the STAs, the tests for inferring STA-STA dependencies need to be performed at regular intervals. In this paper, through analysis and simulation, we have shown that *Type I dependencies* can be ignored as the probability of just STA-STA dependence in multi-AP deployment is negligible. *Type II Dependencies* are time invariant, and depend only on the location of the APs. Therefore, they can be are evaluated after deployment of the APs, and stored for future references. Therefore, we need to be concerned only with *Type III dependencies*, which can be inferred using only $O(m)$ tests [3].

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