



## Estimation of Interference in Wi-Fi Networks

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**Abstract**— *Interference is a troublesome issue that affects the throughput performance of Wi-Fi networks. Therefore it becomes crucial to estimate the interference between nodes and links of a wireless network. This approach includes passive monitoring of traffic which consists of placing multiple sniffers near network nodes to capture the wireless traffic. This traffic is analyzed to conclude about the carrier-sense relationship between nodes by using a machine learning approach. This combined with an estimation of collision probabilities helps us to arrive at the interference relation-ships. The main focus of work is to 1) identify instances when the two nodes attempt to simultaneously transmit, and 2) conclude the deferral behaviors during such instances. This paper offers an overview of the different techniques of measurement-based modeling and estimation of interference associated with wireless networks.*

**Keywords** — 802.11 wireless network, Wi-Fi Interference, Carrier-sensing interference, interference model, receiver interference.

### I. INTRODUCTION

The deployment of IEEE 802.11-based wireless networks is common at offices, educational institutions and homes. The main reason for its popularity is because it removes the need for wires and the ease of access to internet through mobile devices. In spite of these advantages, the problem of interference cannot be overlooked, in which one sender-receiver pair affects the other pairs. A WLAN network might be working fine one day and sluggish the next day, without the user having made any network changes, all due to interference. Interference is the major cause in performance degradation of the wireless networks. Therefore it becomes crucial to understand and manage interference. This also helps in channel assignment [13], network diagnosis [15], routing, transport protocols and capacity planning.

The problem of estimating interference among links in a wireless network is a challenging one and it can be described informally as below: If a set of wireless links is given, determining whether (and by how much) their aggregate throughput will decrease in two cases. First, when all the links are active simultaneously and second, when they are active individually. Comparing both these cases will lead to the conclusion. To improve the performance of the wireless network, the information of which links in the network interfere with one another, and to what extent, is important [3]. The major cause of interference is the co-channel interference or adjacent channel interference which results from assigning radios to bands that have overlapping channels as illustrated in the Fig. 1. The channels might not all be in use by the network—neighbouring company signals can also cause interference. Interference can occur at the sending or the receiving node. The sending interference can also be termed as carrier-sense interference which affects the sender nodes by reducing their transmission rates. The receiver interference leads to collisions due to overlapped packet transmissions at the receiver nodes and hence in the achievable throughput [4].

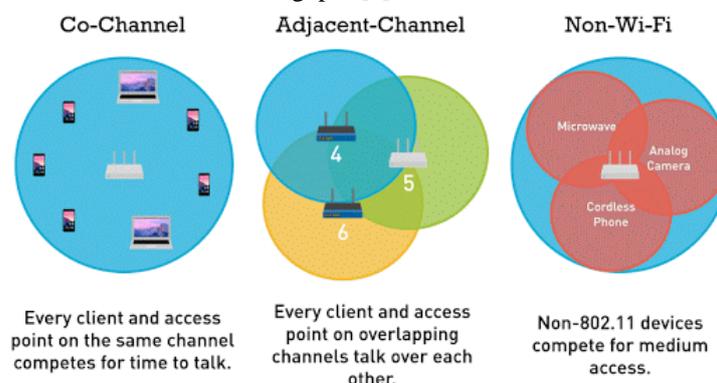


Fig. 1 Types of interferences in Wi-Fi networks [9]

The reduction of the throughput of the network due to interference made researchers work and propose models for the same. The rest of this paper is organized as follows: In next section, Section II addresses the related work. In Section III, the proposed work has been described. Finally, section IV i.e. conclusion summarizes the paper.

## II. RELATED WORK

### A. A Measurement-based Model of Delivery and Interference in Static Wireless Networks

Charles Reis, et.al [1] present practical models for physical layer behaviours of packet reception and carrier sense with interference in static wireless networks. The inputs to these models are measurements from a real network. The basic idea is to perform measurements in an N-node network with N trials. Each sender transmits in turn and receiver's measure RSSI values and packet counts which are easily achievable with the help of wireless cards. The low-level models for packet reception and carrier sense are formulated by considering to the conventional idea of SINR (signal to interference plus noise ratio) [5]. The 802.11 characteristics are investigated, both in a controlled setting with attenuators built on a network. Packet delivery and interference are predicted by the models for different sets of transmitters with similar node placements.

In the first section of studying wireless characteristics, the received signal strength (RSS) values obtained from wireless cards and which is defined to be  $S + I$ , is used in predicting packet delivery probabilities. The nature of external interference is also considered to have a measurable effect on packet delivery across multiple nodes. The other factor that is that the wireless networks change their behaviour from time to time. This is taken in consideration because it allows the user to determine how far into the future a set of measurements can be used to make predictions. Thus it can be said that the measurement-based model is checked for stability across time in order to be effective. The PHY models for wireless delivery with interference are developed by recasting the traditional SINR in terms of the obtained measurements [6]. To predict the performance of a static wireless network, these PHY models are collated with higher layer models such as the MAC model.

The operation of the model is as follows:

1. The network RF profile is measured. Every N sender in the network broadcasts packets whereas the other nodes keep a record of the number of packets received in addition to the RSS values, forming  $N^2$  data points. The measurements considered are special-purpose traffic and not the traditional application traffic.
2. The PHY receiver model along with the RF profile is used to compute the probability of a packet being correctly received from a given sender in the presence of competing transmissions.
3. The PHY deferral model along with the RF profile is used to compute the probability about a sender sensing competing transmissions and deferring its own transmission.
4. To predict the performance of the network, MAC and traffic models are used which are built on PHY models, in a specific configuration. MAC models follow higher-layer protocol rules, e.g. CSMA/CA. The nodes which compete to send packets at the same time with different power levels but same transmit rate and packet size are specified by the traffic models.

### B. A General model of the Wireless Interference

Lili Qui, et.al [2] develops a general model in the presence of interference from other nodes in the network which estimates the throughput between arbitrary pairs of nodes. The measurements required for the model are taken from the underlying network to be more accurate compared to the abstract RF propagation model. This model proposed in this paper is advanced in three different ways. First, it does not consider the traditional pairwise interference but takes into consideration the interference between an arbitrary numbers of senders. Second, it models unicast transmission which is common in addition to broadcast transmissions. Third, it considers modelling the general heterogeneous nodes with varying radio characteristics and traffic demands. The proposed model in this paper consists of three components:

1. An N-node Markov model – To capture interactions among a random number of broadcasting senders. This model is simple and provides accurate approximation to the 802.11 distributed coordination function (DCF). It supports multi-hop wireless networks, asymmetric link quality, unsaturated demands and non-binary interference relationships.
2. A model of packet-level loss rates – Depending on how losses are generated, the packet-level and the slot-level loss rates are different. The packet-level loss rates significantly increase beyond the slot-level loss rates because of the hidden terminals. Based on the above, both the synchronized and unsynchronized packet-level collision losses are captured by the receiver model.
3. Sender and Receiver models with unicast transmissions - Extensions are applied to the broadcast version of sender and receiver models to capture the interactions of unicast transmissions. Two important extensions are developed for this purpose. First extension models the exponential backoff and retransmissions at the sender side and the second extension models the data/ACK, data/data and ACK/ACK collision losses at the receiver side.

The model in this paper takes RF profile and traffic demands as inputs and provides the sending and receiving rates of each node as output. Such a model facilitates network optimization and proves useful for performing what-if-analysis [8]. The concept of one-hop traffic is focused in this paper, which is the traffic sent over only one hop and not routed further. This helps to achieve estimation of end-to-end throughput over multihop paths. The operation of the model is as follows:

1. Measuring RF profile of the network which comprises of allowing each sender to broadcast and have the other nodes measure the loss rates and RSSI values. From these measurements, the RSSI values and the background interference due to external sources are recovered.
2. Applying the sender model and receiver model to estimate the amount of traffic sent by each sender under the given demand and the amount of traffic successfully received respectively.
3. Estimating the parameters of throughput for saturated broadcast demands by computing the stationary probabilities of a Markov model.

4. Estimating the unknown variables of the transition matrix of the Markov model for unicast demands or unsaturated broadcast demands.
5. Applying an iterative framework wherein unknown variables are initialized in the transition matrix and then the stationary probabilities are computed, which finally update the transition matrix.

**C. Estimation of Link Interference in Static Multi-hop Wireless Networks**

Jitendra Padhye, et.al [3] propose a simple empirical estimation methodology that can predict pairwise interference using few measurements. This method can be applied to any wireless network having omnidirectional antennas. The metric defined in this paper to measure interference is link interference ratio (LIR). Assumptions include the IEEE 802.11 protocol for the communication between nodes, the parameters such as data rate; transmit power values set to fixed values. The wireless links are defined using the packet loss rate. LIR is defined to be the ratio of aggregate throughput of the links when they are active simultaneously, to their aggregate throughput when they are active individually. This metric takes values between 0 and 1. The value of LIR when 1 indicates that the links do not interfere because the aggregate throughput does not decrease inspite of both the links being active at the same time.

To estimate the impact of carrier sensing and collision of data packets [14], they have experimented wherein a node is allowed to broadcast packets at a fast rate. Only this node should be active at that particular time. The delivery rate of packets at all receiver nodes is tracked. In a similar way, let each node broadcast in turn. Then, a pair of nodes is selected and allowed to broadcast simultaneously. The delivery rate of packets from each of the two broadcasting nodes is again measured at all the remaining nodes. Similarly, each pair broadcasts in turn. This way, a total of  $O(n^2)$  experiments are carried out. With the data collected by the above method, the metric broadcast interference ratio (BIR) is defined. BIR is the ratio of the combined delivery rates to the individual delivery rate i.e. the total delivery rate with a pair of nodes as the sender to the delivery rate with a single node as the sender.

The supposition is that the BIR is a good approximation of LIR. There are many reasons for their hypothesis to be true because the impact of carrier sensing on the two senders is well captured by BIR. In addition to it, the impact of data packet collisions at the receivers is also captured. This methodology also assists in determining why two links interfere with one another. This is demonstrated by considering a broadcast experiment. Two nodes broadcast packets simultaneously as well as individually i.e. one at a time. Considering the ratio of their send rates, when they were broadcasting together to when they were broadcasting alone. This ratio is called as carrier sense ratio (CSR). Both the nodes are sending packets at the same data rate. When two senders are within the range of each other, then only one of them would be able to send at a time which results in a CSR value of 0.5. As opposed to this, if the senders are not within the each other's carrier sense range, CSR will be 1. Although intermediate values can result from signal strength variations, noise and other factors.

**D. A Systematic Evaluation of Interference Characteristics in 802.11-based wireless Networks**

According to Wee Lum Tan, et.al [4] interference is a main factor that affects the overall performance of wireless networks. Understanding interference is necessary for the efficient operation of these networks. To evaluate the impact of interference in terms of the sender and receiver interference, they have used a conducted test bed that allows controlling the received signal strength and signalling propagation. They prove that the carrier-sense interference cannot be modelled using the binary model of "either carrier-sense or no carrier-sense". When considering the receiver interference, the results show that the interference impact on a data link's throughput is approximately linear with respect to the offered load of the interferer node. Although, it is non-linear with respect to the offered load of the data sender. In short, this paper shows that the commonly made assumptions of interference models are not valid and thus show the limitations of the corresponding models.

This paper does not propose any model but investigates the carrier-sense interference and receiver interference. The carrier-sense interference can be defined as the reduction in a node's sending rate due to interference caused by a competing sender. In the experiment conducted two nodes i.e. a sender and interferer node is connected via an attenuator as shown in the Fig. 2. Both the nodes are allowed to broadcast traffic and the respective sending rates are measured. Their results show that there exists an "interference gray zone" [10] and thus carrier-sensing interference [11] cannot be modeled as a binary process.

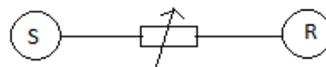


Fig. 2 Carrier-sensing interference topology [4]

The receiver interference is generally a result of packet collisions that take place at the receiver node due to the parallel transmissions from a sender node and the interferer node. The experiment conducted here involves the topology as shown in Fig. 3.

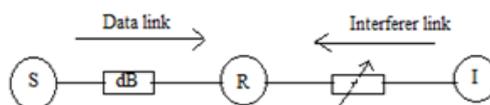


Fig. 3 Receiver-side interference topology

The sender node is unaware of the presence of interferer node i.e. they do no carrier-sense each other and therefore are able to transmit concurrently. The sender node is connected to receiver node via an attenuator having fixed value. The value is

chosen such that results in a good quality link between the sender and the receiver node. The interferer node is connected to the receiver node via a variable attenuator. The attenuation value is varied to vary the link's effective path loss and the interferer node's signal strength that is received at the receiving node. Their results indicate that while the impact of interference is approximately linear with respect to the offered load of the interferer node, its relationship with respect to the offered load of the sender node is non-linear.

### III. PROPOSED APPROACH

This paper presents a technique to estimate the interference between nodes by passive monitoring of wireless traffic. Sniffers are deployed to gather the traffic traces in a wireless network. The traffic traces collected are then merged using merging techniques and a machine learning-based approach is used to analyse the merged trace to conclude about the interference relationships [12]. Fig. 4 shows the overview of the approach. In particular, this approach determines for each node, which other nodes it interferes with, along with the extent of interference. The sender-side interference relation can be used to detect the selfish behaviour of nodes.

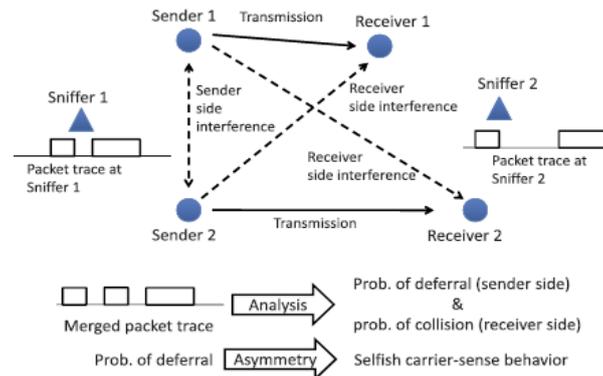


Fig. 4 Overview of the approach [12]

The main requirement of this technique is the sufficient amount of network traffic. The application of this technique is to understand the interference characteristics for radio resource management and to detect the selfish behavior of nodes in an arbitrary Wi-Fi network. In 802.11 based networks, the occurrence of interference can take place either at sender side or at the receiver side. The sender-side interference leads to deferral due to carrier sensing. As the node senses the other node's transmission, it freezes its backoff counter and waits for the transmission to take place. At the receiver-side, collisions are caused due to overlapped packet transmissions. As a result, packet retransmissions are needed. Both the cases cause the sender to go through a backoff period. Thus, the total effect of interference is reduction in the throughput capacity of the network.

This paper considers only the node or link pairs for modelling convenience. However, the physical interference can be captured where a given link is interfered collectively by a set of other links, and not by a single link. This is possible due to the additive nature of the received power. Pairwise consideration is also crucial in practice because in reality, the probability of having multiple parallel transmissions is very small inspite of many active flows in the network. In wireless networks, the best way to express interference is in terms of probabilities due to the fluctuations of the signal power as a result of fading. For the estimation of interference between node pairs, this technique requires to have instances of two nodes attempting transmissions simultaneously. The goal is to identify such instances and conclude about the deferral behaviours during such instances.

The approach involved in this paper uses Hidden Markov model for modeling the interactions between a pair of senders in an 802.11 network and then the sender-side interference relations are inferred. Each sender node in 802.11 MAC protocol can be modeled as a Markov chain. A node is found in any of the following four states – “idle”, “defer”, “backoff”, and “transmit”. A combined Markov model is used where each state is a tuple consisting of states of individual nodes. Transitions into any state with one of the states being a defer state indicates interference. The deferral probability  $p_d$  is given as:

$$\frac{P(D,T) + P(T,D)}{P(D,T) + P(T,D) + P(B,T) + P(T,B) + P(T,T)} \quad (1)$$

The above equation indicates the probability of being in the interfering states when one of the two nodes is transmitting. The receiver side interference leads to collisions that can be easily detected by tracing the retransmissions. The identification of retransmitted packets is done by observing the set “retransmit bit” in the frame header. A retransmitted frame is correlated to its original frame as both these frames carry the same sequence number. Collision occurs when the original frame overlaps with the frame sent by another sender node. As opposed to this, if the original frame does not overlap any other frame, the packet loss is due to the wireless channel errors and not the collision. Thus, the probability of collision  $p_c$  can be given as the ratio of the collision count to the overlapped- frame count [12].

### IV. CONCLUSION

This paper presents the various existing techniques for estimation of interference in Wi-Fi networks. This estimation of interference proves to be important for efficient network design and capacity allocation. Different limitations in the

techniques in the past have led researchers to work on this topic for improvement in this field. The proposed method helps us in understanding and estimates the sender and receiver side interferences in terms of deferral and collision probabilities respectively. Although, this is accomplished considering only a pair of nodes, the overall estimation of the physical interference remains as a future work.

#### **ACKNOWLEDGMENT**

I am indeed thankful to my guide for her able guidance to complete this paper. I extend my special thanks to Head of Department of Electronics and Telecommunications Dr. M. B. Mali who extended the preparatory steps of this paper-work. I am also thankful to the Principal Dr. S. D. Lokhande, Sinhgad College of Engineering for his valued support and faith on me.

#### **REFERENCES**

- [1] C. Reis, R. Mahajan, M. Rodrig, D. Wetherall, and J. Zahorjan, "Measurement-Based Models of Delivery and Interference in Static Wireless Networks," in *Proc. ACM SIGCOMM*, 2006
- [2] L. Qiu, Y. Zhang, F. Wang, M.K. Han, and R. Mahajan, "A General Model of Wireless Interference," *Proc. ACM MobiCom*, 2007.
- [3] J. Padhye, S. Agarwal, V. Padmanabhan, L. Qiu, A. Rao, and B. Zill, "Estimation of Link Interference in Static Multi-Hop Wireless Networks," *Proc. Internet Measurement Conf. (IMC)*, 2005.
- [4] Wee Lum Tan, Marius Portmann and Peizhao Hu, "A Systematic Evaluation of Interference Characteristics in 802.11-based Wireless Networks", in Queensland Research Laboratory, National ICT Australia (NICTA).
- [5] D. Aguayo, J. Bicket, S. Biswas, G. Judd, and R. Morris, "Link-level measurements from an 802.11b mesh network," in *SIGCOMM*, Aug.2004.
- [6] K. Jain, J. Padhye, V. N. Padmanabhan, and L. Qiu, "Impact of interference on multi-hop wireless network performance," in *MobiCom*, Sept. 2003.
- [7] A. Kochut, A. Vasani, A. Shankar, and A. Agrawala, "Sniffing out the correct physical layer capture model in 802.11b," in *ICNP*, Nov. 2004.
- [8] H. Chang, V. Misra, and D. Rubenstein, "A general model and analysis of physical layer capture in 802.11 networks," in *Proc. of IEEE INFOCOM*, Apr. 2006.
- [9] The metageek website, [Online]. Available: <http://www.metageek.com/training/resources>
- [10] W.Kim et.al., "Quantifying the interference gray zone in Wireless Networks: A measurement study," in *Proc. IEEE ICC*, 2007
- [11] T.Kim, H.Lim, and J.C. Hou, "Improving spatial reuse through tuning transmit power, carrier sense threshold, and data rate in multi-hop wireless networks," in *Proc. ACM Mobicom*, 2006
- [12] U. Paul, A. Kashyap, R. Maheshwari, and S. R. Das, "Passive Measurement of Interference in WiFi networks with Application in Misbehavior Detection," in *IEEE Transactions on Mobile Computing*, Vol. 12, No.3, March 2013.
- [13] A.Rainwala and T.Chiueh, "Architecture and algorithms for an IEEE 802.11-based multi-channel wireless mesh network" in *InfComm*, 2005
- [14] D. De couto, D. Aguayo, J. Bicket, and R. Morris, "High-throughput path metric for multi-hop wireless routing," in *MobiCom*, 2003
- [15] Y. Cheng, J. Bellardo, P. Benko, A. C. Snoeren, G. M. Voelker, and S. Savage, "Jigsaw: Solving the puzzle of enterprise 802.11 analysis," in *Proc. of ACM SIGCOMM*, Sept. 2006.