# Collision Detection in Dense Wi-Fi Networks using Self-Interference Cancellation

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***Abstract*—The deployment of dense Wi-Fi networks seeks to serve the growing number of wireless devices, but comes at a cost of interference, as the number of nodes sharing spectrum increases. In this paper, we present a means for detecting collisions at the access point (AP) using in-band full-duplex (FD) technology which allows us to detect collisions due to interference even while transmitting. Once a collision is detected, we propose a greedy algorithm that aims to avoid collisions, making better use of the available resources. Our methods require no modifications to the existing IEEE 802.11 standards nor to the Wi-Fi stations, making it backward-compatible and suggesting changes only to future network infrastructure. We implement our design using Network Simulator 3 (ns-3), which indicates significant throughput gains can be had when employing our algorithm in various dense network scenarios.**

## I. Introduction

In recent years, IEEE 802.11 (Wi-Fi) networks have become more dense as a solution to the ever-growing demand for higher data rates. Dense Wi-Fi networks are usually deployed in populated areas, such as office spaces, stadiums, and large campuses to distribute the network load without degrading performance. These dense networks are characterized by the numerous access points (APs) operating in a small area, seeking to provide high rate communication links to nearby stations (i.e., devices). However, packing many APs into a small area poses significant challenges due to interference between them, leading to packet loss.

In a Wi-Fi network, an AP along with the stations it serves, comprise a basic service set (BSS), where each BSS operates on a frequency channel within the Wi-Fi band. In a dense network, nearby BSSs will likely be operating on the same frequency channel thereby interfering with each other. IEEE 802.11 employs a contention technique where the nodes within a BSS contend for access to the wireless medium using channel sensing, backoff intervals, and control packet exchanges. These channel access techniques have shown to be quite effective for conventional Wi-Fi networks but are not sufficient for particularly dense Wi-Fi networks as they do not address medium access between BSSs.

Over the past decade, in-band full-duplex (FD) communication has become a reality where radios have the ability to simultaneously transmit and receive in the same frequency band. An obvious benefit of such a capability is the potential doubling of spectral efficiency since transmission and reception occur on the same time-frequency resource. Traditionally, however, when attempting to transmit while receiving, a transceiver undesirably receives a portion of its own transmission, commonly referred to as self-interference (SI). The SI is likely many orders of magnitude stronger than a desired receive signal, making successful reception nearly impossible if the SI is not dealt with. FD capability has proven to be possible with various self-interference cancellation (SIC) techniques which seek to cancel the interference by reconstructing the SI, inverting it, and injecting it into the received signal. This cancels the SI and leaves the desired receive signal interference-free [1]. Thus, with SIC, simultaneous transmission and reception can be realized which has led to the consideration of such a capability for use in medium access control (MAC) in addition to its physical layer (PHY) applications.

In Wi-Fi networks, transmission of packets takes place between nodes in the form of aggregated MAC protocol data units (A-MPDUs) which are simply multiple packets aggregated with a shared PHY header. If a collision event occurs during transmission of an A-MPDU, it typically extends through the remaining transmission time of that A-MPDU. Conventionally, sensing of the channel takes place only after the end of the entire A-MPDU transmission. Considering that the duration of a single A-MPDU is generally of the order of milliseconds, a relatively long time, a collision could corrupt a significant portion of the A-MPDU, leading to considerable throughput degradation.

Rather than waiting for the end of the A-MPDU transmission, we propose that the AP *continuously* sense the channel, even during its transmissions, in order to detect collisions that occur mid-transmission. If a collision is detected, we preemptively suspend transmission and redirect resources by transmitting to another station. To achieve continuous channel sensing, our design makes use of SIC technology at the AP which can sense the channel for interference even in the presence of its own transmission.

While the PHY gains with FD are fairly obvious (e.g., increased spectral efficiency), the improvements that could be had by MAC are not as clear, leading to several ideas presented in literature. Shortly before the research on FD PHY and MAC was initiated, much work happened in the area of spectrum sensing to enable cognitive radios. The idea here was to detect when the medium was idle and opportunistically use it for communication without disrupting incumbent transmissions.

In [2], the authors model the case where only the APs have FD capability and describe a MAC which uses distributed power control and signal-strength based backoff. However, this protocol requires new control frames for coordinating the FD transmissions which breaks backward compatibility. In [3], a synchronized contention window FD MAC protocol is described with some of the FD AP and stations coexisting with legacy stations. This work also requires non-standard features, such as exchange of backoff window size information, that is not backward compatible. The work in [4] also uses the scenario where FD APs and legacy stations coexist. This work utilizes packet alignment allowing an AP to communicate with two different stations simultaneously. However, this also requires non-standard modifications to the protocol which breaks backward-compatibility. In [5], the authors consider the case of FD nodes coexisting with legacy nodes and design a MAC protocol for automatic discovery of FD-capable nodes by using the reserved bits in the signaling field of a confirm to send (CTS) frame. Since the legacy nodes are agnostic to this field, this scheme is backward compatible. The scheme enables bidirectional communication between FD-capable nodes and simultaneous unidirectional communication between an AP and two stations where the AP is capable of receiving while transmitting. Collision detection in Wi-Fi networks was studied in [6] and [7] where they put forth analytical discussions on their benefit, but they consider all the nodes to be FD capable.

In contrast to existing works, we propose a MAC solution that requires FD capability only at the AP and does not require changes to the existing Wi-Fi standards, making our solution backward-compatible. We develop a means to detect collisions and take action to better use the resources available to the AP. We have implemented our proposed method in an IEEE 802.11n network using Network Simulator 3 (ns-3), whose results show that our method yields throughput gains in the presence of collisions. Further, simulation results show that these improvements can be seen in various dense network scenarios.

## II. System Model

The network model shown in Fig. 1 exhibits a typical collision scenario in a dense Wi-Fi network. It depicts a single fixed AP associated to a number of stations in the network, comprising a BSS. In a dense Wi-Fi network, it is common for multiple BSSs to overlap, leading to interference and collisions. Consider the case when the AP is transmitting to a particular station, shown as gray in Fig. 1. Assume that a single, fixed interfering node, which could be another AP or a station belonging to a different BSS, is also transmitting on the same frequency channel as the AP of interest. The station is positioned at an angle $\theta$ relative to the interferer. We consider the positions of all nodes, including the interferer, to be fixed.

We consider the case where the AP has a sniffer that continuously senses the channel, even during the AP's transmission by use of SIC. Specifically, we assume perfect SIC is achieved, which implies that our sniffer sensitivity is not degraded by

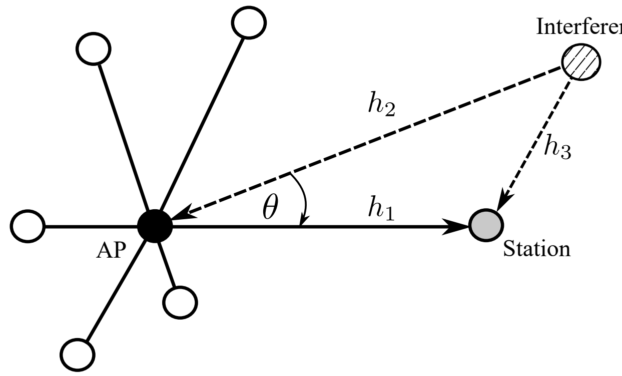


Fig. 1: A wireless network depicting collision.

the AP's transmission. It is worth noting that if perfect SIC is not achieved, any residual SI from the AP's transmission will limit our sniffer's receive sensitivity, preventing it from detecting weak interference (which may not necessarily be weak at the station).

We assume that the stations are conventional Wi-Fi devices without modification to their hardware or software. In other words, our proposed design relies only on the AP being equipped with SIC and having MAC modifications according to our algorithm presented in Section III and IV. We further assume that the signal-to-noise ratio (SNR) of the AP-station link is known at the AP, which we justify with channel reciprocity of the AP-station link. Using its sniffer, the AP can directly measure the SNR of the interferer-AP link.

We assume that the transmit powers of all the stations in the network along with the AP and the interferer are equal, denoted as $P_\mathrm{t}$. The signal-to-interference-plus-noise ratio (SINR) of the AP's transmission at the receiving station in presence of interference from the interfering node can be expressed as

$$\mathrm{SINR} = \frac{P_\mathrm{t}|h_1|^2}{P_\mathrm{t}|h_2|^2 + N_0} \tag{1}$$

where $N_0$ is the noise variance and $h_1$ and $h_2$ are the complex channel gains of the AP-station link and the interferer-station link, respectively. We assume that all channels are Rayleigh-faded and are subject to Friis path loss.

## III. Collision Detection

In this section, we analyze the scenario that was previously described, wherein an AP transmits to a station in the presence of interfering node. In particular, we derive an expression for the probability of collision at the station given the amount of interference power sensed at the transmitting AP. Furthermore, we use this information to propose a technique to predict potential packet losses due to collisions.

A collision in a wireless network is attributed to the loss of a packet due to interference at the receiving station. The event of collision, denoted as $E_C$, has a likelihood that depends on the SINR at the receiving station and the SINR threshold, $\Gamma$, a characteristic of the modulation and coding scheme (MCS) in use. The probability of $E_C$ can be expressed as

$$\mathcal{P}(E_C) = \mathcal{P}\left(\text{SINR} < \Gamma\right). \tag{2}$$

Using (1), we can write

$$\mathcal{P}(E_C) = \mathcal{P}\left(\frac{P_{\text{t}}|h_1|^2}{P_{\text{t}}|h_2|^2 + N_0} < \Gamma\right). \tag{3}$$

Having Rayleigh-faded channels, if we assume the SINR is interference-limited, we can approximate (3) as

$$\mathcal{P}(E_C) \approx \mathcal{P}\left(\frac{X_1}{X_2} < \Gamma\right) \tag{4}$$

where $X_1 \sim \exp(1/\gamma_1)$ and $X_2 \sim \exp(1/\gamma_2)$ are random variables representing $P_{\text{t}}|h_1|^2$ and $P_{\text{t}}|h_2|^2$, and $\gamma_1$ and $\gamma_2$ are their respective average SNRs. From functions of random variables, (4) can equivalently be expressed as

$$\mathcal{P}(E_C) \approx \frac{\Gamma\gamma_2}{\gamma_1 + \Gamma\gamma_2} = \hat{\mathcal{P}}(E_C). \tag{5}$$

For the AP to predict collisions occurring at the station, it must evaluate (5). We assume that the AP can infer the value of $\gamma_1$ through the average received power of prior packet exchanges with the station and by channel reciprocity. However, the AP does not explicitly have knowledge of $\gamma_2$ as we state in Section II. Fortunately, $\gamma_2$ can be obtained from $\gamma_1$ and $\gamma_3$ by applying the law of cosines and the Friis path loss formula to Fig. 1. The average received interference energy at the AP's sniffer provides $\gamma_3$ directly. Consequently, the AP can compute $\gamma_2$ in terms of $\gamma_1$ and $\gamma_3$ as shown in (6). While the AP does not directly know $\theta$, the positioning of the interferer relative to the receiving station, we show later that such information is not essential to our proposed design.

$$\gamma_2 = \frac{\gamma_1\gamma_3}{\gamma_1 + \gamma_3 - 2\gamma_1\gamma_3\cos\theta} \tag{6}$$

The subsequent task at the AP is to presume whether collision occurred at the station from the estimated value of $\mathcal{P}(E_C)$, where we reference [6], [7]. Now, given the value of $\hat{\mathcal{P}}(E_C)$ from (5) and (6), our strategy to decide if the collision happened at the station is

$$\text{Decision} = \begin{cases} \text{collision occurred,} & \text{if } \hat{\mathcal{P}}(E_C) \geq 0.5 \\ \text{no collision,} & \text{otherwise.} \end{cases} \tag{7}$$

Note that our decision method is *deterministic* when conditioned on the calculated $\hat{\mathcal{P}}(E_C)$. An alternate decision method would be to *probabilistically* decide if a collision occurred based on the value of $\hat{\mathcal{P}}(E_C)$. For example, if $\hat{\mathcal{P}}(E_C) = 0.7 \geq 0.5$, our method would assume that *every* transmission to the station in the presence of interference would result in collision. The probabilistic method, on the other hand, *randomly* guesses that a collision occurs 70% of the time.

To understand why our method is better than such a probabilistic method, we consider the analogy between collision and the outcome of a coin toss with bias probability of $q$, which represents the true probability of collision. Let's say

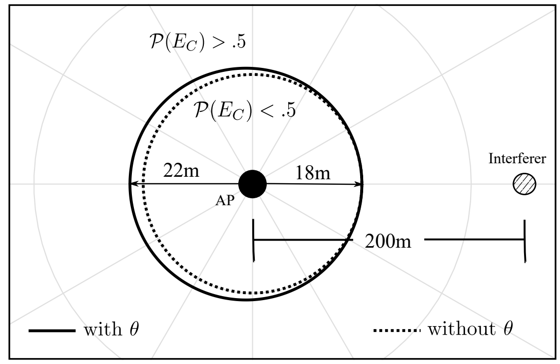


Fig. 2: Decision region corresponding to (7) with respect to AP. The circles depict the separation were $\hat{\mathcal{P}}(E_C)$ crosses 0.5.

$E_C$, the event representing collision, corresponds to a coin toss of heads. Our task of deciding whether a collision has occurred or not is equivalent to predicting the outcome of the biased coin with $\mathcal{P}(\mathcal{H}) = q$. While the true probability of collision is not known at the AP, we estimate it as $\hat{\mathcal{P}}(E_C) = p \approx q$. With our strategy, the expected number of errors that we make in predicting collision is $1 - q$ while that with the probabilistic method is $q(1-p) + (1-q)p$. The difference in the expected number of errors is given as

$$\begin{aligned} \Delta E &= (1-q) - (q \cdot (1-p) + (1-q) \cdot p) &(8)\\ &= (1-2q) \cdot (1-p) &(9)\\ &< 0, &(10) \end{aligned}$$

when it is assumed that $q > 0.5$. For the case with $q < 0.5$, it's easy to verify the difference of the expected number of errors is $(2q-1)p < 0$. This shows that our method results in a lower expected number of detection errors than the probabilistic method.

From a network perspective, the decision boundary of (7), which corresponds to $\hat{\mathcal{P}}(E_C) = 0.5$, represents a circle around the AP. The dependence of decision boundary on $\theta$ can be attributed to (6) which makes it non-uniform around the AP. An illustration of this is shown in Fig. 2 where the interferer location is fixed. The solid line depicts the decision boundary when $\theta$ is incorporated in computing $\hat{\mathcal{P}}(E_C)$, whereas the dotted line depicts that when $\theta$ is ignored. The impact of this result is that calculating $\hat{\mathcal{P}}(E_C)$ only depends on the absolute distances of the station and interferer from the AP and not their exact positioning relative to one another. We have observed that this holds true for the network scenarios we have considered.

$$\gamma_2 = \frac{\gamma_1\gamma_3}{\left(\sqrt{\gamma_1} + \sqrt{\gamma_3}\right)^2}. \tag{11}$$

It is clear from the the previous discussion that the collision detection technique basically involves computing $\hat{\mathcal{P}}(E_C)$ by estimating the average SNRs of the channels between the nodes. During network operation, the AP logs the measured

SNR of its link with the station along with the measured SNR of the received interfering signal at the sniffer. Logging these SNRs over time allows it to calculate their average SNRs, which are then used directly to compute $\hat{\mathcal{P}}(E_C)$ for each station using (5) and (11).

## IV. Throughput Improvement

In this section, we propose an algorithm to reallocate resources from the stations where collisions are detected. We first derive the optimal aggregate throughput for a multi-node network both with and without interference. Then, we show that our proposed algorithm is a constant factor approximation of the optimal throughput in the presence of interference.

### A. *Optimal Aggregate Throughput*

In order to evaluate the performance of our algorithm, we need to first establish the optimal aggregate throughput of the system. Let $\lambda_i$ denote the rate at which packets are generated for station $i$ at the AP. Consider a fixed, large enough time interval that comprises of a fixed number of MAC protocol data unit (MPDU) slots. The optimal aggregate throughput during transmission to the stations is obtained by solving the following maximization problem over the entire time interval.

$$\max_{\{c_i\}_i} \sum_i \min(\lambda_i, c_i \log(1+\text{SINR}_i)) \tag{12}$$

$$\text{s.t.} \quad \sum_i c_i = 1 \tag{13}$$

$$0 \leq c_i \leq 1, \quad \forall i. \tag{14}$$

Here $c_i$ is the integer fraction of total slots in the time interval that is assigned for a particular node $i$. Without loss of generality, we sort the indices in descending order of average SINR. It is easy to observe that the optimal solution is obtained by equivalently filling the arrival rate up until finding an index $i^\star$ such that $\lambda_{i^\star} > (1 - \sum_{j=1}^{i^\star-1} c_j)\log(1+\text{SINR}_{i^\star})$. We have the optimal time-sharing ratio $\{c_j^\star\}_{j=1}^{i^\star}$ as

$$c_j^\star = \frac{\lambda_j}{\log(1+\text{SINR}_j)}, \quad 1 \leq j \leq i^\star - 1 \tag{15}$$

$$c_{i^\star}^\star = 1 - \sum_{j=1}^{i^\star-1} c_j^\star, \tag{16}$$

and the optimal aggregate throughput OPT for any given $\{\text{SINR}_i\}$ can be expressed as

$$\text{OPT} = \sum_{j=1}^{i^\star-1} \lambda_j + c_{i^\star}^\star \log(1+\text{SINR}_{i^\star}) \tag{17}$$

$$= \sum_{j=1}^{i^\star} c_j^\star \log(1+\text{SINR}_j) \tag{18}$$

$$= \mathbf{c}^\mathsf{T}\mathbf{R} \tag{19}$$

where $\mathbf{c} = [c_1^\star, \ldots, c_{i^\star}^\star]^\mathsf{T}$ is the optimal time-sharing vector and $\mathbf{R} = [\log(1+\text{SINR}_1), \ldots, \log(1+\text{SINR}_{i^\star})]$ is the corresponding rate vector. We can express the optimal aggregate throughput in the presence of external interference for $\eta$ fraction of the slots as

$$T_\star = (1-\eta)\mathbf{c}^\mathsf{T}\mathbf{R} + \eta \mathbf{c}'^\mathsf{T}\mathbf{R}' \tag{20}$$

Here $\mathbf{c}$ and $\mathbf{c}'$ are the time-sharing vectors that maximize the throughput for rate vectors $\mathbf{R}$ and $\mathbf{R}'$ without and with interference, respectively. This could be easily derived by dividing the time interval into two separate slots and solving (12) individually. It is worth mentioning that the aggregate throughput is an average term over the entire time interval, which does not have physical meaning for a single A-MPDU slot.

### B. *Greedy Algorithm Technique*

We first compute an aggregate throughput expression for the general case when the AP has no collision detection capability. In the absence of interference, to maximize throughput, we choose the time-sharing vector $\mathbf{c}$ as was explained above. In the presence of interference, the rate vector changes and so does the optimum time-sharing vector. If the AP has no collision detection capability, it will continue with the old time-sharing vector $\mathbf{c}$. This corresponds to the AP continuing transmission to the same station for the entire A-MPDU slot, even when collision happens, which is sub-optimal. The aggregate throughput in this case can be expressed as

$$T_1 = (1-\eta)\mathbf{c}^\mathsf{T}\mathbf{R} + \eta \mathbf{c}^\mathsf{T}\mathbf{R}'. \tag{21}$$

When the AP has the ability to detect collisions mid-transmission, it can reallocate resources. Thus, we propose a greedy algorithm, shown in Algorithm 1, for rerouting resources to the station with the best SINR. For this algorithm, we prove the following theorem.

**Theorem 1.** *Algorithm 1 is a $\beta$-approximation algorithm for the throughput with any collision, where $\beta = \lambda_1 / \sum_{j=1}^{i^*} \lambda_j$.*

**Algorithm 1:** Collision detection & greedy algorithm.

**Input:**
$\gamma_{1i} \leftarrow$ average received station power, $i = 1, 2, \ldots, N$
$\gamma_3 \leftarrow$ received interference power
$k \leftarrow$ current receiving station
$\Gamma \leftarrow$ SINR threshold based on MCS
**Output:**
$\zeta \leftarrow$ next destination
$n_0 \leftarrow$ number of packets to aggregate

```
Compute γ_2i = γ_1i γ_3 / (√γ_1i − √γ_3)^2,  i = 1, 2, ..., N
Compute SINR_i = γ_1i / (γ_2i + N_0),  i = 1, 2, ..., N
Compute P̂(E_Ck) = Γγ_2k / (γ_1k + Γγ_2k)
if P̂(E_Ck) ≥ 0.5 then
    ζ = arg max_i (SINR_i)
    n_0 = remaining MPDU packets
end
return ζ, n_0
```

*Proof.* Looking at any A-MPDU slot that is lost due to collision, the aggregate throughput optimization problem is still characterized by (12), (13), and (14), but with the rate vector in presence of interference $\mathbf{R}'$. Solving the optimization problem gives the optimal time-sharing vector $\mathbf{c}'$. However, due to the indivisibility of an A-MPDU slot, we cannot further operate the time-sharing scheme, but rather choose one station to transmit to. We follow the greedy algorithm to redirect packets to the station with the highest SINR. Thus, the throughput optimization problem over a single A-MPDU slot is as follows.

$$\max_{\{c_i\}_i} \sum_i \min(\lambda_i, c_i \log(1 + \text{SINR}_i)) \tag{22}$$

$$\text{s.t.} \quad \sum_i c_i = 1 \tag{23}$$

$$c_i \in \{0, 1\}, \quad \forall i. \tag{24}$$

Next, we compare the greedy algorithm throughput with the optimal aggregate throughput in the presence of interference. Here, we abuse notation and discard the primes on the time-sharing vector $\mathbf{c}'$ and the rate vector $\mathbf{R}'$ for simplicity. Let the throughput be represented as $T_{2I}$.

For $\lambda_1 < \log(1 + \text{SINR}_1)$, we have

$$\begin{aligned} T_{2I} &= \lambda_1 && (25)\\ &= \frac{\lambda_1}{\sum_{j=1}^{i^\star} \lambda_j} \sum_{j=1}^{i^\star} \lambda_j && (26)\\ &= \frac{\lambda_1}{\sum_{j=1}^{i^\star} \lambda_j} \left( \sum_{j=1}^{i^\star - 1} \lambda_j + \lambda_{i^\star} \right) && (27)\\ &\geq \frac{\lambda_1}{\sum_{j=1}^{i^\star} \lambda_j} \left( \sum_{j=1}^{i^\star - 1} \lambda_j + c^\star_{i^\star} \log\left(1 + \text{SINR}_{i^\star}\right) \right) && (28)\\ &= \frac{\lambda_1}{\sum_{j=1}^{i^\star} \lambda_j} \text{OPT} && (29)\\ &= \beta \cdot \text{OPT}, && (30) \end{aligned}$$

where $\beta = \lambda_1 / \sum_{j=1}^{i^\star} \lambda_j$. For $\lambda_1 < \log(1+\text{SINR}_1)$, we simply have $T_{2I} = \text{OPT} > \beta \cdot \text{OPT}$. $\square$

Applying Theorem 1 on each collision, we get aggregate throughput as

$$\begin{aligned} T_2 &= (1 - \eta)\mathbf{c}^\mathsf{T}\mathbf{R} + T_{2I} && (31)\\ &\geq (1 - \eta)\mathbf{c}^\mathsf{T}\mathbf{R} + \beta\eta\mathbf{c}'^\mathsf{T}\mathbf{R}'. && (32) \end{aligned}$$

Notice $T_2 \geq T_1$ is guaranteed by the optimality. Further, notice in the analysis in this subsection, we assume any interference immediately leads to collision and there is rate even when collision happens. Moreover, there are false positives and false negatives in the collision detection so each term in (32) can be further split into two terms with respect to positives and false positives (negatives and false negatives). We keep the current assumptions for the simplicity of analysis.

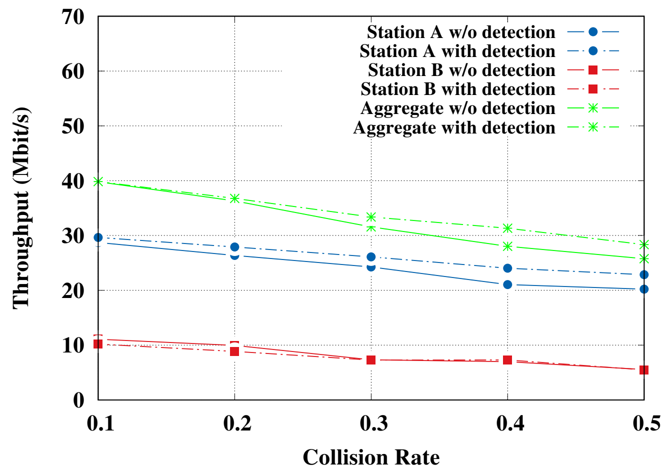


Fig. 3: Aggregate throughput with and without detection in a two node scenario with Station B at 80 meters from the AP.

## V. NS-3 IMPLEMENTATION

In order to evaluate the performance of Algorithm 1, our technique was simulated on an IEEE 802.11n network using ns-3. We used the 2.4 GHz Wi-Fi band, frequency channel 1, and a channel bandwidth of 20 MHz. The channel fading model was chosen to be Rayleigh and the loss model was chosen to be Friis path loss model, as was assumed in our system model. The transmit power for all the nodes in the simulation was set to 16 dBm. All packets were sent with a fixed MCS of 7. User datagram protocol (UDP) packets of size 1472 bytes were generated for all the stations at a combined rate of 60 Mbps, which sets a upper bound on the achievable aggregate throughput. The rate of collision, $\eta$, was throttled by the rate at which packets were generated at the interferer.

## VI. RESULTS AND DISCUSSION

We first demonstrate our proposed method in a simple network with the AP and two stations, A and B, along with the interferer. Station A was fixed at a distance of 5 meters from the AP in the direction opposite to the interferer, while station B was fixed at a distance of 80 meters from the AP in the same direction as the interferer. The interferer was placed 150 meters from the AP. Varying the rate of collision, the throughput of the individual stations and the aggregate throughput measured is shown in Fig. 3. A collision ratio of 0.5, for example, is approximately equivalent to a collision occurring in every A-MPDU at varying points and is equivalent to collisions occurring during half the total transmission time. An obvious improvement in aggregate throughput was observed when our collision detection algorithm was active. The improvement can be attributed to the fact that when our method detects a collision when transmitting to station B, it reroutes resources to station A, whose SINR is strong enough to avoid collisions. This claim is supported by observing the increase in the throughput of station A while the throughput of station B is marginally decreased due to misclassification of collisions.

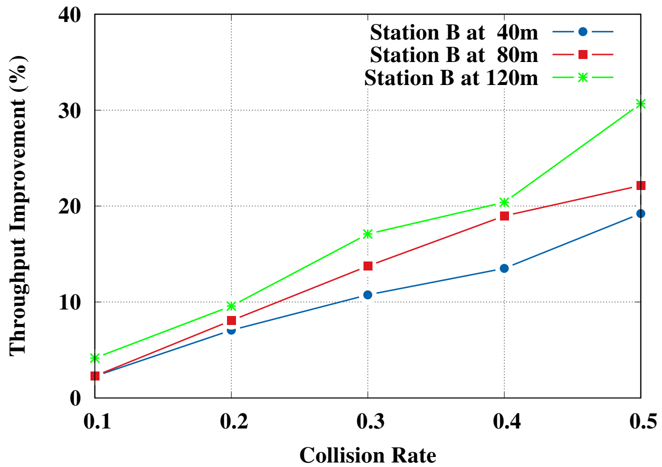


Fig. 4: Aggregate throughput improvement for varying distances of station B.

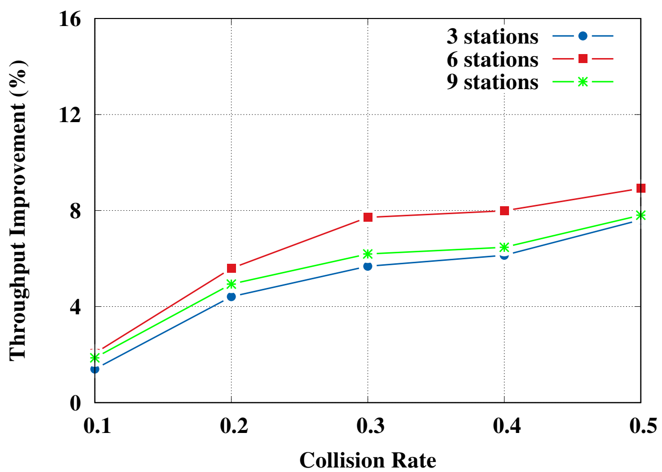


Fig. 5: Aggregate throughput improvement in a multi-node network.

The same network was used to observe the aggregate throughput gain with varying collision rates when station B is placed at different distances from the AP. It is evident that the improvement grows nearly linearly with the increase in collision rate. The improvement is as high as 30% when station B is 120 meters from the AP and the collision rate is 0.5. These results can be attributed to the fact that our detection algorithm is more reliable as the distance of station B grows. As the collision rate increases, the resources routed to station A lead to a significant increase in aggregate throughput, due to its high SINR having close proximity to the AP.

Referring to Fig. 5, it can be seen that our proposed algorithm is also effective in scenarios with multiple stations. In these scenarios, we distribute the stations uniformly within a circular region around the AP with radius 85 meters. The results in Fig. 5 show that as the number of stations varies, the improvement in aggregate throughput is similar for a given collision ratio. This is due to the fact that the stations are spread over the same circular area and the same number of A-MPDUs are affected by collision but the time-share for a given station is decreased as more stations are introduced.

## VII. Conclusion

In this paper, we have presented a collision detection scheme that uses continuous sensing of the channel at the AP to detect interfering nodes that may be present in dense Wi-Fi networks. Using this, we propose the use of a greedy algorithm to redirect resources when collisions are detected mid-transmission. Our collision detection method requires no hardware changes to existing Wi-Fi stations and is backward-compatible with the current IEEE 802.11 standards. An ns-3 implementation shows that our proposed methods can provide throughput gains in the presence of interference in a variety of network scenarios. In this work, we assume that we have packets for the station with best SINR. However, in Wi-Fi there is no guarantee that such would be the case. Therefore, the throughput results that we have showcased are a conservative approximation of the actual throughput that could be achieved. Intelligent resource allocation, along with collision detection, can provide even higher throughput improvement. We reserve an extensive study of this for the journal version of this work.

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