Novel Metrics and Experimentation Insights for Dynamic Frequency Selection in WLANs

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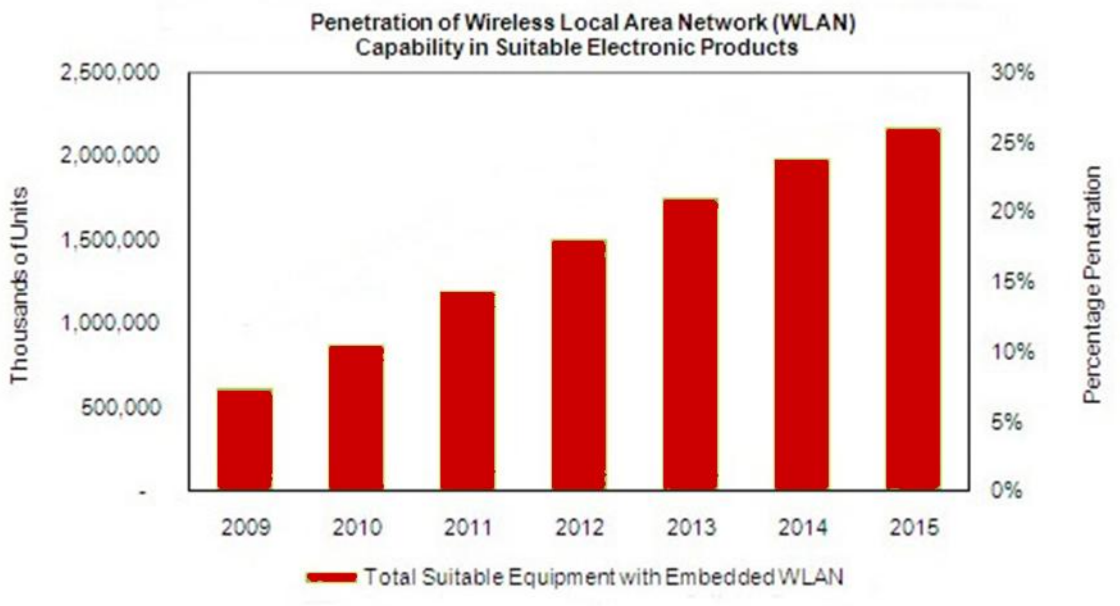
Introduction

- The tremendous growth of 802.11 WLANs.



Outline

- DFS in 802.11 WLANS
- Interference Model
- Performance Metrics
- Protocol Description
- Experimental Evaluation
- Insights and Future work

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DFS in 802.11 WLANS

- In IEEE 802.11 WLANs, channel selection is performed at the access point (AP).

- Common approach:
  - Configuration through manual input upon network initialization.

- State-of-the-art approaches:
  - Select the channel that offers the lowest received signal strength (RSSI), during the scanning process.
  - Avoid highly congested frequencies, based on traffic measurements.

- Static channel assignments <-> Dynamic nature of wireless medium.

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Our Contribution

- Dynamically switch the operating channel, taking into account several factors that affect end-user performance:
  - Overlapping channels interference
  - Contention
  - Co-channel interference

- Contributions:
  - Novel Client-assisted interference estimation
  - Adaptability to varying traffic conditions through calculation of Channel Occupancy Time (COT)
  - First complete driver level implementation
  - Extensive experiments in both RF-isolated as well as in interference-rich environments

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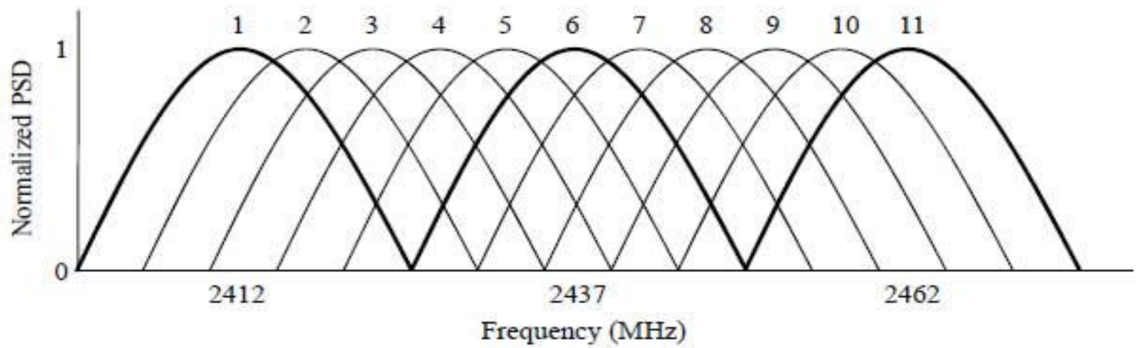
Overlapping Channels Interference

➢ The popular 2.4 GHz band, used by 802.11b and 802.11g standards offers 11 consecutive channels spaced 5 MHz apart and occupying 22 MHz of bandwidth.



➢ In our work, we use the notion of $\mathbf{I_{factor}}$ to model the degree of overlapping between transmissions on two certain frequencies.

Channel Separation ($\lvert m-n \rvert$)	0	1	2	3	4	5	6
Measured I_{factor}	1	0.75	0.37	0.1	0.02	0	0

$$RSS_j(m) = RSS_j(n) * I(m,n)$$

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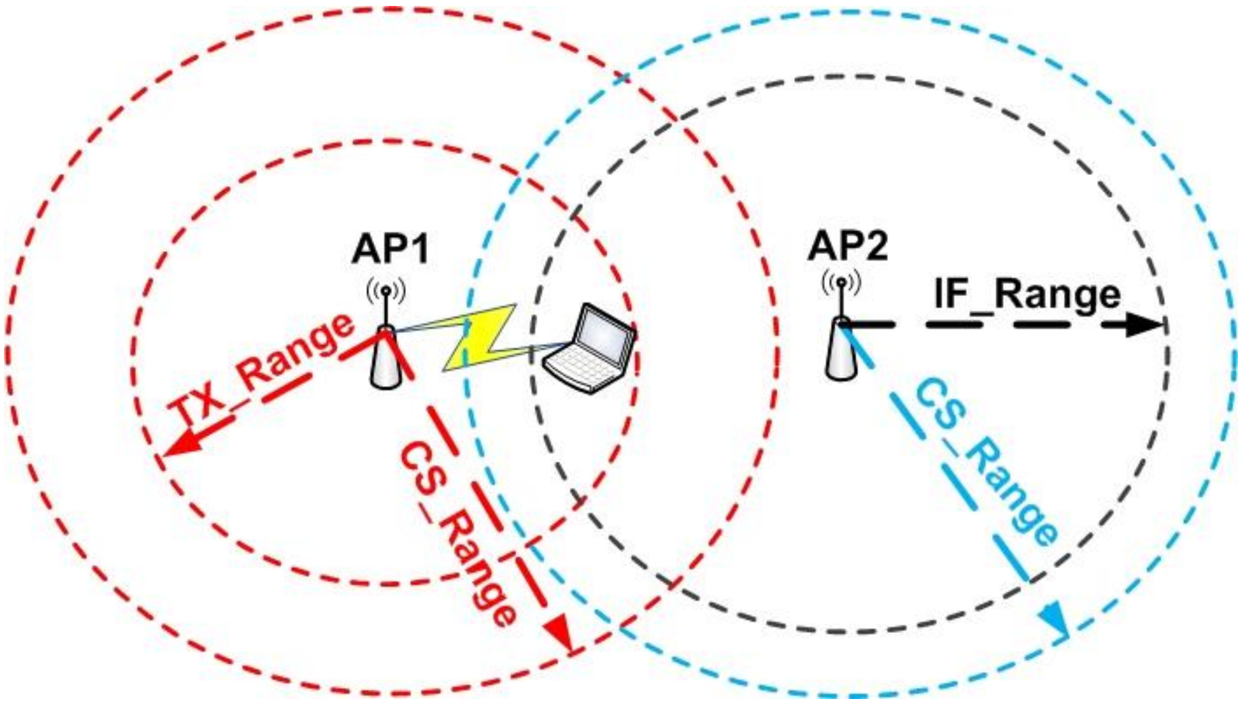
Contention and Co-channel Interference

Hidden Terminal problem in
IEEE 802.11 infrastructure networks:



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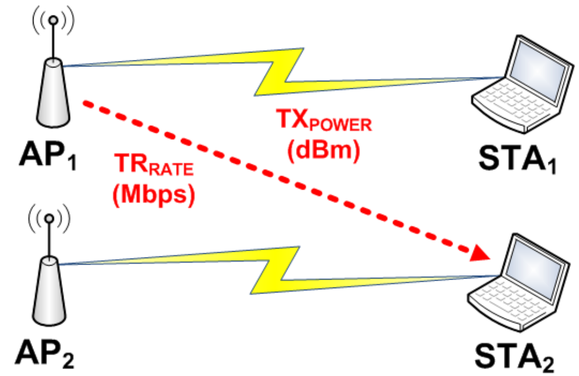
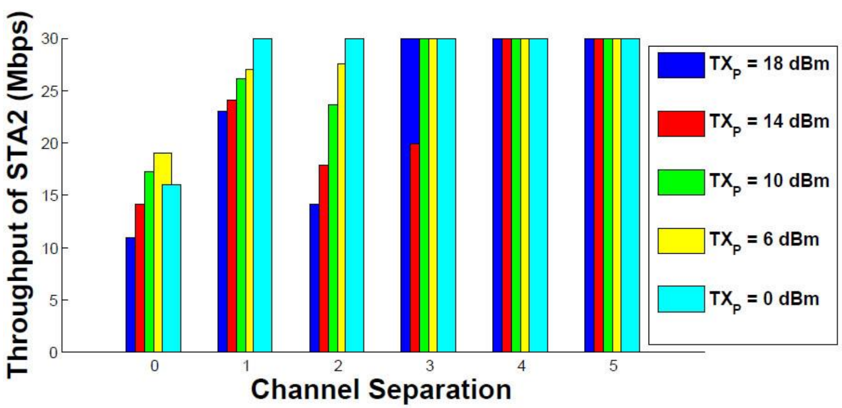
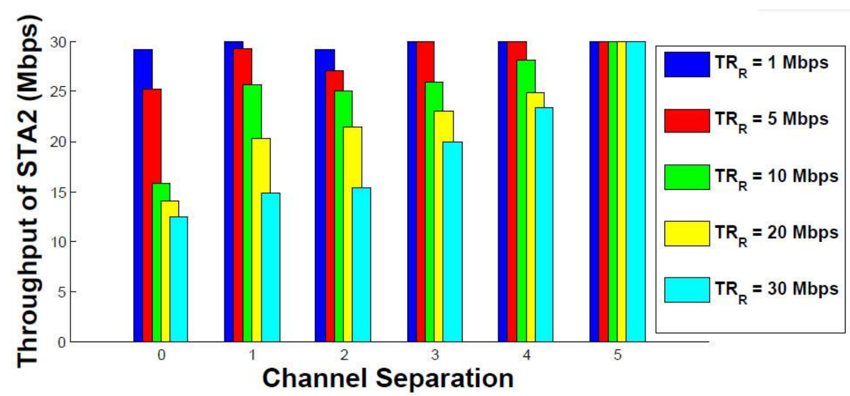
Motivating Experiment

- Investigate impact of interference on throughput by varying:
  - Transmission Power - Channel Separation
  - Traffic Activity - Channel Separation





Throughput - Transmission Power of AP1



Throughput - Traffic Rate of AP1

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Performance Metrics (1/2)

- **First requirement:** Adjacent BSSs are assigned different channels.
  - RSS metric

$$\sum_{j \in \mathcal{B}} RSS_j(n) * I(m,n)$$

- **Second requirement:** Estimate the level of congestion a node experiences on each channel.
  - COT metric

$$COT(m) = \sum_{k=1}^{F_m} \frac{L_k}{R_k}$$

- To model the effect of channel congestion, we use COT as:

$$\sum_{j \in \mathcal{B}} RSS_j(n) * I(m,n) * COT(m)$$

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Performance Metrics (2/2)

- Our algorithm supports feedback from both associated STAs, as well as from STAs that belong to other adjacent BSSs.
- We use A to denote the set of nodes that provide feedback, by transmitting measurement frames.
- The AP calculates the average metric value, over the total number of nodes providing measurements and selects channel m, such that the following quantity is minimized:

$$\frac{1}{|\mathcal{A}|}\sum_{i\in\mathcal{A}}\sum_{j\in\mathcal{B}} RSS_{ij}(n) * I(m,n) * COT(m)$$

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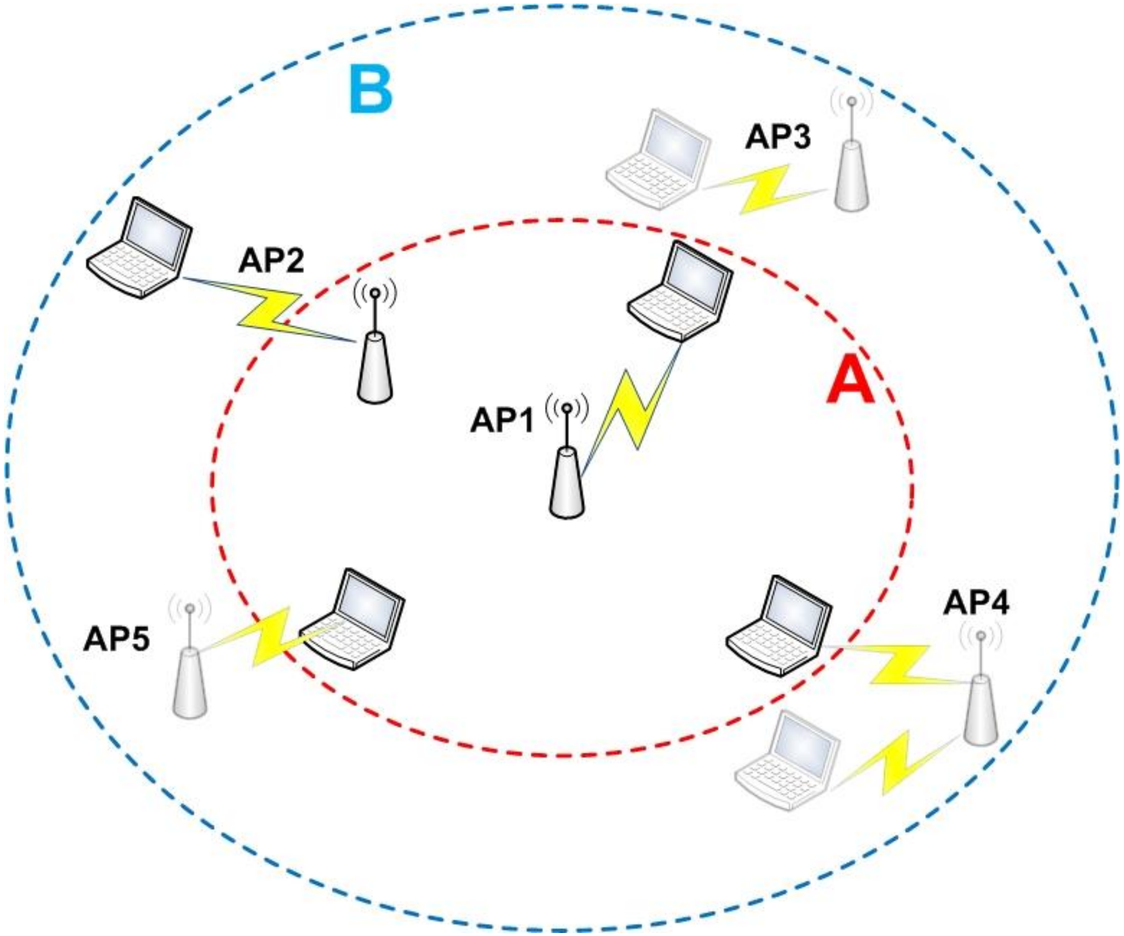
Client Feedback Mechanism(1/3)



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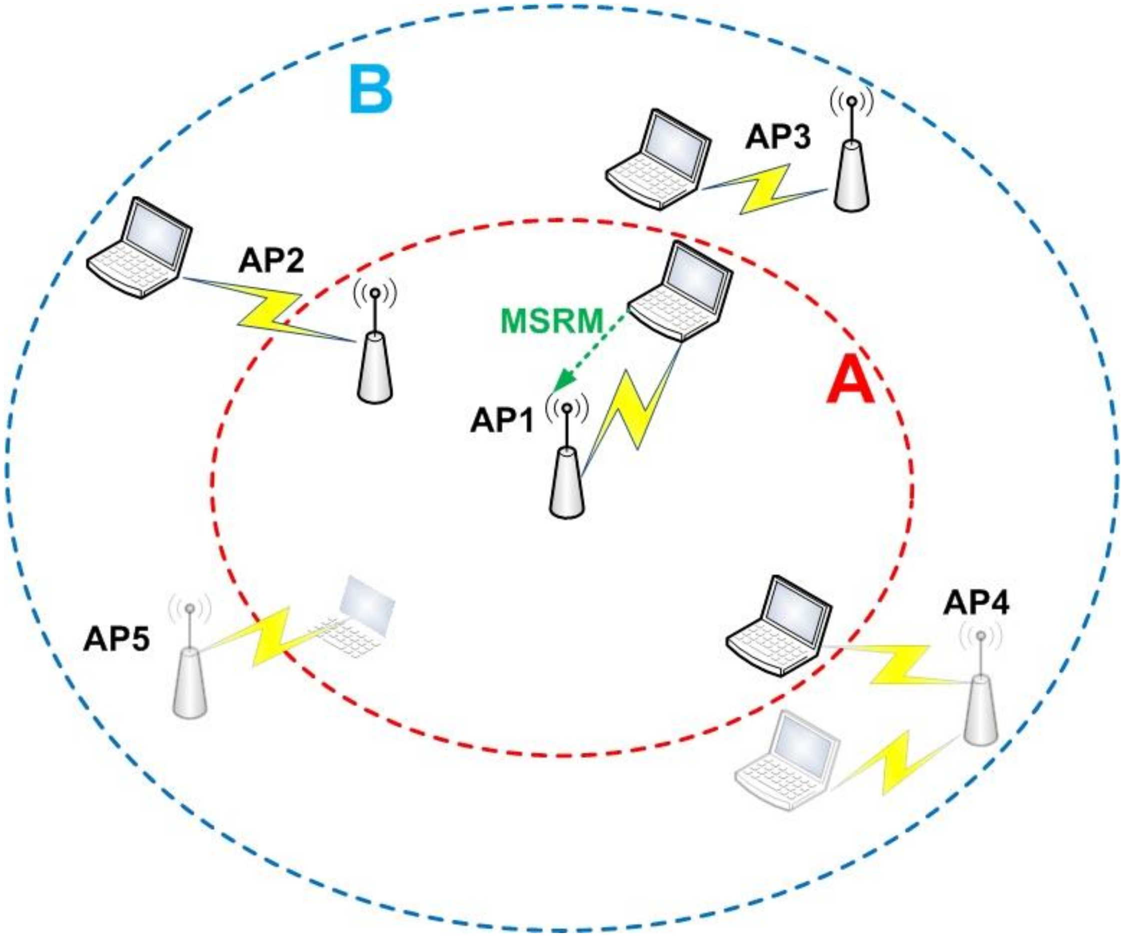
Client Feedback Mechanism(2/3)



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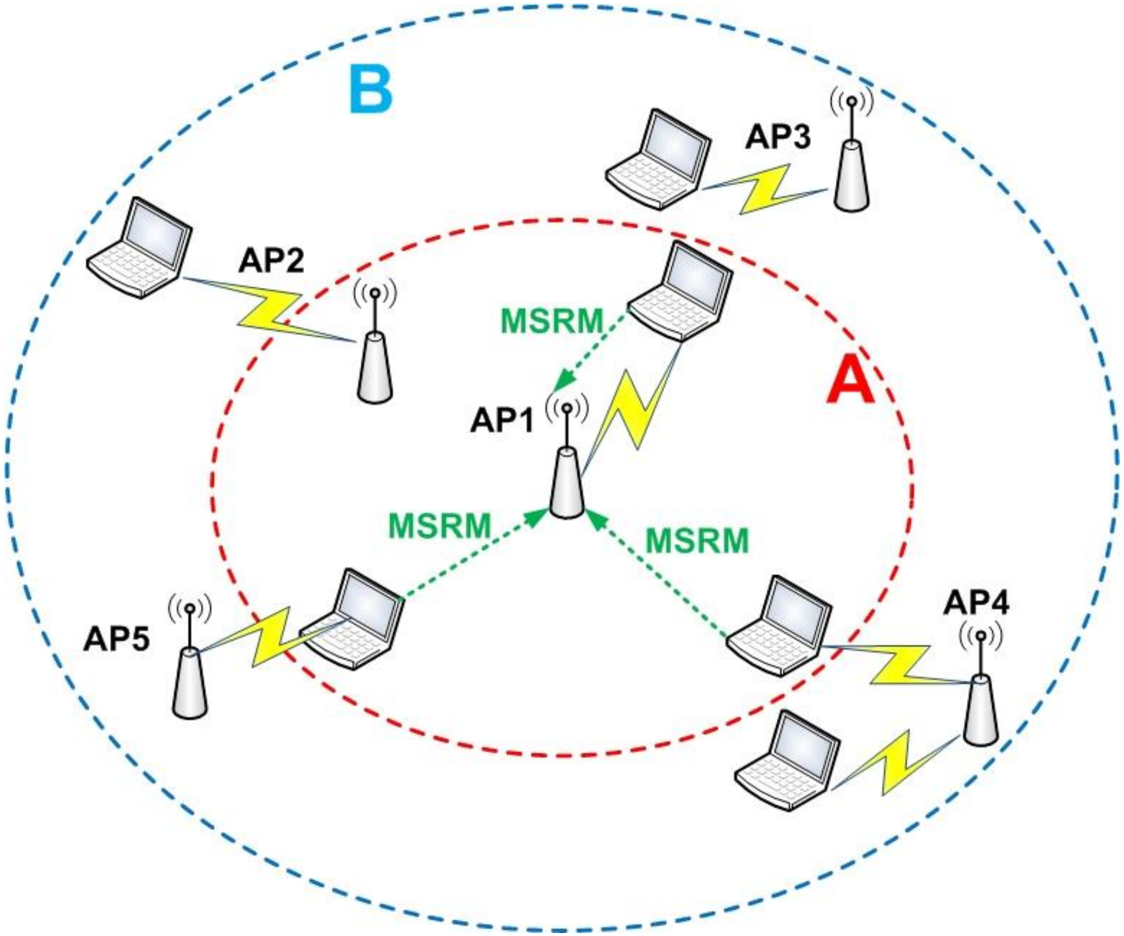
Client Feedback Mechanism(3/3)



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Protocol Description (1/2)

- **STEP 1:** Periodic calculation of COT by APs and piggybacking in Beacon and Probe-Response frames.

Beacon - Probe Response frame format

[8]	[2]		[tlv]	[2]	[3]		[tlv]
Timestamp	Beacon interval	……	Country code	COT metric	Power constraint	……	AtherosXR parameters

- **STEP 2:** Periodic repetition of BGscan by both STAs and APs, to gather information about interfering BSSs.
- **STEP 3:** Broadcasting of measurements by the STAs.

Measurement Report frame format

			calculated metric per channel										
[24]	[3]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]
ieee80211_header	"dfs"	sequence number	ch 1	ch 2	ch 3	ch 4	ch 5	ch 6	ch 7	ch 8	ch 9	ch 10	ch 11

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Protocol Description (2/2)

- **STEP 4:** Collection of measurements by the APs.
- **STEP 5:** Calculation of average metric values per channel at the AP by considering:
  - 1) AP BGscan measurements
  - 2) measurements of associated STAs
  - 3) measurements of neighboring STAs of other BSSs.
- **STEP 6:** Selection of the channel that offers the lowest calculated value.
- **STEP 7**: Broadcasting of CSA frame to advertise channel switching, in the case that the selected channel is different from the one currently in use.
- **STEP 8:** Switching to the new channel after a specific interval, defined in the CSA frame.

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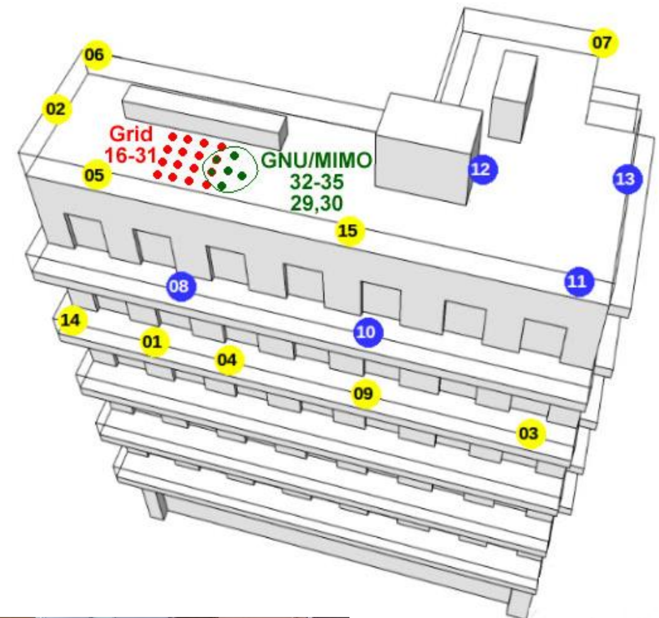
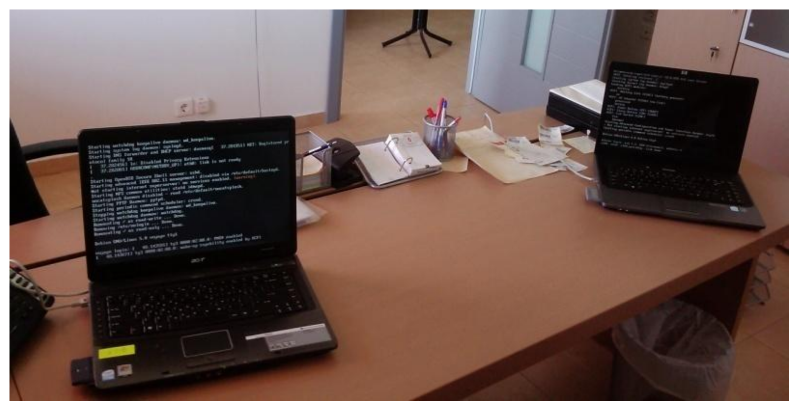
Experimental Configuration

- **NITOS** testbed constists of 40 wireless nodes



- Indoor testbed consists of 6 laptops



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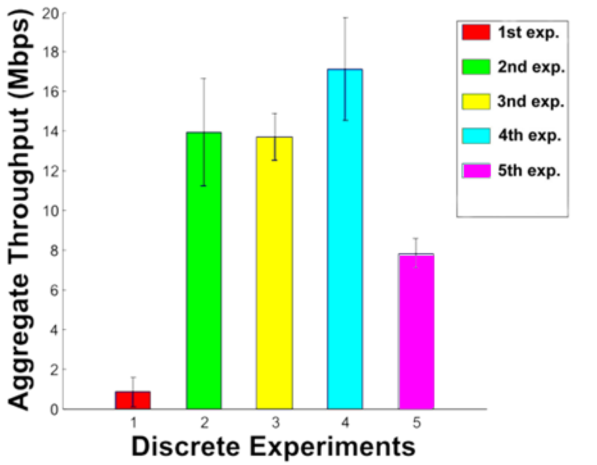
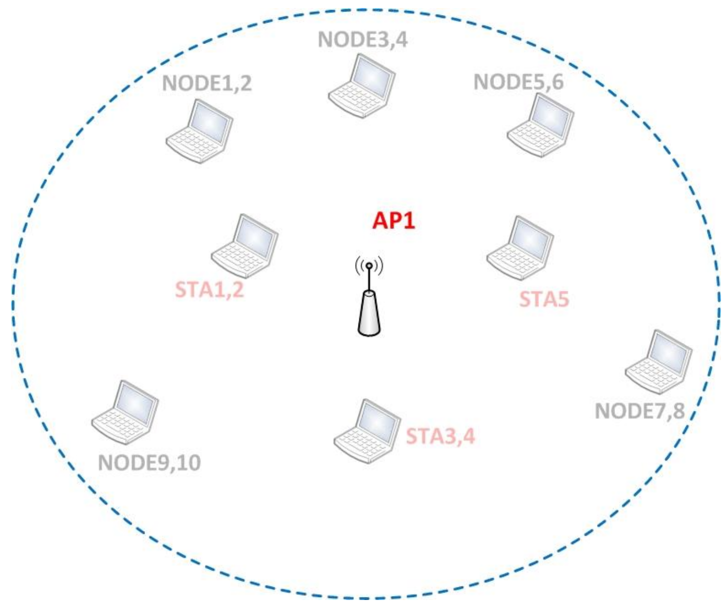
First set of Experiments (1/6)



(a) Throughput - Discrete Experiments.



Different Versions	Selected Channel	Throughput (Mbps)
Unmodified Madwifi	2	0.843
AP (+overlapping)	7	13.96
+ 5 associated STAs	10	13.71
+ 10 neighboring STAs	8	17.14
+ 2 interfering APs	4	13.83

RSSI and Overlapping-based experiments in the 2.4 GHz band

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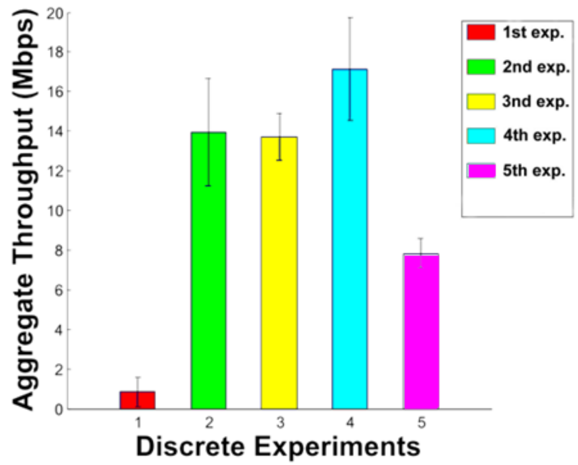
First set of Experiments (2/6)



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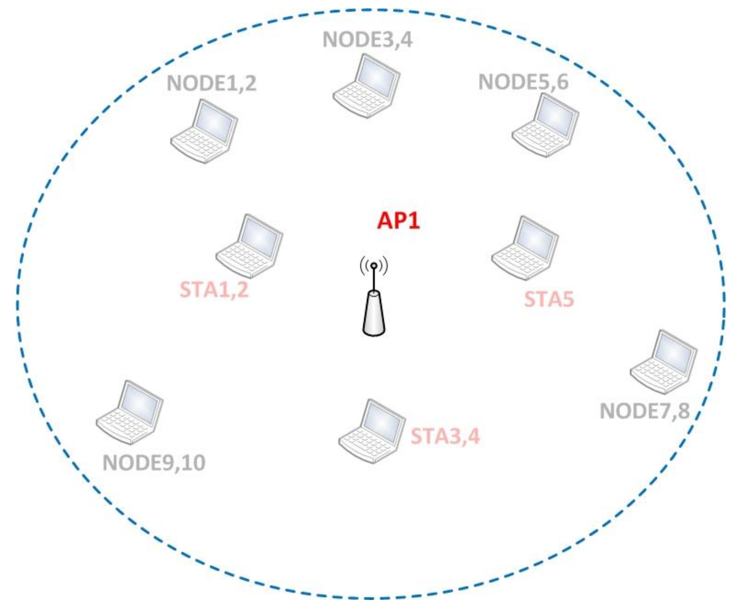

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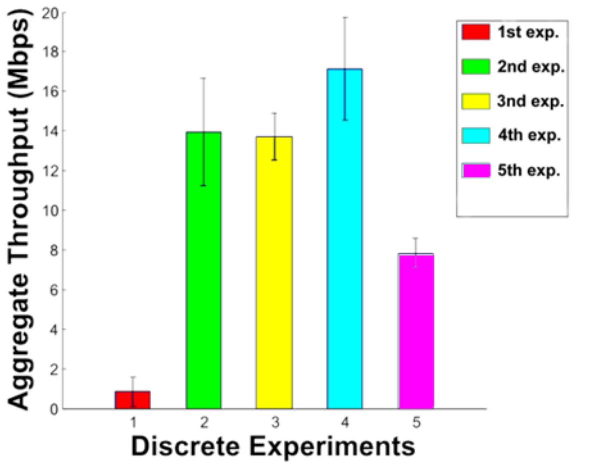
First set of Experiments (3/6)



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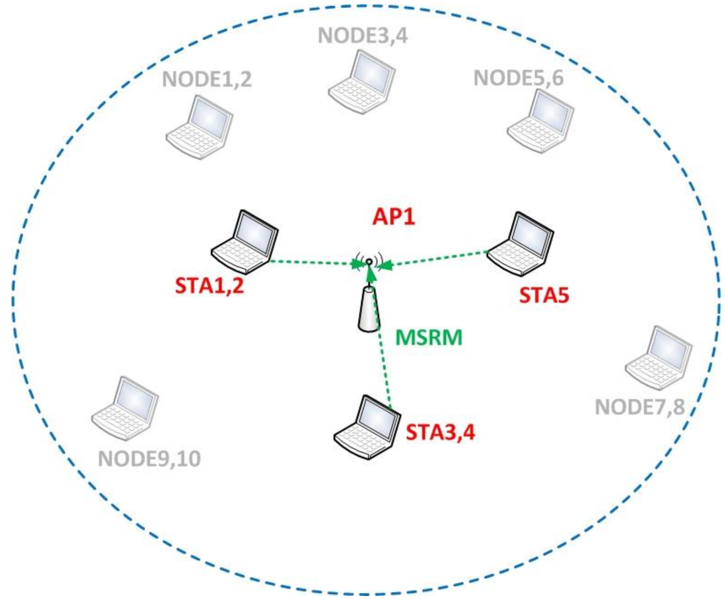

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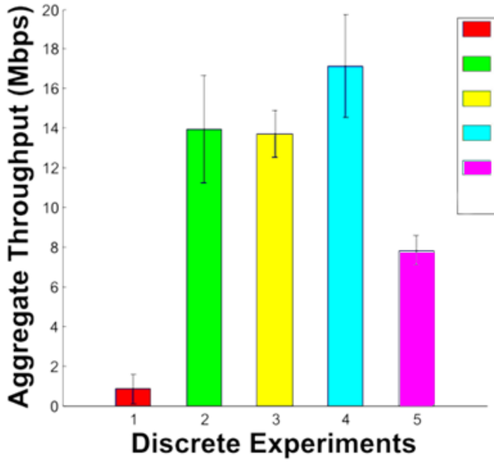
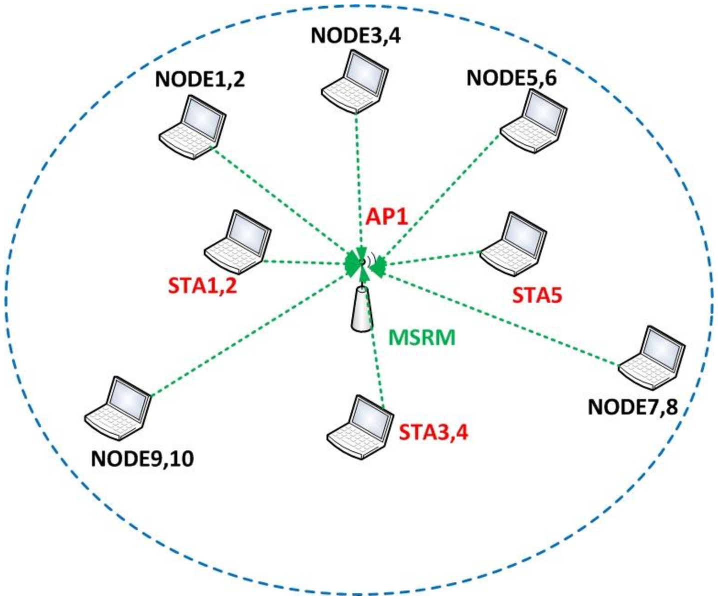
First set of Experiments (4/6)



(a) Throughput - Discrete Experiments.



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RSSI and Overlapping-based experiments in the 2.4 GHz band

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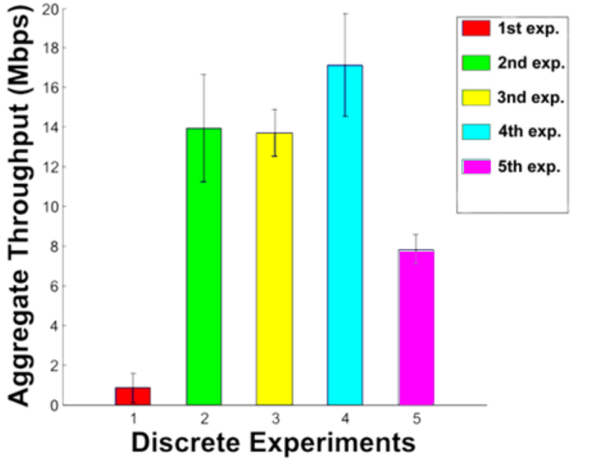
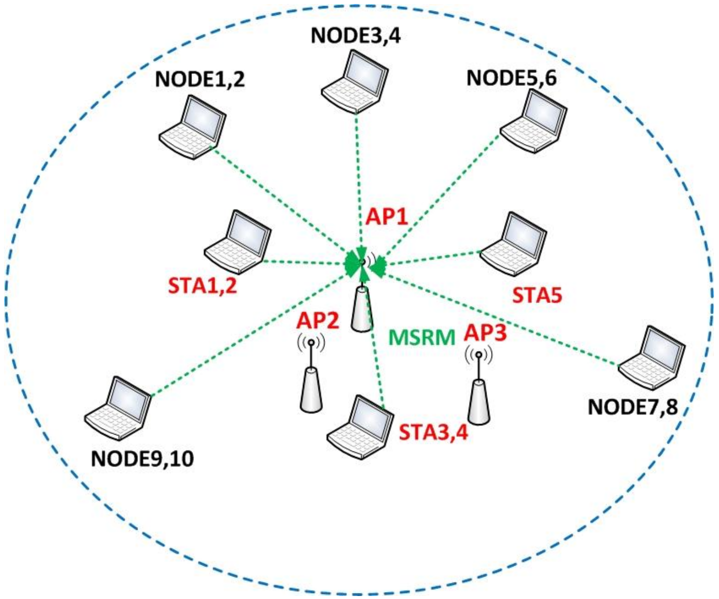
First set of Experiments (5/6)



(a) Throughput - Discrete Experiments.



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RSSI and Overlapping-based experiments in the 2.4 GHz band

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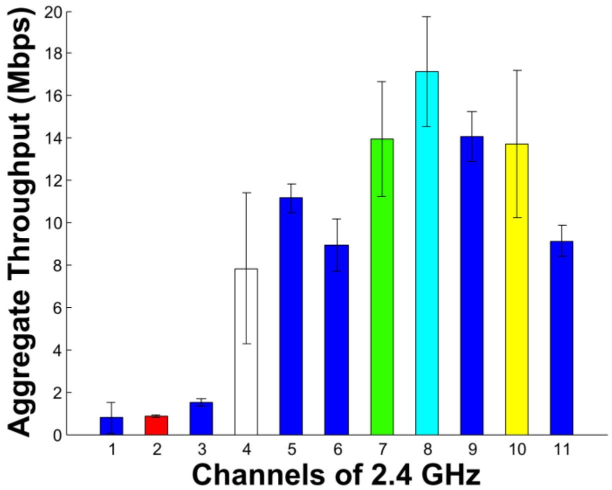
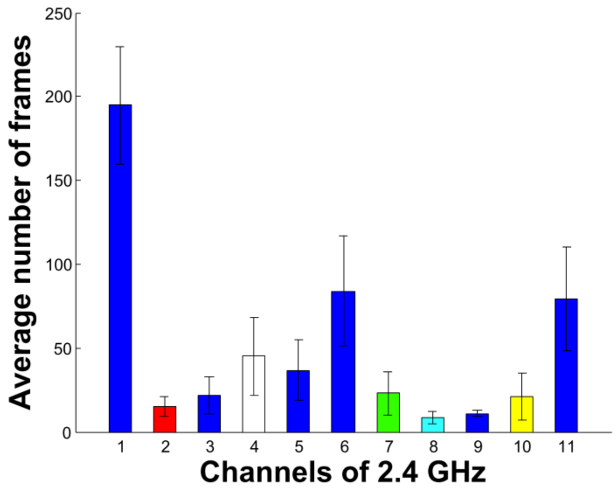
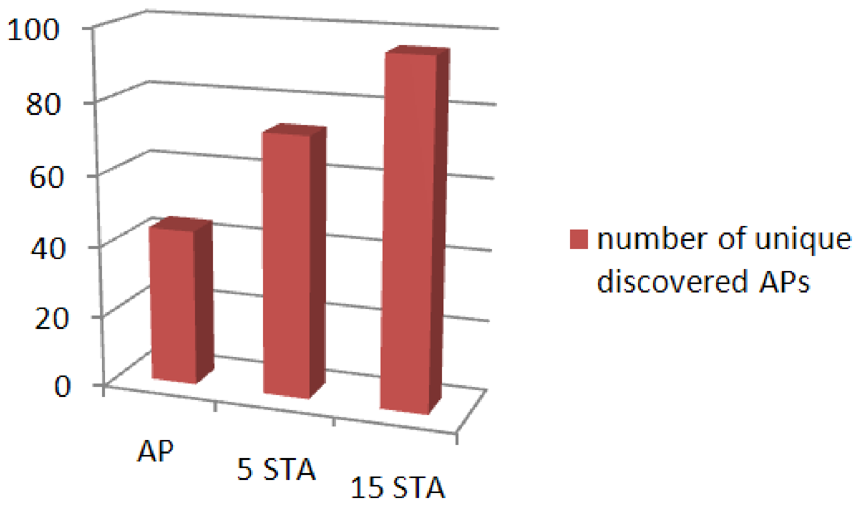
First set of Experiments (6/6)







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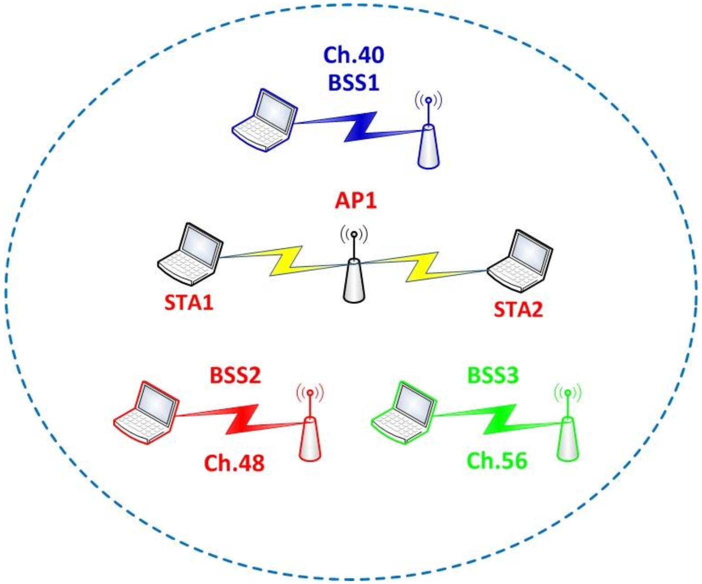
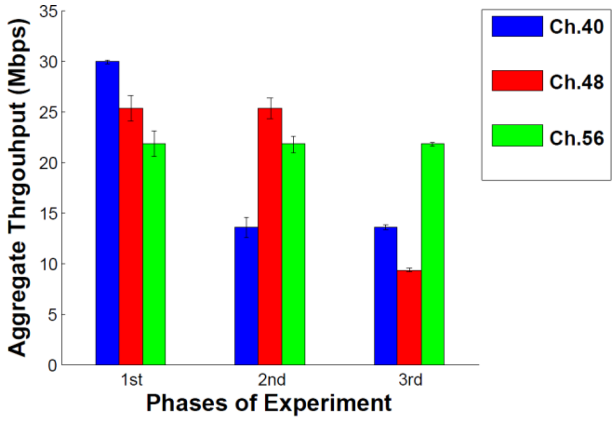
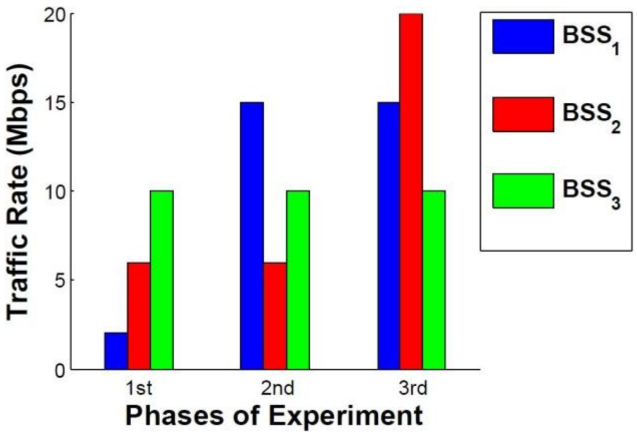
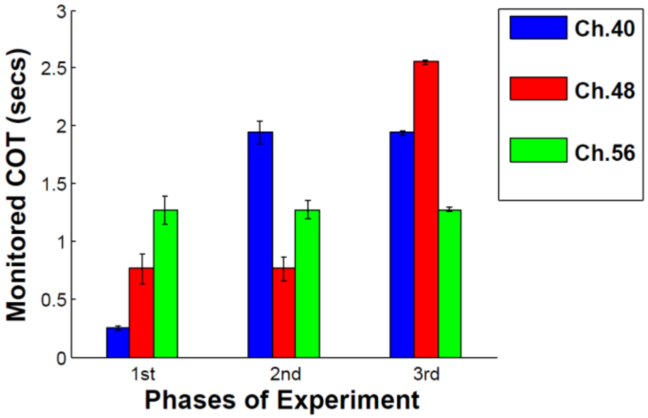
Second set of Experiments









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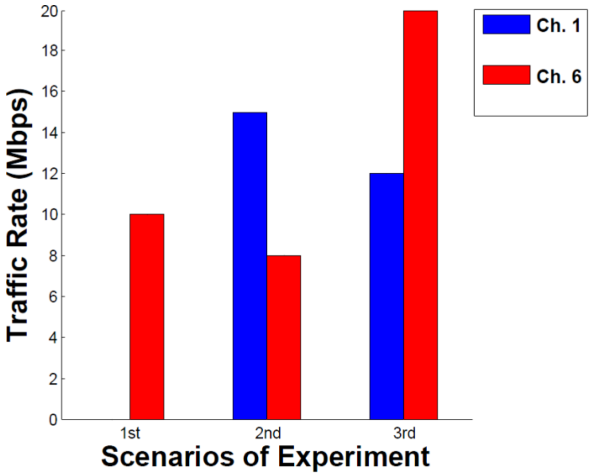
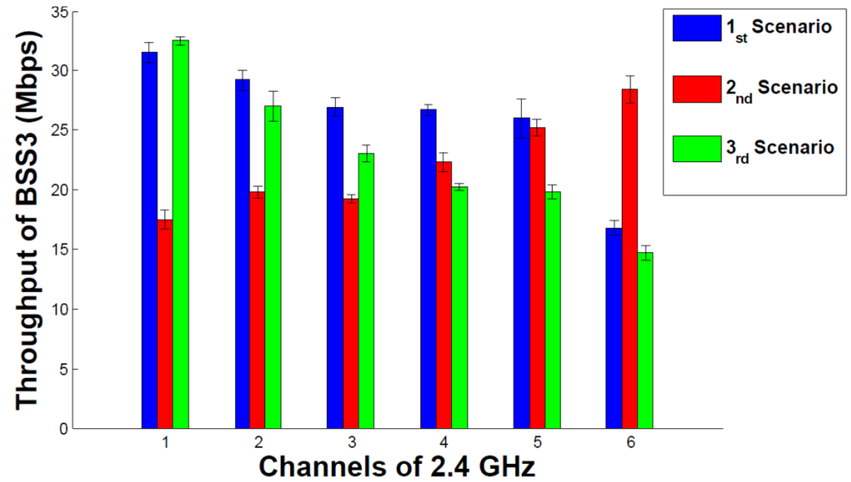
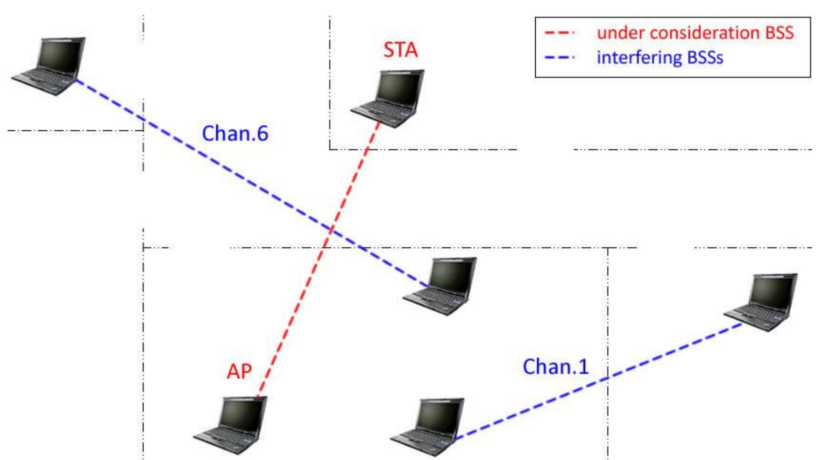
Third set of Experiments







- Indoor Testbed
- All features Simultaneously enabled

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Insights and Future Work

- Experimental Insights:
  - Transmissions received with RSS lower than 10 points in the RSSI scale do not affect throughput.
  - Interference exists even for nodes operating on channels separated by more than 6 channels.
  - Certain topology and TXpower configurations lead the Capture Effect to affect throughput either positively or negatively.

- Future Work:
  - Extend the mechanism to detect STAs as well.
  - Assign weights to STAs to improve estimation quality.
  - Take our own measurements about I-factor.
  - Incorporate the RSS threshold in our mechanism.
  - Further investigate the impact of Capture Effect.

Thank You!

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