Next-Gen WiFi Throughput Prediction

by

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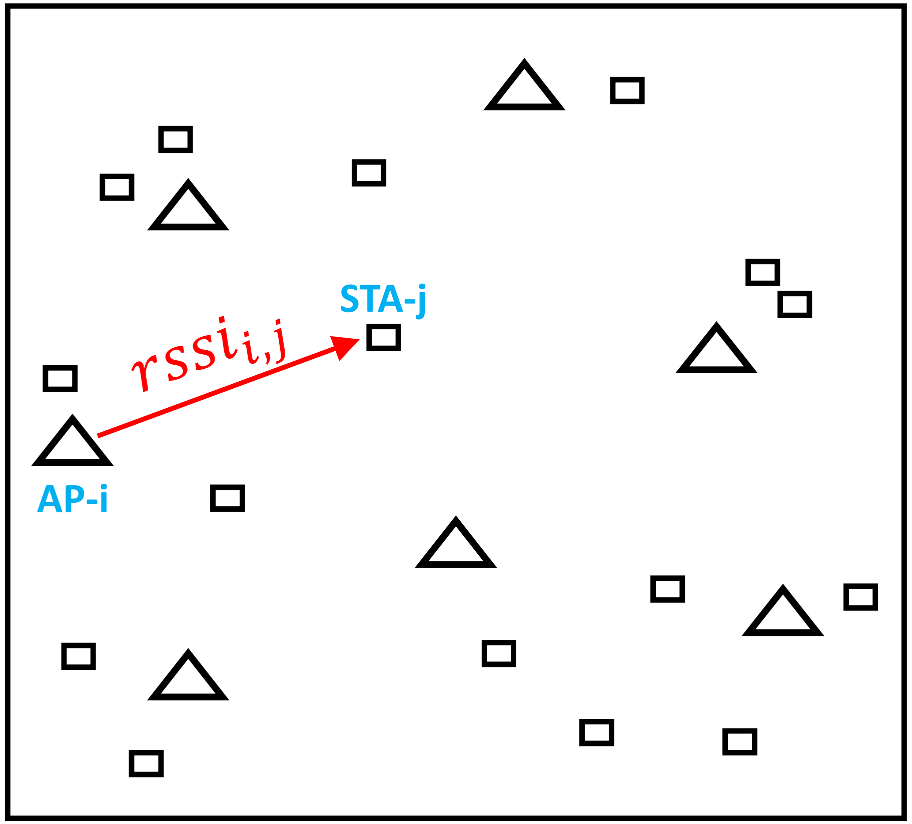
Objectives

A "deployment" of the wireless setup



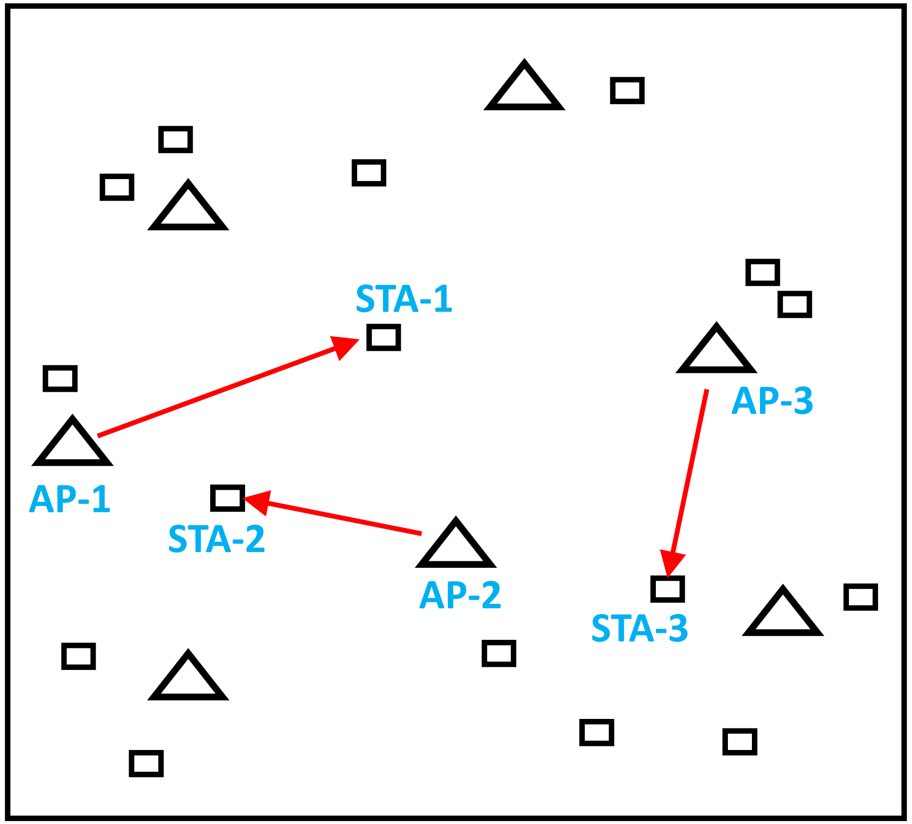
△ Access Point (transmitter)

□ Station (receiver)

- We are given a radio environment consisting of access points (AP) and stations (STA).
- The transmission strength between AP-i and STA-j is characterized by scalar called received signal strength indicator, $rssi_{i,j}$.
- Objective 1: Given a set of AP-STA pairs, and the $rssi_{i,j}$ for all $i's$ and $j's$, develop a predictive model to compute the throughput of each AP-STA pair in the set.
- Objective 2: Given $rssi_{i,j}$ for all $i's$ and $j's$, and the number of desired AP-STA pairs, find the set of AP-STA pairs that has the maximum net throughput.

Objective 1 (Predictive Modeling)

A “deployment” of the wireless setup



△ Access Point (transmitter)

□ Station (receiver)

- The set of AP-STA pairs is show in the figure.

- Suppose we want to compute the throughput of AP-2.

- Based on domain knowledge, throughput of AP-2 depends on:
  - $rssi_{2,2}$: Throughput **increases** with increase in $rssi_{2,2}$.
  - $rssi_{1,2}$: Throughput **decreases** with increase in $rssi_{1,2}$ because of interference/collision.
  - $rssi_{3,2}$: Throughput **decreases** with increase in $rssi_{3,2}$ because of interference/collision.

- Hence, the throughput of AP-2 is

$$\mu_{2,2} = f\left(rssi_{2,2}\,, rssi_{1,2}\,, rssi_{3,2}\right)$$

Objective 1 (Predictive Modeling)

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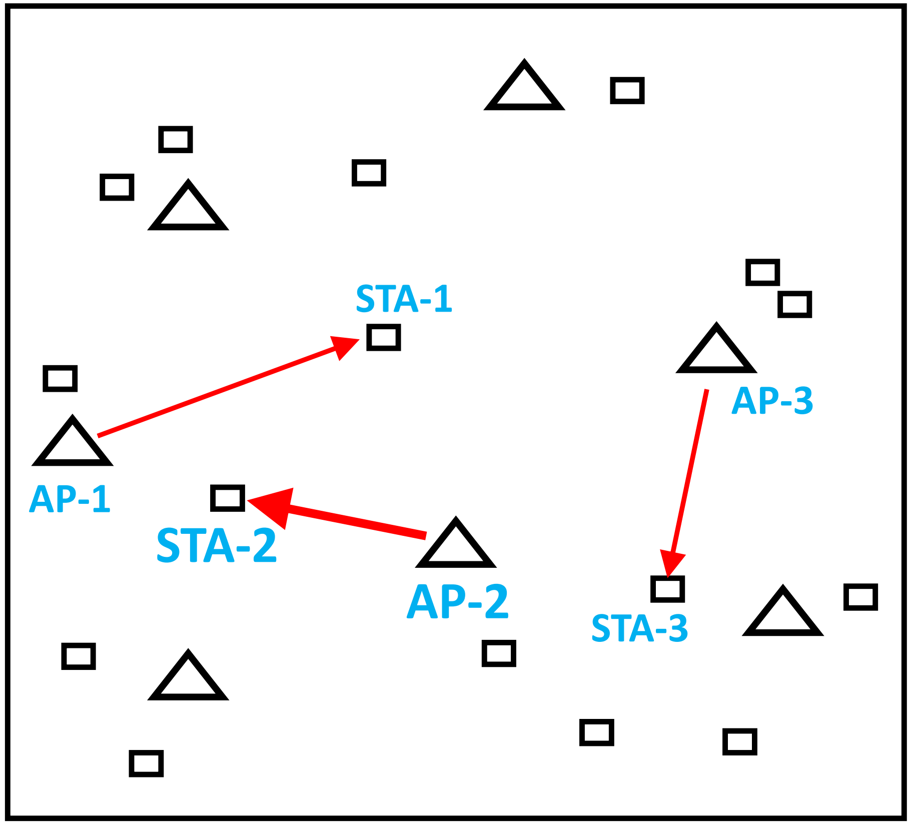

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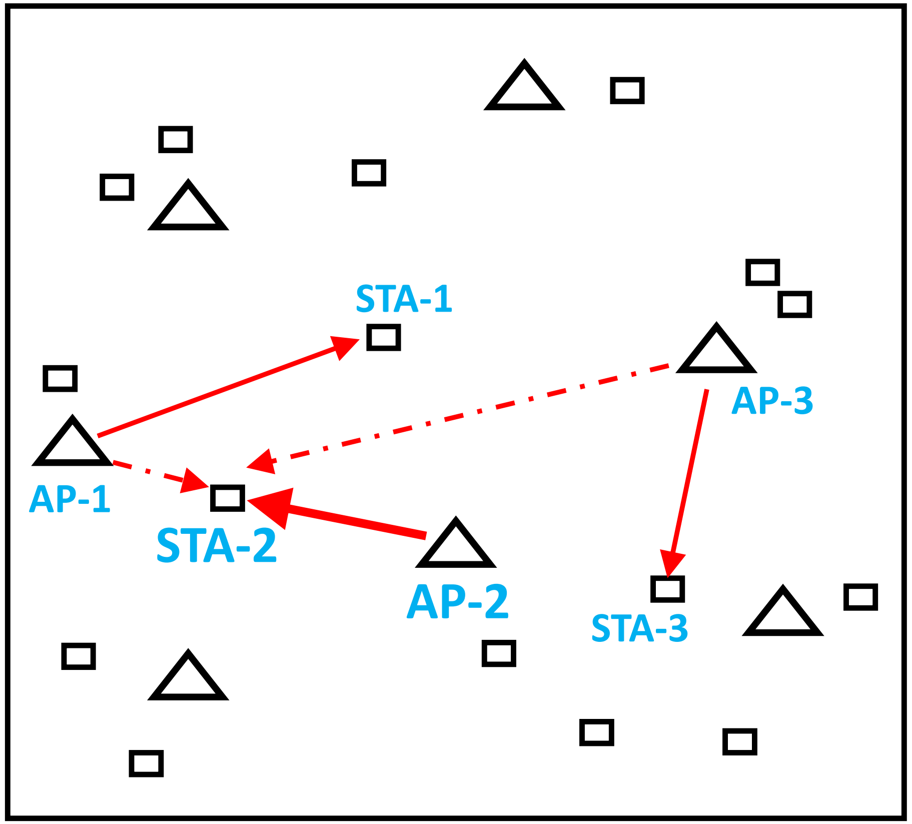

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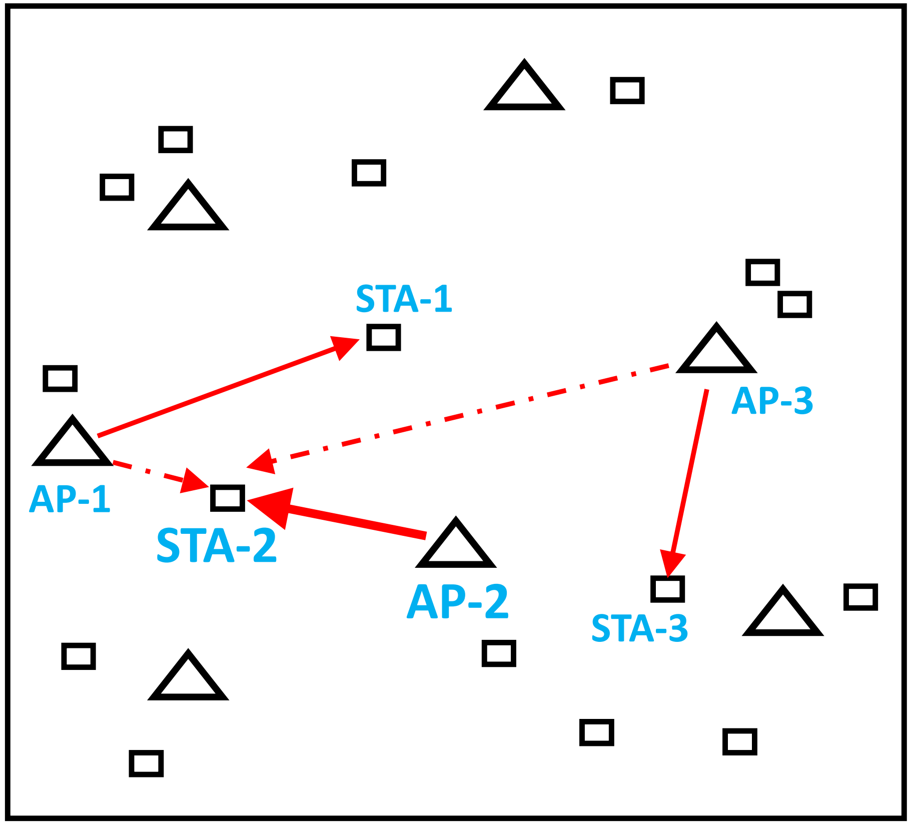

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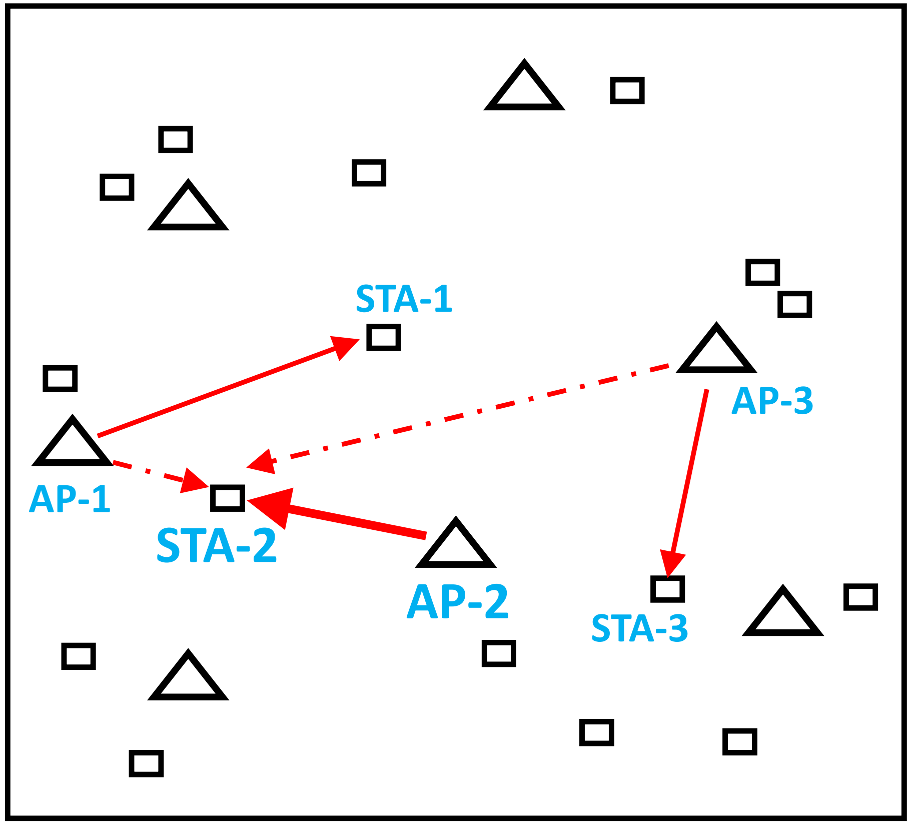

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- Hence, the throughput of AP-2 is

$$\mu_{2,2} = f\left(\underbrace{rssi_{2,2}}_{\text{1st column is the rssi of the AP-STA pair whose throughput we want to predict}}, \underbrace{rssi_{1,2}, rssi_{3,2}}_{\text{Remaining columns is \textbf{descending} order of rssi strength.}}\right)$$

While creating the feature-target table for training.

Objective 1 (Predictive Modeling)

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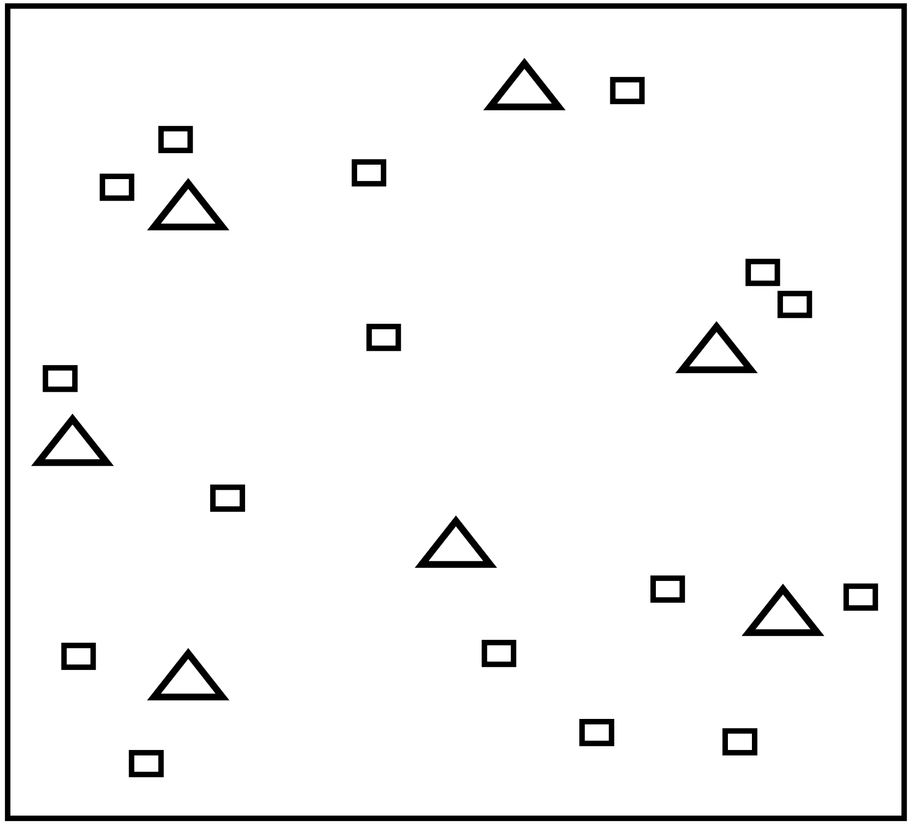

△ Access Point (transmitter)

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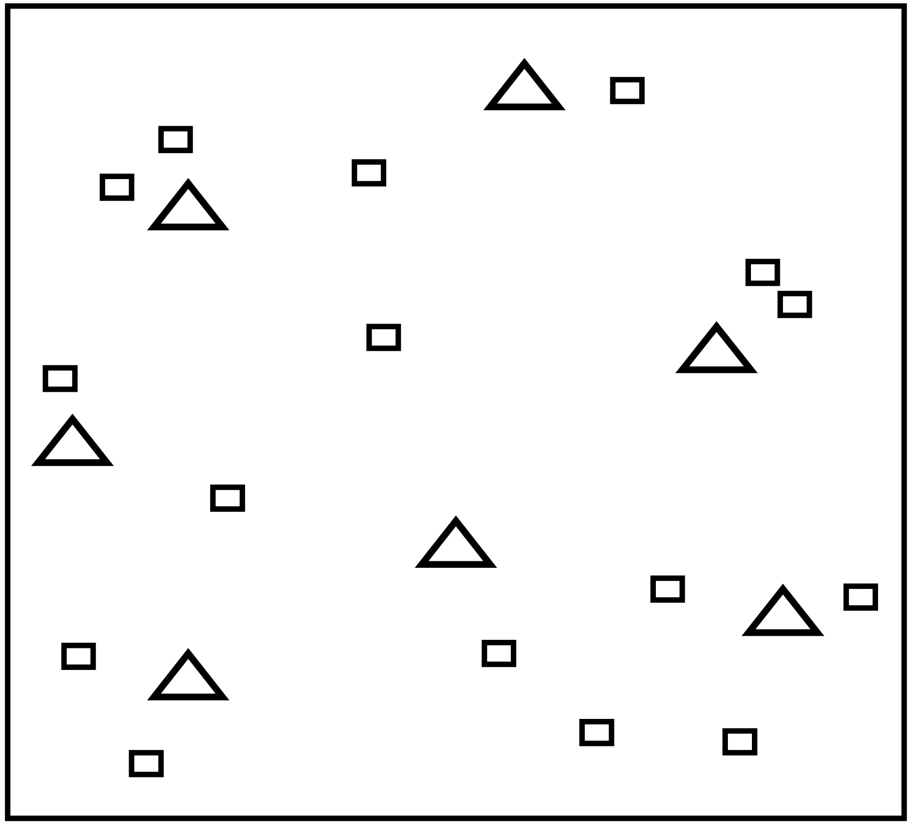
- Accordingly we make the training/validation datasets.
  - **Four** in total, one for each “number of AP-STA pair” in a transmission slot.
- We train four **XGBoost** regressor models using **4-fold cross validation**; one model for each of the four datasets.
  - Why XGBoost?: Most winning entries for ML competitions involving tabular datasets is some boosting-based model; XGBoost is a popular one.
  - Non-zero prediction error for validation dataset if **depth was less than 8**.
- During testing (prediction), we **average** the predicted throughput of the four models trained using cross validation.

Objective 2 (Combinatorial Optimization)

A “deployment” of the wireless setup



△ Access Point (transmitter)

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- Objective: Given:
  1. $rssi_{i,j}$ for all $i's$ and $j's$.
  2. number of desired AP-STA pairs, $m \leq n$, where n is the number of APs.

find the set of AP-STA pairs that has the maximum net throughput.

Objective 2 (Combinatorial Optimization)

RSSI Matrix

Access Points

Stations

	1	2	3	4	5	6	7
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							

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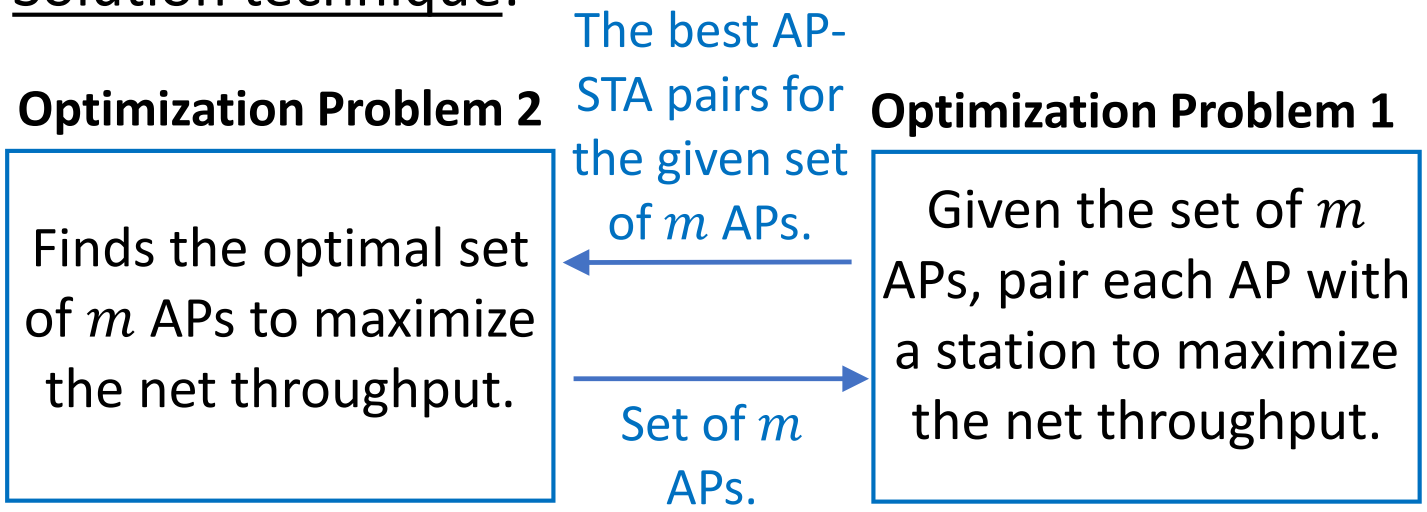
- Solution technique:



Optimization Problem 2

Finds the optimal set of m APs to maximize the net throughput.

The best AP-STA pairs for the given set of m APs.

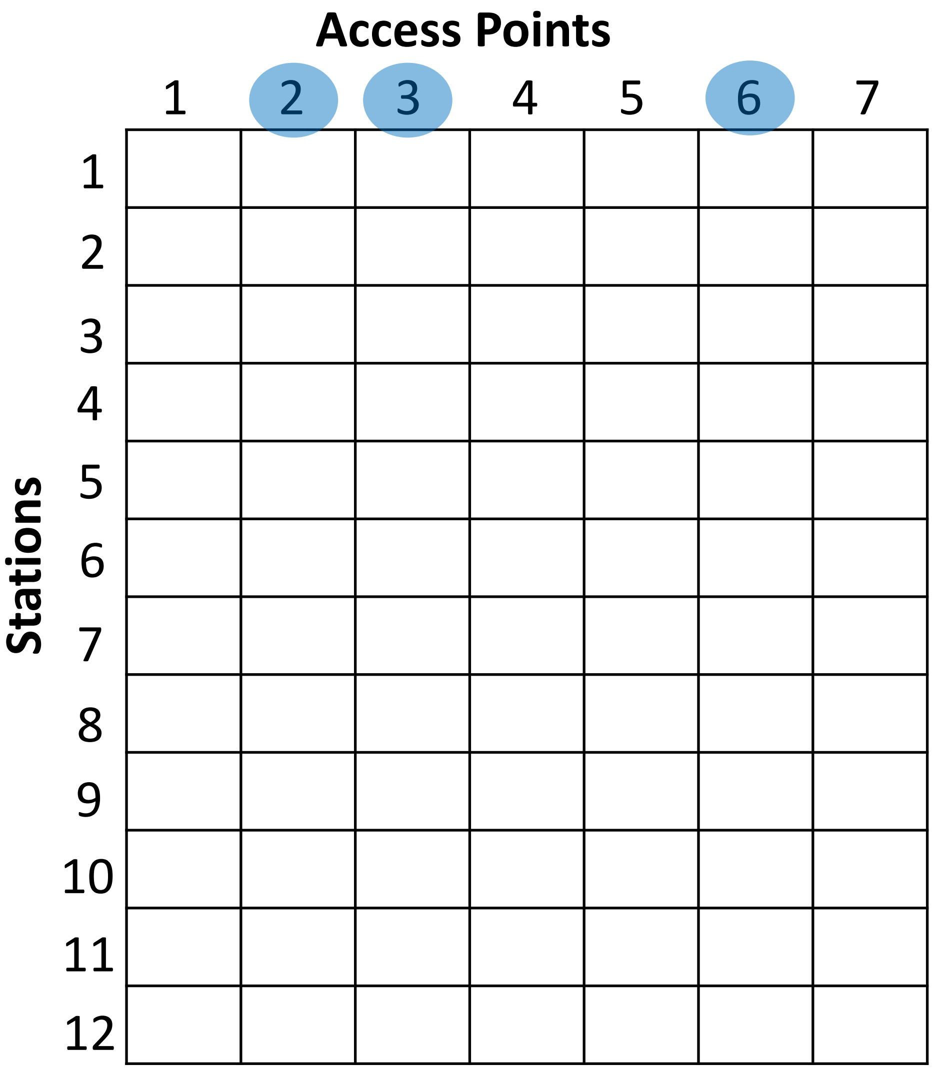
Set of m APs.

Optimization Problem 1

Given the set of m APs, pair each AP with a station to maximize the net throughput.

Objective 2 (Combinatorial Optimization)

RSSI Matrix



Access Points

Stations	1	2	3	4	5	6	7
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							

Optimization Problem 1

- The original RSSI matrix.
- Let $m = 3$. Let the set of GIVEN APs be $\{2,3,6\}$.

Objective 2 (Combinatorial Optimization)

RSSI Matrix

Access Points

Stations

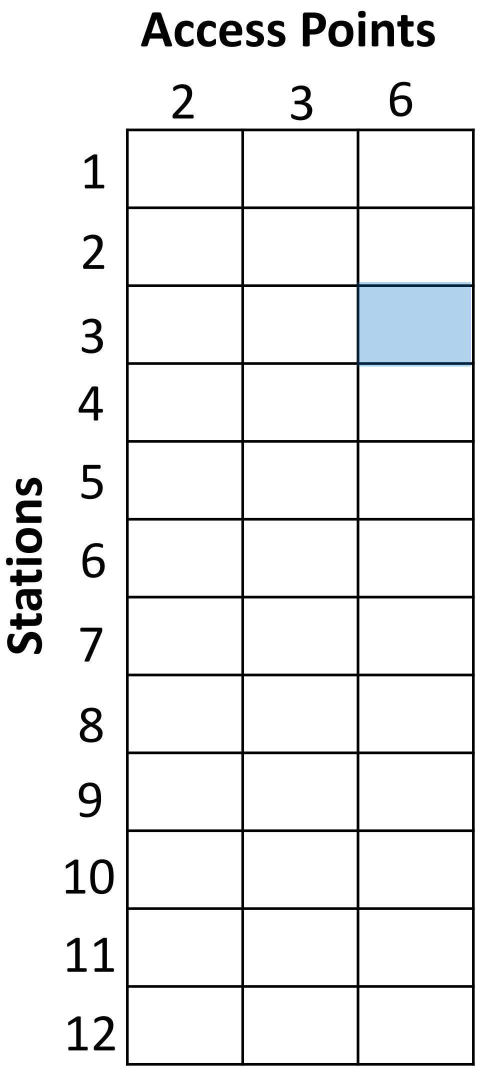
	2	3	6
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

Optimization Problem 1

- The original RSSI matrix.
- Let $m = 3$. Let the set of GIVEN APs be $\{2,3,6\}$.
- The modified RSSI matrix is shown.

Objective 2 (Combinatorial Optimization)

RSSI Matrix



Access Points

Stations

	2	3	6
1			
2			
3			▨
4			
5			
6			
7			
8			
9			
10			
11			
12			

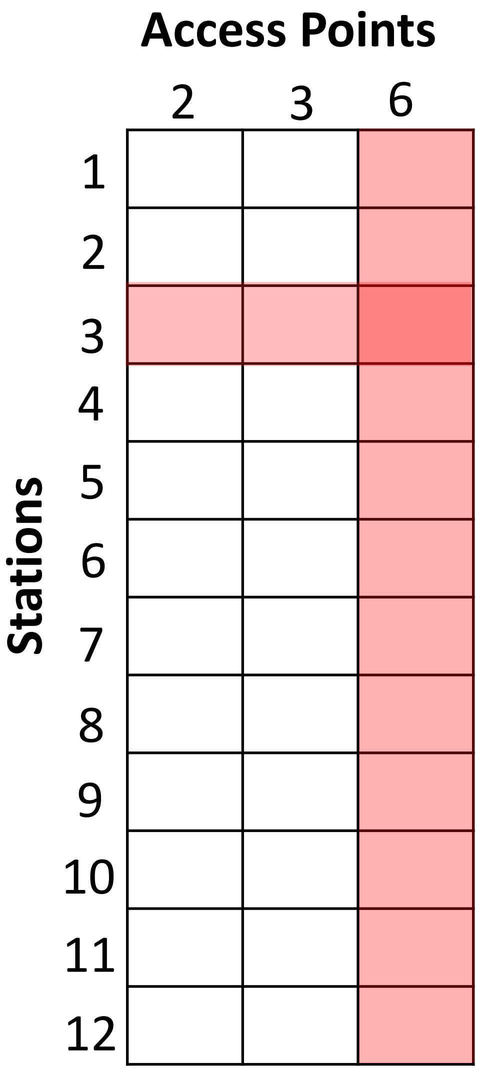
Optimization Problem 1

- An iteration of optimization problem 1:
  1. Find the cell of the current RSSI matrix with the highest RSSI value. Let is be the $(i, j)^{th}$ cell where i is the station index and j is the AP index. E.x. let $rssi_{3,6}$ be that value.
  2. We pair AP-j with STA-i. E.x. we pair AP-6 with STA-3.

     Why? Otherwise AP-j will create a strong interference for STA-I and the rssi strength of other APs for STA-i is less than $rssi_{i,j}$.
  3. Remove rows and columns associated with AP-j and STA-I from the current RSSI matrix.

Objective 2 (Combinatorial Optimization)

RSSI Matrix



	2	3	6
1			🟥
2			🟥
3	🟥	🟥	🟥
4			🟥
5			🟥
6			🟥
7			🟥
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10			🟥
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    3. Remove rows and columns associated with AP-j and STA-I from the current RSSI matrix. E.x. the red-boxes are not considered in the next iteration.

Objective 2 (Combinatorial Optimization)

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Optimization Problem 1

- The think that the solution strategy for optimization problem 1 is **optimal**.
- The proof of optimality should be straightforward and can be a component of the paper.
- Time complexity: $\boldsymbol{\mathcal{O}\left(m^2 N_{sta}\right)}$ where N_{sta} is the number of stations.

Objective 2 (Combinatorial Optimization)

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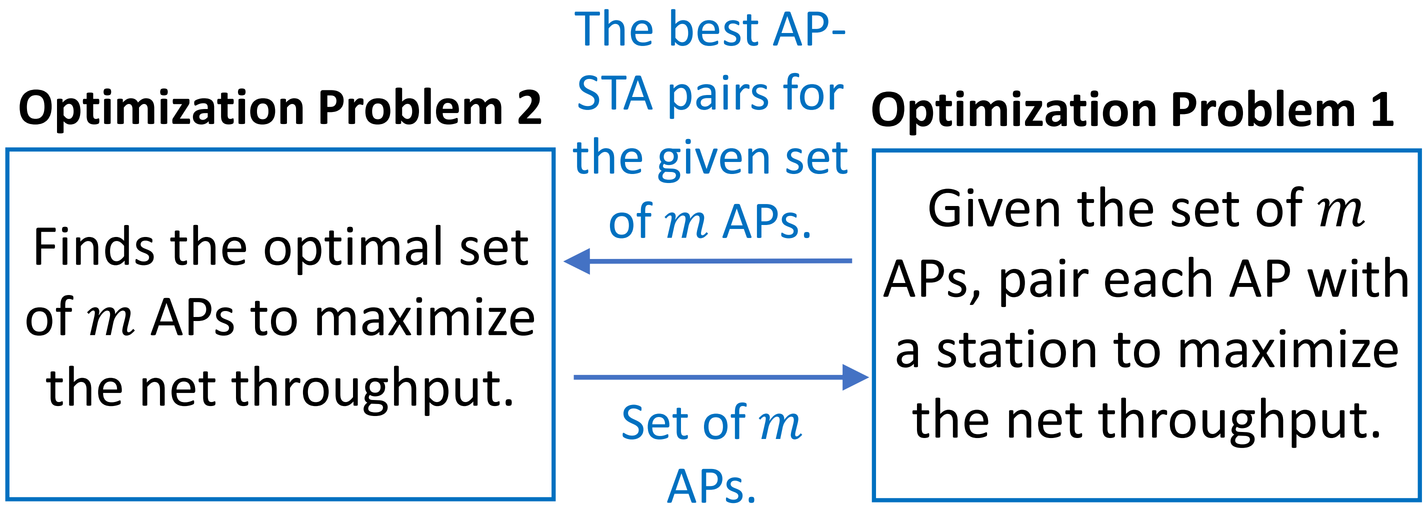
Optimization Problem 2



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Set of m APs.

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- For the given set of m APs, $\mathcal{A}$, let the optimal AP-STA pair be given by the function $h(\mathcal{A})$.
- We can use the **predictive model** that we developed to compute the net throughput for $h(\mathcal{A})$.

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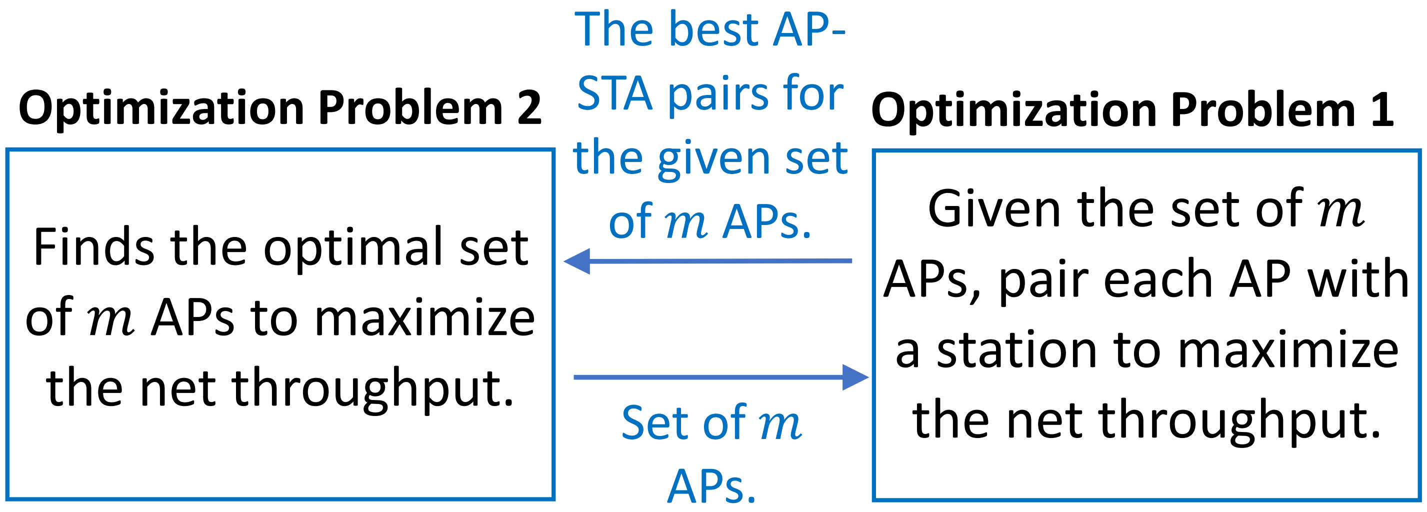

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- We can iterate over all the $\binom{n}{m}$ pairs of m APs to find the set of m APs with the maximum throughput.
- This technique makes sense because n is small $(n = 9)$ and hence $\binom{n}{m}$ is not large.

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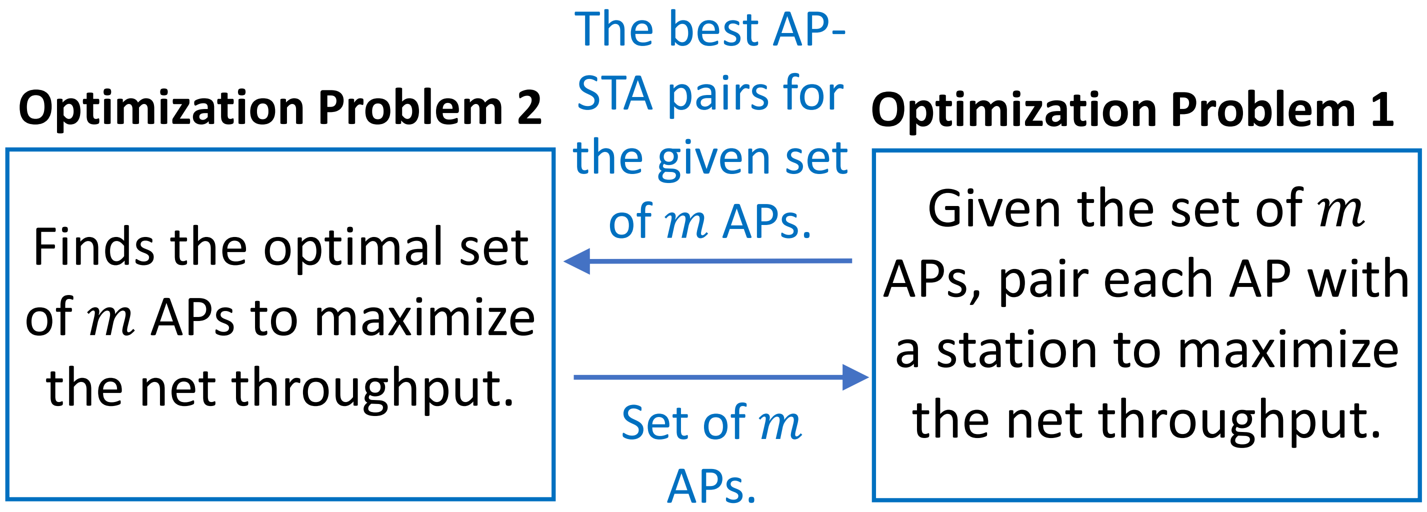

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- FUTURE WORK: Develop a heuristic for optimization problem 2 along with some performance bounds.

Thank You!

Questions?