Machine Learning for Networking

Introduction: What is ML?

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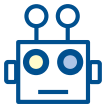


What is ML?

- **Definition**: Algorithms / techniques / mechanisms that improve **their performance** with more experience / more data.

- **Artificial Intelligence**: sense (get the data), reason (interpret the data), act (based on how the data is interpreted), enjoy (or not) the result
  - It can use ML to extract "knowledge" from the data
  - Data + ML Algorithms + Reasoning → (A)Intelligence
- **Deep Learning:** A ML technique that uses multi-layer Neural Networks

What is a model?

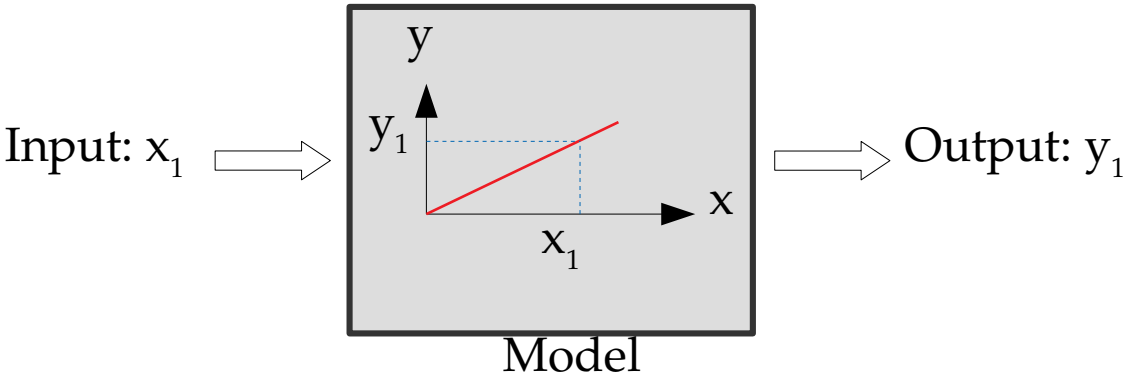
- A model is a representation / abstraction of a complex system.
- Are models useful? Well… they can be used for predicting the future…

Question → Model → Answer

- If we know what the future nay do things in a different way.

ML for building models

- ML for b**uilding models** from data / experience.



- Many companies such as X,Y and Z are now modeling our likes, dislikes, behaviors, etc. from our data. Are we predictable?

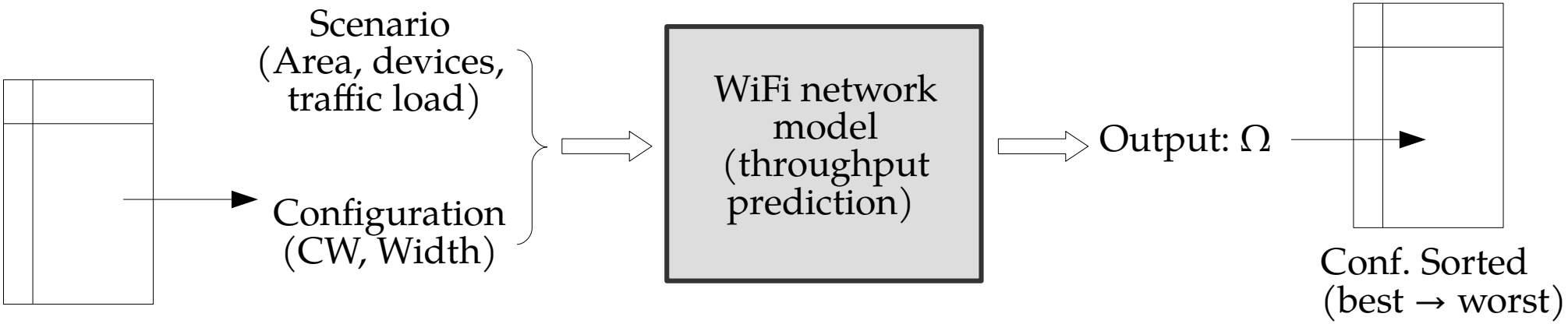
Applications in Networking

- Identify security attacks by comparing 'patterns'
- Classifying traffic flows
- Predicting network failures in advance
- …
- Predicting IoT data from sensors so we can avoid unnecessary transmissions → Lab 2
- Predicting the performance of a certain 'network configuration' in advance, so we just apply those that work
- Learning what to do in presence of uncertainty…

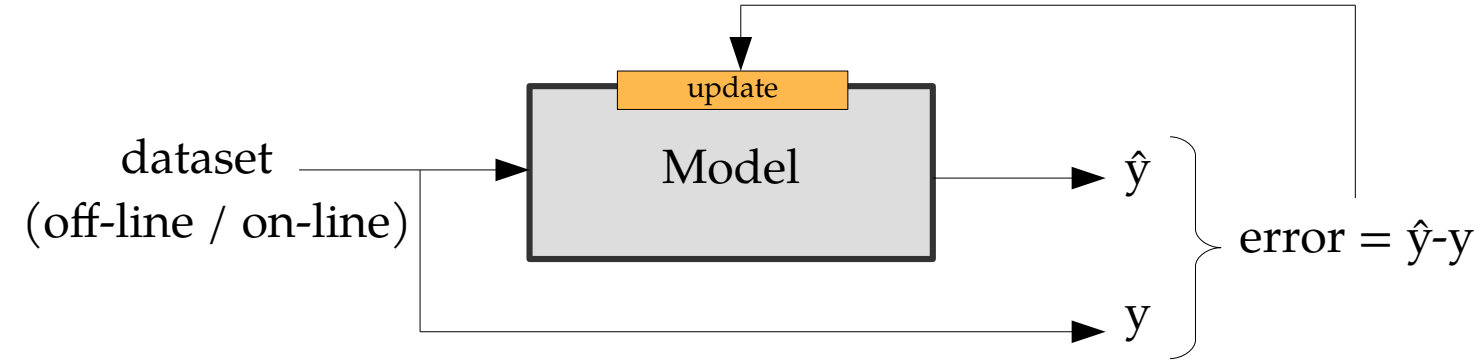
Ok, all that sounds good… but if the model is not accurate… nothing to do!

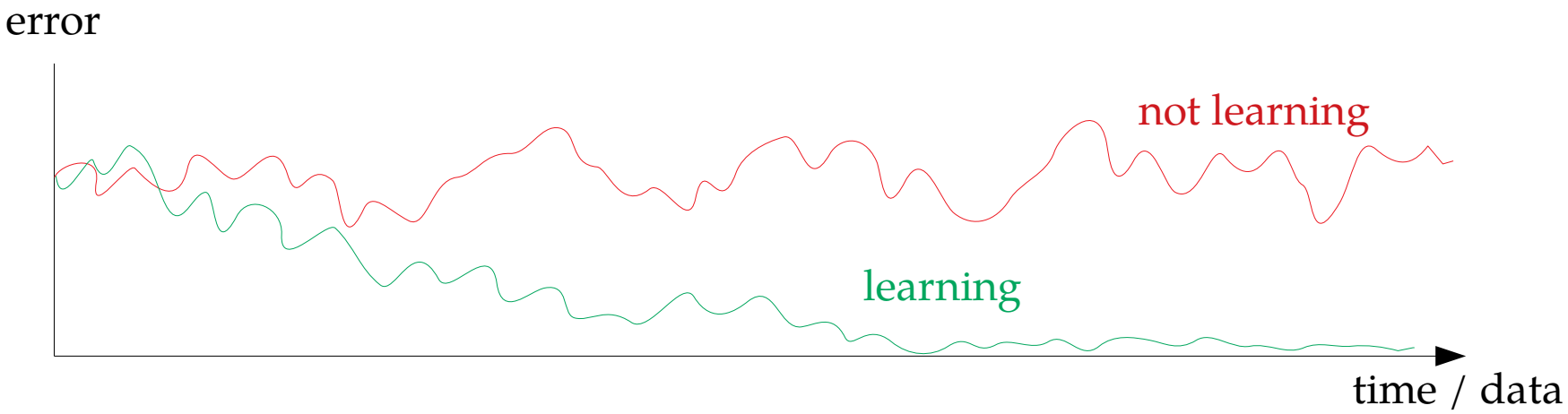
WiFi network optimization

- Brute force: I test many configurations (few seconds), and choose the best one.

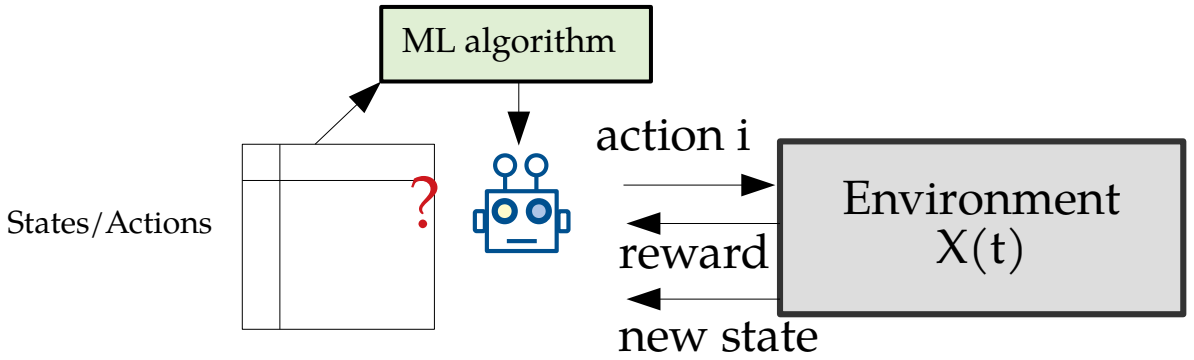


Create a ML model: training (supervised learning)



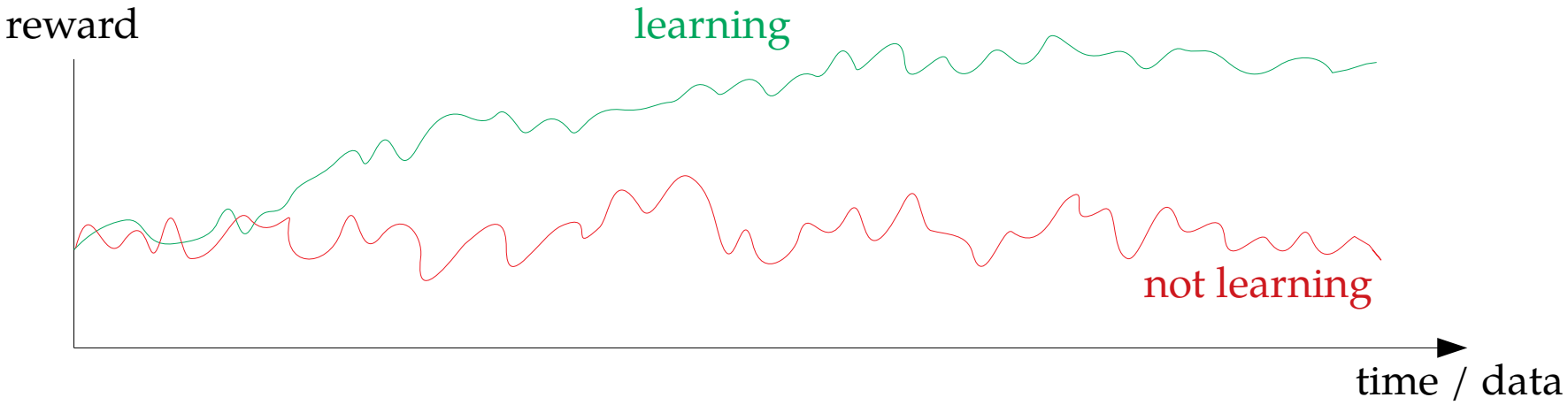


Train an agent (reinforcement learning)

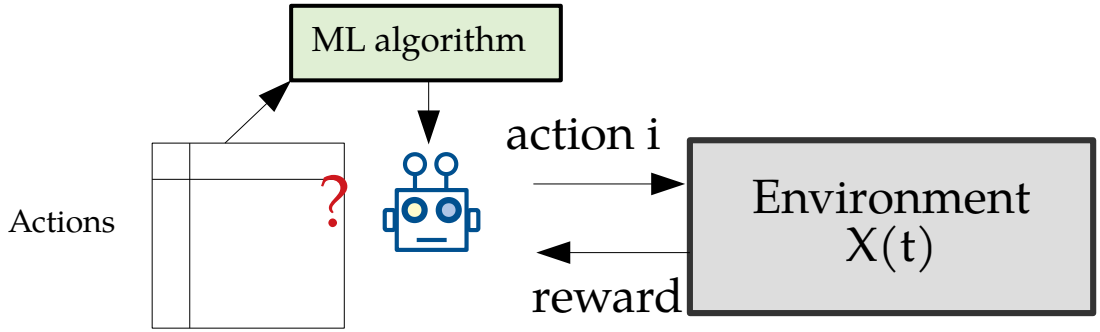


The agent learns by interacting with the environment.

The ML algorithm tells the agent how to do that interaction to maximize the reward.

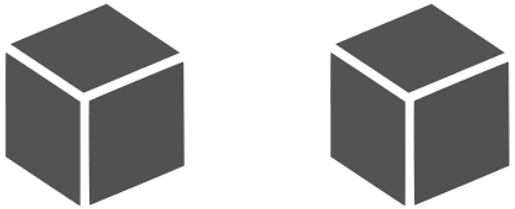


Example



?

Which box will give me the best reward?

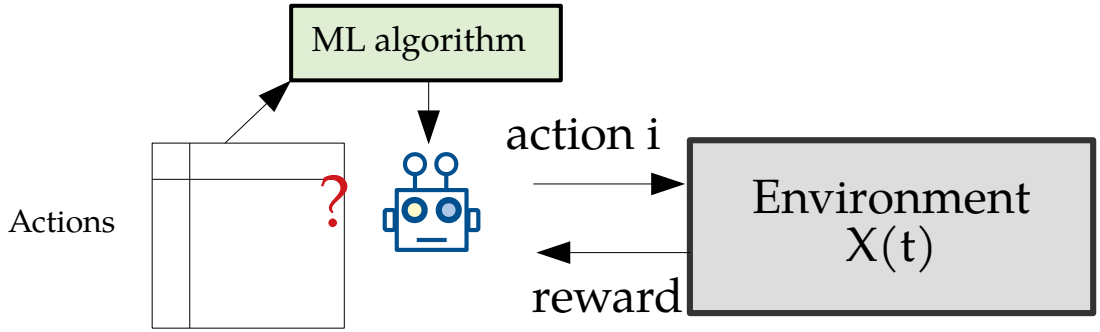


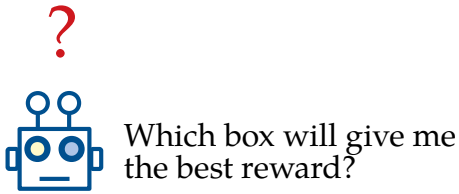
Execute ExampleLecture1.m

Each box can have different rewards, so we need to learn which is the best one

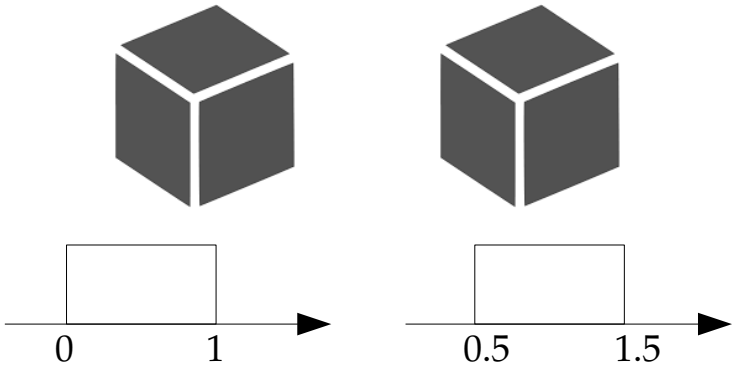
Do we know it in advance? If yes, we already have the knowledge, so let's use it. If not, we will need to explore (learn!) in an efficient way.

Example



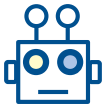


Which box will give me the best reward?



Distribution of the reward (unknown for the agent)
Uniform distribution, different potential values

Execute ExampleLecture1.m



Machine Learning for Networking

- Lectures (Boris) → Reinforcement Learning
  - Random selection, ExpExp-tradeoff, MABs, MDPs, Q-learning, etc.
- Seminars (Marc) → Supervised Learning
  - Regression, Classification, Decision Trees, Neural Networks, etc.
- Labs (Marc)
  - Lab 1: AP selection using MABs (link)
  - Lab 2: Optimizing a IoT network using ML (link)
    - *Learning the optimal sampling rate from the data using RL*

Keep Matlab open in all sessions!

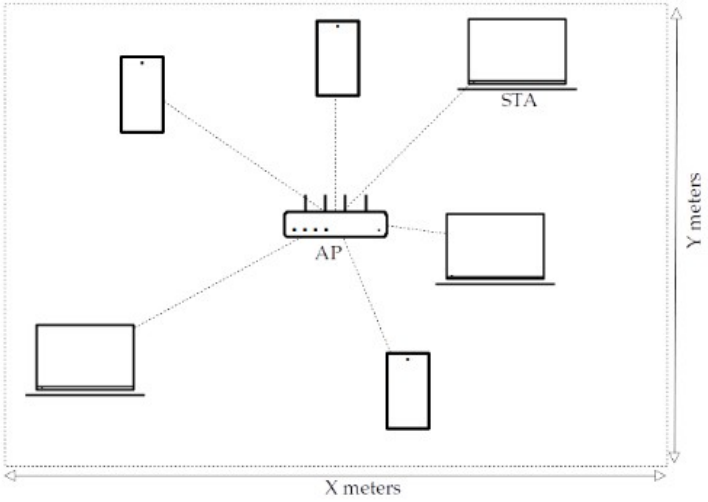
Machine Learning for Networking

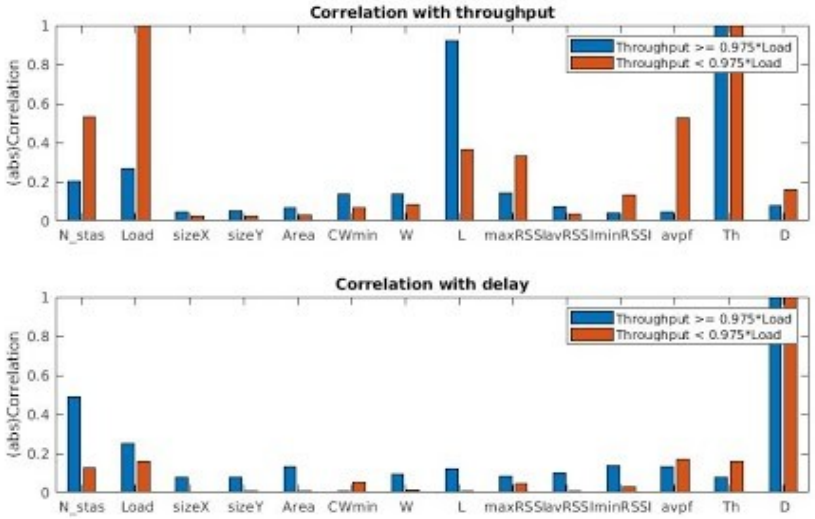
- Report “project” seminars: 20 %
- Report (+code) Lab 1: 20 %
- Report (+code) Lab 2: 20 %
- Exam: 40 % (this is the only evaluation activity than can recovered in July)

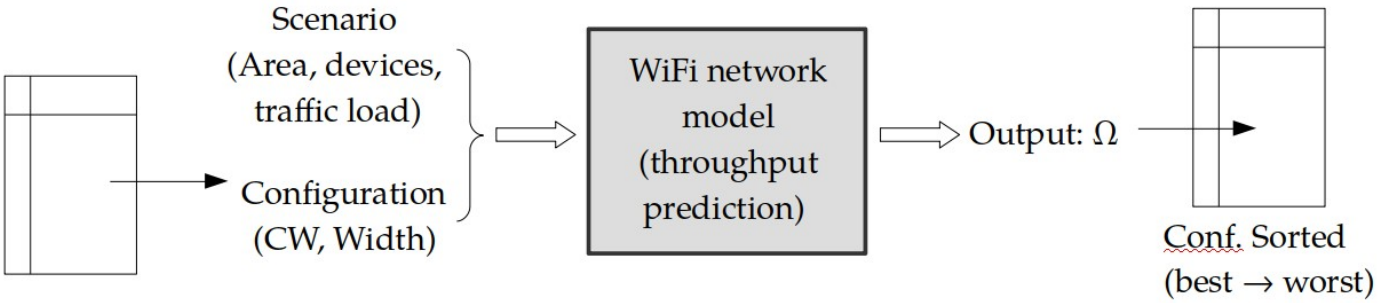
Machine Learning for Networking

- Lecture 1 - What is ML? Introduction to WiFi
- Lecture 2 - WiFi performance models I
- Seminar 1 - Analyzing a (WIFI) dataset (pdf, link to dataset)
- Lecture 3 - WiFi performance models II
- Lecture 4 - WiFi performance models III
- Lab 1 - AP selection using MABs: Scenario set-up
- Seminar 2 - Regression and decision tree models
- Lecture 5 - Are we lucky? Random exploration without learning
- Lecture 6 - Reinforcement Learning: states, actions and rewards
- Lecture 7 - Multi-armed bandits
- Lab 2 - AP selection using MABs: Hands on
- Seminar 3 - Classification models
- Lecture 8 - Multi-armed bandits - Creating a dataset using agents employing MABs?
- Lecture 9 - MDPs
- Lecture 10 - Q-learning I
- Lab 3 - AP selection using MABs: design your own MAB!
- Seminar 4 - Neural Networks
- Lecture 11 - Q-learning I and other state-based RL techniques
- Lecture 12 - IoT Data Analytics
- Lab 4 - Introduction to ThingSpeak
- Lab 5 - IoT Data collection and prediction using ThingSpeak
- Seminar 5 - Comparative of different prediction models
- Lab 6 - IoT Data collection and prediction using ThingSpeak

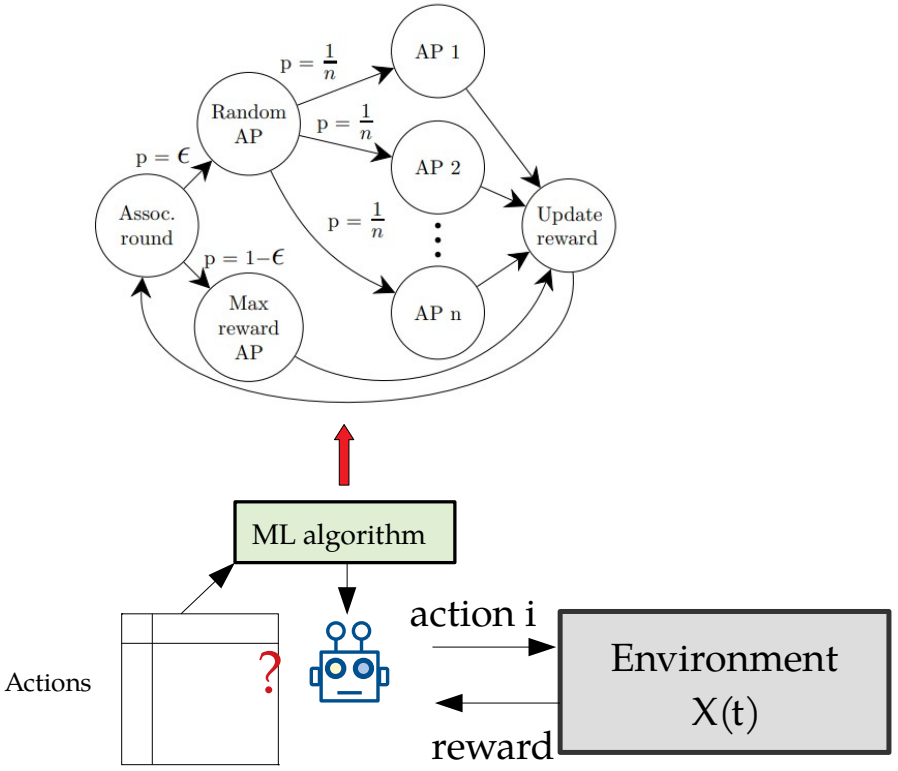
Learning Wi-Fi performance

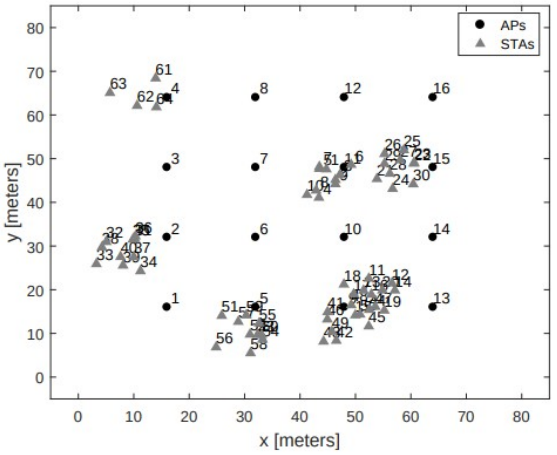


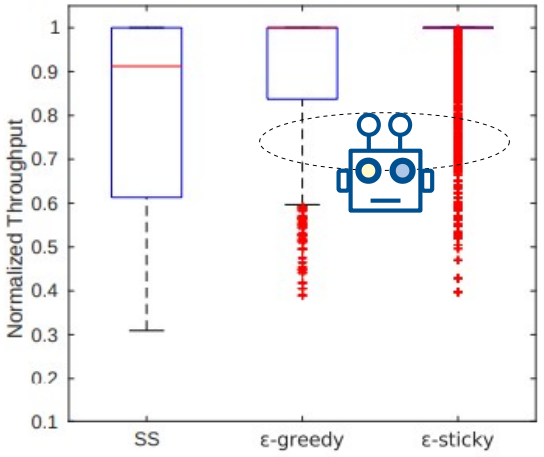




AP selection in Wi-Fi networks







Optimizing an IoT network from data (FEM IoT project)