ITUEvents

ITU-ML5G-PS-013: Improving the capacity of IEEE 802.11 WLANs through Machine Learning

10 July 2020

(Universitat Pompeu Fabra, Barcelona)

ITU

AI/ML in 5G Challenge

Applying machine learning in communication networks

ai5gchallenge@itu.int

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1 Introduction

The UPF

Eight disciplines spread across **three campuses** in Barcelona (Spain):

- Health and life sciences
- Political and social sciences
- Communication
- Law
- Economics and business
- **Engineering and information and communication technologies**
- Humanities
- Translation and language sciences

The problem statement in a nutshell

- **Channel Bonding (CB) problem in IEEE 802.11 WLANs:**
  - All the information here: https://www.upf.edu/web/wnrg/ai_challenge
  - Dataset available here: https://zenodo.org/record/3879458 - .Xwa7hJMzbyg
- **Timeline:**
  - Registration: 31 July 2020
  - Global Round duration: June - October 2020
  - Deadline to submit a solution: 15 September 2020
  - Announcement of the winners: October 2020
- **How to participate?**

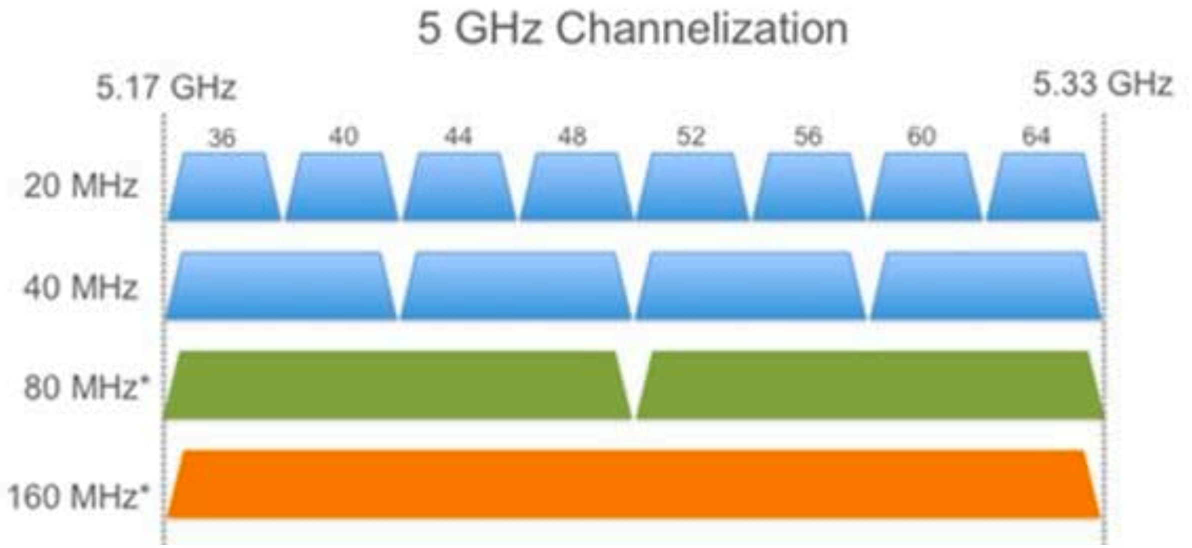
1. If you don't have an ITU account, please follow the guidance to create one for challenge registration.
2. Register on ITU AI/ML in 5G challenge website with your ITU account.
3. Fill out the ITU AI/ML in 5G Challenge Participants Survey to select problem statement **ITU-ML5G-PS-013**. You can enroll as a team with 1-4 members.
4. Begin to work on this problem and submit your results. We will begin to accept submissions from **July 31, 2020** and the submission deadline is **September 15th, 2020**.

2

Channel Bonding in IEEE 802.11 WLANs

Background in Channel Bonding

- Firstly introduced in 802.11n
- Further developed in 11ac, 11ax, 11be…
- Improve capacity by bonding frequency channels
- Up to 160 MHz bond
- Some references [1-2]



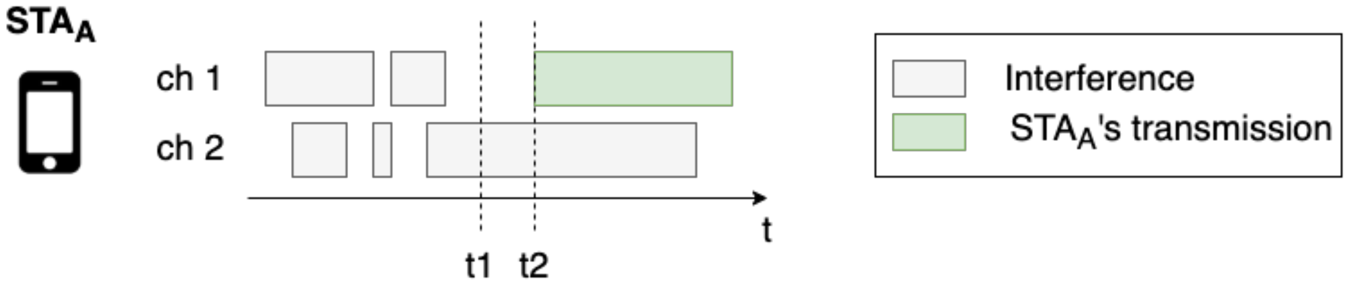
Source: https://www.sourceonetechnology.com/802-11ac-wireless-channel-bonding-mimo-spatial-streams-and-beamforming/

[1] Barrachina-Muñoz, S., Wilhelmi, F., & Bellalta, B. (2019). Dynamic channel bonding in spatially distributed high-density WLANs. *IEEE Transactions on Mobile Computing*.

[2] Barrachina-Muñoz, S., Wilhelmi, F., & Bellalta, B. (2019). To overlap or not to overlap: Enabling channel bonding in high-density WLANs. *Computer Networks*, *152*, 40-53.

Policies for Channel Bonding

- The way channel is accessed may vary according to the policy
  - Static vs Adaptive approaches
- We consider a dynamic policy whereby the maximum possible channel is selected
- Example:



t1: Check channel before transmitting (1:free, 2:busy)
t2: Transmit over free channels (1)

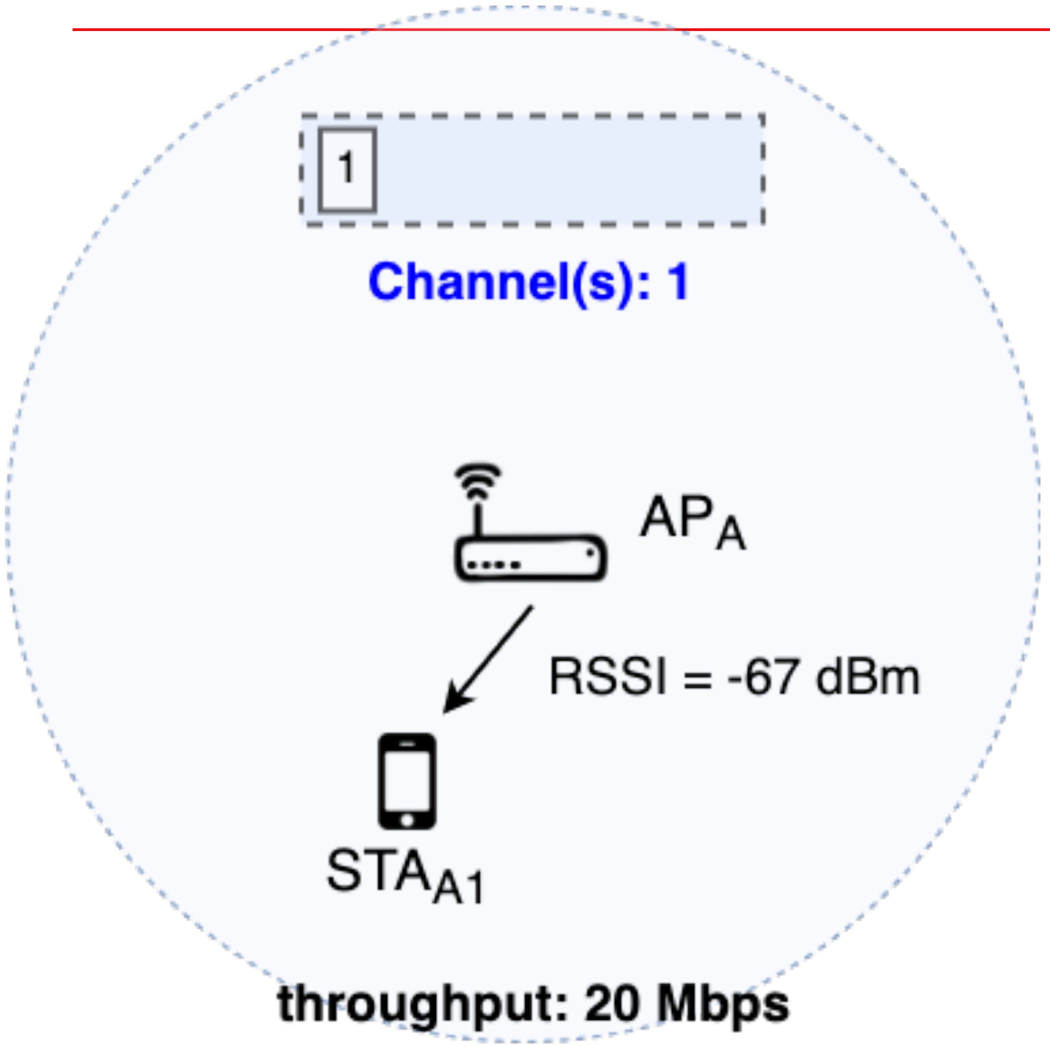
Challenges of Channel Bonding

- Trade-off between channel width, data rate, and contention

$$C = B \cdot \log_2(1 + SINR)$$

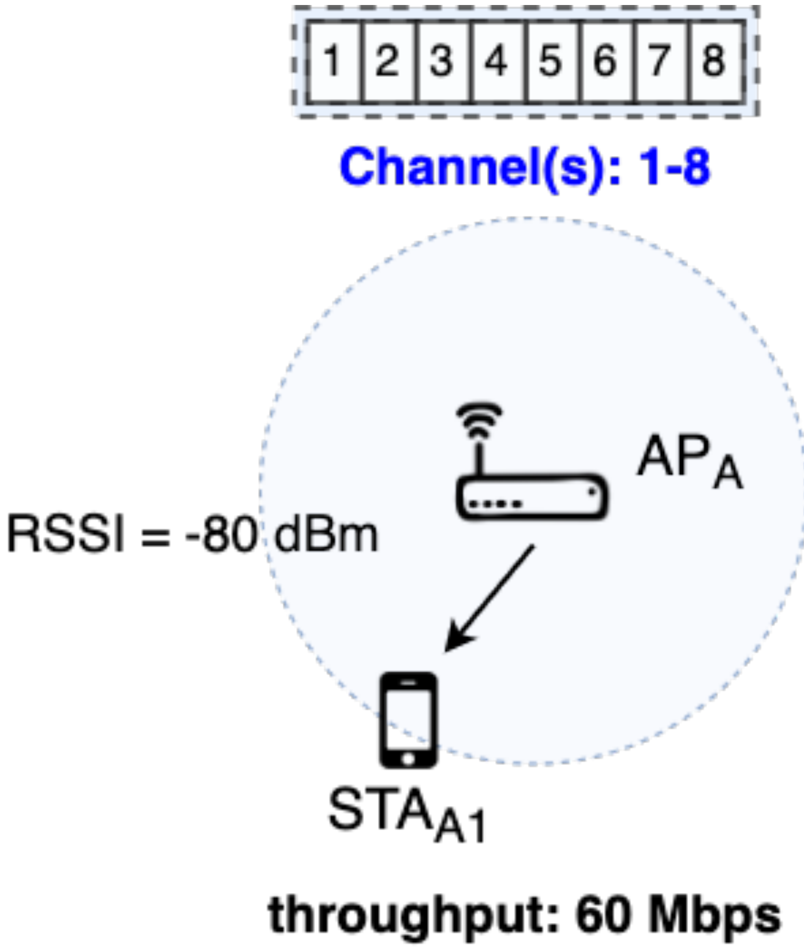
- Next-generation deployments are complex
  - Crowded
  - Multiple interactions
  - Combinatorial action space

Example of Channel Bonding



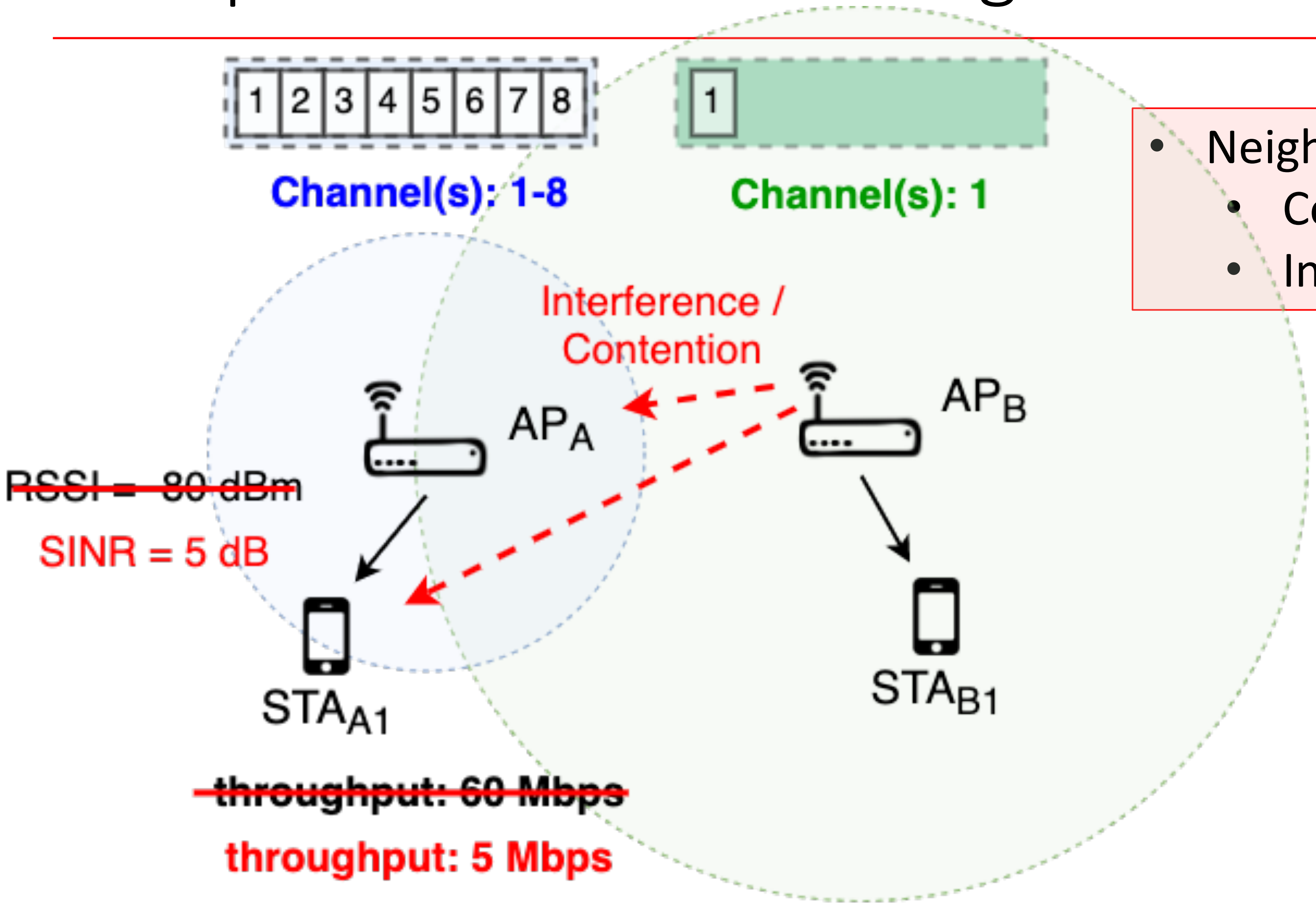
- The quality of the transmission depends on the Tx power & Channel effects

Example of Channel Bonding



- Throughput is not x8
- Transmission power is spread across the spectrum

Example of Channel Bonding



- Neighbouring devices:
  - Contention
  - Interference

3 Komondor Simulator

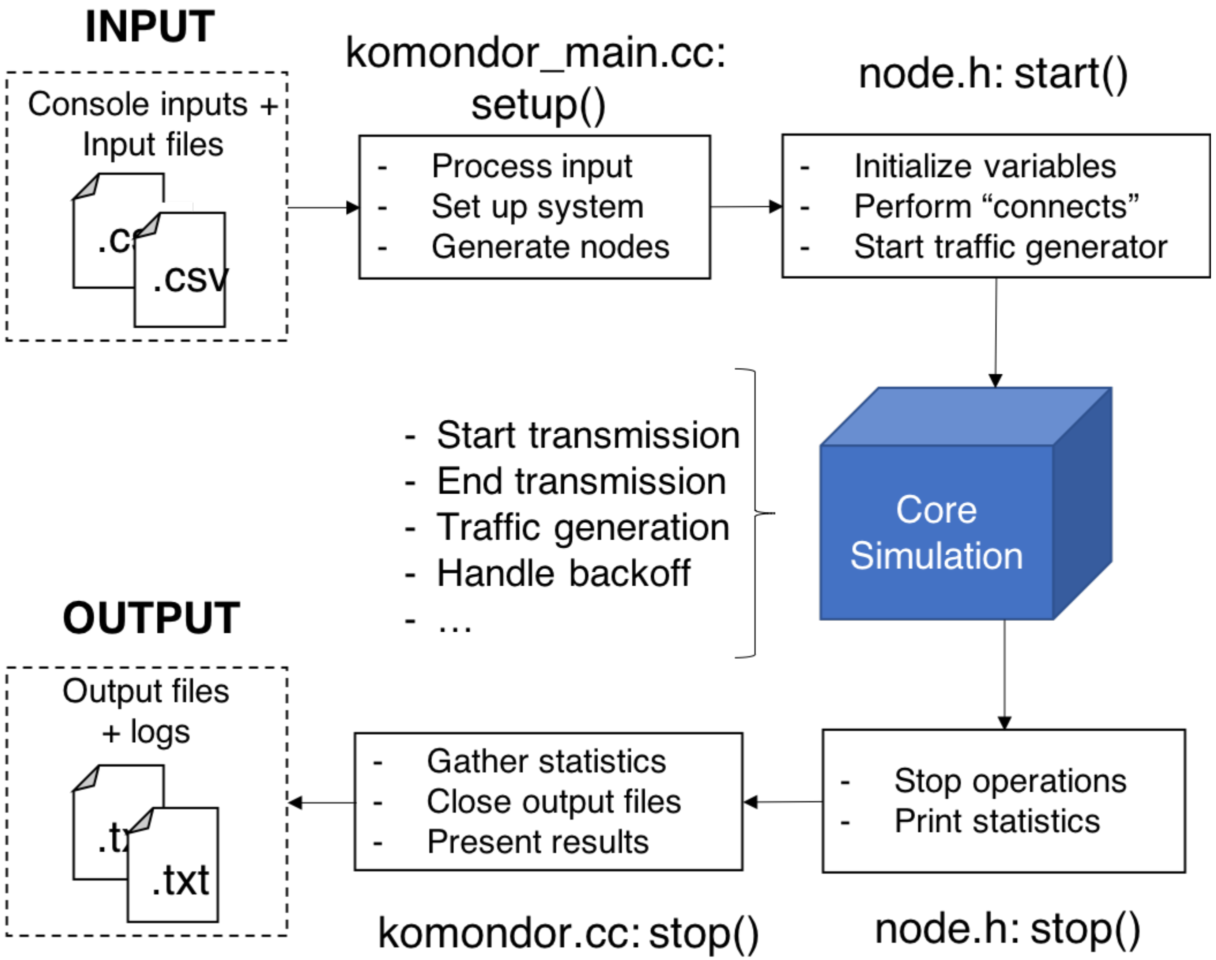
Introduction to the Simulator

Komondor (https://github.com/wn-upf/Komondor)

- Written in C/C++
- Characterizes IEEE 802.11 WLANs
- Validated against ns-3 [3]
- Includes novel functionalities such as channel bonding and spatial reuse
- Affordable simulation time
- Particularly oriented to develop AI solutions for WLANs
  - Online learning module (online learning, iterative methods, etc.)
  - Customizable output (generate training datasets)

[3] Barrachina-Muñoz, S., Wilhelmi, F., Selinis, I., & Bellalta, B. (2019, April). Komondor: a wireless network simulator for next-generation high-density WLANs. In *2019 Wireless Days (WD)* (pp. 1-8). IEEE.

How was the dataset generated? (I)

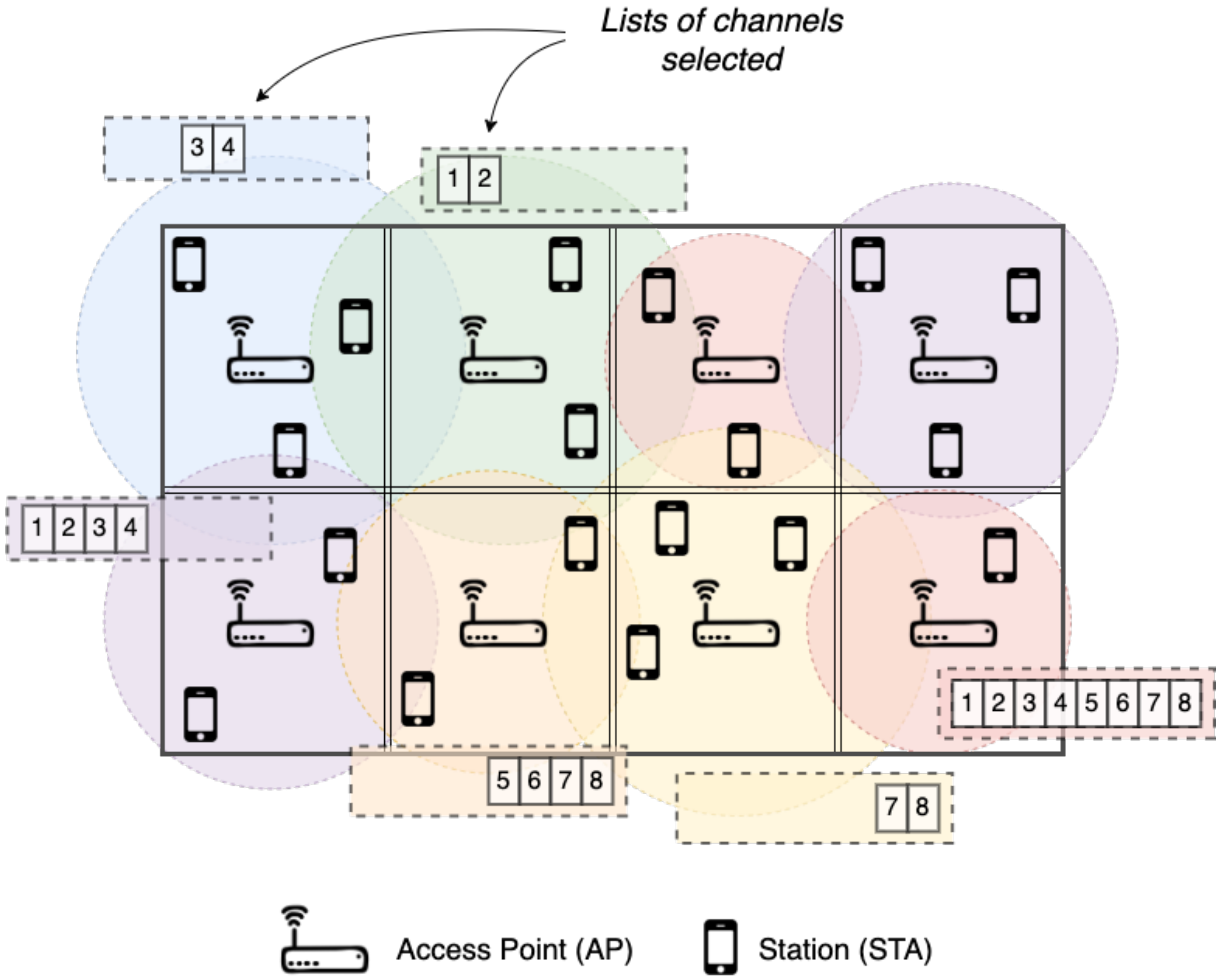


Dataset

- Commit: 93063aa
- Downlink UDP traffic (different traffic loads considered)
- Duration: 100 seconds
- Random channel allocation, number of nodes, nodes position

How was the dataset generated? (II)

- 2 scenarios (12 and 8 BSSs)
- 3 map sizes per scenario e.g., (80x60 m, 70x50 m, 60x40 m)
- 50 random deployments per scenario and map size
  - Random number and position of STAs
  - Random channel allocation



4 Dataset

Introduction to the dataset

- **Open** dataset
- Multiple simulated deployments where CB is applied
  - Input features (nodes position, CB configuration, interference map, etc.)
  - Output performance (throughput)

- **Goal:** train a model to predict the throughput of BSSs (minimize error)
- Split the dataset into training + validation
- A test dataset will be provided to evaluate your solution

- Solution is **open**
  - *Approach:* Deep Learning, linear regression, SVR…
  - *Tools:* Matlab, Python, R…
- Challenges: understand the problem, process the dataset, define an ML model

Overview of the dataset

Files (1.7 MB)

Name	Size	
input_node_files.zip md5:89f241d03f7315c4e8c09bd79d0e2e72	1.3 MB	Preview Download
output_simulator.zip md5:05d50b1ab5409626453216d66ebdc4f9	412.0 kB	Preview Download

Overview of the dataset (II)

Nodes input files

CSV

- Node ID
- BSS ID
- Position
- Channels selected
- Transmission capabilities (tx power, sensitivity, etc.)
- Other information (CW, traffic load, etc.)

Output Komondor

TXT

- RSSI list (power that each STA receives from its AP)
- Interference map (power sensed by each AP from other APs)

Features

- Throughput (effective transmission rate)
- Airtime (percentage of time occupying the channel)

Labels

Example (I)

Input nodes file: sce1a/input_nodes_sce1a_deployment_000.csv

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	node_code	node_type	wlan_code	x(m)	y(m)	z(m)	central_freq(	channel_bon	primary_cha	min_channel	max_channe	tpc_default(	cca_default(
2	AP_A	0	A	10	10	0	5.0	4	4	4	5	20	-82
3	STA_A1	1	A	0.0713	108.079	0	5.0	4	4	4	5	20	-82
4	STA_A2	1	A	19.627	41.427	0	5.0	4	4	4	5	20	-82
5	STA_A3	1	A	137.849	167.538	0	5.0	4	4	4	5	20	-82
6	STA_A4	1	A	67.112	17.487	0	5.0	4	4	4	5	20	-82
7	STA_A5	1	A	131.934	23.628	0	5.0	4	4	4	5	20	-82
8	STA_A6	1	A	176.857	76.662	0	5.0	4	4	4	5	20	-82
9	STA_A7	1	A	194.473	84.359	0	5.0	4	4	4	5	20	-82
10	STA_A8	1	A	43.802	20.739	0	5.0	4	4	4	5	20	-82

Example (II)

Output Komondor: script_output_sce1a.txt

- *KOMONDOR SIMULATION 'sim_input_nodes_sce1a_deployment000.csv' (seed 1992)*

1. Per-STA throughput (including aggregate in AP) in Mbps (ordered list) [1, #APs+#STAs]
2. Airtime per BSS (auxiliary label) [1, #APs]
3. RSSI list (APs' own signal marked as Inf) in dBm [#APs, #STAs]
4. Interference map (AP-AP interactions) in dBm [#APs, #APs]

Example (III)

script_output_sce1a.txt

Scenario ID

```
KOMONDOR SIMULATION 'sim_input_nodes_sce1a_deployment_000.csv' (seed 1992)
```

Throughput per STA

```
,7.53,7.37,2.00,7.99,2.07,4.76,4.99,7.60,1.15,2.38,3.00,4.22,43.05,3.49,1.98,2.46,2.80,3.10,4.72,4.92,4.30,3.49,4.58,
.38,4.53,3.84,6.99,5.91,6.37,1.61,5.61,57.14,7.45,0.69,7.07,5.53,0.08,7.83,0.08,3.38,7.14,2.00,0.00,4.07,0.15,3.38,7.
5,0.54,0.38,7.53,48.08,2.94,1.57,5.68,3.76,4.04,3.63,2.53,4.72,3.66,4.53,1.92,5.15,3.96,90.93,9.37,8.52,9.45,12.52,5.
.61,0.23,0.00,0.23,3.07,0.54,0.61,3.30,2.53,0.31,0.84,3.38,185.09,17.89,16.90,16.67,19.28,15.44,16.82,15.67,16.82,4.0
```

Airtime

```
{0.11,11.59,19.81,16.46,35.48,0.96,9.88,11.51,22.02,2.24,12.91,0.13}
```

RSSI lists

```
2.16,Inf,-67.94,-65.62,-64.13,-68.37,-68.18,-55.09,-66.02,-66.43,-58.11,-67.41,-66.83,-61.76,-52.60,-66.25,-66.26,-65
7,-58.02,-59.81,-59.78,-65.31,-53.29,Inf,-61.12,-62.56,-60.28,-63.43,-67.26,-66.15,-66.51,-68.28,-64.42,-54.39,-60.57
47.70,-60.46,-64.42,-56.19,-68.86,-65.15,-62.06,-69.77,-71.11,-66.60,-64.31,-65.73,-52.91,-69.58,-70.72,Inf,-59.22,-7
69.11,-54.56,Inf,-63.68,-63.52,-58.63,-58.82,-61.61,-60.35,-61.99,-60.93,-64.54,-57.52,-62.13,-56.31,-64.42,Inf,-61.5
76,-64.35,-60.08,-65.89,Inf,-58.79,-69.48,-64.61,-70.35,-70.99,-70.10,-61.73,-69.77,-69.29,-58.55,-54.68,-70.78,-68.4
```

Interference map

```
-79.34,Inf,-82.35,-100.95,-91.84,-85.36,-94.85,-105.59,-108.60,-106.97,-108.60,-116.81;
-100.95,-79.34,Inf,-79.34,-108.60,-94.85,-85.36,-88.83,-119.82,-111.61,-103.96,-105.59;
-119.98,-100.95,-82.35,Inf,-125.96,-111.61,-94.85,-79.34,-133.97,-122.83,-108.60,-100.95;
-79.34,-88.83,-108.60,-122.95,Inf,-85.36,-106.97,-119.98,-82.35,-94.85,-108.60,-122.95;
-88.83,-79.34,-91.84,-105.59,-82.35,Inf,-85.36,-100.95,-91.84,-85.36,-91.84,-105.59;
-105.59,-88.83,-82.35,-88.83,-103.96,-85.36,Inf,-79.34,-108.60,-94.85,-82.35,-88.83;
-122.95,-105.59,-91.84,-79.34,-122.99,-106.97,-85.36,Inf,-125.96,-111.61,-91.84,-79.34;
-100.95,-105.59,-119.82,-130.96,-82.35,-94.85,-111.61,-122.95,Inf,-85.36,-103.96,-119.98;
-105.59,-100.95,-108.60,-116.81,-91.84,-85.36,-94.85,-105.59,-82.35,Inf,-82.35,-100.95;
-116.81,-105.59,-103.96,-105.59,-108.60,-94.85,-85.36,-88.83,-103.96,-85.36,Inf,-79.34;
-130.96,-116.81,-108.60,-100.95,-125.96,-111.61,-94.85,-79.34,-122.99,-106.97,-82.35,Inf}
```

Evaluation Criteria

1. Participants must use the provided dataset to **train** a machine learning algorithm.
2. The output of the ML algorithm should **predict** the performance obtained in a **new** network deployment.
3. The choice of the ML approach is decided by each participant (neural network, linear regression, decision tree, etc.).
4. A test dataset will be provided to evaluate the performance of the proposed algorithms.
5. The evaluation of the proposed algorithms will be based on the average squared-root error obtained along with all the predictions compared to the actual result in each type of deployment.
6. The solution should be properly justified and participants must provide insights on the pros/cons of applying AI to solve the CB problem in WLANs
7. The winners will be invited to publish the results in an academic publication.

ITUEvents

ITU-ML5G-PS-018: DNN Inference Optimization Challenge (Adlik/ZTE)

17 July 2020

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AI/ML in 5G

Challenge

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