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Resource Allocation Mechanism for Massive MIMO

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Short resume of Professor Christos Bouras

- Christos Bouras is Professor in the University of Patras, Department of Computer Engineering and Informatics. Also he is a scientific advisor of Research Unit 6 in Computer Technology Institute and Press - Diophantus, Patras, Greece. His research interests include 5G and Beyond Networks, Analysis of Performance of Networking and Computer Systems, Computer Networks and Protocols, Mobile and Wireless Communications, Telematics and New Services, QoS and Pricing for Networks and Services, e-learning, Networked Virtual Environments and WWW Issues. He has extended professional experience in Design and Analysis of Networks, Protocols, Telematics and New Services. He has published more than 450 papers in various well-known refereed books, conferences and journals. He is a co-author of 9 books in Greek and editor of 2 in English. He has been member of editorial board for international journals and PC member and referee in various international journals and conferences. He has participated in R&D projects.

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Introduction – 5G Networks

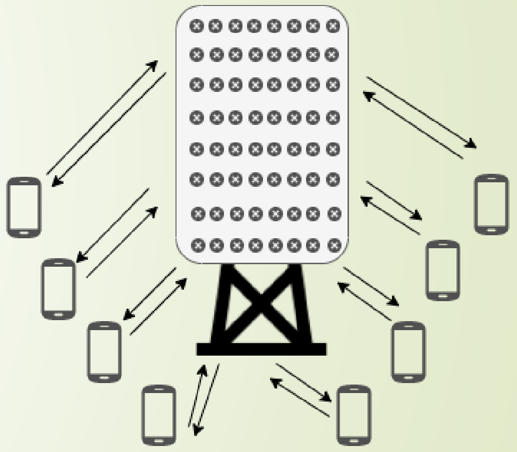
- Nowadays, mobile users need faster data speeds and more reliable service.
- This leads us to the fifth generation of wireless communications technologies (5G), which supports cellular data networks.
- 5G technologies offer a significant quantity of mobile data traffic in a really big number of wireless connections.
- 5G delivers better cost and energy efficiency, as well as QoS in respect of communication delay, reliability, and security.
- Five brand-new technologies are designed: millimeter waves, small cells, Massive MIMO (Ma-MIMO), full duplex, and beamforming.

MIMO – Massive MIMO (1/2)

- MIMO stands for Multiple-input multiple-output.
- Multi-antenna technologies, such as MIMO, are anticipated to play a key role in 5G systems.
- MIMO technology handles much higher speeds than today's cellular networks and greater network traffic.
- It is characterized by wireless systems, that allow to transmit and receive simultaneously more than one data signal over the same radio channel.
- MIMO technology in 5G networks is studied in this paper, with emphasis on the achieved performance in terms of achieved Bandwidth.
- Specifically, we will refer to Massive MIMO (Ma-MIMO) technology.

MIMO – Massive MIMO (2/2)

- Ma-MIMO technology is a key enabler and foundational component when it comes to creating the next generation of network standards.
- MIMO technology uses separate antennas in the transmit and receive end for each data signal.
- The word *Massive* refers to the number of the base stations’ (BS) antennas, which are used to serve many terminals simultaneously, in the same time-frequency resource.
- 4G BS have a dozen ports for antennas that handle all cellular traffic. From those twelve, eight of them are for transmitters and four for receivers.
- 5G BS can support about a hundred ports, which signifies that on a single array many more antennas can fit.



Proposed Mechanism

- In our research, a resource allocation mechanism is proposed from the BS to the available antennas, using the Knapsack Problem (KP) algorithm in a Ma-MIMO system.
- This algorithm is a different approach of MIMO technology, as it seeks to serve as many User Equipment (UE) as possible, with the support of a great service level.

Our goal:

- Evaluate user access throughput to the antennas
- Study the case where the BS allocates resources, according to the channel rate it receives from each UE.
- Evaluate the Quality of Service (QoS) that is provided to the UE by the BS, with the resource allocation technique that is proposed.

- The scenario executed is about serving the maximum number of UE connected to the BS, in high quality services, in terms of achieved Bandwidth, whereas some UE are on limits of a cell.

Algorithm 1 Resource Allocation Mechanism for UE – A KP Formulation

```
Number of BS_j
Number of UE_i
for each BS_j do
    allocate same RB (W)
        for each UE_i do
            find distance from BS_j
            v_i = distance
            check w_i, v_i
            if w_i < W then
                create list with w_i, v_i
            end if
            else reject UE_i and check next
                while counter <= W do
                    check list and allocate RB to UE_i with the
                    minimum v_i
                end while
        end for
end for
```

Previous Research Work

- Previous research work have explored the resource allocation technique using the KP formulation.

N. Ferdosian, M. Othman, B. Mohd Ali, and K. Yeah Lun, "Greedy–knapsack algorithm for optimal downlink resource allocation in LTE networks"

- A greedy–knapsack algorithm is proposed to analyze system performance and evaluate UE that wait to be served. The authors choose from a set of UE to maximize system performance in an optimal way, without exceeding the available bandwidth capacity in LTE networks.

R. Husbands, Q. Ahmed, and J. Wang, "Transmit antenna selection for massive MIMO: A knapsack problem formulation"

- The authors remodel the number of transmit antennas as a KP.

J. Jing and X. Zheng, "A Downlink Max-SINR Precoding for Massive MIMO System"

- The authors investigate the Signal-to-Interference-plus-Noise Ratio (SINR) precoding for Ma-MIMO systems, since they need to bring quality to a satisfactory level.

Knapsack Problem (1/2)

- For the purpose of reaching a satisfying level of QoS, in our approach we apply the 0-1 Knapsack Algorithm.
- The KP is an implementation of combinatorial optimization.
- Considering a set of objects, each with weight (w_i) and value (v_i), it determines the number of each object in a collection so that the total weight is less than or equal to a given threshold (W) and the total value is as high as possible.
- Given a set of items (suppose *n* items) we want to maximize our profit:

$$\sum_{i=0}^{n} U_i X_i$$

  - U_i ⟹ value of the item in the knapsack

Knapsack Problem (2/2)

- We assume that we have a bag that can hold a set of m (m < n) items.
- For each item we define a variable Xi:
  - Xi = 1 ➡ an item belongs in the set of selected items.
  - Xi = 0 ➡ an item is not chosen.
- For our set of selected items:

$$\sum_{i=0}^{n} U_i X_i \leq W$$

  - W ➡ Knapsack's capacity.

Our goal:

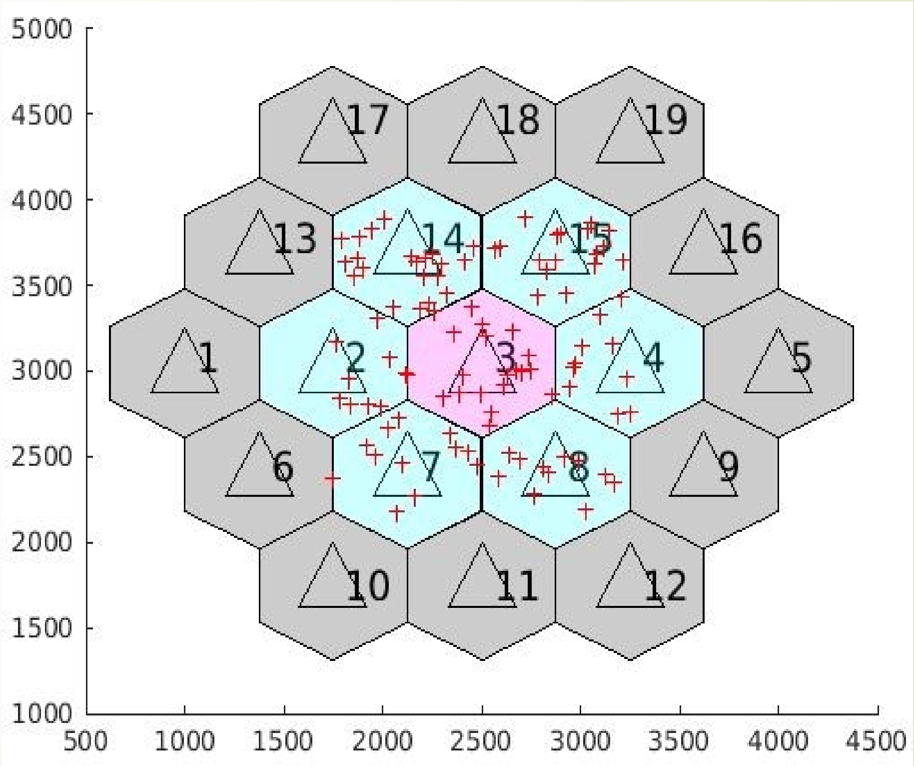
- Maximize the sum of the values of the items, so that the sum of the weights, is less than or equal to the knapsack's limited space (W). ➡ The best Knapsack!

Scenario Executed

- Knapsack Parameters:
  - w_i ➡ bandwidth that the UE needs (Uplink) ➡ [50 – 400 MHz], randomly generated
  - $\mathrm{v_i}$ ➡ distance between the UE and the BS ➡ is computed
  - W ➡ total bandwidth in BS (Downlink) ➡ 400 MHz
  - $\mathrm{X_i} = 1,$ ➡ when a UE is selected to be served by the BS
  - $\mathrm{X_i} = 0,$ ➡ when a UE is not selected to be served by the BS
- The proposed mechanism is applied to our *COST Hata Model*, which includes *19 Macro Cells*, in a *MIMO transmission* with *uniform distribution* among the UE.
- Therefore, our mechanism is trying to serve the biggest number of UE with the minimum distance from the BS, in an optimal performance.

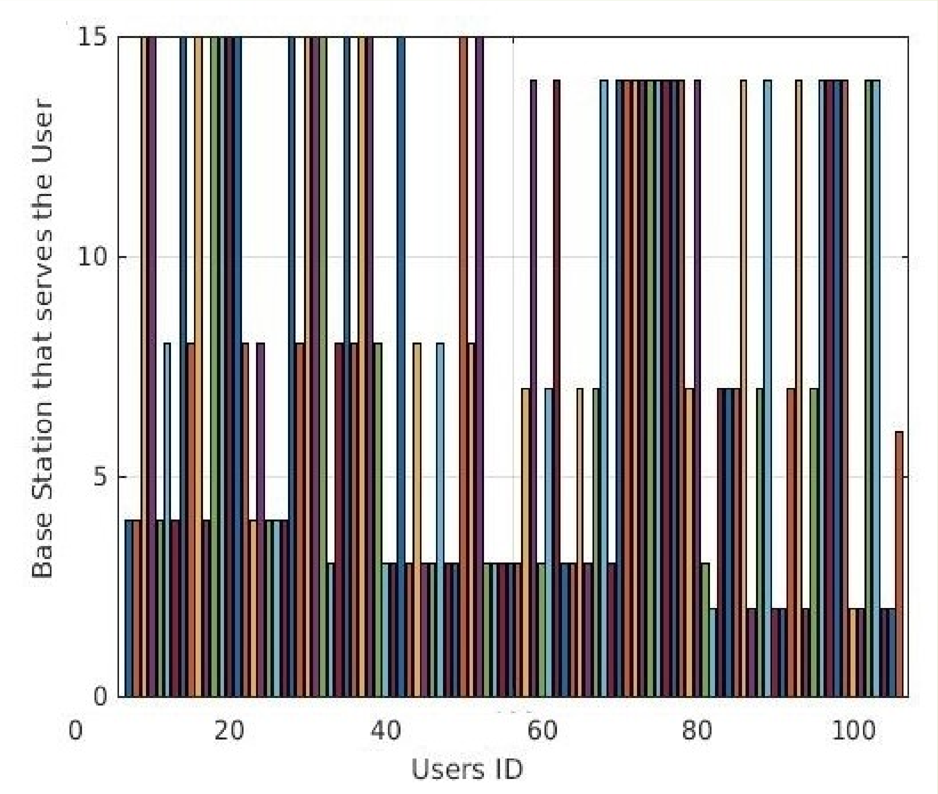
Simulated Network

- Example of simulated network with *K* = 100 UE that demand resources of our network.
- All UE are randomly generated with a personalized chance of appearing inside our area of interest that is served by a Macro Cell.
- Regarding the deployment scenario, we simulated our experiments for a different number of UE (*K*).
- We model the network's performance for *K* UE.



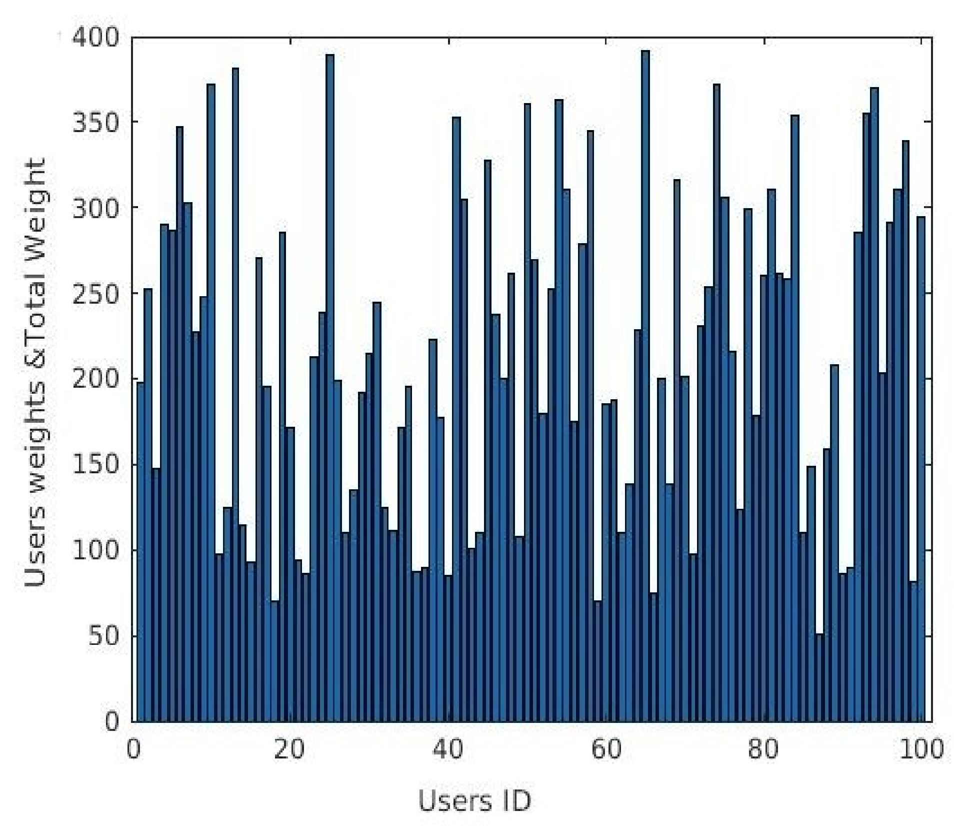
Simulations & Results (1/3)

- The results were simulated in MATLAB environment.
- This Figure shows exactly in which Macro Cell each UE will connect, under normal conditions.
- UE are presented with different colors.
- Each UE's distance from each BS is computed and therefore we know which BS will serve the UE, according to the minimum distance between them.



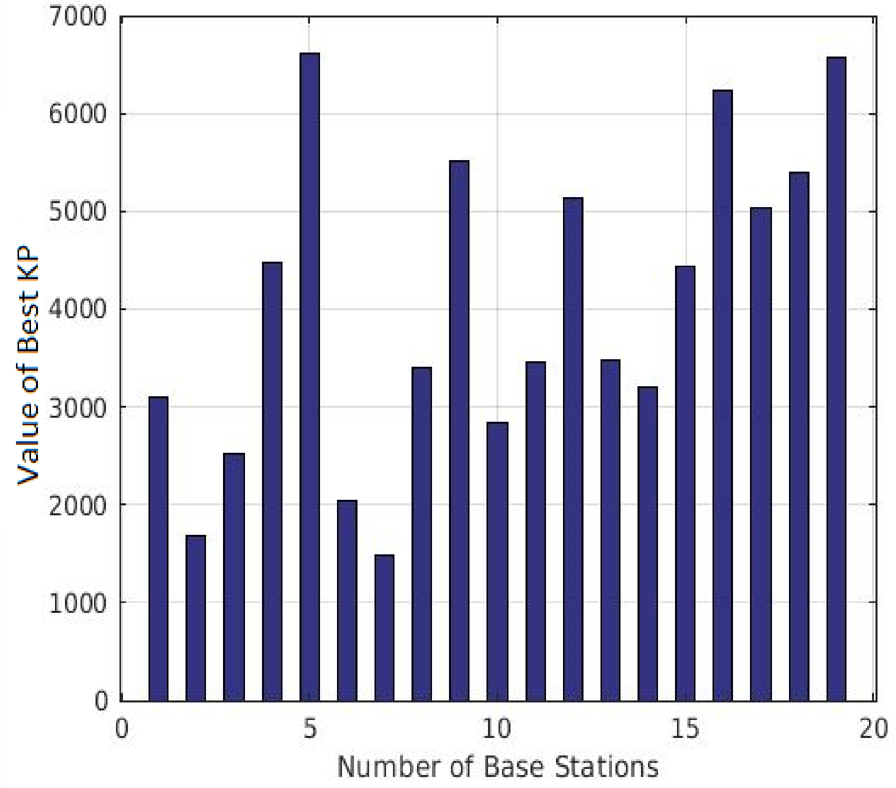
Simulations & Results (2/3)

- This Figure presents the bandwidth that each UE demands (w_i) and the total Bandwidth of every BS (W).
- It depicts each UE's weight that is connected to a BS with a total weight of 400MHz.
- In every Knapsack formulation, the "*amount of use*" of each UE that is served by the BS was also computed. This refers to the variable X_i, which is X_i = 1, when a UE is selected to be served by the BS and X_i = 0, when a UE is not selected.
- The "*amount of use*" was computed for every UE in every BS and represents which UE were served by every BS.



Simulations & Results (3/3)

- This Figure presents the values of the best possible Knapsack in each BS.
- The value of the best possible Knapsack is computed as the sum of all the minimum distances of the UE that can be served by the BS, based on their weights, that is each UE's quantity for bandwidth that they demand.
- Therefore, the best possible Knapsack in each BS, is trying to serve the biggest number of UE with the minimum distance from each BS, in an optimal performance.



Conclusion & Future Work

Conclusion:

- From the above simulations we can clearly see that the results are different in each BS, but comparatively the values of the best possible Knapsack are optimal, because the distance in most of them remains small.
- The conclusion made, is that the KP formulation is a good technique to use when there is a great need to serve a *maximum number* of UE, with an *optimum QoS*, in respect of the achieved *Bandwidth*.

Future Work:

- Further research should be done using the KP formulation in a network deployment with Macro Cells and Pico Cells, where Macro Cells serve UE with the maximum distance, while Pico Cells serve UE with the minimum distance.
- More research is needed in Ma-MIMO when using KP formulation, as it can be an optimum solution when it comes to serving the maximum number of UE, each with a great QoS, while it can reduce interference.
- Machine Learning used in Ma-MIMO can produce different scenarios when using KP formulation, while it can supply us the tools to modify these mechanisms in real time and predict UEs' and BSs' behavior.

Thank you!

Questions?

Remarks?

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