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Cross-layer Resource Allocation for 5G Heterogeneous Software Defined Networks

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Erlangen, October 7, 2015

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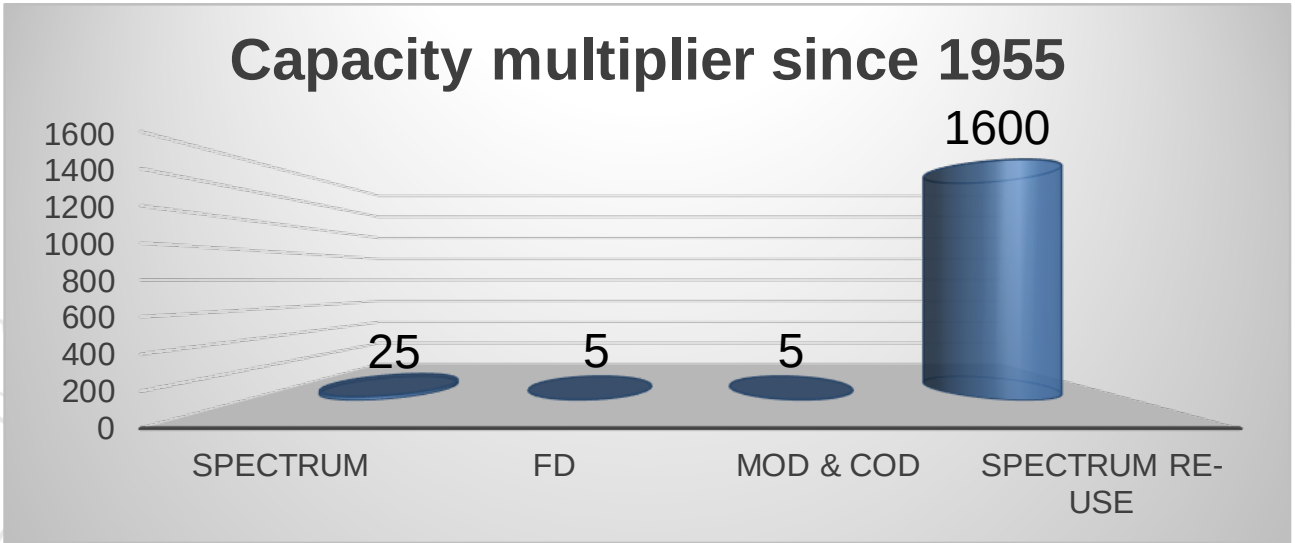
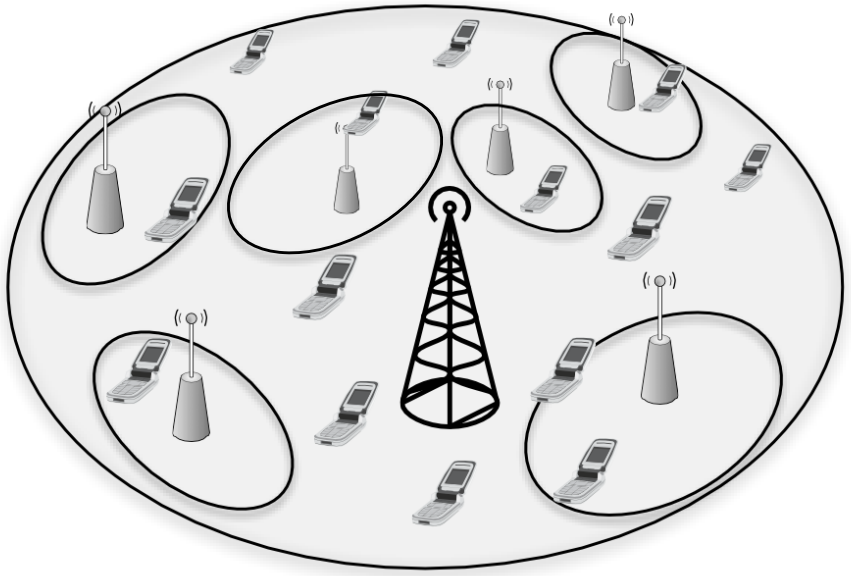
Introduction

- 5G requirements: 1000x capacity increase
- Cooper Law: 1Mx increase since ≈ 1955
- Key enabler: **densification**
- Can we cope with future demand?



Heterogeneous deployment

- **Integration** of low-power low-range cells
- Ad-hoc capacity increase
- Deployment strategies
  - Unplanned (open and restricted access)
  - Planned



Access Network

- **Problem**: intra-cell interference (macro-cell vs femto-cell)

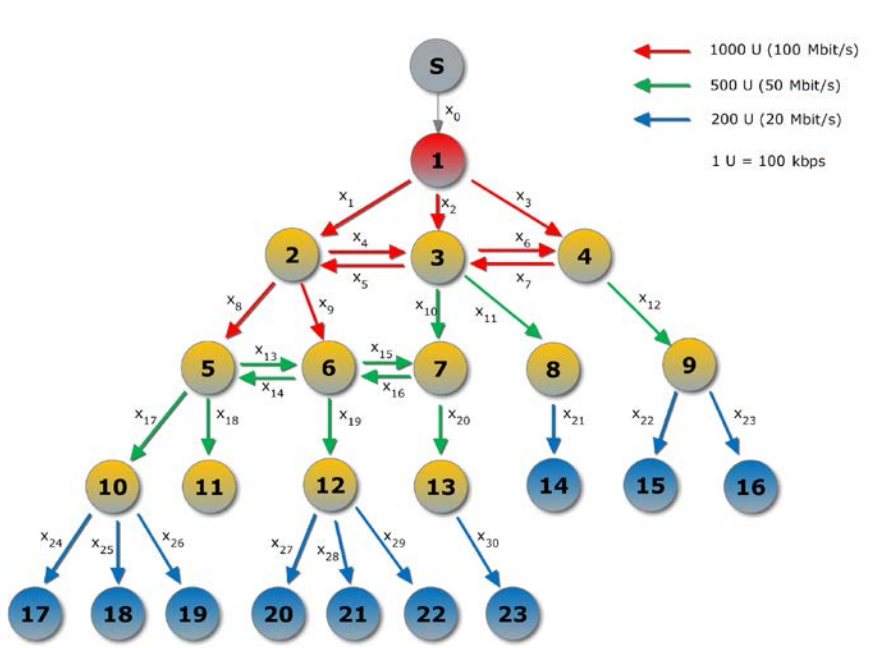
$$R_u = b\log_2 \frac{P_u}{N + \sum_{\substack{i=1 \\ i \neq u}}^{U} P_i} \qquad N_{PRB}^{(u)} = \frac{Q_u}{R_u}$$

- **Solutions**: depend on the deployment
- Unplanned deployment → cognitive approaches
- Planned deployment → adaptive management of coordinated schemes
  - **Smart association**
  - ICIC
  - CoMP

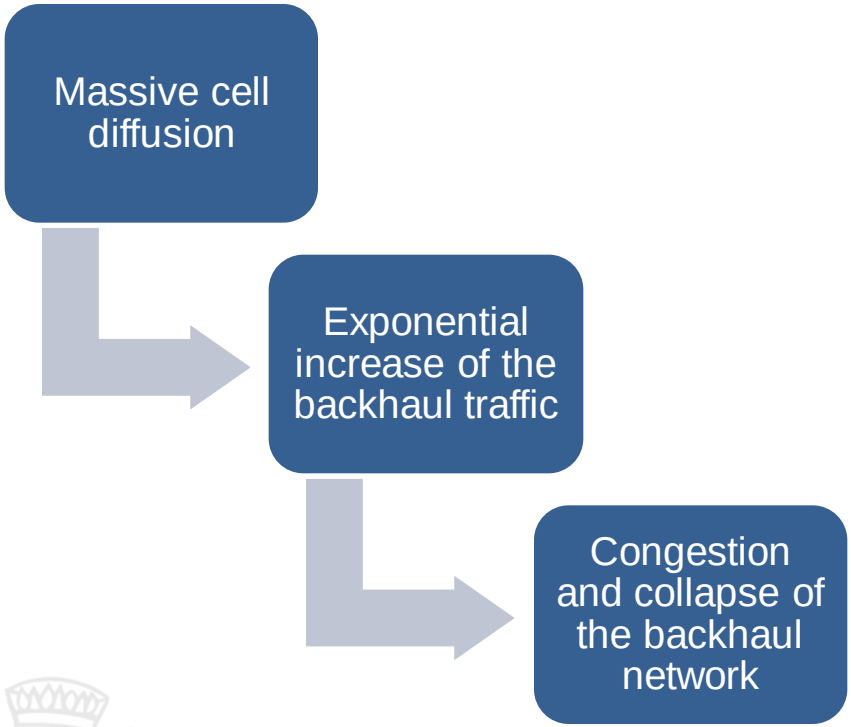
→ Need for **robust** and **flexible** backhaul

Backhaul Network

- HetNet characterized by:
  - 1 Macrocell
  - M micro-cells
  - F femto-cells
  - U users (UEs)
- Tree topology where:
  - Macrocell is the root
  - Small cells represent intermediate nodes and leaves of the tree.



Software Defined Network (SDN) approach

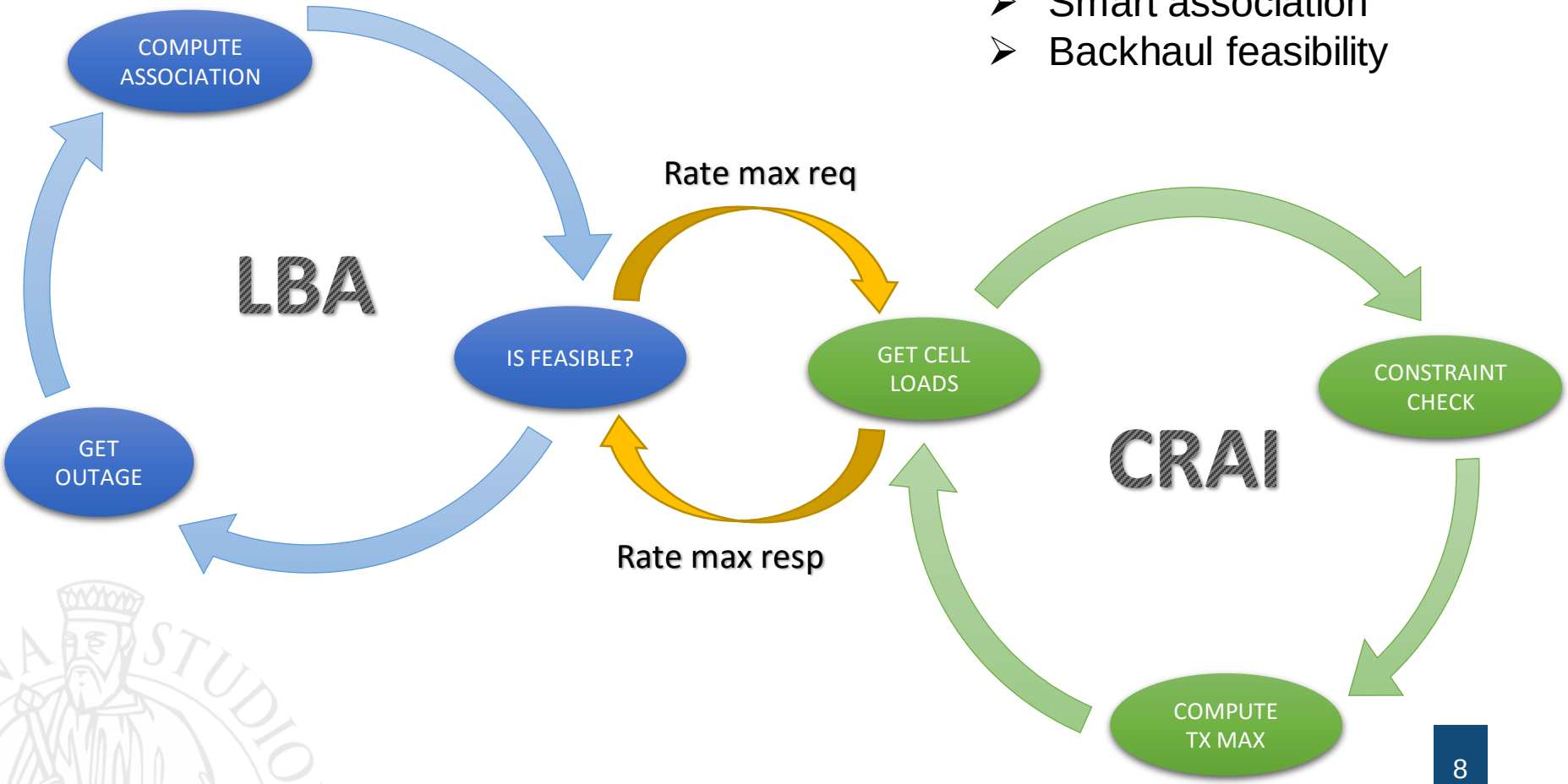


- SDN abstraction provides a simplified view of underlying network to the RAN SDN application.
- SDN control software is able to efficently coordinate the network.
- **Network Virtualization allows instantaneous routing decisions based on bandwidth requests from the radio access network**

What do we aim to?

Development of a cross-layer approach, considering

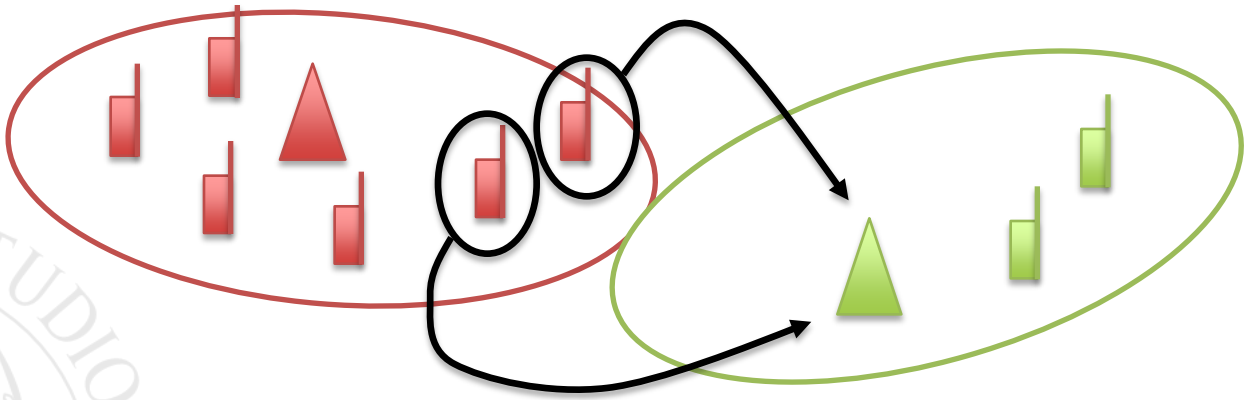
- Smart association
- Backhaul feasibility



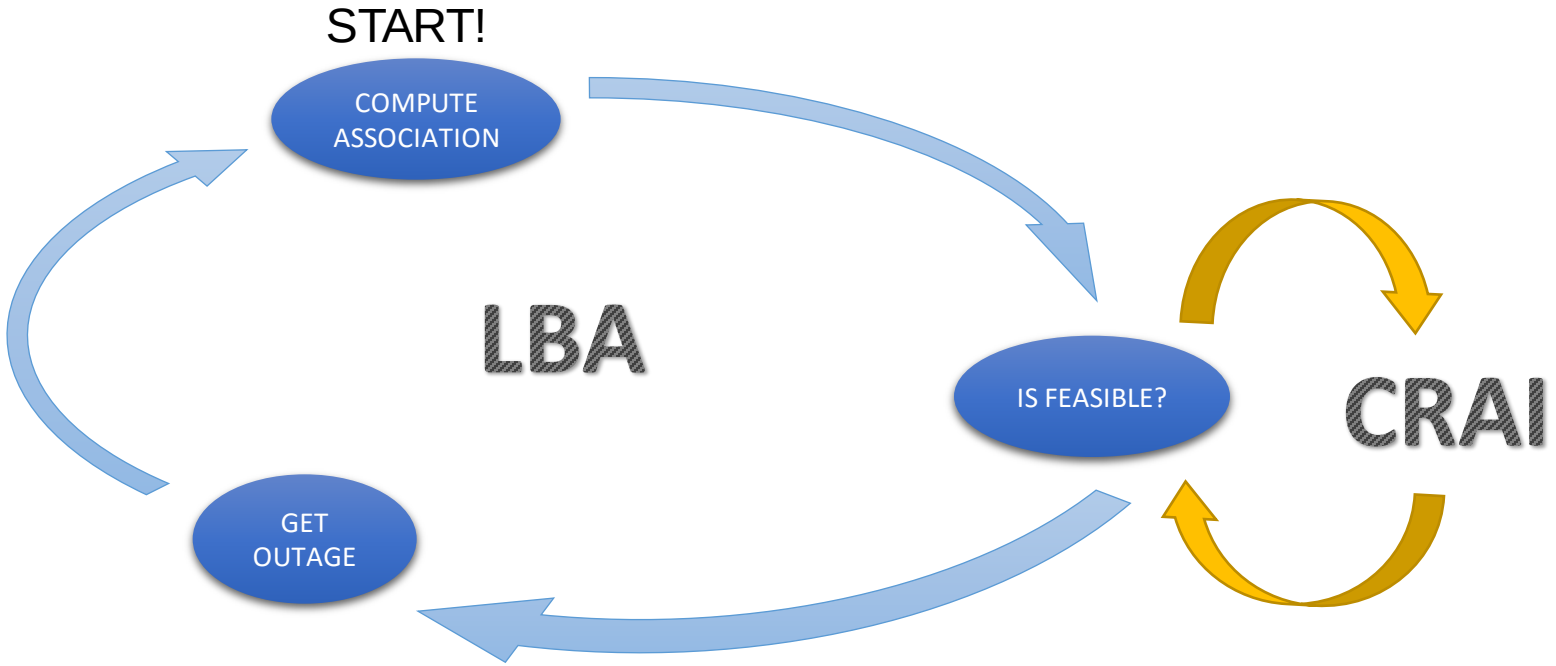
Access Network Solution

- LBA: Load Balancing Association, given cell capacities, finds the most suitable association
  - Maximum capacity used at the first step

- Load sharing of saturated cell
  - Migration of most suitable users
  - Attention to oversaturation of the destination cell



Access Network Solution



- Iterative approach
  - Destination cell are filled **beyond saturation** (up to 125%)
  - Following steps will aim to move and share the load
  - At the same time, backhaul information is updated

CRAI solution

- Defining a flow as a function $x: A \to \mathbb{Z}_{\geq 0}$, the minimum-cost flow problem can be formulated as follows:

$$\min\left(z(x) = \sum_{(i,j)\in A} c_{ij}x_{ij}\right)$$

subject to:

$$l_{ij} \leq x_{ij} \leq u_{ij} \text{ and } \sum_{j:(i,j)\in A} x_{ij} - \sum_{j:(j,i)\in A} x_{ji} = b_i$$

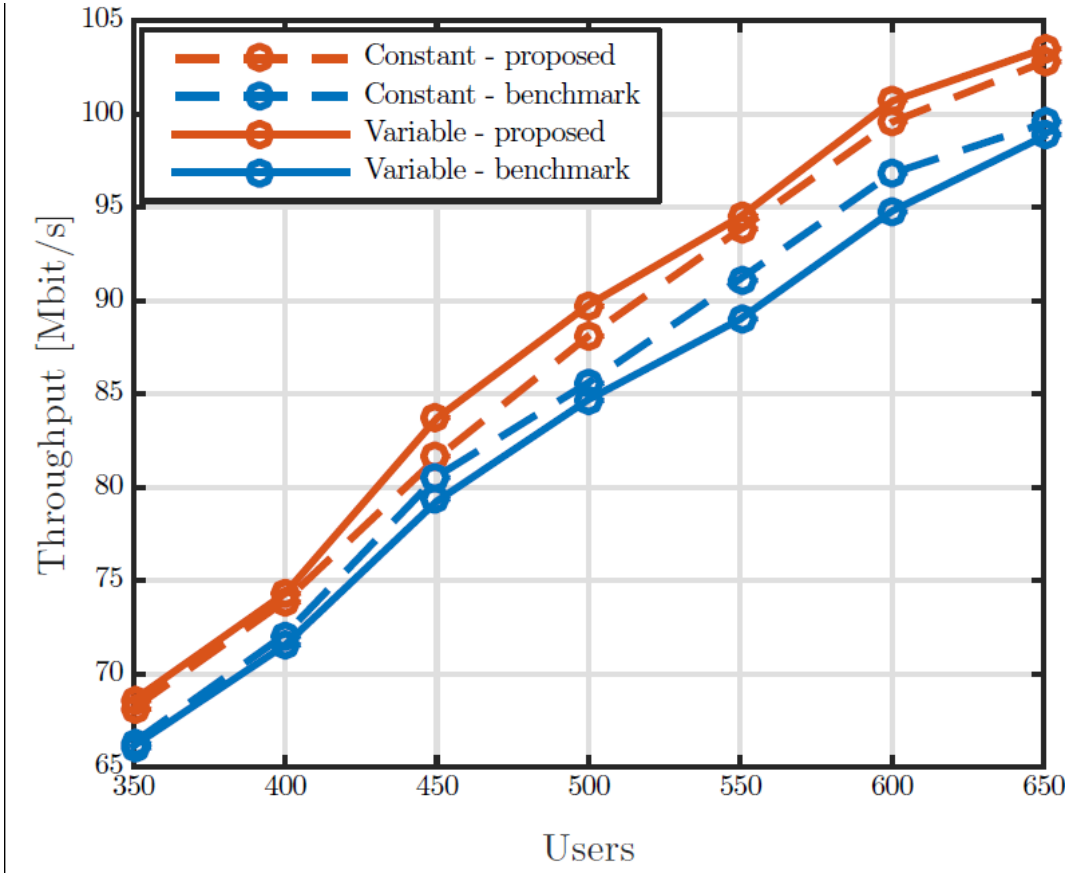
where:

- N is the set of nodes,
- A is the set of directed arcs,
- $l: A \to \mathbb{Z}_{\geq 0}$ is the lower capacity function on the arcs,
- $u: A \to \mathbb{Z}_{\geq 0}$ is the upper capacity function on the arcs,
- $c: A \to \mathbb{Z}$ is the flow cost-per-unit function on the arc,
- $b: A \to \mathbb{Z}$ is the node mass balance function on the nodes

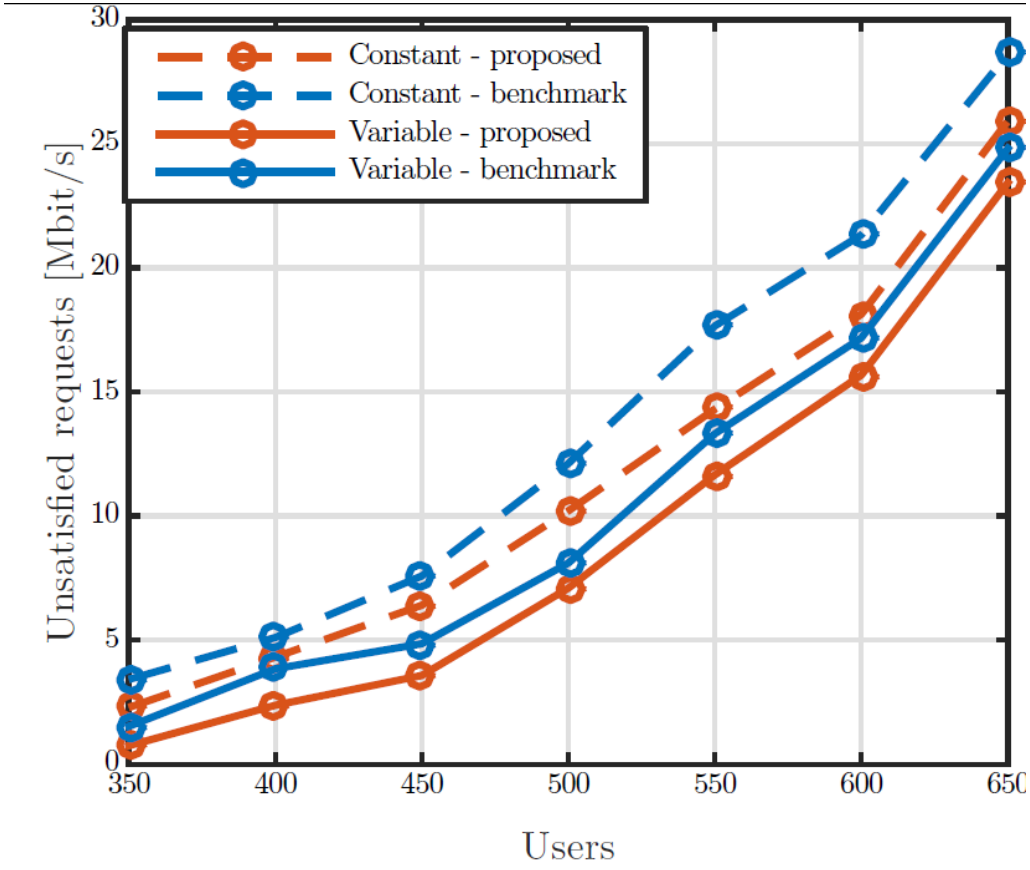
CRAI iterative approach

- Basing on the request vector from the PHY layer as input parameter, the approach is the following:
  - if a solution for the minimum-cost flow problem is found, the algorithm stops.
  - otherwise an iterative approach is used to determinate the additional minimum capacity for the arcs thanks to which input requests can be fully satisfied.
- Once a solution is found, the NET layer notifies to the PHY layer for each node the quantity of units U_B available for additional traffic or exceeding the maximum limit causing cell outage.

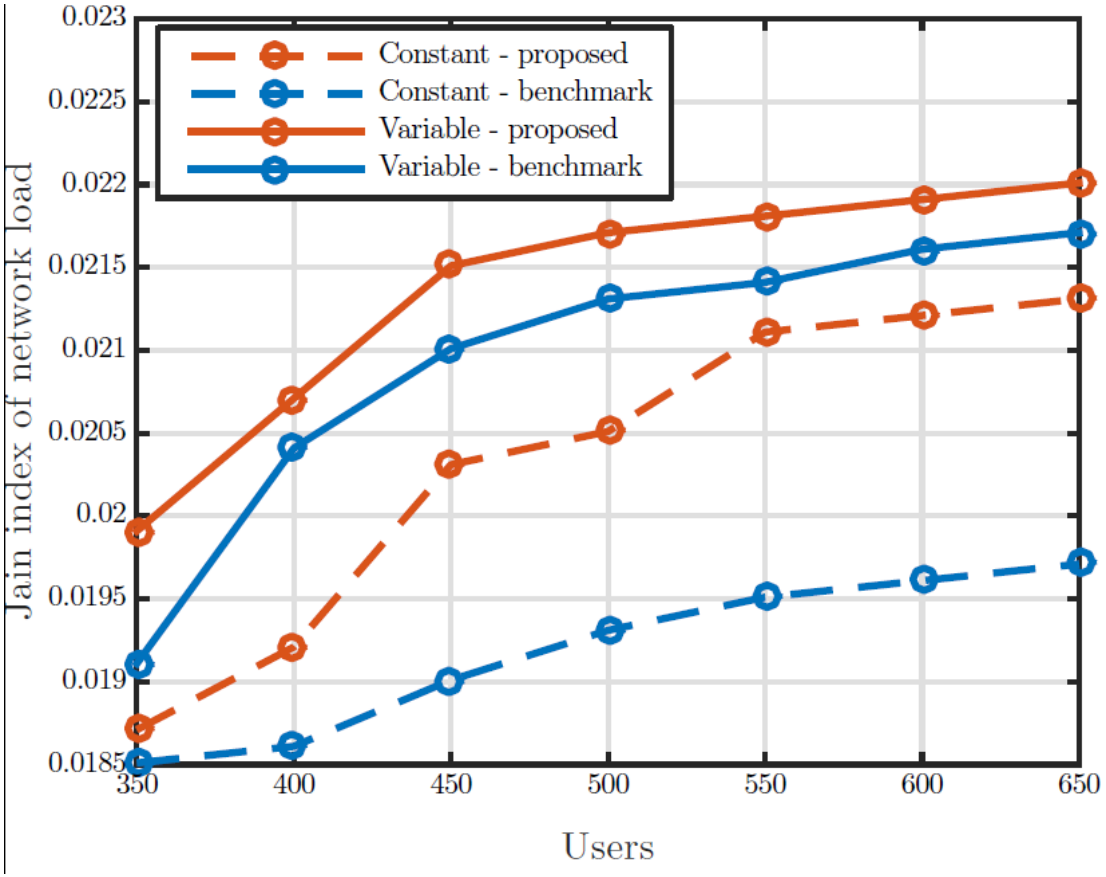
Numerical results - Network throughput



Total unsatisfied data rate requests



Loading fairness



Conclusions and Future Developements

- We provided an iterative cross layer approach for heterogeneous software-defined networks
- Alternative interference management schemes, like ICIC and CoMP are under analysis
- CRAI will improve performance being equipped with several learning methods such as:
  - Chunking
    - Remember decisions on previous similar situations
  - Reinforced Learning
    - Statistical modification of the preferences
  - Semantic Memory
    - Procedural cause-effect rules

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