Resource Allocation and Optimization for the Non-Orthogonal Multiple Access

IDIA students'day, Institut Polytechnique de Paris

PhD student: Lou Salaün

Supervisors: Prof. Marceau Coupechoux, Télécom Paris, France
Dr. Chung Shue Chen, Nokia Bell Labs, Paris-Saclay, France

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Context

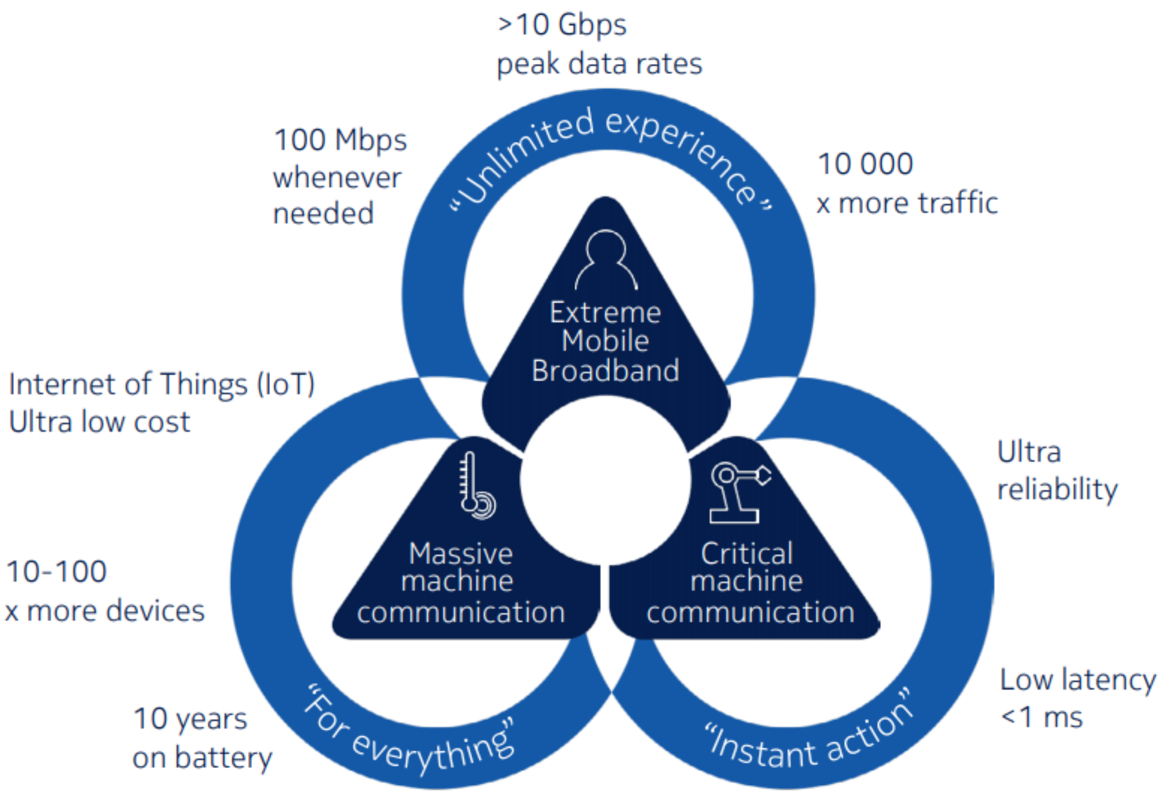


Fig. 5G enables new capabilities beyond mobile broadband

[White paper: 5G new radio network, use cases, spectrum, technologies and architecture," Nokia, Tech. Rep., 2019]

Non-Orthogonal Multiple Access (NOMA)

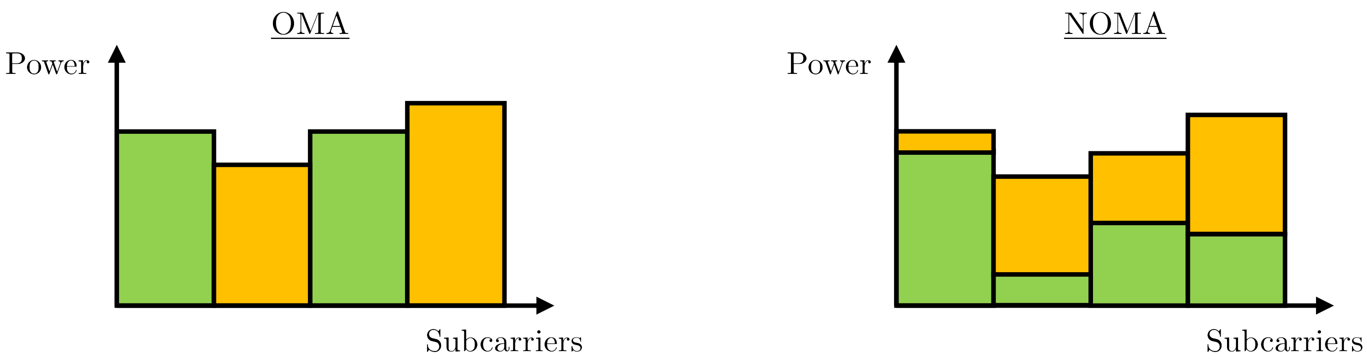
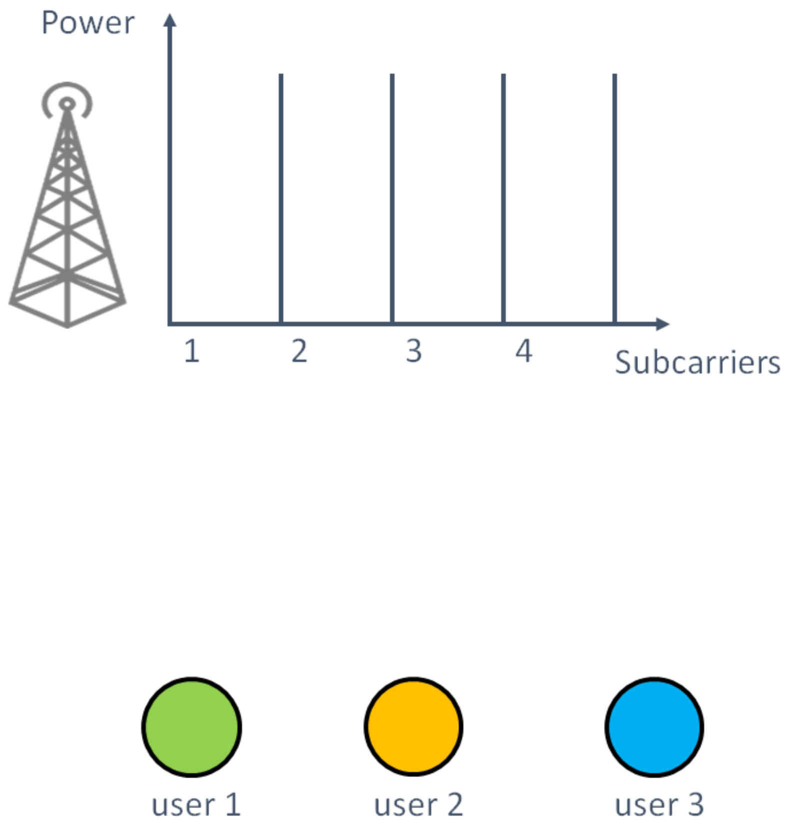


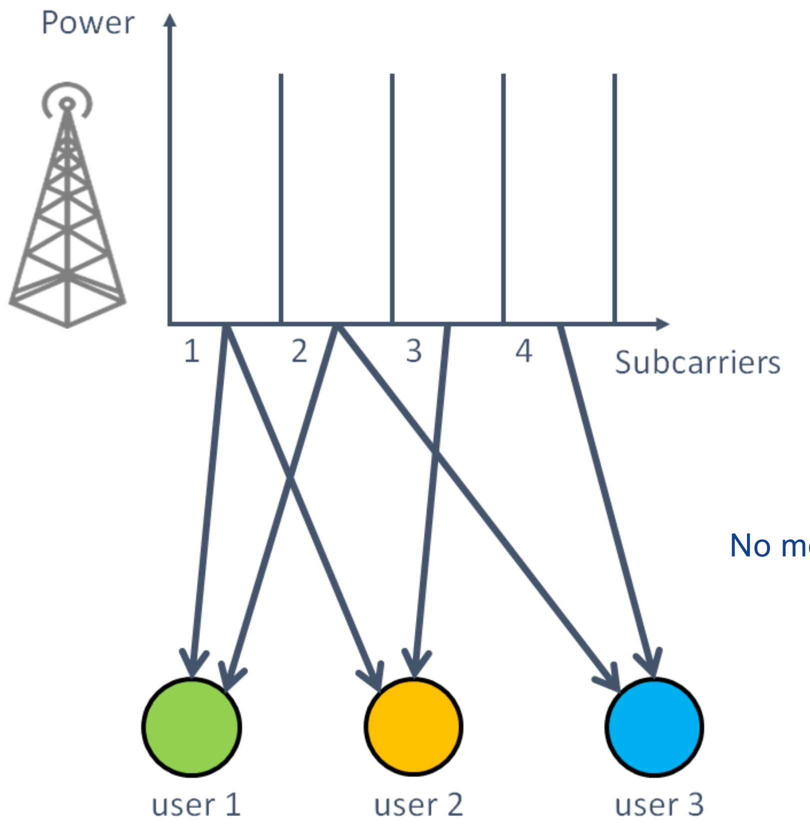
Fig. OMA vs NOMA. The two colors represent the transmit power of two different users' signals

- NOMA allows to superpose several signals on the same subcarrier in the power domain:
  - Increase network spectral efficiency
  - Support massive connectivity
  - Improve cell-edge users performance
  - Complex decoding (interference cancellation) at the receiver
  - Optimization of the radio resource: joint subcarrier and power allocation

Joint Subcarrier and Power Allocation



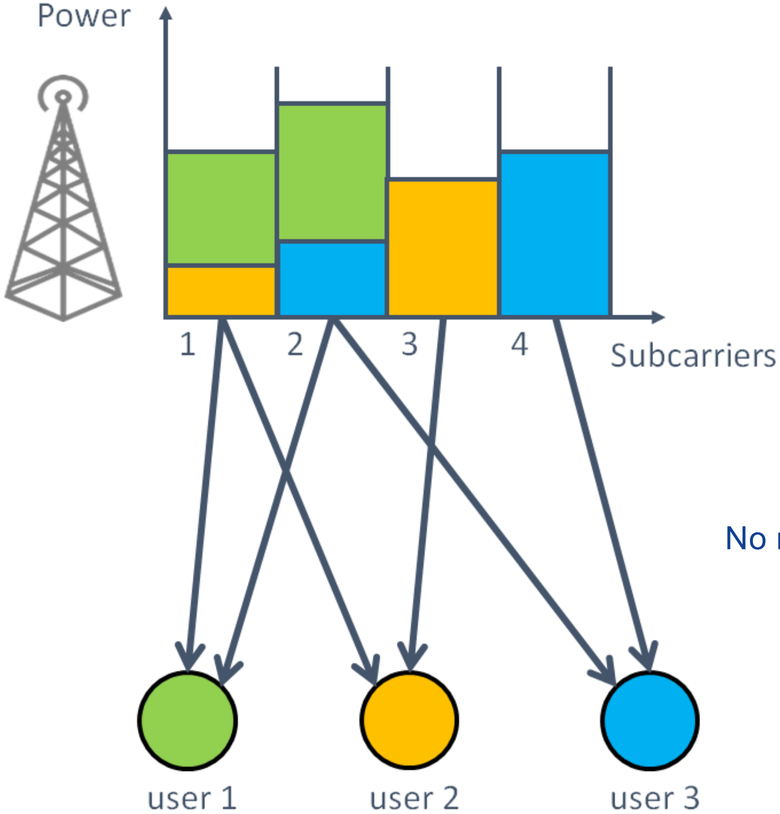
Joint Subcarrier and Power Allocation



Subcarrier allocation (user selection):
No more than M users per subcarrier (here $M = 2$)

Joint Subcarrier and Power Allocation

Power control subject to power budget constraints



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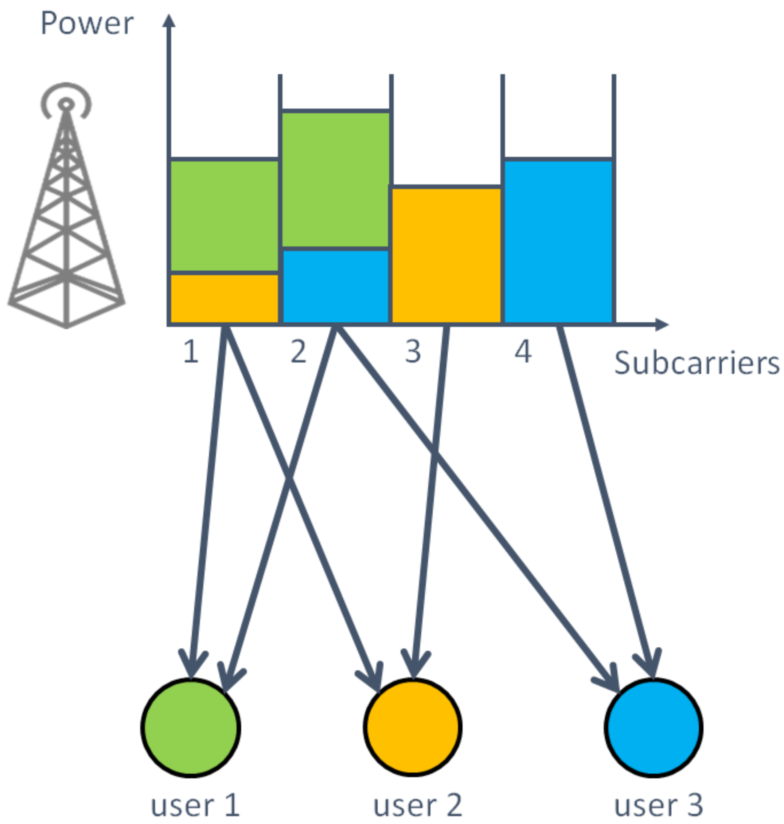
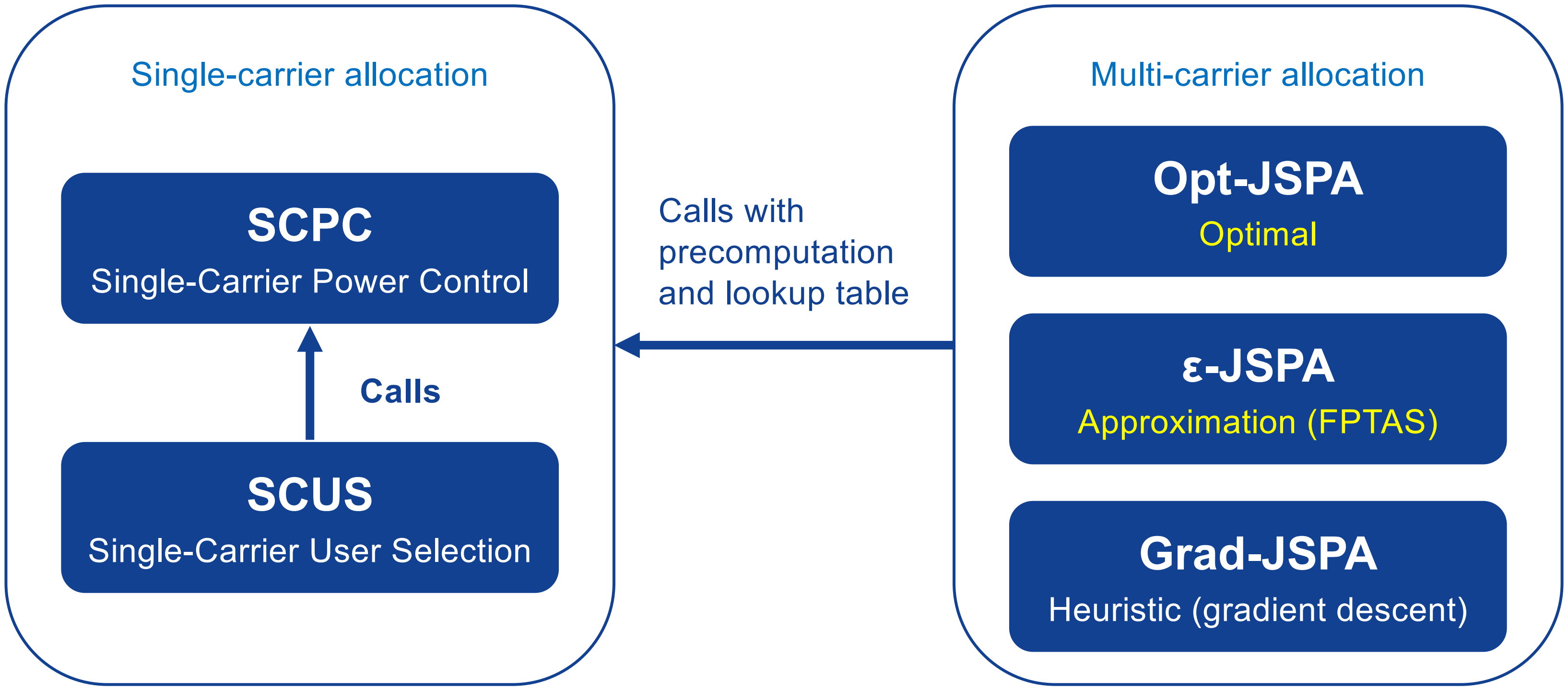


Open challenges:

- No unified framework
- No low-complexity algorithms with performance guarantees

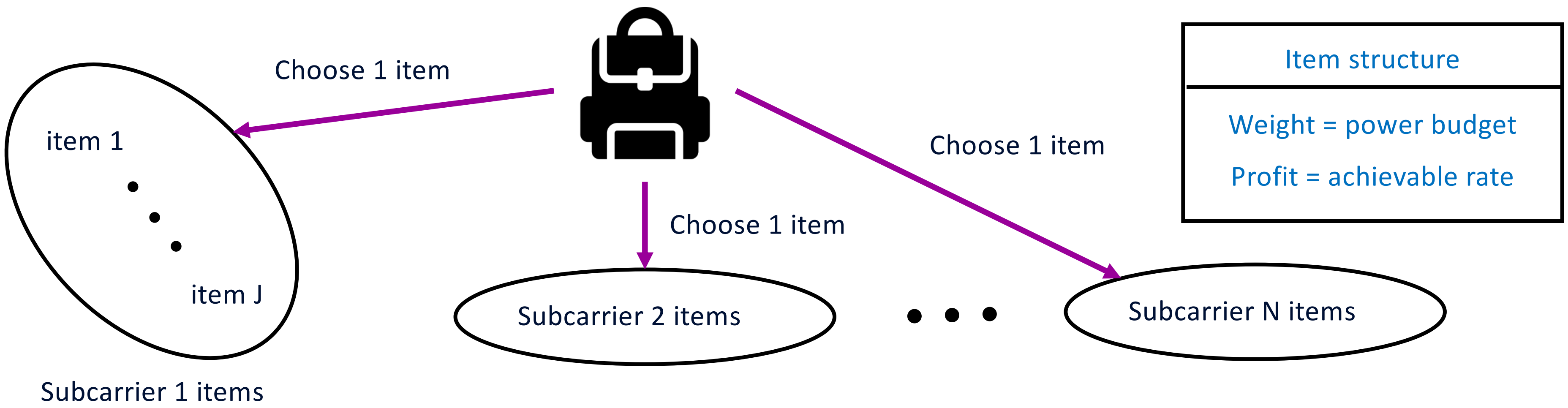
Radio Resource Management: an Optimization Framework

- Each module solves a sub-problem with respect to its problem structure: separability, convexity, knapsack constraints, combinatorics, etc.



Multi-Carrier Allocation: Opt-JSPA and ε-JSPA

- Based on the multiple-choice knapsack problem
- Opt-JSPA: **optimal** with lower complexity than the state-of-the-art
- ε-JSPA: first **fully polynomial-time approximation scheme** (FPTAS) developed for this problem



Multi-Carrier Allocation: Grad-JSPA

- Grad-JSPA: Projected Gradient Descent
- Search direction: gradient computed by **SCPC** and **SCUS** ⟶ **Separability**
- Piece-wise concave ⟶ **fast convergence to a local optimum**

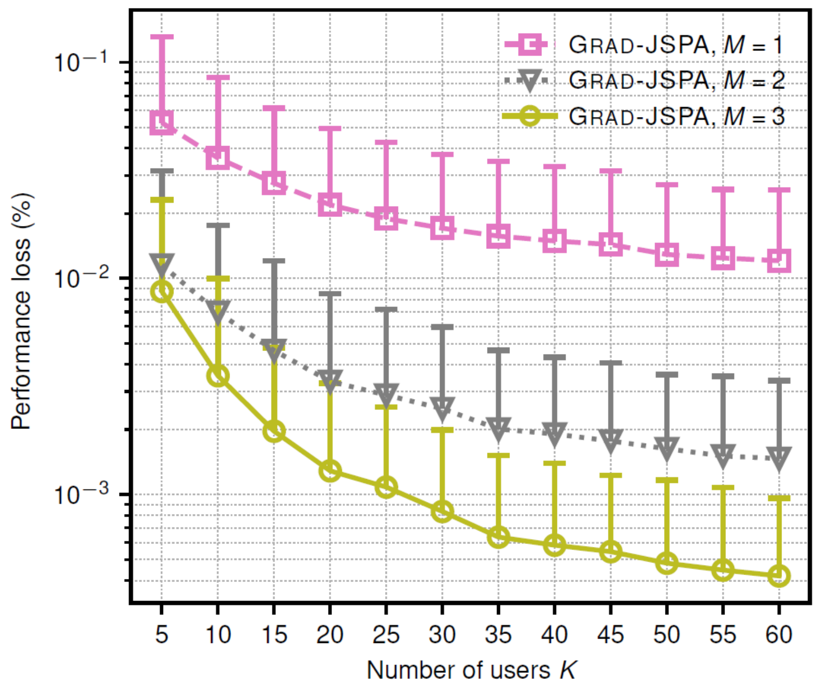
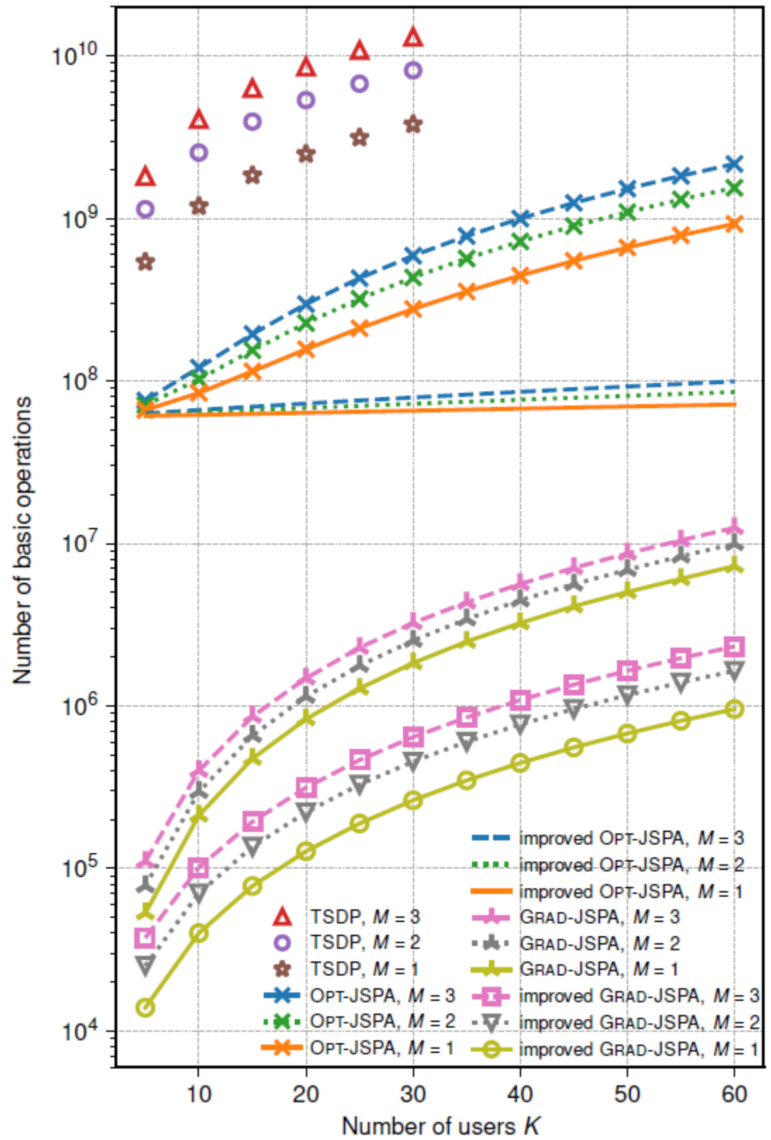


Fig. Performance loss of Grad-JSPA compared to the optimal (M: maximum number of users per subcarrier)

Multi-Carrier Allocation:

Algorithm	Performance guarantee	Complexity for J discrete power values
Monotonic optimization with outer polyblock approximation [7]	Optimal	Exponential in K and N
TSDP [6]	Optimal	$O(J^2NMK)$
OPT-JSPA	Optimal	$O(NMK^2 + JNMK + J^2N)$
ε-JSPA	FPTAS	$O\left(NMK^2+\min\left\{\log(J)\,\frac{N^2MK}{\varepsilon}+\frac{N^3}{\varepsilon^2},\ JNMK+J^2N\right\}\right)$
GRAD-JSPA	Heuristic	$O(NMK^2+\log(J)NMK)$

Decrease in complexity



Conclusion

Unified optimization framework for NOMA:

- Covers a general family of utility functions and system constraints:

  → Solutions under cellular power constraint (downlink): Opt-JSPA, JSPA, Grad-JSPA

  → Solutions under individual power constraints (uplink): Centralized and distributed algorithms → Nash equilibrium

- Extensive complexity and approximability analysis

- Decomposition into sub-problems with interesting properties

  → Facilitate the algorithm design

  → Provable performance guarantees

  → Extendable to new constraints and scenarios

Thank you for your attention