Resource Management Problem in NOMA-based MEC systems

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Outline

- Non-Orthogonal multiple access - based Mobile edge computing (NOMA-based MEC) systems
- Resource management problem in NOMA-based MEC systems
  - Whale optimization algorithm (WOA)
  - Simulation results & Conclusions

Mobile Edge Computing

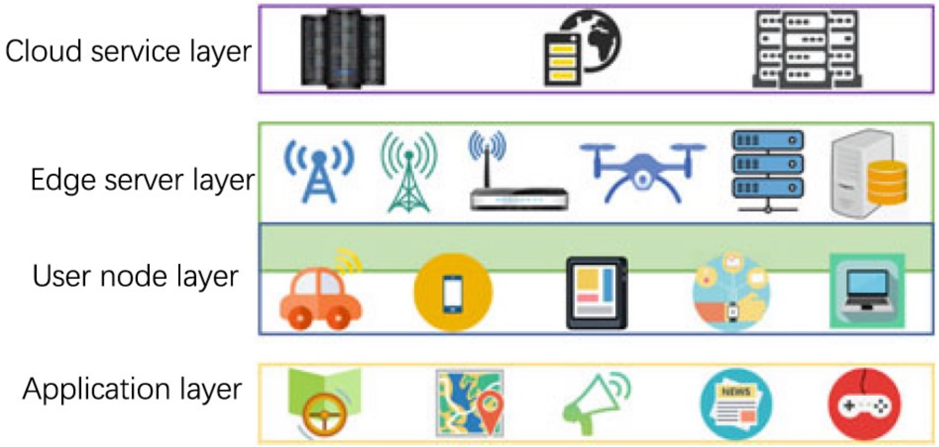


Fig: Hierarchical MEC architecture [2]

- MEC provides *cloud services* (computation, storage capacities) at the *network edge*, close to end users
  - Enable computation intensive applications to resources limited devices
  - Enable delay sensitive applications, reduce end-to-end delay

Non-orthogonal multiple access

- NOMA serves multiple devices in a resource block (RB)
- NOMA can be devided into two categories
  - Code-domain NOMA
  - Power-domain NOMA

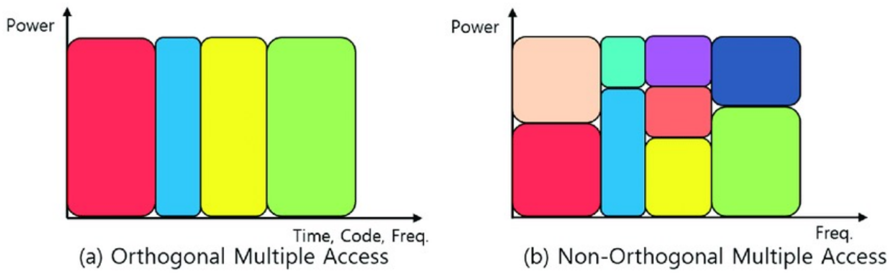


Fig: The difference between OMA, NOMA,
the resource allocated to different user is colored differently[3]

- How can power-domain NOMA (NOMA) serve multiple users?
  - Superposition coding (SC) at the transmitter side, and
  - Successive interference cancellation (SIC) at the receiver side

Superposition coding NOMA

- SC superposes the signals from multiple users to simultaneously transmit the information $X(n) = \sqrt{P\beta_1}\, S_1(n) + \sqrt{P\beta_2}\, S_2(n)$

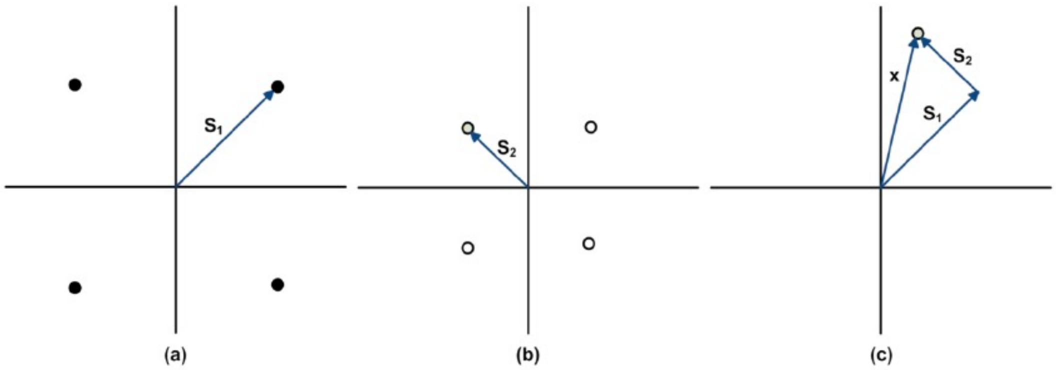


Fig: An example of SC encoding
(a) $S_1(n)$ with higher transmitting power $\sqrt{P\beta_1}$, channel gain h_1
(b) $S_2(n)$ with lower transmitting power $\sqrt{P\beta_2}$, channel gain h_2 $(|h_2| > |h_1|)$
(c) Superposed signal $X(n)$ [4]

- NOMA exploits the channel gain difference between multiplexed users. $\frac{P_2 |\, h_2|^2}{P_1 |\, h_1|^2} \geq \gamma_{th}, P_1 = \sqrt{P\beta_1}, P_2 = \sqrt{P\beta_2}$

Successive interference cancellation NOMA

- SIC allows user signals are successively decoded
- In uplink, the base station successively decodes and cancels the signals of strong users (users with higher channel gain), prior to decoding the signals of weak users

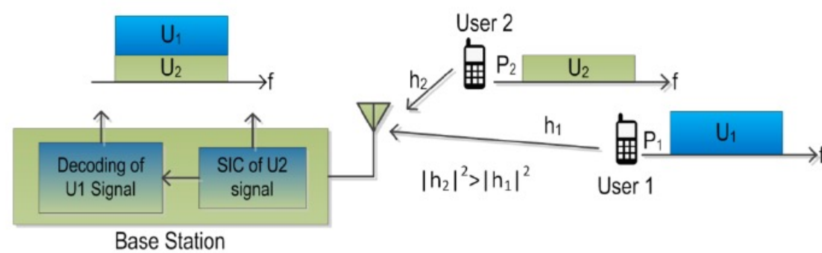


Fig: NOMA in an uplink scenario[4]

- In downlink, strong users successively decode and cancel the signals of the weak users, prior to decoding their own signals

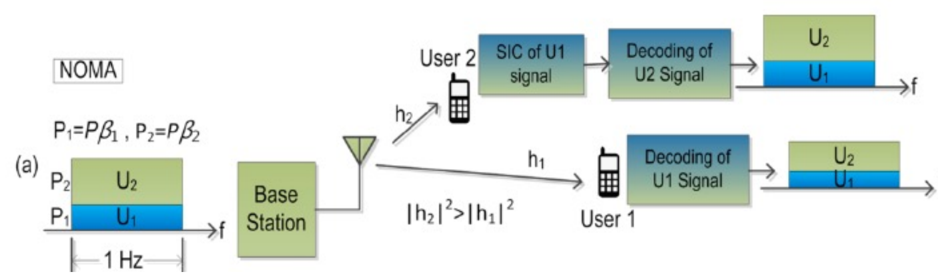


Fig: NOMA in a downlink scenario [4]

NOMA-based MEC systems

- Taking advantages of NOMA and MEC:
  - Spectral effificiency in the scare communication systems
  - Enable computation-intensive, delay-sensitive applications
- We consider a NOMA-based MEC system:
  - 1 MEC server
  - N user equipment (UE)

  $\boldsymbol{N} = \{1, 2, \ldots, N\}$ that

  have computional tasks
  - S subchannels (SC)

  $\boldsymbol{S} = \{1, 2, \ldots, S\}$

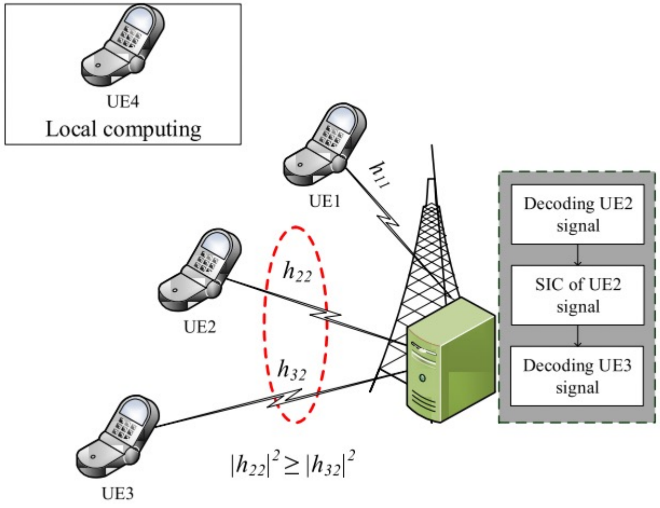


Fig: A cellular NOMA-based MEC system with N = 4, S = 2
h_{ij}: the channel gain of UE i over SC j
UE 2, 3 use the same SC 2

Resource management problem in NOMA-based MEC systems

- Objective:

To minimize both completion time and energy consumption of UEs
By maximize the system utility (function of time and energy consumption)

UE i	Remote Execution		Local Execution	
	Time	Energy	Time	Energy
Uplink	T_i^{off}	E_i^{off}		
Execution	T_i^{exe}		T_i^l	E_i^l
Downlink	omitted			
Total	T_i^r	E_i^r	T_i^l	E_i^l

- Resource management:
  - Computing resource allocation **(CRA)**: CPU frequency of the MEC server for offloaded tasks?
  - Transmit power control**(TPC)**: transmit power of UEs to offload ?
  - SC assignment **(SA)**: user-grouping over SCs?

Whale Optimization Algorithm

- A heuristic optimization algorithm
- Mimic the bubble net hunting behavior of humpback whales

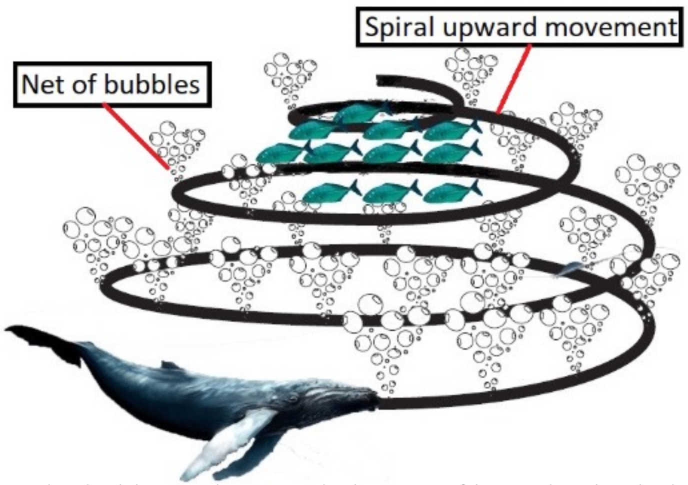


Fig: The buble-net hunting behavior of humpback whales [5]

- The humpback whale moves along the bubles of the net until reach the targeted fishes (the optimal solution)

We apply WOA to address TCP, and SA;

CRA is solved by a convex optimization technique

Simulation results

<u>System parameters</u>

I_i		Task of UE i
$N = 18$		# UEs
$S = 5$		# SCs
$r = 250$	m	Cell radius
α_i = 420	kbits	Input data size of I_i
β_i= 1000	cycles	CPU requirement for completing I_i
f_0	cycles/s	CPU frequency of server
$p_i^0 = 24$	dBm	Max transmit power of UE i
W = 1	Hz	Bandwidth of SC j
λ_t = 0.5		UE's i preference coefficient in time

Simulation results & Conclusions

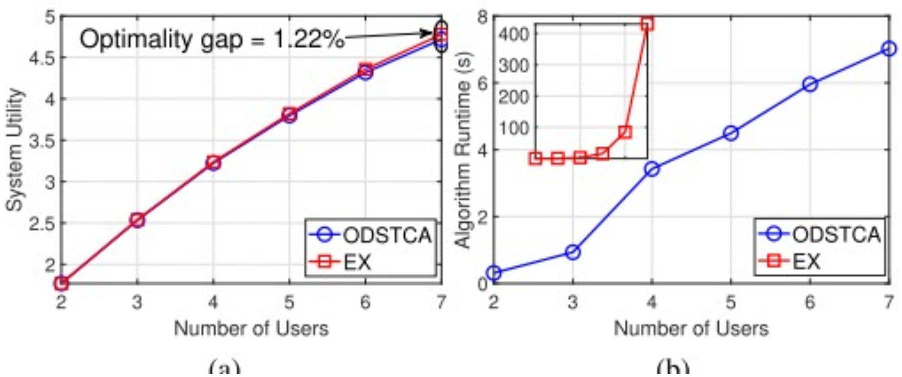


Fig: Our resource management for NOMA-based MEC systems by WOA (ODSTCA) vs. Exhaustive search (EX)

- Proposed resource management with WOA brings the sub-optimal solution with small optimality gap while greatly reduced the execution time

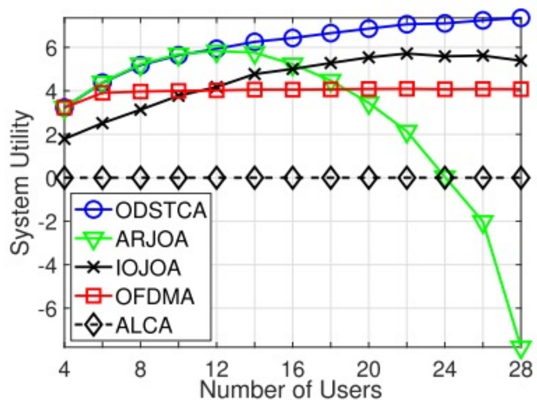


Fig: ODSTCA compared with other scenarios
ARJOA: All remote joint optimization algorithm
IOJOA: Independent offloading joint optimization algorithm
OFDMA: OFDMA-based MEC systems
ALCA: all locally computation algorithm

- Proposed NOMA-based MEC yields a good performance compared to other scenarios

References

[1] Y. Liu, M. Peng, G. Shou, Y. Chen and S. Chen, "Toward Edge Intelligence: Multiaccess Edge Computing for 5G and Internet of Things," in *IEEE Internet of Things Journal*, vol. 7, no. 8, pp. 6722-6747, Aug. 2020, doi: 10.1109/JIOT.2020.3004500.

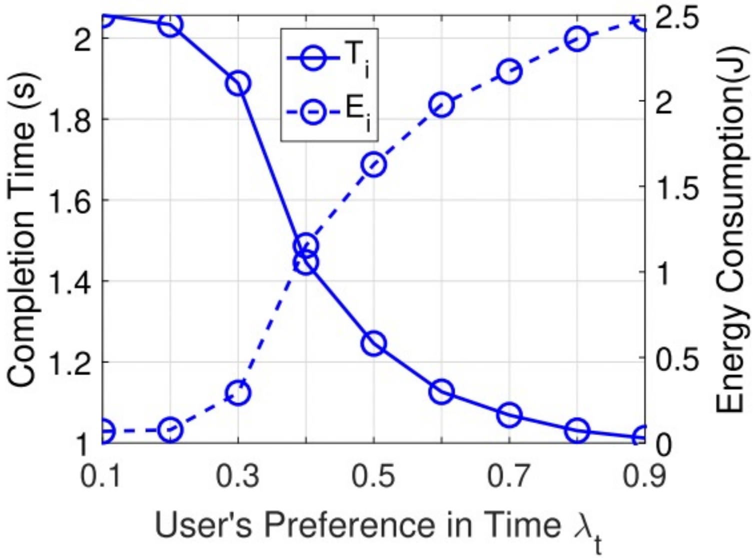
[2] Y. Zhang, "Mobile Edge Computing", in *Simula SpringerBriefs on Computing*, doi: 10.1007/978-3-030-83944-4

[3] Cheon, Jinyong, and Ho-Shin Cho. "Power allocation scheme for non-orthogonal multiple access in underwater acoustic communications." *Sensors* 17.11 (2017): 2465.

[4] S. M. R. Islam, N. Avazov, O. A. Dobre and K. Kwak, "Power-Domain Non-Orthogonal Multiple Access (NOMA) in 5G Systems: Potentials and Challenges," in *IEEE Communications Surveys & Tutorials*, vol. 19, no. 2, pp. 721-742, Secondquarter 2017, doi: 10.1109/COMST.2016.2621116.

[5] Q. Pham, S. Mirjalili, N. Kumar, M. Alazab and W. Hwang, "Whale Optimization Algorithm With Applications to Resource Allocation in Wireless Networks," in *IEEE Transactions on Vehicular Technology*, vol. 69, no. 4, pp. 4285-4297, April 2020, doi: 10.1109/TVT.2020.2973294.

Thank you for your attention



T_i
E_i
Completion Time (s)
Energy Consumption(J)
User's Preference in Time λ_t
2
1.8
1.6
1.4
1.2
1
2.5
2
1.5
1
0.5
0
0.1
0.3
0.5
0.7
0.9