Ultra-Dense Cell-free Massive MIMO Network Deployments for Beyond-5G Wireless Communications

Stefano Buzzi

Dept. of Electrical and Information Engineering "M. Scarano"
University of Cassino and Lazio Meridionale, Italy
buzzi@unicas.it

Acknowledgements

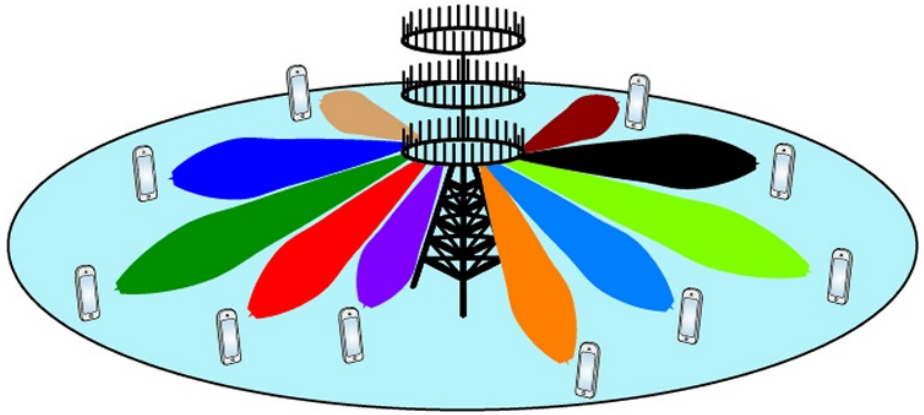
This talk comes from joint work with:

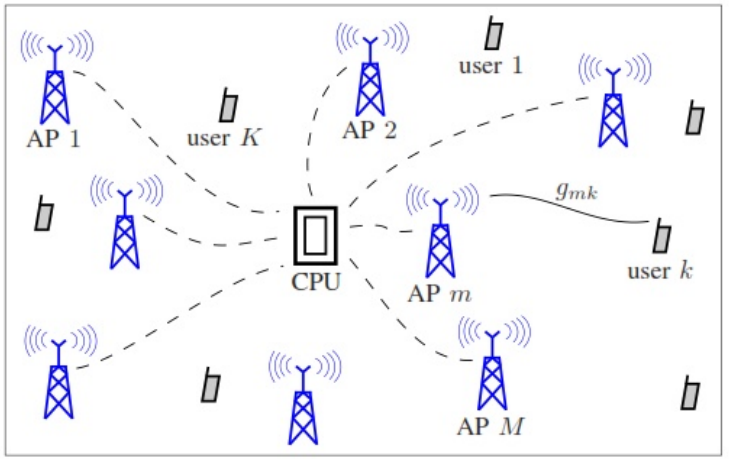
- Carmen D'Andrea (Post-doc @Unicas)

Part of this talk is inspired by our recent paper:

C. D'Andrea, A. Garcia-Rodriguez, G. Geraci, L. Galati Giordano, and S. Buzzi, "Cell-free massive MIMO for UAV Communications," to be presented at the *2nd Workshop on Integrating UAVs into 5G and Beyond (IU5GB)*, in conjunction with *2019 IEEE International Conference on Communications*, Shanghai, May 2019. Also available on ArXiv.

Cell-free massive MIMO[1] versus co-located massive MIMO



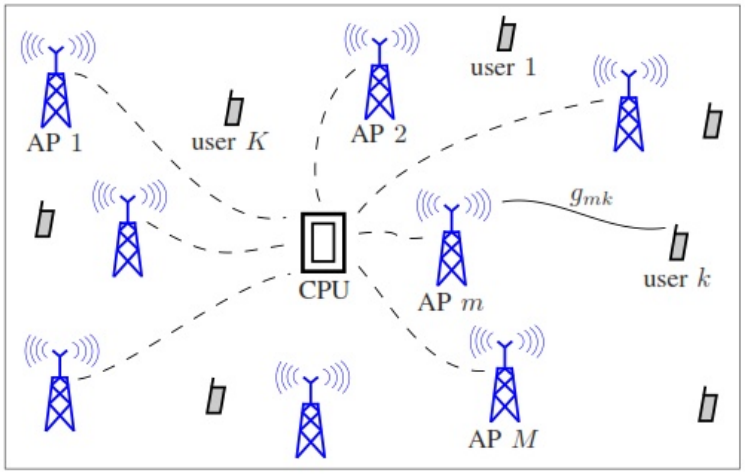


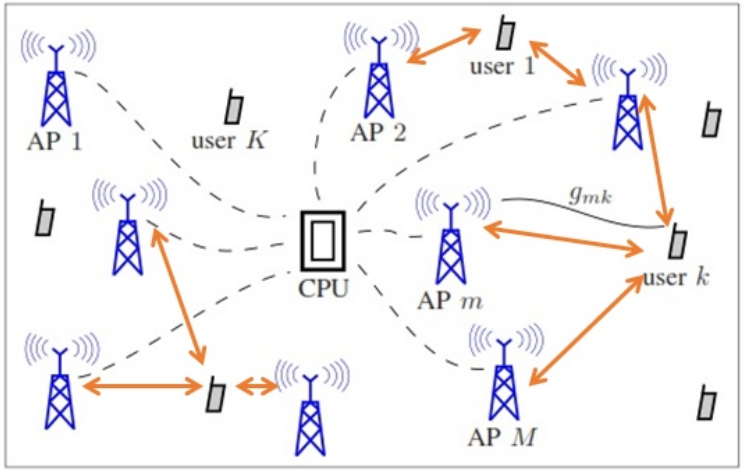
- Cell-free massive MIMO is the "scalable" way of doing CoMP; it merges key aspects of massive MIMO and cloud-RAN
- Cell-free massive MIMO alleviates the cell-edge problem and provides macro-diversity
- On the other side, it achieves less channel hardening

References

[1] H. Q. Ngo, A. Ashikhmin, H. Yang, E. G. Larsson, and T. L. Marzetta, "Cell-free massive MIMO versus small cells," *IEEE Transactions on Wireless Communications*, vol. 16, no. 3, pp. 1834–1850, 2017

Cell-free versus User-Centric Massive MIMO [2, 3]





In the UC approach, proper AP-MS association rules need to be designed

References

[2] S. Buzzi and C. D'Andrea, "User-centric communications versus cell-free massive MIMO for 5G cellular networks," in *Proc. 21st International ITG Workshop on Smart Antennas*, 2017

[3] ——, "Cell-free massive MIMO: User-centric approach," *IEEE Wireless Communications Letters*, vol. 6, 2017

Distinguishing features of UC and CF massive MIMO systems (1/2)

- The APs are connected by means of a backhaul network to a central processing unit (CPU) wherein data-decoding is performed.
- all communications take place on the same frequency band (as customary in massive MIMO)
- uplink and downlink are separated through time-division-duplex (TDD)
- on the downlink, only data symbols travel on the backhaul
- on the uplink, only scalar sufficient statistics travel on the backhaul
- channel estimation is made locally at the APs and is not sent to the CPU

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Distinguishing features of UC and CF massive MIMO systems (2/2)

- the channel coherence interval is thus divided into three phases:
  (a) uplink channel estimation
  (b) downlink data transmission
  (c) uplink data transmission.
- no need for channel estimation at the MS

The communication protocol

The communication procedure is made of three different phases:

- In phase (a) the MSs send pilot data in order to enable channel estimation at the APs and perform AP-MS association
- In phase (b) APs use channel estimates to perform channel-matched beamforming and send data symbols on the downlink
- In phase (c) MSs send uplink data symbols to the APs; while in the CF architecture *all the APs* participate to the decoding of the data transmitted by all the MSs, in the UC approach APs just decode the data from the *nearby MSs*.

A Beyond-5G Technology

Ultra-dense cell-free massive MIMO deployments are an excellent match for:

- Large data-rates with low power
- Capability to support larger number of connections
- Higher reliability
- Low latency
- Increased energy-efficiency
- MEC-ready

Directly from the MWC 2019: RADIO STRIPES

EMERGING TECH

Ericsson wants to make 5G networking easier with packing tape

An use-case: Support of UAVs and GUEs communications

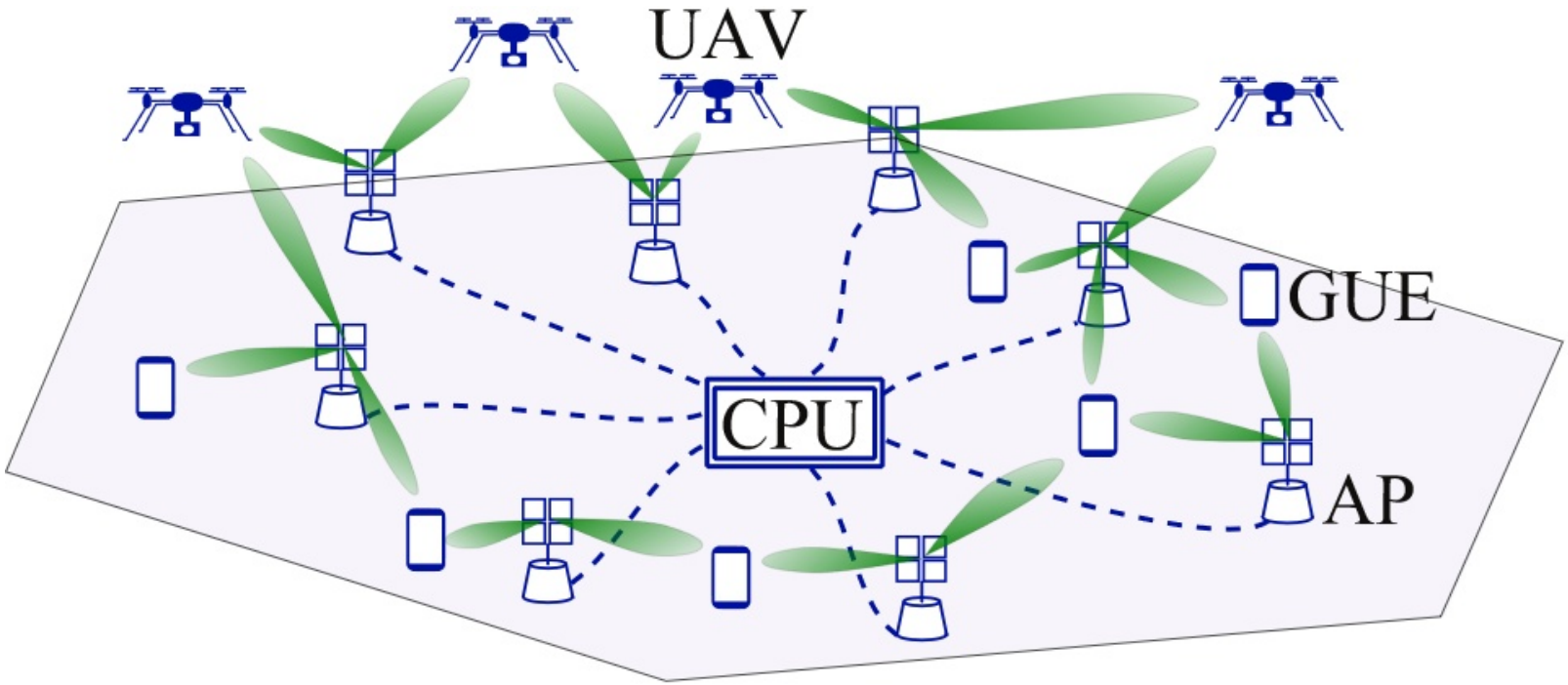
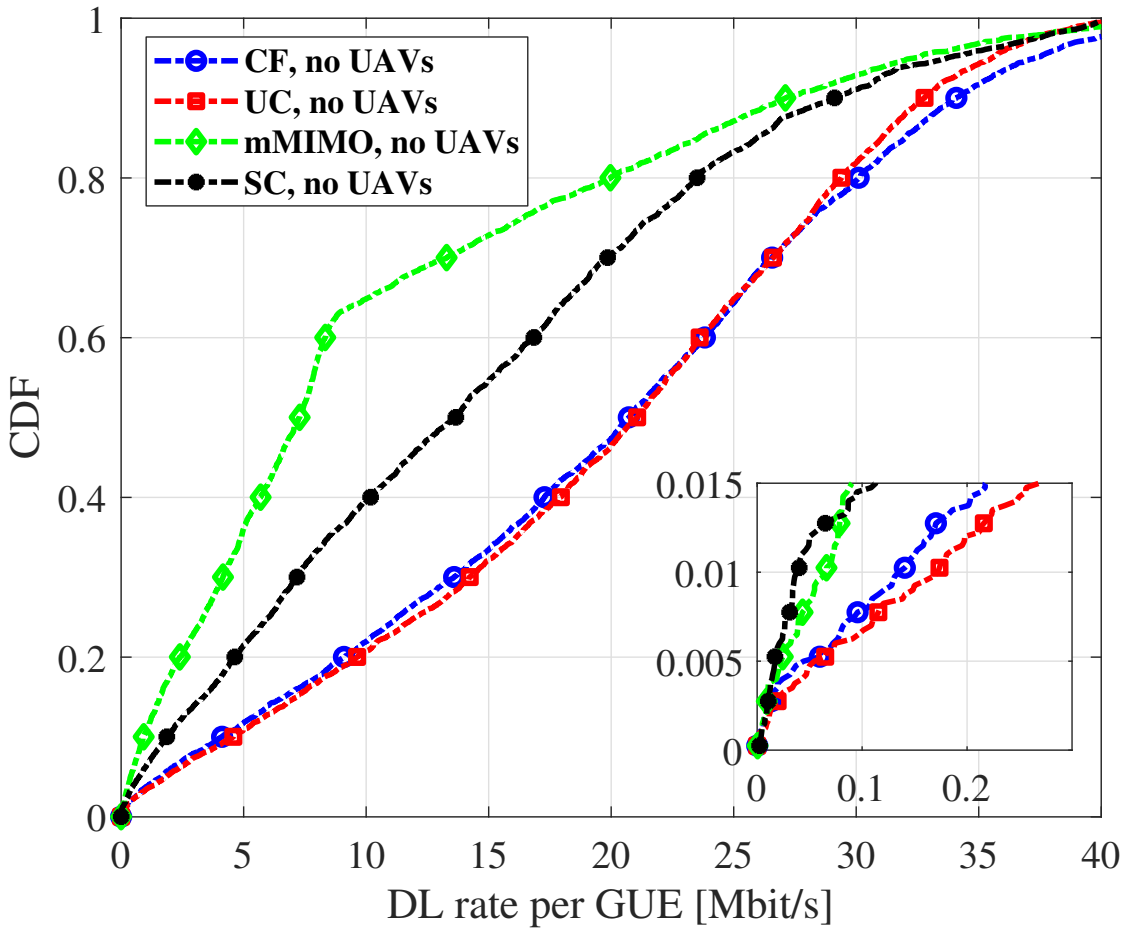


Figure taken from:
C. D'Andrea, A. Garcia-Rodriguez, G. Geraci, L. Galati Giordano, and S. Buzzi, "Cell-free massive MIMO for UAV Communications," *IU5BG Workshop*, in conjunction with *IEEE ICC 2019*, Shanghai, May 2019. Also available on ArXiv.

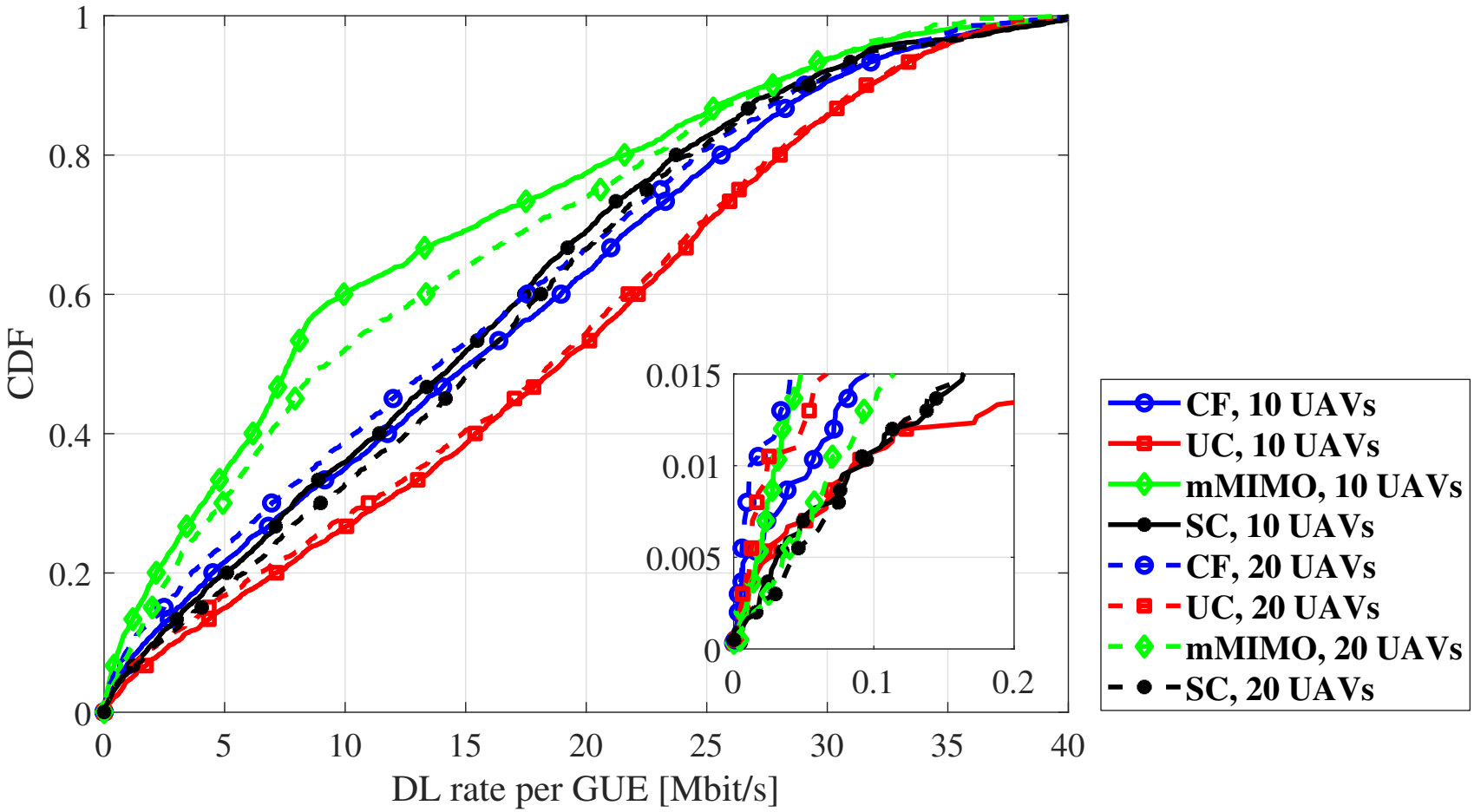
Numerical Results: Simulation setup

- We consider a square area of 1000 $\times$ 1000 sqm.
- Four scenarios are considered:
  1. 4 colocated massive MIMO BSs with 100 antennas each with 5W transmit power per BS
  2. 20 BSs, randomly deployed, with 20 antennas each, and 1W transmit power per BS
  3. 100 APs with 4 antennas each, randomly deployed, with 200mW transmit power per BS; **CF strategy**: all the APs serve all the MSs in the system
  4. 100 APs with 4 antennas each, randomly deployed, with 200mW transmit power per BS; **UC strategy**: each MS is served by the 10 best APs.
- MMSE channel estimation; pilot length: 16 (i.e., there is pilot contamination)

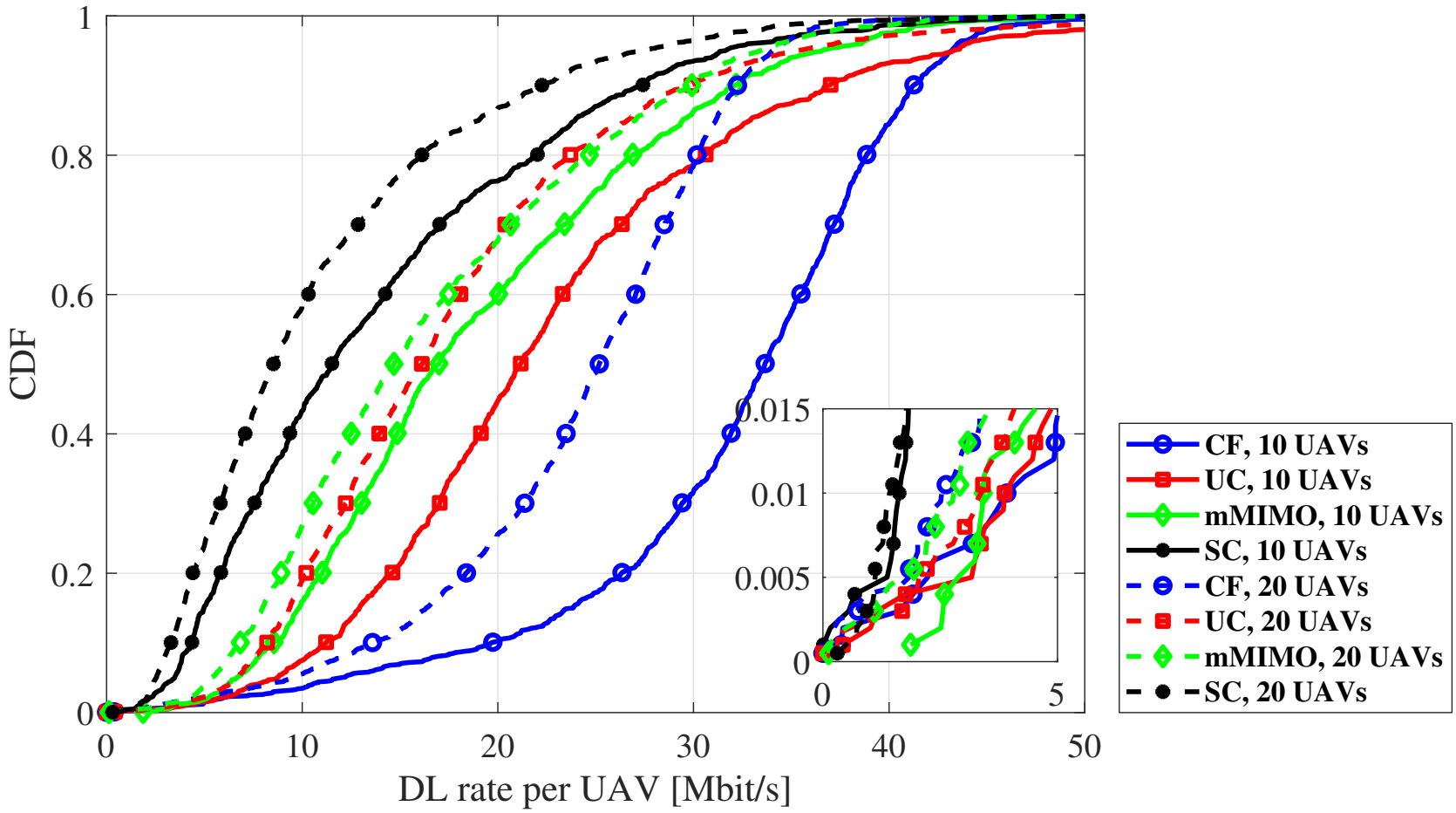
Downlink achievable rate-per-user, GUE performance, no UAVs; #GUEs=40



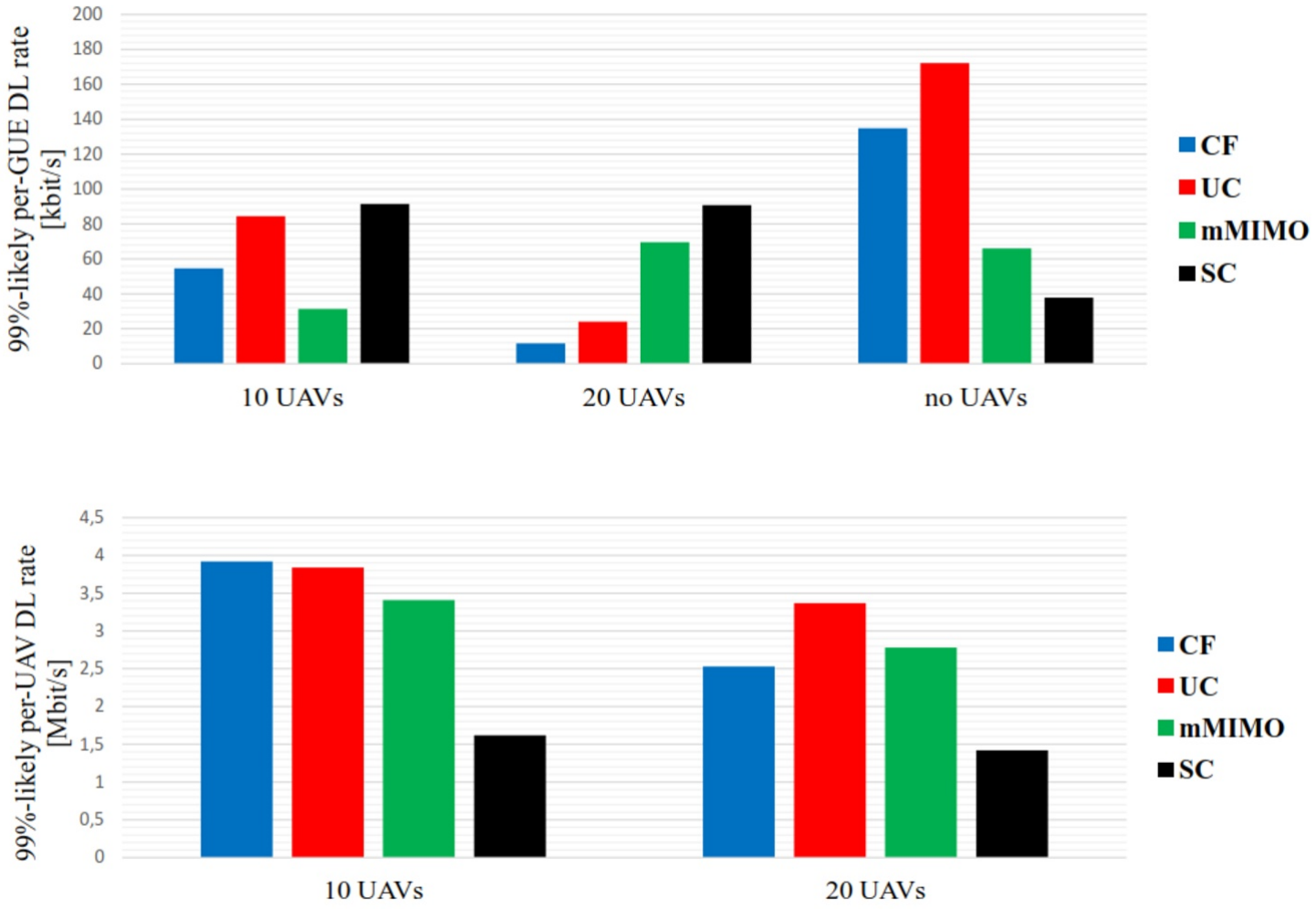
Downlink achievable rate-per-user, GUE performance, with UAVs; #GUEs + #UAVs=40



Downlink achievable rate-per-user, UAV performance; #GUEs + #UAVs=40



99%-likely per user DL performance



Conclusions

- The cell-free, user-centric deployment is a beyond-5G concept
- It is the "scalable way" to introduce network MIMO in wireless networks
- It can solve the cell-edge problem and, at the same time, increase energy-efficiency and reduce latency. It naturally blends with MEC applications and provides support for URLLC and mMTC
- Patents based on this technology have been already issued (i.e., radiostripes by Ericsson)
- Lots of interesting avenues for future research: support for high data-rate mMTCs, use of UAVs for increased coverage and backhauling, on-off switching of unused APs, ...

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