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***Abstract*— Cellular networks have been improved since 2G and have achieved a good amount of data rate, but it lacks low variation of data rate in all coverage area. User-centric cell-free is an emerging architecture for mobile communications, the focus of this article is to show differences between cell-free and cellular networks and how cell-free can be much better than a cellular architecture in an uplink channel UE-AP.**

I. Introduction

Cellular network is based on a limited cell, a single AP serving UEs in its coverage area. This architecture creates a problem that UEs in cell-edge have much lower data rate than UEs in cell-core [1]. Cell-free is a new deployment for mobile communications. It is the concept that an AP does not have a core or an edge, it consists on a set of preferred APs serving an UE. That is called user-centric cell-free.

A. Problem with cellular network

Cellular network was developed in 1950 to serve voice calls. So if you have a SNR above a threshold that makes possible a stable connection, you have a stable voice call, and if you have much more SNR than threshold, it does not increase much quality from the service. But nowadays mobile communication serves data transmission and data receiving. The SNR that makes possible voice calls does not serve enough data rate. This is the problem with cellular networks, UEs close to AP have peaks of quality that UEs far from AP do not have. In a scenario of 1 UE, the data rate is lower far from AP because of the distance, according to [1], It's common (40dB) difference between cell-center and cell-edge . To improve quality for UEs in cell-edge was developed small cells, that is a high density of APs in certain coverage area. It decreases the distance between cells because of the high amount of cells, but the number of cells can not be that large. If there are many more cells than simultaneously active UEs, deploying another cell would cause higher inter-cell interference in the system.

II. User-centric Cell-Free

In a cell-free design, there are L distributed APs jointly serving UEs in certain area. It is not the focus of this article to explain how APs are connected, but in summary, a central processing unit connected to the core network via backhaul link serves a set of APs via fronthaul link. This is commonly called as C-RAN.

A. Benefits of cell-free

In a cellular network small cells SNR is:

$$SNR = (P \div \sigma^2)\beta(d)$$

In which P is the power transmitted, σ^2 is the power noise and $\beta(d)$ is the power received at AP l. As in cellular networks each UE is assigned to one cell and only served by its AP, $\beta(d)$ is the highest number in in the path gain vector of all L APs. (OBS: não sei se devo chamar de path gain vector, mas se há um vetor com o modelo de propagação calculado para cada AP, $\beta(d)$ é o maior).

In a cell-free network SNR is:

$$SNR = (P \div \sigma^2)\sum_{l=1}^{L}\beta(dl)$$

Now $\beta(d)$ is not the highest path gain, but a sum of all path gains at all L APs.

III. System model

The total band in the system is 100 Mhz

$$\beta(d) = (\alpha PK) \div d\hat{}n$$

Propagation model assumes the equation above. α is the shadowing effect that assume a form of a log normally random variable, P is the power transmitted and is equal to 1 W, K is a constant and is equal to $10\hat{}(-4)$, d is the distance between UE and AP and n is the path loss exponent and is equal to 4.

The SNR assumes the equation already discussed in the past section and it is assumed phase-synchronization among signals. σ^2 is the power noise and assumes this equation:

$$\sigma^2 = K0band \div N$$

In which K0 is a dimensional constant in watt/Hz, band is the total available band and N is the number of channels. The equation to calculate link capacity follows the form below and is known as Shannon equation:

$$C = (band \div n)log2(1 + SNR)$$

C is given in bits per second. Energy efficiency calculates how much data rate the system provides for each joule and follows the equation below:

$$ee = C \div \sum_{l=1}^{L} P$$

The sum is the power transmitted to L assigned APs, so if the UE assigns 4 APs, assuming that power transmitted is always 1 W, the sum is equal to 4 W.

IV. Results

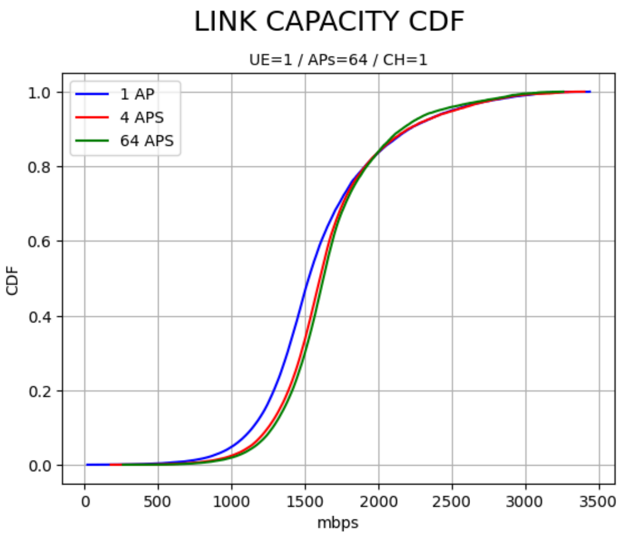

Fig. 1. This figure is the link capacity CDF in an uplink channel UE-AP

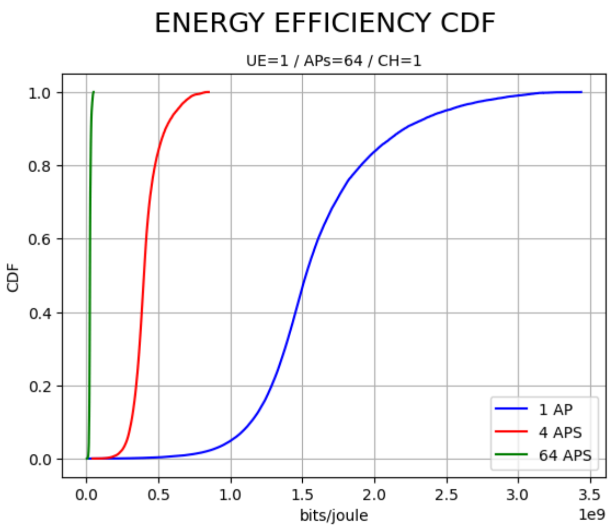

Fig. 2. This figure is the energy efficiency CDF in an uplink channel UE-AP

V. Conclusion

In Figure 1, we can see that because of the sum of all SNRs in connected APs there is an improvement in link capacity at the 90% likely, which shows that in extreme scenarios, in cell-edge for example, cell-free is better.

In Figure 2, we can see that there is a high cost of energy using all APs for useful data receiving. Figure 1 shows that there is not a high improvement to use a cluster with all APs, so it is correct to affirm that it is worse use all APs for useful data receiving considering the cost to have a negligible improvement. So considering a scenario with 64 APs, a cluster with 4 APs satisfies energy efficiency and link capacity QoS.

References

[1] L. Lamport, *A Document Preparation System: LATEX, User's Guide and Reference Manual.* Addison Wesley Publishing Company, 1986.

[2] F. C. Silva e J. J. Sousa, "This reference is just an example", Journal of *Examples*, v. 5, pp. 52–55, Maio 1999.

Appendix