[12] considers a DC enabled uplink with one macro and one pico node and proposes optimal rate and power control solutions for a cost minimization problem with per-user minimum rate constraints. Power optimization over a DC enabled Hetnet has been considered in [18] where distributed algorithms for the uplink that account for backhaul capacity have been proposed. Power optimization is also investigated in [13] where non-orthogonal multiple access (involving successive interference cancellation at the receiving nodes) was additionally exploited in a DC enabled downlink comprising of a single macro base station and a single small cell access point to improve the throughputs. On the other hand, [14] considers resource partitioning at only the macro node in a DC enabled downlink to optimize the PF utility. [16] proposes an efficient sub-optimal algorithm for the problem of determining the sum rate maximizing user association under the restrictions that for each user only the low-power node yielding the highest SINR can be chosen and each node employs round robin scheduling. [17] evaluates algorithms that aim to maximize the number of satisfied users, .i.e., aim to satisfy minimum rate requirements for as many users as possible via single-TP association as well as DC. [17] shows that a smartly designed heuristic to exploit DC can significantly improve user satisfaction. We note that our work formally captures the notion of considering the association of all users to optimize a system utility (which also incorporates user satisfaction). [19] employs stochastic geometry based tools to demonstrate the benefits of dual connectivity together with decoupled associations in the uplink and downlink. [15] reuses existing algorithms for user association and investigates data forwarding and flow control problems, whereas packet scheduling algorithms for expoiting DC in the downlink have been proposed in [20]. In this work we consider a general DC enabled HetNet downlink with multiple users and TPs. Our key contributions are the following:

- We propose an efficient algorithm that yields a user association that is optimal for the PF system utility up-to an additive constant. To the best of our knowledge, this is the first such approximation algorithm for DC and the PF utility. Using this algorithm, we demonstrate the significant gains enabled by DC especially at low network loads.
- We also show that the user association problem to optimize the weighted sum rate utility subject to per-user minimum and maximum rate constraints can be formulated as a *constrained non-monotone submodular set function maximization*. This allows us to derive