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RESEARCH ARTICLE

An Energy-Efficient Small-Cell Operation Algorithm for Ultra-Dense Cellular Networks

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ABSTRACT The ultra-dense network (UDN) incorporates a high densification of small cells, resulting in improved capacity and coverage for a fifth-generation (5G) cellular network. However, the proliferation of small cells within the 5G network has led to a notable surge in energy consumption. To improve energy efficiency in a UDN, this paper proposes a small-cell operation algorithm considering sleep mode and active mode switching for small cells. The algorithm periodically monitors the radio resource status of the macro cells and small cells for the mode-switching process. If a macro cell with a lower radio load is detected, the algorithm triggers a small cell sleep mode switching. To that end, the algorithm finds a small cell with the lowest radio load within the coverage of the macro cell. Therefore, the algorithm switches the small cell to sleep mode estimating the accumulated load in the macro. An active mode switching is triggered by the algorithm when a macro cell with a high radio load is detected. The algorithm then generates a location dataset consisting of the location information of inactive small cells and static UEs. A clustering technique is adopted on the dataset to find clusters containing at least one small cell. Considering the average reported reference signal received power (RSRP) of the UEs, a cluster is selected, and the small cells in the cluster are switched to active mode. Through system-level simulations, the performance of the proposed algorithm is evaluated. The simulation results showed that the proposed approach can ensure a higher energy efficiency than previous algorithms.

INDEX TERMS Ultra-dense cellular network, energy efficiency, user equipment, physical resource block, quality of service, throughput.

I. INTRODUCTION

The fifth generation (5G) considered an ultra-dense deployment of small cells as a key technique to support a thousand times more traffic compared to its predecessor, fourth generation (4G) networks. The operators also deploy the small cells in the present cellular networks considering the peak quality-of-service (QoS) requirement by the user equipments (UEs). Therefore, the 5G network is expected to be a highly dense heterogeneous network [1]. Even though an ultra-dense deployment of small cells can provide enhanced coverage, higher capacity, and improved user experience, it also brings great challenges to network operation and management [2] [3]. With an increased number of low-power small-cell base stations, the network structure becomes increasingly complex, and also energy consumption will increase dramatically. The high density of small cells results in shorter distances between the base stations and end-user devices; however, power consumption increases for the operation of these small cells [4]. Moreover, the infrastructure required to support these small cells, including terrestrial and non-terrestrial backhaul connections [5] and cooling systems, further adds to the energy consumption [6]. This increased power consumption leads to elevated energy costs

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