Energy Efficient of Multi-Connectivity in Ultra Dense Networks

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1 Introduction

High-Capacity and Ultra-reliable communication are the research focus of current wireless communication networks. A simple and effective way to provide ultra-high resource reuse factors is the ultra-dense deployment of the system framework with Millimeter-wave frequencies. The ultra-dense deployment of Base Station(BS) will cause frequent switching of user equipment(UE) between cells, and links in mmWave networks are highly susceptible to blocking and may suffer from rapid variations in quality. However, Radio link failures and service interruption times in a multi-connectivity session can be reduced or ideally avoided by means of simultaneous connections of multiple BSs.

multi-connectivity provides user-centric services and a reliable connection method to deal with the dynamic network environment, which facilitates a smoother and more stable network experience for mobile users. multi-connectivity can increase the user average throughput at low user density scenarios[1]. as in [2]-[3], in Multi-connectivity, reasonable management of the serving cell enables improvement in mobility robustness. In Research on energy efficiency[5] expressed spectrum and energy efficiency of UDNs with stochastic geometry and also showed the improvements and limitations of network densification. Other works focus on new cell association schemes for HetNets and UDNs, such as [6]-[7]. However, The above work focuses on the robustness of the connection or the energy consumption in the case of a single Connectivity and does not consider the energy consumption in the case of multiple Connectivity in an ultra-density network. My research questions will focus on energy efficiency under multiple Connectivity in heterogeneous networks with millimeter-wave units.

links in mmWave networks are highly susceptible to blocking and may suffer from rapid variations in quality. Connectivity to multiple cells - both in the mmWave and in the traditional lower frequencies - is thus considered essential for robust connectivity.
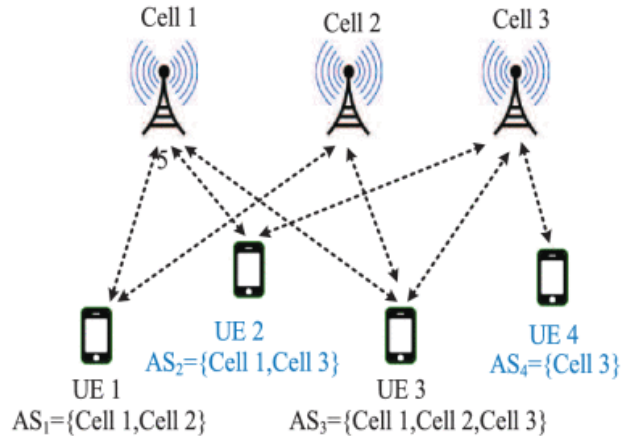

Figure 1: System Model of Multi-connectivity in UDN

2   System Model

In telecommunications, the ITU defines energy efficiency as the relationship between the specific functional unit for a piece of equipment and the energy consumption of that equipment [32]. It is expressed in (bit/J).

We can write the energy efficiency η_{MC} as:

$$\eta_{MC} = \frac{R_{MC}}{P_{MC}} \tag{1}$$

where R_{MC} is the user bit rate and P_{MC} is the user power consumed.

We further define the bits rate as:

$$R_{MC} = R_{master}(u) + \sum_{c \in C_{\text{sec}}} R_{\text{sec}}(u) \tag{2}$$

where u is a user, U_{MC} the set of active users in the network, $R_{master}(u)$ the bit rate for the user u by its master cell. $R_{sec}(u)$ is the bit rate from the other secondary cell. C_{sec} the set of connect user other secondary cell.

Because multi-connectivity generate a large number of virtual users, user data packet scheduling is very frequent. Processing latency of any BS

$$T_C^q = \vartheta(\gamma_{Mc} - \lambda_{Mc}) \tag{3}$$

where γ_{Mc} and λ_{Mc} represent the package of Unprocessed and already processed, ϑ represents the processing capacity of different base stations in a Hetnet.

$$P_{MC} = P_M(SNIR, T_{master}^q) + \sum_{c \in C_{\text{sec}}} P_{\text{sec}}(SNIR, T_{\text{sec}}^q) + P(N_c) \tag{4}$$

$SNIR$ determines the lowest transmit power, T^q represents the time of transmission, $P(N_c)$ Scheduling and maintaining power consumed by multi- connectivity

3   Problem Formulation

The formulated power control problem is given as follows:

$$
\begin{aligned}
P1: \quad & \max \sum_{u \in U} \eta_{MC}^u(N_c, P_{MC}) \\
& C1: \rho_{MC} \geq \rho_{MC}{}^0, \\
& C2: 0 \leq P_{MC}^u \leq P_{MC}^{\max} \\
s.t. \quad & C3: 0 \leq T_c^q \leq t_{mc}, \\
& C4: \lambda_{MC} \leq \gamma_{MC} \\
& C5: \partial \leq x,
\end{aligned} \tag{5}
$$

here $C1$ represent the UE transfer Connectivity rate, C2 represent the maximum transmission power threshold, C3 represent Transmission delay time, C4 represent the computing capability constraints, C5 represent random outage rate.

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