



**INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI  
SHORT ABSTRACT OF THESIS**

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**SHORT ABSTRACT**

The design of wireless communication networks continues to evolve in order to meet the ever-increasing requirements for higher spectral efficiency (SE) and the need to support diverse technologies, services and applications. The data rates and the number of users that can be served depend heavily on the wireless spectrum that is available. However, below 6 GHz, we do not have sufficient free spectrum available for new technologies. This has motivated spectrum regulatory bodies around the globe, for example, the Federal Communications Commission (FCC) in the USA to actively consider spectrum sharing as a potential solution to enable efficient reuse of the already allocated spectrum. In this thesis, we focus on concurrent spectrum sharing, where the cognitive user (CU) also referred to as the unlicensed user may transmit simultaneously with the incumbent primary user (PU) who owns the spectrum provided it satisfies an interference constraint. To prevent adverse impact of spectrum sharing on the primary performance, the CU must adapt its transmit power, which, in turn, limits its SE measured in bits/s/Hz.

To this end, we first investigate the use of massive number of antennas at the cognitive base station (BS) in reducing interference caused to PUs under incomplete and/or imperfect channel state information (CSI) without deteriorating the sum SE of CUs. We derive analytical expressions for complement of interference outage probability (IOP) with incomplete and/or imperfect CSI. These novel expressions provide ballpark number for the amount of back-off required to meet the interference constraint. We deduce new expressions for sum SE of CUs with MR beamforming under incomplete and/or imperfect CSI. We show that under imperfect CSI, by deploying more antennas at cognitive BS, IOP can be reduced while keeping sum SE of CUs fixed. Furthermore, IOP reduces as number of channels  $S$  to which CSI is available increases, since the constraint is violated less often. The impact of spatial correlation on performance is also elucidated.

Thereafter, we investigate the use of cell-free massive multiple input multiple output (mMIMO) systems in serving unmanned aerial vehicles (UAVs) and ground user equipments (GUEs) in underlay spectrum access mode by

considering UAVs as CUs and GUEs as PUs. We derive a new lower bound on the complement of IOP. This result helps determine the power margin required at secondary access points (APs) to meet the IOP constraint. We deduce new analytical expressions for SE and bit error rate (BER) of UAVs and GUEs. We prove that for lower pilot power, a larger power margin is required to keep IOP fixed. We show that for a given IOP, the larger the interference threshold is, the greater (lower) the likelihood for the UAVs (GUEs) to obtain higher SE is. For a given interference threshold, probability that UAVs attain higher SE increases as IOP increases for a fixed number of secondary APs ( $N$ ) or as  $N$  increases for a given IOP.

We then analyze the uplink (UL) of a cell-free mMIMO based underlay network over limited capacity fronthaul in which the CUs transmit under an IOP constraint and the impact of quantization is modeled based on Bussgang decomposition. We develop novel statistical models for the squared  $l_2$ - norm (SLN) of the true and the quantized channel estimates (QCE) based on Gamma distribution and find the corresponding shape and scale parameters. We also develop new expressions for IOP and UL SE of CUs and PUs as a function of the Bussgang gain and quantization noise variance, which in turn depends on the number of quantization levels. We show that to keep IOP fixed, larger back-off in SU transmit power is required when fewer bits are employed for quantization. Furthermore, the likelihood of PUs or CUs achieving a higher SE increase as number of quantization bits increases and 4 bits are sufficient to obtain same performance as an infinite capacity fronthaul.

