Introduction

- Spectrum aggregation for fragmented spectrum use
  - In order to meet the spectrum demands for 5G, spectrum shared on licensed, license-exempt and a dynamic spectrum access basis has been considered.
  - The detected idle spectrum is likely to be fragmented and distributed over multiple bands.
  - Spectrum aggregation (carrier aggregation in LTE-Advanced) can be exploited to overcome the spectrum fragmentation.

- Opportunistic spectrum use for dynamic spectrum sharing
  - When the network uses spectrum on a shared basis, collisions can occur between different transmissions.
  - Two types of collisions due to (i) asynchronous transmission and (ii) imperfect sensing

- Spectrum handoff can be utilised to provide reliable communications.
  - It will result in
    1) spectrum handoff delay along with
    2) short-term interference to other networks

Problem Statement

- When more spectrum is accessed for higher data rates by spectrum aggregation, collisions can occur more frequently.
  - How to aggregate spectrum opportunities considering complexity and overhead for spectrum aggregation and handoff?

System Model

- The downlink for multiple users in a centralised secondary network sharing spectrum with a primary network
  - Due to priority, primary transmissions can access any sub-channels secondary transmissions are using. In all cases of PU/SU transmission overlapping, collisions occur.
  - Spectrum sensing can be inaccurate with missed detection and false alarm probabilities. Due to imperfect sensing, collisions can also occur.
  - The secondary network can obtain information on the primary traffic loads for sub-channels
  - The secondary network is collision tolerant; Given a collision probability threshold, effective communication is possible while the collision probability remains below the threshold
  - Independent & Rayleigh fading-models are assumed. In addition, average SNR and PU traffic loads are assumed the same for different sub-channels in the same band and different for sub-channels in different bands.

Approach 1

- Problem formulation: How to allocate spectrum to increase data rates, while guaranteeing a certain level of QoS?
  1) Identify the relationship between spectrum aggregation & data rate
    - The data rate increases with aggregated spectrum except for low SNR
  2) Identify the relationship between spectrum aggregation & collision occurrence
    - The collision probability vs. multiple sub-channel use by aggregation
    - \( P(\text{collision}) = f(\text{transmit params}, \text{sensing accuracy}, \# \text{ of used channels for aggregation, other network’s traffic load}) \)

  3) Formulate the optimisation problem of spectrum aggregation to maximise the data rate under the collision probability constraint and solve it
    - Derive the optimal \( n^* \) of sub-channels for aggregation for the given threshold of collision probability
    - \( n^* = f(\text{transmit params}, \text{sensing accuracy, other network’s traffic load, the collision probability threshold}) \)

  - Propose dynamic (intra-band) spectrum aggregation for collision-sensitive networks to maximise the data rate
    - The proposed algorithm outperforms the benchmark (inflexible with a fixed number of aggregated channels) while aggregating spectrum adaptively according to the environment.

Approach 2

- Problem formulation: How to allocate spectrum to minimise collisions considering spectrum handoff delay and short-term interference
  1) Derive the expected number of collisions occurring by using different SNR & network traffic loads over different sub-channels
  2) Formulate the optimisation problem of spectrum aggregation to minimise collision occurrence and solve it

Summary

- Address the challenges of spectrum utilisation under dynamic spectrum sharing with opportunistic access
- Considering a practical case of asynchronous transmission & imperfect sensing
- We propose suitable spectrum sharing approaches by means of (intra-/inter-band) spectrum aggregation and spectrum handoff.