Optimal Spectrum Sharing for Multi-hop Software Defined Radio Networks

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Software Defined Radio Networks
- Software-based radio
- Can sense available spectrum
- Can use multiple bands at the same time
- Each node may have a different set of available spectrum (or bands)
- Each frequency band likely has different bandwidth

Our Problem
- Problem setting
  - A multi-hop SDR network
  - Available bands at each node may be different; each may be of different size
  - A set of communication sessions, each with a rate requirement
- Question
  - How to minimize network resource (spectrum bandwidth) to support given communication sessions?
  - Other capacity related question can also be asked (and solved) along the same line

Sub-band Division
- A set of un-equal bands in the network
  - Each node has a sub-set of bands from these bands
  - Size of each band (e.g., those allocated by FCC) is very much different
  - Necessary to further divide each band into sub-bands for optimal scheduling

Scheduling and Interference Constraints
- A node cannot use the same sub-band for transmission and reception
- A receiving node cannot be in the interference range of any other transmitting node on the same sub-band
- A node cannot transmit to or receive from multiple nodes on the same sub-band

Flow Routing constraints
- For each session, allow flow splitting (multipath) for maximum flexibility (and optimality)
- Flow balance constraints
  - For each session, the total out-going rates is equal to the total in-coming rates
- Link Capacity Constraint
  - For each link, aggregate flow on this link cannot exceed its link capacity

Our Approach
- The formulated problem is a mixed-integer non-linear program (MINLP)
  - NP-hard in general
- Aim to develop a near-optimal solution
- But need to find a criterion to measure optimality
  - A lower bound for the objective function can be used for this purpose
    - If the proposed solution is close to the lower bound, then
      - the lower bound is tight;
      - the proposed solution is near-optimal.

Our Approach (cont’d)
- A lower bound can be found via a linear relaxation to the MINLP problem
  - Relax binary variables to continuous variables in [0, 1]
- Sequential Fixing (SF) Algorithm
  - Determine all binary variables iteratively via a sequence of linear relaxation
  - Once all binary variables are fixed, the routing problem can be solved via a single linear program

Performance Evaluation
- Performance comparison with the lower bound via linear relaxation
- Will show that results from SF algorithm are very close to those from the lower bound
  - Indicating the lower bound is very tight
  - Results from SF algorithm are near optimal

Network setting
- 20 nodes in a 50 x 50 area
- 5 communication sessions with a rate in [10, 100]
- 5 bands with bandwidth of 60, 185, 26, 83.5, 125

Results for 20-node Network

Normalized Results: Results from SF Algorithm / Results via Lower Bound

![Normalized Cost (Min. Lower Bound)](image)

Average 1.04; Standard derivation: 0.07

Summary
- Investigated resource allocation problem for SDR networks
- Developed mathematical models for SDR networks at multiple layers
- Formulated a cross-layer optimization problem
- Developed a near optimal solution via SF technique
- Near optimality is substantiated by comparing a lower bound solution to the MINLP problem