Resource Management Optimization in the Return Link of Satellite Communications
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Context

- Geostationary satellite networks have become relevant to cover white areas (approx. 3 billion people).
- Multi-beam antennas & Super High Frequency Bands (Ka at 20GHz and Ka at 30GHz) ⇒ Transition from Broadcast to Broadband
- Two links:
  - The Forward Link (FL): DVB-S2: Aggregation of frames in BBFrames
  - The Return Link (RL): DVB-RCS2: MF-TDMA with DAMA
- Adaptive Coding and Modulation to adjust to different transmission conditions

Multi-Beam Antennas Satellites

- 100 to 300+ Beams with specific antennas
- Part of the beams use the same frequency/polarization → co-channel interference:
  \[ SNIR_{FL}(u_i) = \frac{G_i P_{\text{att}}(\alpha_i)}{\sigma^2 + \sum_{\forall \alpha_k \neq \alpha_i} G_k P_{\text{att}}(\alpha_k)} \]
  \[ SNIR_{RL}(u_i) = \frac{G_i P_{\text{att}}(\alpha_i)}{\sigma^2 + \sum_{\forall \alpha_k \neq \alpha_i} G_k P_{\text{att}}(\alpha_k)} \]

Shannon Capacity:

\[ C_{\text{Shannon}}(u_i) = W \cdot \log_2(1 + SNIR(u_i)) \]
⇒ Increasing the number of beams using a carrier decreases the capacity

Resource Allocation in the RL: Optimization

Inputs:
- Users demands (from DAMA Requests)
- Users positions (GPS given at login)

Objectives:
- Choose the best interferers to improve user experience.
- Increase system Frequency Reuse Factor, and hence, its capacity.
- Add system flexibility against demand and weather variations.

Main issues:
- Highly Combinatorial problem: \( \prod_{\alpha_k \neq \alpha_i} N_{\text{users}}^{\text{colors}} \) possibilities
- Millions of users to coordinate every 25 ms
- Time-varying demand and channel conditions
- Possibly decentralized resource allocation

Homogeneous Frequency Reuse Patterns

A first approach is to consider Regular and Geometrical frequency reuse schemes (similarly to cellular networks)

Performance assessed on worst-case scenarios only

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Fig. 1: Satellite Network Architecture, with FL/RL flows
Fig. 4: Classical FFR schemes
Fig. 3: Interference principles in the Forward link and in the Return link
Fig. 5: Dynamic Heterogeneous Frequency Reuse principle (top) and comparison with 3 color scheme (bottom)