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SWIFT-SAT: Efficient and On-Demand Spectrum Coexistence for Satellite-Terrestrial Systems

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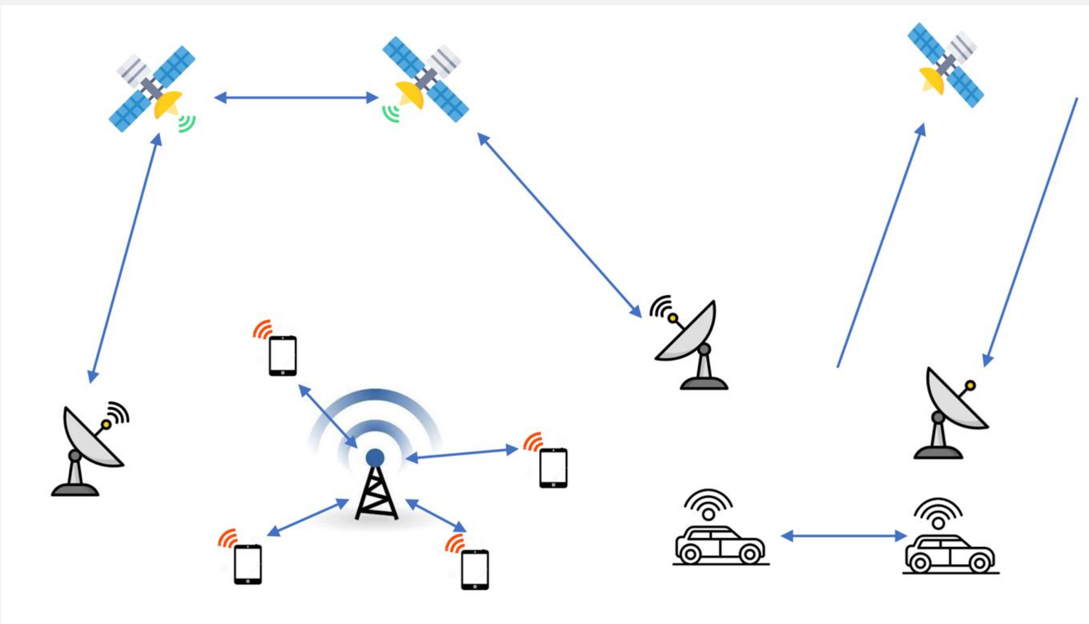
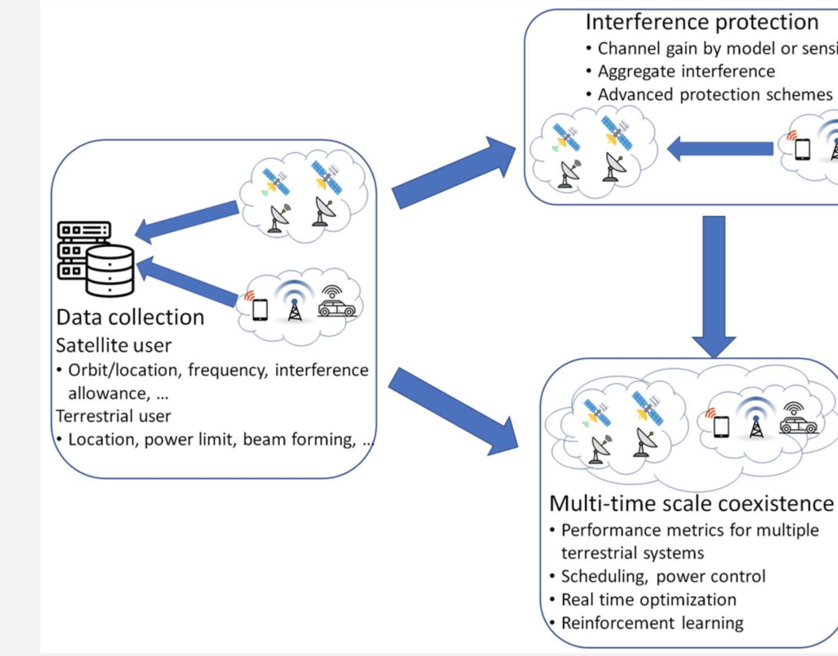
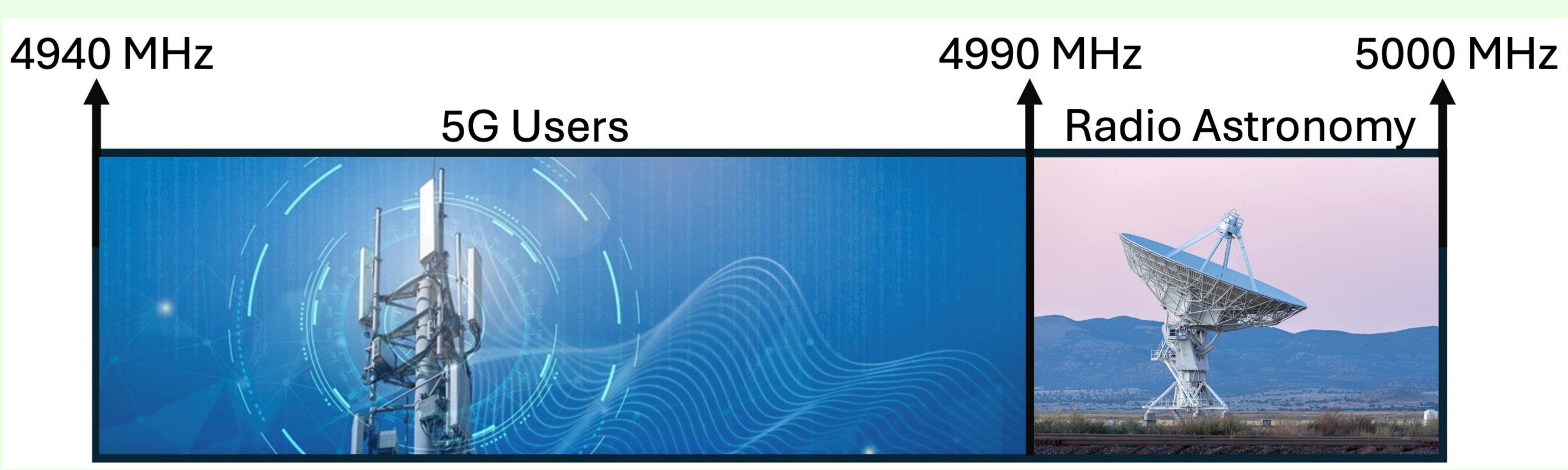
Project Summary



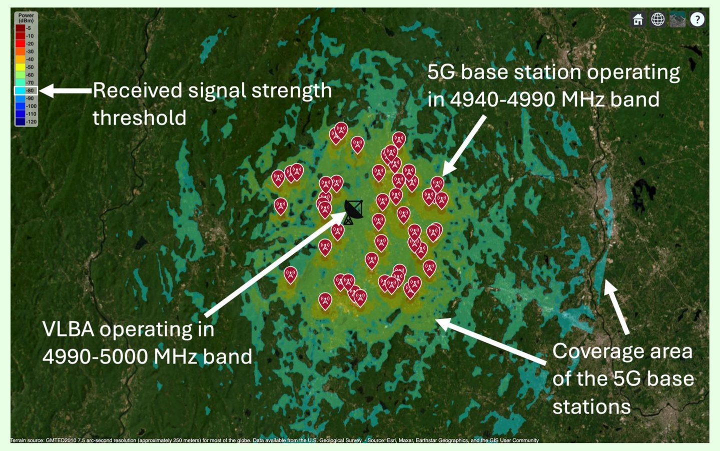
- **Objective**: Design efficient spectrum coexistence schemes for satellite and terrestrial systems
  - Challenge: **Passive users** in satellite systems are extremely sensitive to interference
- **Research Thrusts**
  - Develop a system architecture for data collection, interference protection, and spectrum coexistence
  - Ensure interference protection for satellite systems
  - Design a multi-time scale coexistence scheme to support different satellite services



Introduction



- 4990-5000 MHz band: Used for radio astronomy (RA)
  - Very sensitive passive receiver
  - Detects naturally emitted radiation from cosmic sources
- Recently FCC unveiled 4.9 GHz band (4940 – 4990 MHz) for public safety users
  - Enable sharing with commercial 5G users
  - Band Manager
    - Ensures coordinated spectrum use between public safety and 5G users
    - Protects adjacent-band RA from interference
- **Problem**: 5G users in the public safety band produce **out-of-band (OOB) interference** to RA
- **Objective:**
  - Maximize the total 5G network coverage area in the 4.9 GHz band
  - Ensure its OOB interference to the RA remains below the regulatory threshold

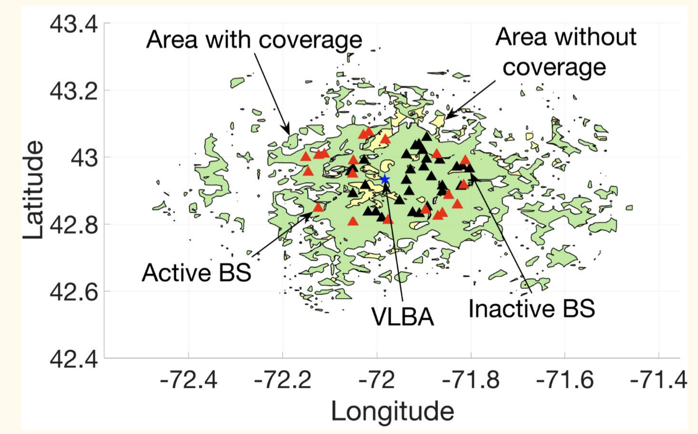


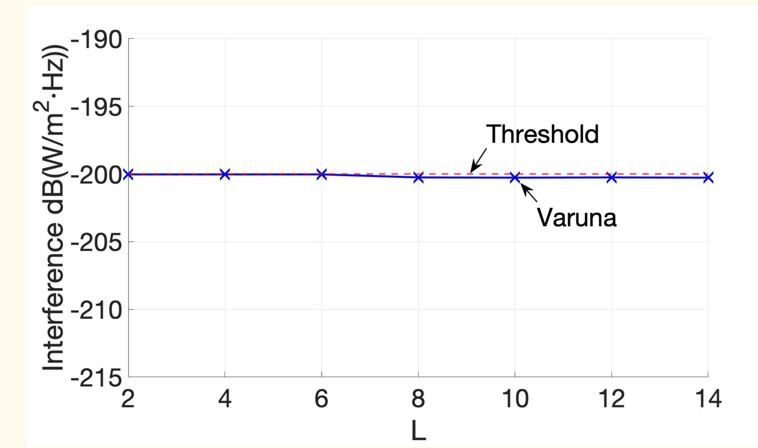
Approach

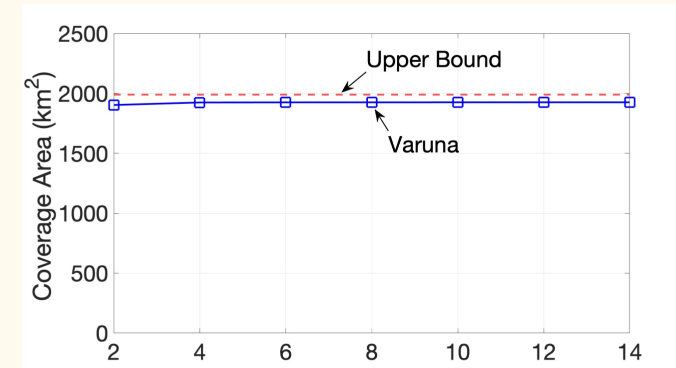
- Employ ITM to capture realistic signal propagation over irregular real-world topography
- Quantize base station's (BS) transmit power into L levels within $[P_{min}, P_{max}]$ for controlled flexibility
- Iteratively select the BS with the lowest **coverage-loss to interference-reduction ratio** for power adjustment
- Achieve RA compliance with **near-optimal coverage** and low computational overhead

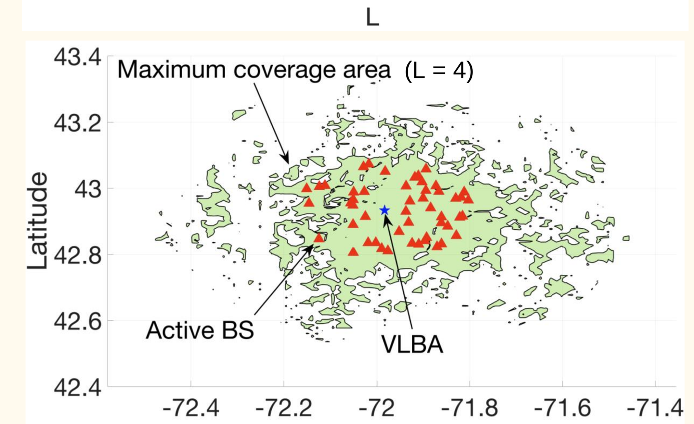
Case Study:

- 50 base stations in Hillsborough County, NH. $[P_{min}, P_{max}] = [15,62]$ dBm/MHz









Transmit power at each BS when L = 4.

BS No.	Latitude, Longitude	Final p_b (dBm/MHz)	BS No.	Latitude, Longitude	Final p_b (dBm/MHz)
1	{43.0580, -71.8938}	0	26	{42.9613, -71.9288}	0
2	{42.9980, -72.1514}	62	27	{42.9727, -71.8182}	0
3	{42.9487, -72.0516}	46.33	28	{42.8337, -71.9241}	0
4	{42.8107, -71.9763}	62	29	{42.8319, -71.8607}	62
5	{42.8307, -71.9098}	0	30	{43.0067, -71.9370}	0
6	{42.9879, -72.0499}	62	31	{42.9407, -71.8841}	0
7	{43.0081, -72.1115}	62	32	{42.9146, -72.0248}	0
8	{42.9880, -71.8119}	62	33	{43.0508, -71.9823}	30.67
9	{42.9557, -72.0565}	0	34	{42.8955, -71.8612}	0
10	{42.9132, -71.8608}	0	35	{42.8852, -71.8474}	62
11	{42.9300, -71.9374}	0	36	{42.9933, -71.8945}	0
12	{42.9692, -71.8301}	0	37	{42.8230, -71.8702}	62
13	{42.8467, -72.1247}	62	38	{42.8899, -72.0512}	0
14	{42.9542, -72.1459}	62	39	{43.0648, -72.0285}	62
15	{42.8352, -72.0022}	0	40	{42.8689, -71.9521}	0
16	{42.8569, -71.8288}	62	41	{42.9653, -72.0510}	0
17	{42.8410, -71.8962}	46.33	42	{42.9906, -71.8662}	0
18	{42.9698, -71.9003}	0	43	{43.0049, -72.1239}	62
19	{42.8057, -72.0510}	62	44	{42.8176, -71.9895}	0
20	{42.9636, -71.8028}	0	45	{42.8353, -72.0187}	0
21	{43.0376, -71.9106}	0	46	{42.9153, -71.8155}	46.33
22	{43.0072, -71.8726}	62	47	{43.0334, -71.9181}	0
23	{42.8968, -71.9316}	0	48	{42.9899, -72.0270}	0
24	{43.0730, -72.0172}	62	49	{42.8505, -71.8927}	0
25	{42.9122, -71.8211}	0	50	{43.0194, -71.9028}	0

Intellectual Merit

- Developed a novel algorithm based on penalty metric to **maximize the Next-G BS coverage**
- Determined interference protection requirement and an OOB interference model, formulating corresponding constraint for the 4.9 GHz band
- Exploited power control (including turn off completely) at 5G BS to meet the **interference protection** constraint

Broad Impacts

- Three GRAs involved in this project receive advanced training and gain valuable skills in wireless communications, security, optimization, machine learning, and spectrum policy
- Developing teaching materials for ECE courses at Virginia Tech based on the research findings

On-going Tasks/Future Directions

- Enhance system architecture for improved satellite-terrestrial coexistence across diverse scenarios
- Develop advanced interference mitigation techniques for broader satellite system protection
- Design more spectrum coexistence schemes for other satellite-terrestrial coexistence scenarios