Collaborative Research: SWIFT: Context-Aware Spectrum Coexistence dEsign aNd implementation in satellite bands (ASCENT)

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Background and Motivation

- Satellite bands potential candidate for spectrum sharing
- Simple spectrum sharing techniques (CBRS band) not appropriate as satellite bands have **complex spectrum operations** due to passive incumbents, fades due rainfall, inability to move incumbents, high sensitivity of the incumbent's applications etc.
- SAS-like spectrum sharing solutions are **overly simplistic** and not appropriate **built for the worst-case**
 - Consideration of limited set of user priorities Federal first, PAL second, and Unlicensed third
 - Lack of awareness of contexts, i.e., weather, operation setting etc.
 - Absence of intelligent spectrum sharing solution for interference mitigation, management, and resiliency

Why 12GHz?

- Better coverage: favorable propagation characteristic than mmWave band.
- Higher capacity: five 100MHz downlink & uplink channels.
- 500 MHz contiguous bandwidth
- Co-primary Incumbents No sensitive federal incumbents in the band
 - Direct Broadcast Satellite Service (DBS) (Co-primary)
 - Non-Geostationary Orbit Fixed Satellite Service (NGSO-FSS) (Co-primary)

Satellite downlink Interference SG downlink SG System SG System

Context-aware Spectrum Sharing Framework

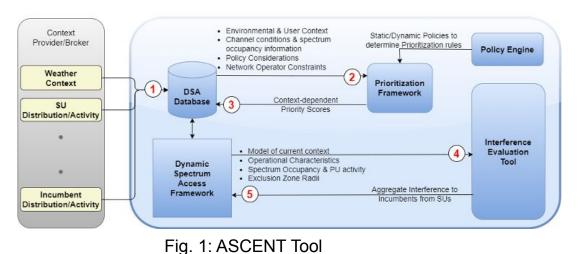
- This project proposes to create a holistic, multi-disciplinary, context-aware spectrum sharing approach to address the **coexistence of broadband wireless systems** in satellite bands..
- **Contexts:** Operation setting (normal, emergency, other non- emergency special events), User diversity, Weather, Incumbents' information, Radio links' information, Band characteristics etc.
- Utilize **12 GHz (12.2 12.7 GHz) as a case study** for the design and implementation of our proposed context-aware spectrum sharing approach.
- Develop the **ASCENT Tool & DigiCaM Framework** (Digital Twin (DT)-assisted context-aware macro base station control) which combines a simulation environment with a decentralized DSA framework, enabling comprehensive simulations to support **spectrum sharing research**, **advanced algorithms**, and **policy development**.

Research Publications and Demonstrations

- 1. T.R. Niloy, S. Kuma., A. Hore, Z. Hassan, C. Dietrich, E. Burger, J. Reed, V. Shah, "ASCENT: A Context-Aware Spectrum Coexistence Design and Implementation Toolset for Policymakers in Satellite Bands," IEEE Intl. Symposium on Dynamic Spectrum Access Networks (DySPAN). Washington, DC. May, 2024. (**Publication**)
- 2. T.R.Niloy, Z. Hassan, R. Smith, V. R. Anapana, and V. K. Shah, Context-Aware Spectrum Coexistence of Terrestrial Beyond 5G Networks in Satellite Bands, in IEEE DySPAN, 2024. (**Publication**)
- 3. T.R. Niloy, Z. Hassan, N. Stephenson, V. Shah, "Interference analysis of coexisting 5G networks and NGSO FSS receivers in the 12 GHz band," in IEEE Wireless Communication Letters, vol. 12, no. 9, pp 1528-1532, Sept. 2023, DOI 10.1109/LWC.2023.3281769. (Publication)
- 4. Z. Hassan, E. Heeren-Moon, J. Sabzehali, V. Shah, C. Dietrich, J. Reed, E. Burger, "Spectrum sharing of the 12 GHz band with two-way terrestrial 5G mobile services: Motivations, challenges, and research roadmap," in IEEE Communications Magazine, vol. 61, no. 7, pp 53-59, July 2023, DOI: 10.1109/MCOM.007.2200699. (Publication)
- 5. E. Heeren-Moon and E.W. Burger, A Survey of Policy Issues in Spectrum Sharing on the 12GHz Band, in IEEE DySPAN, 2024. (Publication)
- 6. J. Tolley and C. B. Dietrich, "Algorithms to Identify Copied and Manipulated Spectrum Occupancy Data in Cognitive Radio Networks," in IEEE Open Journal of the Communications Society, vol. 6, pp. 5135-5154, 2025, doi: 10.1109/OJCOMS.2025.3576749. (Publication)
- 7. Vijay K. Shah, "Collaborative Research: SWIFT: Context-Aware Spectrum Coexistence Design and Implementation in Satellite Bands (ASCENT)," Demonstration, Spectrum Week, Alexandria, VA, April 24, 2023. (Demo)
- 8. NSF HCRO-NRDZ Spectrum Sharing Demonstration", NSF NRDZCOM2, April,2023. (Demo)
- 9. Kumar, Saurav. "A Context-Aware Dynamic Spectrum Access System for Spectrum Research and Development." Virginia Tech, 2024. (M.S. Thesis)
- 10. J.H. Reed distinguished lecture to the IEEE Futures Forum, Dec. 2023 on "Insight into 6G Based on Today's Research". (Invited Talk)
- 11. SWIFT ASCENT Comments on Report & Order FCC 23-36. Federal Communications Commission Proceedings WTB 20-443. Dec. 2023. Retrieved from: https://www.fcc.gov/ecfs/document/1211638903438/1. (Report)

Key Issues Addressed

- How can passive FSS-ES be protected from harmful interference given their inability to sense or report interference?
- How can DSS evolve beyond static, exclusion zone based approaches to more sophisticated approaches while accounting for terrain, weather, and other contexts?
- How to design intelligent, adaptive algorithms that enables harmonious coexistence while addressing dynamic traffic & interference conditions (and overall network performance optimization)?



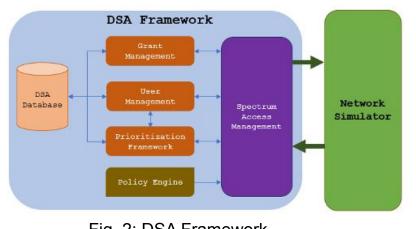


Fig. 2: DSA Framework

Key Results

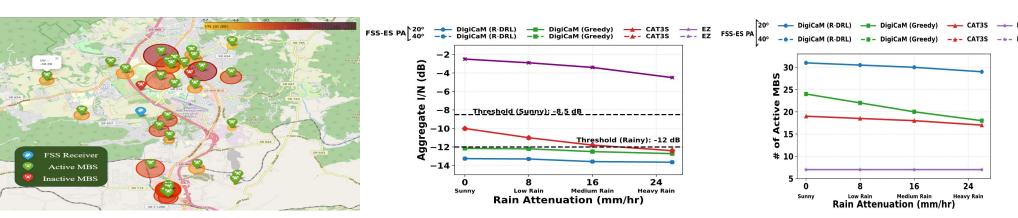
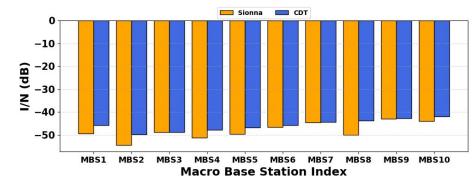


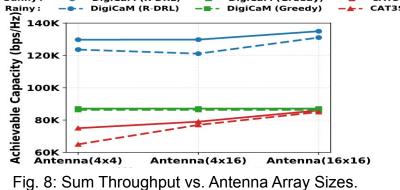
Fig. 4: ASCENT GUI (Deployment Scenario)

Fig. 6: Aggregate I/N ratio vs. Rain Attenuation

Fig.7: # Active MBS(s) vs. Rain Attenuation







rig. o. Suiti Tilloughput vs. Antenna Array Sizes.

- ASCENT tool is much faster than Sionna, execution time of interference analysis and experimental setup is few milliseconds.
- Proposed spectrum sharing framework (DigiCaM) enables safe and efficient spectrum sharing with passive FSS-ES, improving spectral efficiency by 81% and supporting 65% more BSs than heuristic and traditional exclusion zone based approaches for considered real-world case study of Blacksburg, VA.

Broader Impact

Trained 3 PhD students, 4 MS students, and several undergraduate students. Contributed to policy and regulatory engagement through 1 FCC report filing. Two live demonstrations and several invited talks and presentations.

What's Next:

- Enhance/extend the ASCENT tool with other identified contexts (besides weather, user traffic), and satellite orbital/frequency information and evaluate various "what-if" spectrum sharing scenarios.
- Demonstrate over-the-air (OTA) field validation of full ASCENT system using real-world FR3 wireless testbed.