Broadband Opportunities in C-Band

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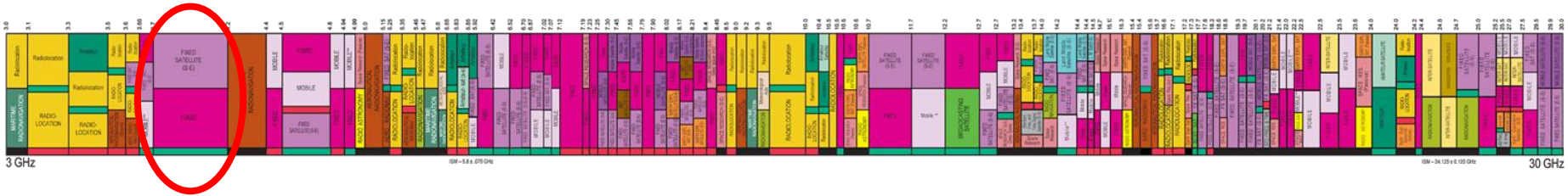
C-Band Opportunities

- 500 MHz of wireless spectrum in the frequency band 3700-4200 MHz
  - 10x more spectrum than currently available for commercial licensed point-to-multipoint (P2MP) broadband services below 6 GHz
  - More spectrum than cellular, PCS, AWS-1/2/3, 600 MHz, and 700 MHz mobile broadband bands combined
- Gross throughput capacity approaching 2 gigabits per second
  - Rivals consumer fiber optic broadband capacity, but without the digging

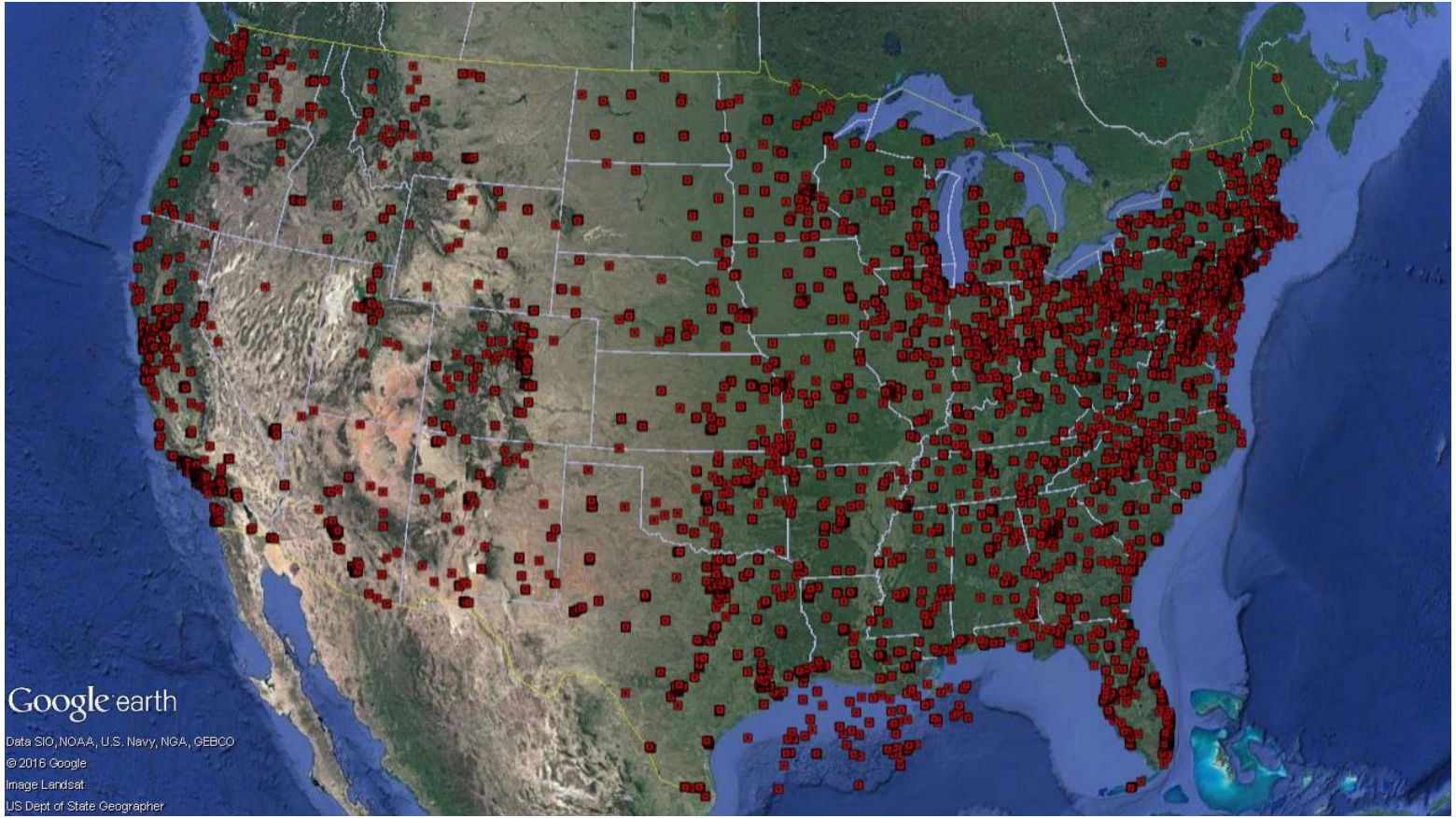


Spectrum is generally carved up into little chunks for different services.
C-Band is one of the bigger chunks.

Today's C-Band Landscape

- Used mainly by commercial satellite dishes receiving geostationary satellite transmissions ("fixed-satellite service" or FSS). Also allocated for long-haul point-to-point microwave systems, but little use due to FSS.
  - C-Band is the lowest frequency band used by FSS and is less affected by weather than other FSS bands
  - Satellite dishes are referred to as earth stations
- C-Band FSS supports distribution of a wide range of content
  - Cable TV program distribution
  - Audio and video broadcasting content distribution
  - Live events
  - News
  - International programming
- In the U.S., C-Band is not used for direct-to-consumer ("backyard dishes")

Locations of C-Band Dishes Registered with FCC

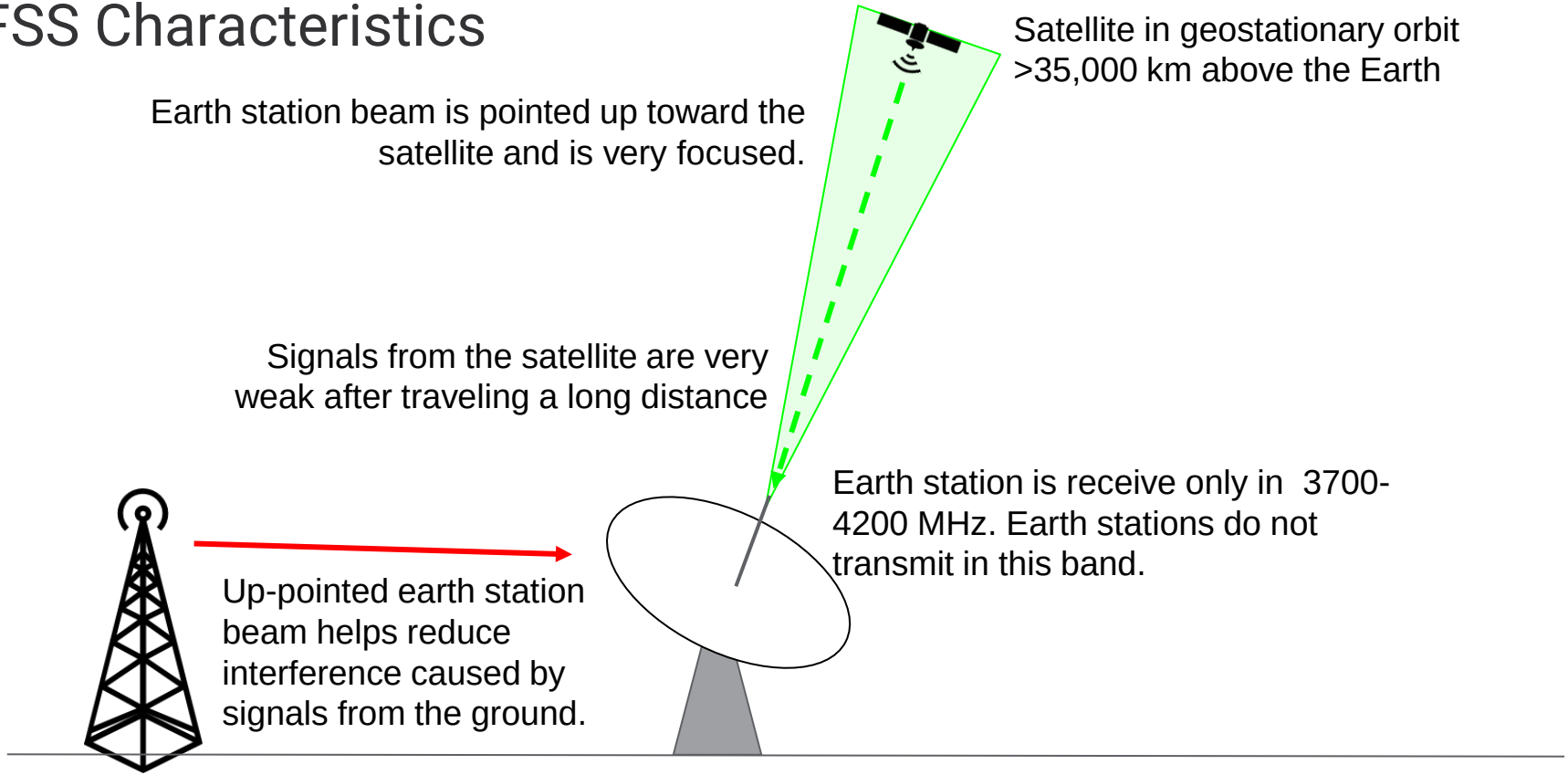


FSS Characteristics

Satellite in geostationary orbit >35,000 km above the Earth

Earth station beam is pointed up toward the satellite and is very focused.

Signals from the satellite are very weak after traveling a long distance



Earth station is receive only in 3700-4200 MHz. Earth stations do not transmit in this band.

Up-pointed earth station beam helps reduce interference caused by signals from the ground.

Location of earth station is well known and doesn't change

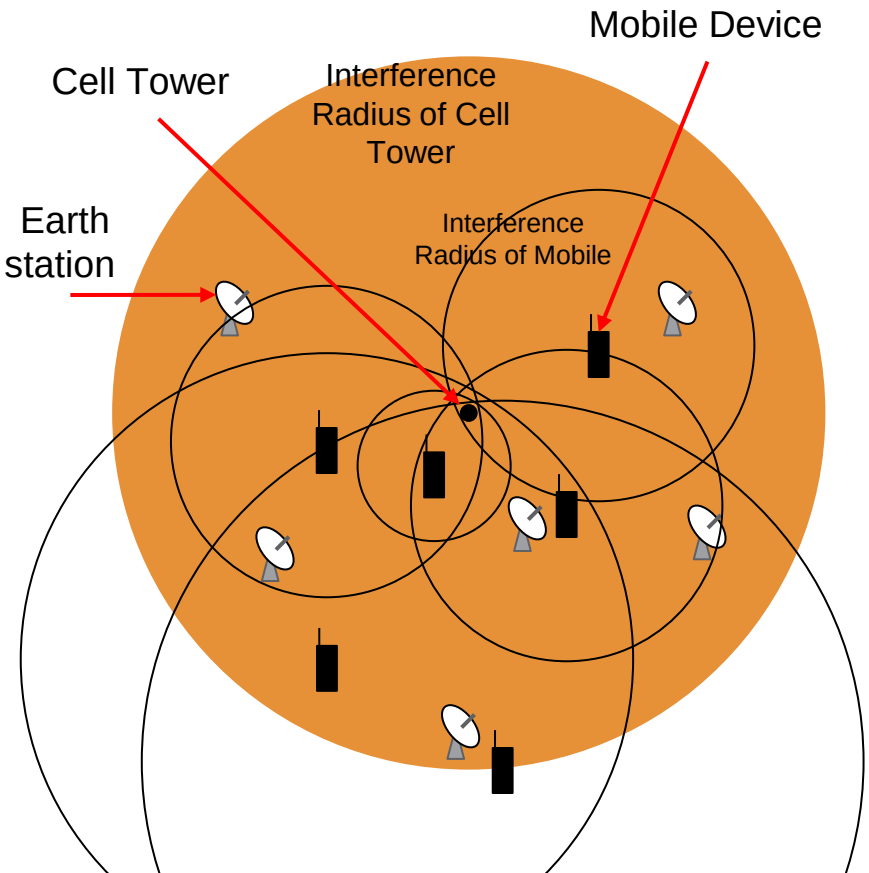
Why the Recent Interest in C-Band?

- Continued rising demand for wireless broadband
  - Both fixed and mobile wireless broadband continue their double-digit annual growth
  - Greater demands due to deployment of small cells, 5G, IOT, bridging the digital divide
- Desirable mid-band spectrum characteristics balance coverage and capacity
- Adjacent to new Citizens Broadband Radio Service (CBRS) band, and to a band transitioning to CBRS that is now used for P2MP broadband service, particularly in rural areas
- Partially overlaps international standard mobile broadband spectrum
- Advent of automated spectrum sharing systems that can mitigate interference between services
- Recent broadband industry proposals for more intensive use
- FCC inquiry and upcoming NPRM

Can Satellite and Broadband Share the C-Band?

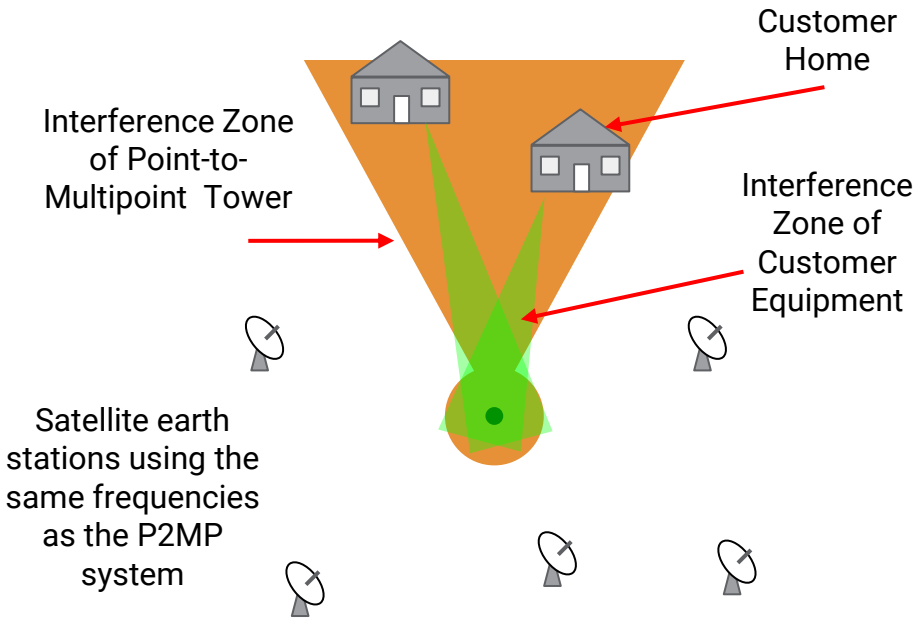
- Fixed use case: P2MP (e.g., providing broadband services to rural homes from a central tower)
  - Plausible to share with FSS due to ability to plan a broadband network around FSS's known characteristics
  - Can beam fixed service only where needed to avoid interference in other directions
  - No disruption caused to FSS operation
  - Can be deployed almost immediately -- equipment and technology ready to go
- Mobile use case: Ubiquitous broadband coverage to mobile devices from traditional cell towers or small cells
  - Very difficult to impossible to share the same frequencies because of interference to FSS due to mobile cell site characteristics and unconstrained mobile device locations
    - Base stations usually beam signals across wide areas, if not in all directions
    - Mobile devices can wander in close proximity to FSS dishes
  - Moving FSS operations from all or a portion of C-Band is an almost certain prerequisite to allow mobile use in the band

Mobile Scenario



- Base station radiates in all directions for ubiquitous coverage
- Satellite earth stations are in the main beam of the base station
- Mobile stations can be located anywhere, including close to FSS
- Like base station, mobile stations radiate in all directions
- Mobile transmit power increases as distance from base station increases
- FSS dishes end up within interference zone of both base station and some mobiles

P2MP Scenario



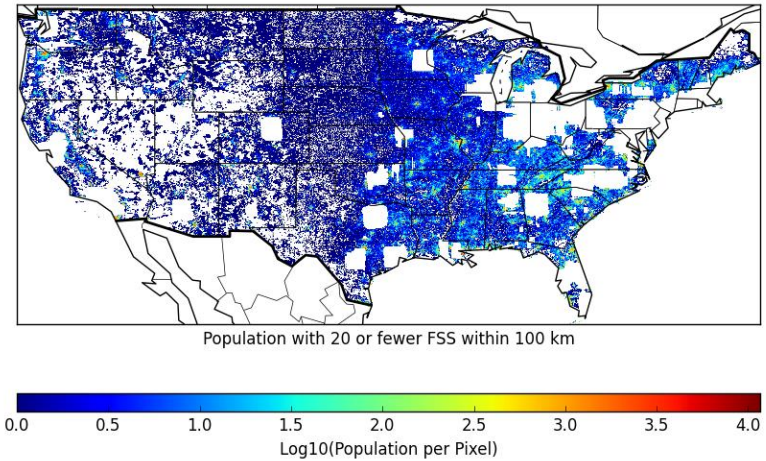
Example of geographic sharing that allows co-channel sharing of satellite spectrum with P2MP broadband

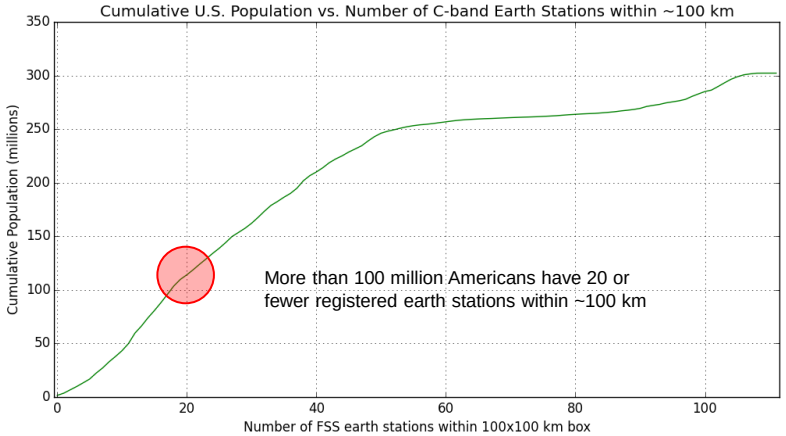
- Base station uses directional antenna; radiates main beam in direction of customers
- In all other directions, only the sidelobes of the base station antenna are at issue
- Customer sites are fixed and well known
- Customer sites use directional antennas back to base station
- All parameters with respect to potential FSS interference are known at design time, well before deployment

See additional details in Google's technical presentation on sharing C-Band with P2MP, in GN 17-183, March 29, 2018

Coordinating Shared Use of C-Band for P2MP Broadband

Successful coordination between existing FSS use of the C-Band and a new P2MP broadband underlay will depend on the number of FSS earth stations in a desired area and the distance to the closest dish





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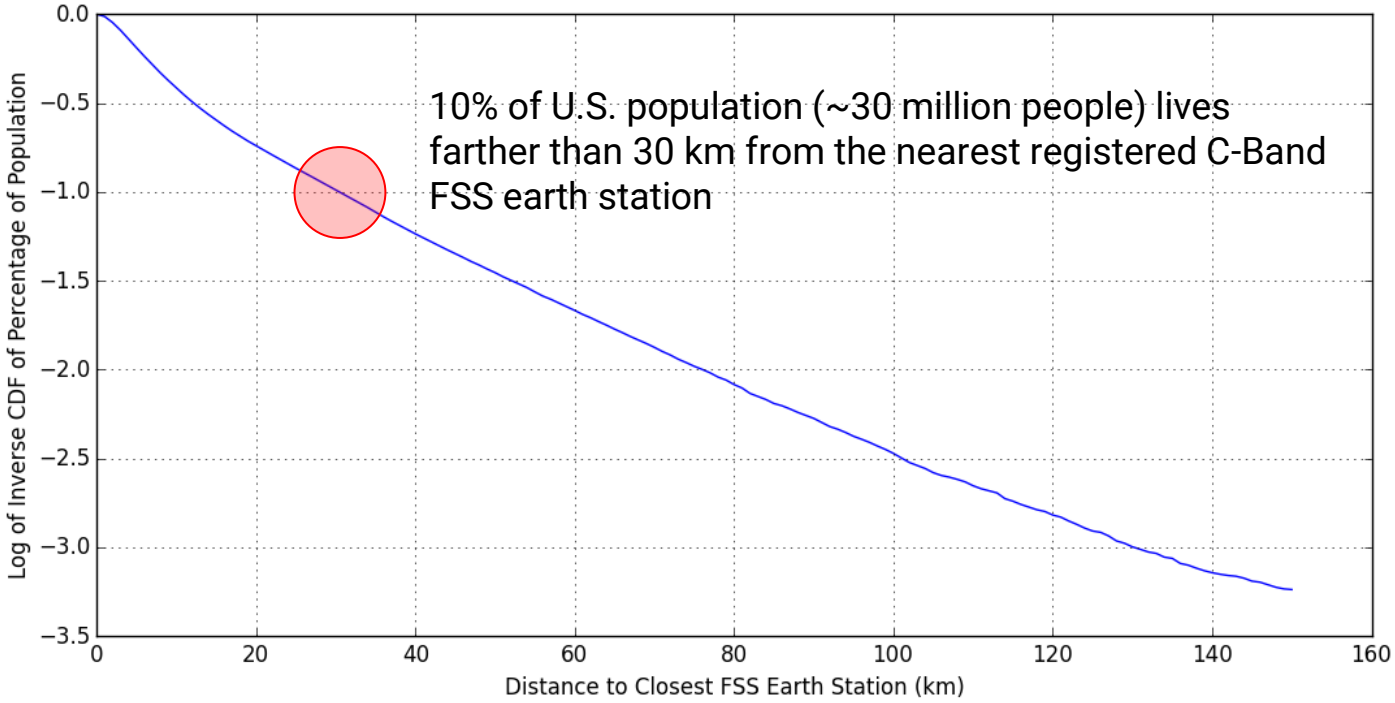

Shared Use of C-Band

- Shared use of C-Band for P2MP could bring multi-hundred-megabit-class broadband service to potentially ~100 million Americans, many in rural areas
- Shared used for P2MP would have no impact on use of the band for satellite services, and can be deployed almost immediately
- Mobile broadband use of a portion of C-Band would require relocating some satellite services to other frequencies
- Use of part of C-Band for mobile broadband would still allow for P2MP underlay in the remainder

A Potential Win-Win-Win Scenario

- Modify FCC rules slightly to allow P2MP underlay services
  - Across 3700-4200 MHz outside of dense urban areas; and 3800-4200 MHz in areas in which mobile broadband uses 3700-3800 MHz
  - Light-touch automated admission control could be used for the coordination process based on mutually-agreed coordination criteria
- Reconfigure FSS use of C-Band to allow use of 3700-3800 MHz for 5G mobile broadband and other applications in dense urban areas
  - Corresponds to portion of C-Band that overlaps international standard LTE band 43
- Allow continued use of C-Band for FSS and protect satellite services from harmful interference
- Necessary first steps
  - Improve satellite earth station registration data in FCC database
  - Limit registration to actual frequencies and directions that the earth station dish is using