5G Transformation with Open Source

Citizens Broadband Radio Service as "Open" Spectrum

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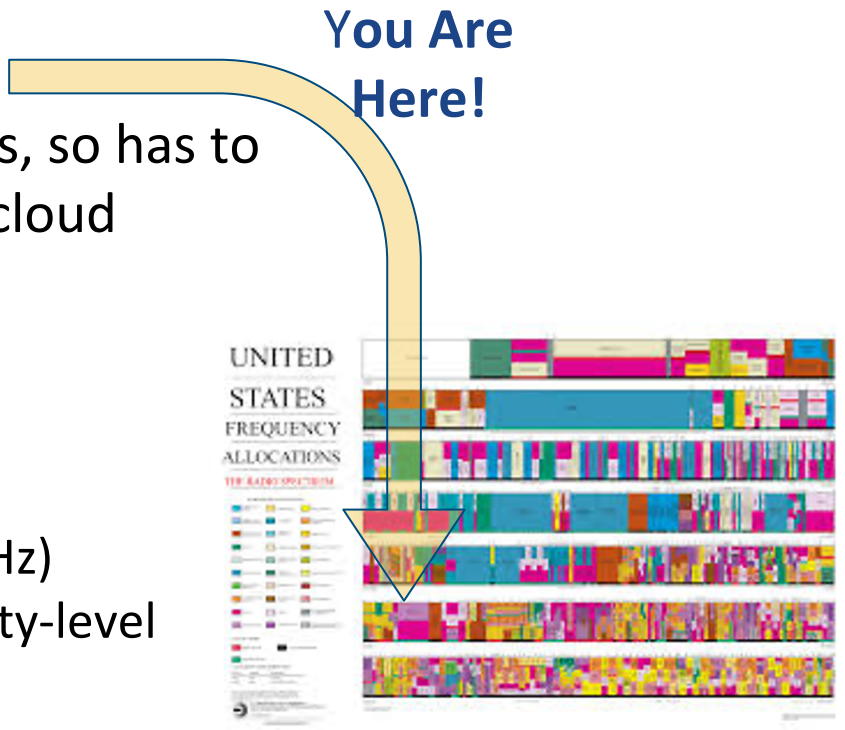
Full Disclosure

I am not a dispassionate analyst of CBRS!

- While at USC, functioned as unofficial “Chief Scientist” for the original Presidential study that led to CBRS
- Public advocate for the study at industry events, Congressional hearing, …
- Later joined Google to make CBRS happen
- Created and chair the Wireless Innovation Forum Spectrum Sharing Committee; developing the spectrum sharing standards for CBRS
- Founder and Chair the Board of CBRS Alliance; developing industry standards and advocacy for use of LTE/5G in CBRS band

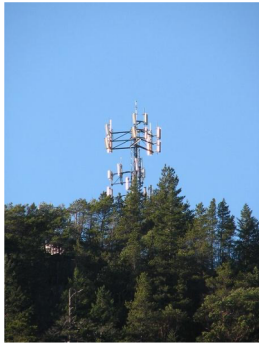
What is CBRS?

- New Band Allocated in US by the FCC
  - 3.55-3.7 GHz (Midband)
- Shared With DoD ship and other radars, so has to have spectrum sharing managed by a cloud service
- No exclusivity for any user
- Band offers two levels of protection:
  - No Protection (80 MHz)
  - Purchase "*Right of Protection*" (70 MHz)
  - Protection licenses auctioned at county-level
- Unused protected spectrum available to any user



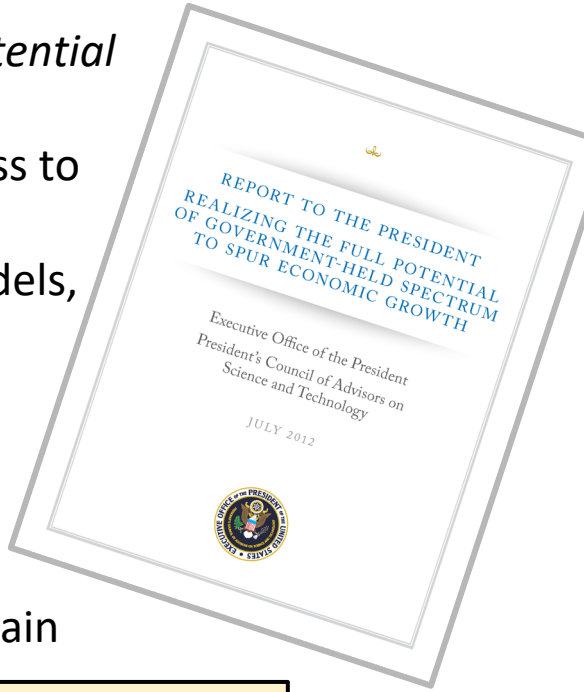
What Makes CBRS Unique and Open?

- CBRS is an international cellular band
  - Straddles 3GPP Band 42 and 43
  - Industrial base ready to support 4G and 5G in CBRS
  - Products existed, and many now CBRS
- US mobile operators have embraced it
  - All operators have access to the entire band
- Most 2020 mid and premium handsets are supporting CBRS (3GPP Band B48 (4G) and soon N48 (5G))



CBRS and the PCAST Policy Objectives

- CBRS was based on 2012 PCAST Report: *Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth*
- Principle was that innovation required flexible, scalable access to spectrum, which spectrum auctions did not provide
  - Evolve not just new technologies, but new business models, services, etc that were not ready to invest billions
- Proposed that a single band should offer:
  - Assured access to some spectrum
  - Multiple levels of protection
  - Growth paths for innovative ideas to scale
  - Less fragmented spectrum leading to a robust supply chain



Not all these Ideas made it into the Regulations, but the Building Blocks for New Ecosystems are there!

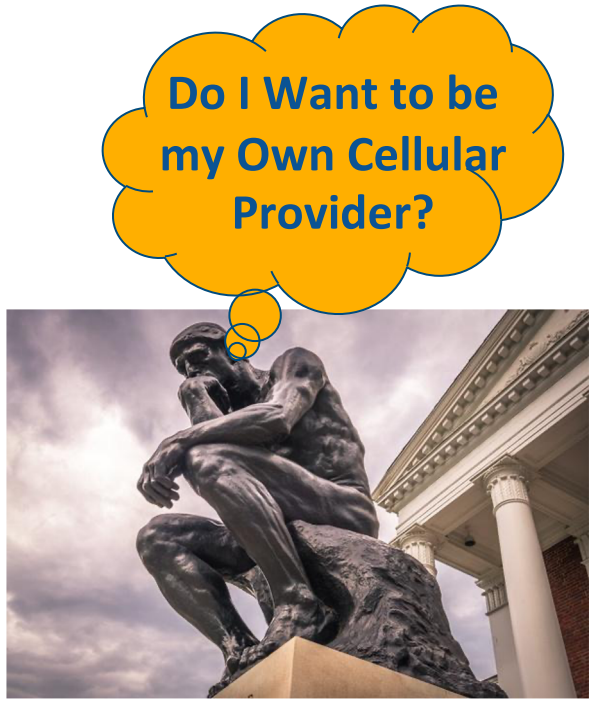
Although All of the PCAST Vision is Not Captured - - CBRS Presents Unique Opportunity

- Spectrum Access
  - County-sized spectrum licenses makes it possible for massive increase in participation in spectrum auctions (22,000+ licenses, 271 bidders, $4.5B+ Bid as of 25 Aug)
  - Robust secondary market makes possible scalable, highly local, short term, on-demand, … protected spectrum available
- 5G technology has unique features that can support highly flexible fixed networks with advanced antennas, beamforming, multi-user
- CBRS is in the midst of future midband 5G Allocations
  - US intent is 5G Services from 3.45 to 3.98 GHz. CBRS is ≈27% of this

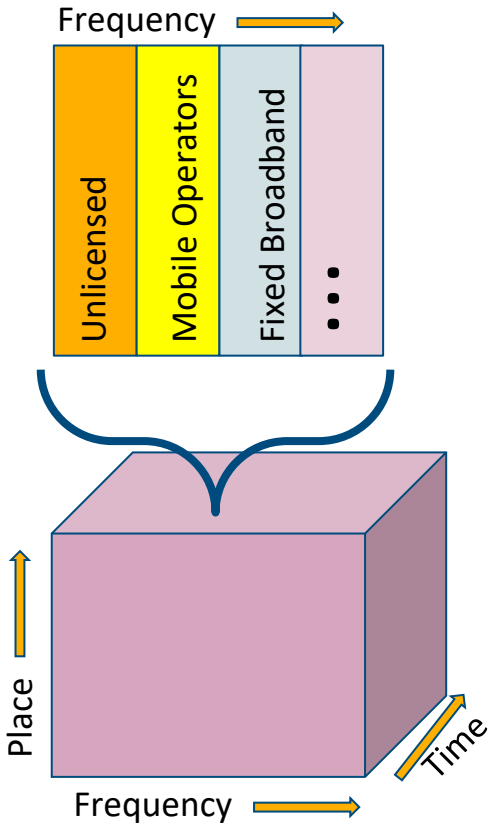
CBRS Opportunity

Unique opportunity for anyone to:

- Leverage the same technology as mobile operators (handover, security, management, …)
  - Seamlessly extend the mobile device experience through private or non-operator networks
  - Repurpose the cellular technology for other missions, such as IoT & IIoT, SCADA, …
- Develop, validate, and deploy new business models and technology scalably



What Makes the CBRS Opportunity Unique



- Not partitioning the spectrum, users and supply chain into little, suboptimal stovepipes
  - Before: Spectrum policy drove towards one set of bands and technologies for operators, one for unlicensed, one for wireless broadband, …
  - Often creating small, sub-optimal markets that lacked viability
- There will be a massive community of devices in people's hands
- In the same band, have the option of operating with, or without protection
  - Localized scope of protected spectrum *should* enable a robust and dynamic secondary market

Some Example Use Cases

- Neutral Host
  - A single network and RAN that serves multiple operators
- MNO or MVNO Offload
  - High Density offload service for one or more MNOs/MVNOs
- Private Networks
  - Create internal networks using 3GPP technology
- Hybrid Networks
  - Integrate public and private services into one seamless net
- Fixed Wireless Broadband

Neutral Host and 3GPP-based Private Networks are New Option!

Neutral Host Use Case

- Neutral Host
  - A single network, RAN and EPC that serves multiple operators
  - Leverages the fact that all operators have use of a single band
  - Presumed that operators not directly managing the RAN, unlike DAS
  - Schedule depends on natural growth in B48/N48 handset penetration
- Would represent adoption of an entirely shared infrastructure
- Many business models proposed
  - “Condominium” build funded and shared by multiple operators
  - Provided as an additional service of a private network
  - Built by premises owner/manager, as in DAS
- Monetization Models
  - As a service to building users (as in DAS)
  - Charged back to operator

Challenge is a Business(s) Model that Work for all Parties

MNO/MVNO Offload Use Case

- Purpose-built network to offload traffic for a specific MNO or MVNO
  - Deeply integrated with the existing network control infrastructure
- May use LTE/5G (Coverage and offload)or LAA (Offload capacity only)
- Positive Support from several MNOs, but details vague in the public statements
- Possible hint as to their real plans and priorities?
  - Carriers generally are familiar with operations in protected spectrum
  - Degree of commitment to PALS acquisition might be instructive
  - Available shortly from auction outcomes

Deployment not time-pressured due to Necessity to wait for Handset Penetration

Private & Hybrid Network Use Cases

- Private Networks
  - Use for dedicated, non-public use
  - Considerable interest for SCADA, LMR-substitute, IIoT, voice, paging, …
  - Advancing because many use cases not dependent on public handset adoption
  - Has security advantages with local breakout, behind-firewall, admission control
  - Potentially new business and technical models since reduced handset dependency for many cases
- Hybrid
  - Single network infrastructure with both a public and private side
  - Inherits other characteristics and blockers from neutral host

Potential Structural Impacts

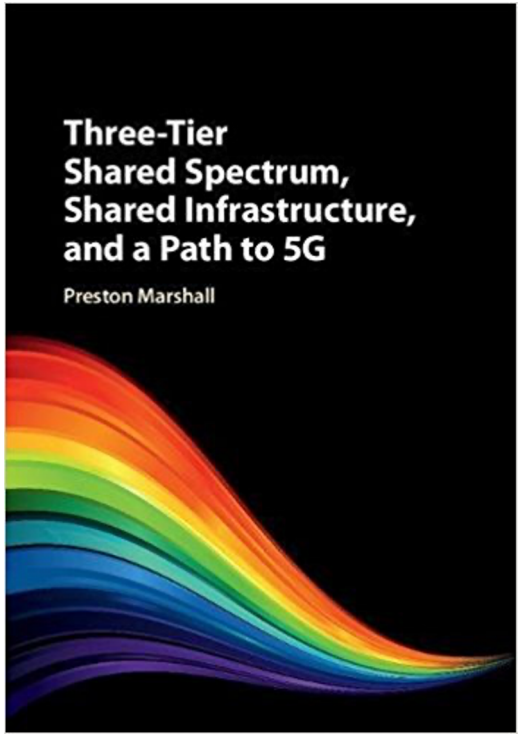
- Its a “Make” or “Buy” decision now
  - Now have ability to buy, or to privately deploy, very equivalent functional LTE/5G capability for dense usage locations
  - Technology no longer dictates strategy
- Neutral Host potentially introduces several new structural entities
  - Wholesale providers that serve multiple carriers
  - Integrators who package bandwidth
  - Could look more like fiber capacity, with its decentralization, and supply through the lowest marginal cost supplier
- Drivers and customers of the 3GPP ecosystem become more diverse and reflective of the general economy
- Reduction of the degree that spectrum IS “THE” barrier to entry in mobile

Where are We at with CBRS?

- We have completed the necessary Government policy development
- The technical work has achieved a baseline capability; operations in the band are fully enabled
  - The fixed broadband use case is deploying rapidly
- Remaining challenges in the “vision” for CBRS are the marketplace validation of the various use cases
  - Auction interest and bidding appear to validate at least some of the use cases

More Material on CBRS and Multi-Tier Spectrum Sharing -- An Unabashed Book Plug

- Detailed development of the PCAST concepts, the FCC implementation, and the WinnForum and CBRS Alliance standards
- Focus on the general problems of implementing multi-tier spectrum policies, not just the US initiatives
- Analysis of world-wide candidate bands for implementation of the three tier regime
- Analysis of the emergence of neutral host networks, and the potential to use this model for low cost, rapid 5G deployment



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Thank You

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