RYSAVY RESEARCH

Spectrum Sharing
Advanced (201)

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1

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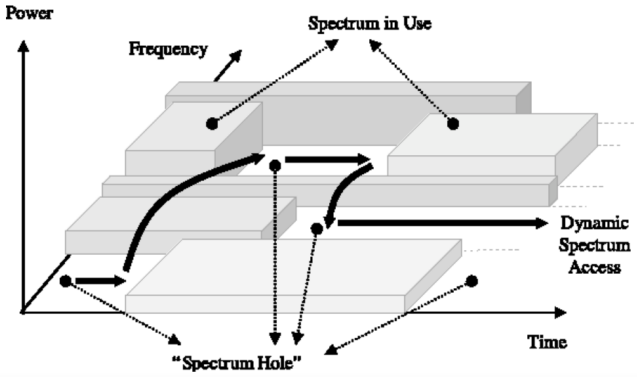
He has been analyzing and writing about spectrum sharing since 2016.

Advanced Spectrum Sharing Developments

- Contents
  - CBRS for future spectrum sharing
  - NTIA Incumbent Informing Capability (IIC)
  - National Science Foundation on DSS/DSA
  - Nation Spectrum Consortium
  - DoD RFI on dynamic spectrum sharing
  - Different scenarios for DOD sharing
  - FirstNet approach and RAN sharing
  - Wholesale model
  - 6G AI solution for spectrum sharing



https://www.semanticscholar.org/paper/NeXt-generation%2Fdynamic-spectrum-access%2Fcognitive-A-Akyildiz-Lee/95ba0f3a9759cce4edfdb125cc173e883411b0a9

2

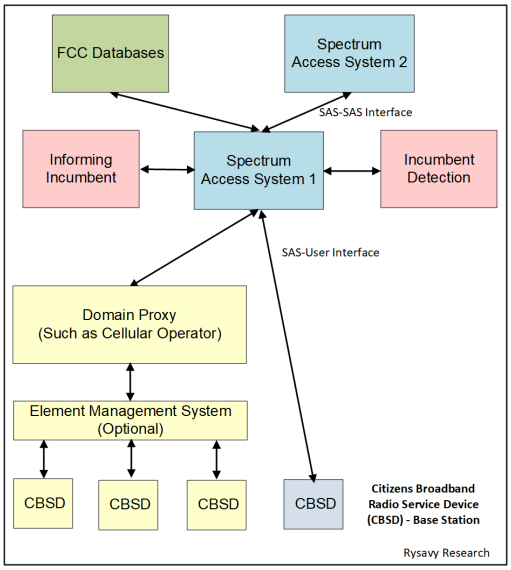
This slide lists the contents of this presentation.

The figure is from an academic paper on dynamic spectrum access, illustrating the concept of how intelligent devices sense the spectrum in use and adjust their operation to transmit in unused spectrum, which the figure calls "spectrum holes."

As good as this approach sounds in theory, real world implementations are difficult. First, the sensing of spectrum by other users may not detect all the users in an environment, referred to as the "hidden terminal" problem. Second, to provide predictable quality of service, an entity needs to know its resources and if it suddenly has to compete with other users, the resources can vary, and hence service quality may be degraded. For example, a network cell that could support 100 telephone calls might only be able to support 50 when another system becomes active.

CBRS for Future Spectrum Sharing

- Citizens Band Radio Service (CBRS) remains most complex spectrum management system in the world
- Environmental Sensing Capability (ESC) for incumbent detection considered problematic (even by CBRS Alliance[1]), but originally mandated
- Future Incumbent Informing Capability (IIC) could "fix" ESC but an entirely new approach that will take years to develop, test, and deploy
- Other possible enhancements, such as more real-time capability, will also take years to develop, test, and deploy
- 5G industry desperately needs cleared spectrum as evidenced by C-band auction and prices compared to CBRS auctions



[1] https://ecfsapi.fcc.gov/file/1120181292963/CBRSA%2019-348%20comments%20final%20112020.pdf

3

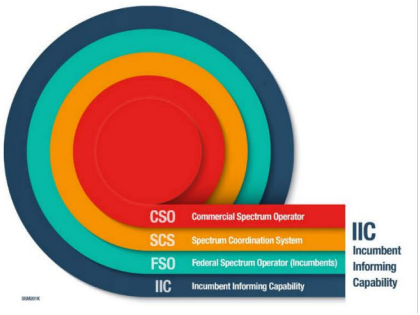
CBRS has three tiers of users: incumbent government systems, licensed users with Priority Access Licenses (PALs), and unlicensed users, referred to as General Authorized Access (GAA). PAL and GAA base stations must coordinate with a Spectrum Access System (SAS) database. CBRS not only coordinates spectrum using the SAS, but it also employs a network of sensors along the coast called the Environmental Sensing Capability (ESC). When the ESC detects Navy radar, it informs the SAS, and for affected areas, the SAS instructs commercial networks to cease operation in specific radio channels. For all these reason, CBRS is the most complex spectrum system in the world.

The NTIA and DOD have proposed an alternate approach called the Incumbent Informing Capability (IIC), but this is an entirely new approach that will take years to develop, test, and deploy.

Some have proposed the CBRS architecture for new spectrum bands, but with enhancements that make it work closer to real-time. Again, such enhancements will take years to develop. Given the importance of U.S. 5G networks being able to compete with those in other countries, making badly-needed new mid-band spectrum contingent on new sharing architectures will delay availability of this crucial spectrum resource. Recent auction results valued spectrum with C-band types of rules as four times as valuable as spectrum with CBRS types of rules. (See https://rysavyresearch.files.wordpress.com/2021/02/2021-02-5g-mid-band-spectrum-deployment.pdf.)

Incumbent Informing Capability (IIC)

- NTIA and DOD proposal
- DOD and other federal spectrum users can submit information about spectrum use
- Planned as replacement and improvement of Environmental Sensing Capability (ESC) in CBRS
- Could also be used for direct incumbent/operator coordination in future bands
- Tentatively scheduled for possible CBRS operation by 2025-2026
- Enhanced IIC tentatively scheduled for new bands 2028 or later
- IIC could evolve in future to an "Everyone Informs" model supporting heterogeneous coexistence



NTIA, "Incumbent Informing Capability (IIC) for Time-Based Spectrum Sharing
https://www.ntia.doc.gov/files/ntia/publications/iic_for_time-based_spectrum_sharing.pdf

The National Telecommunications and Information Administration (NTIA), which manages the Federal government's use of spectrum, and the Department of Defense (DOD), have proposed a new mechanism called the Incumbent Informing Capability (IIC), by which DOD and other federal spectrum users could inform commercial users about their planned use of certain frequencies. For example, if navy radar on a ship were to be operational near a specific city on a specific day, the IIC would inform cellular operators within a Dynamic Protection Area (DPA) to not use affected frequencies for a specific time period.

The IIC could replace the Environmental Sensing Capability (ESC) in CBRS. Industry generally supports the IIC concept, particularly because it could be more effective than the ESC, eliminating some ESC problems, such as radio interference between CBRS deployments and sensors. IIC, however, will take significant time to specify, design, and develop.

IIC works in conjunction with a Spectrum Coordination System (SCS) that in CBRS could be the CBRS Spectrum Access System (SAS). In theory, the IIC could also interface directly with operator networks in an architecture that does not use CBRS.

NTIA envisions IIC as a long-term project with successive iterations, conceivably becoming an "Everyone Informs" system that optimizes efficiency of spectrum use across heterogeneous users.

National Science Foundation on DSS/DSA

- "In the full-blown scenario, CR [cognitive radio] -"smart" radio systems would collectively sense and analyze their local radio environment, negotiate optimal sharing arrangements, and then adapt their radio operating parameters (i.e., frequency, power, modulation, transmission timing, direction of transmission, and other waveform characteristics) to maximize shared use of local spectrum resources… Although significant progress has been made in developing CR, SDR, and other smart radio technologies, **we are still far from being able to actually realize the full-blown scenario described above**." [emphasis added, still true in 2021]

  Source: National Science Foundation, *An Overview of Dynamic Spectrum Sharing: Ongoing Initiatives, Challenges, and a Roadmap for Future Research*, Apr. 2018, https://winser.ece.vt.edu/wp-content/uploads/2018/04/overview_dynamic-spectrum.pdf

- NSF has Spectrum Innovation Initiative

  "The focus of a spectrum research SII-Center must chart out a trajectory to ensure United States leadership in future wireless technologies, systems, and applications in science and engineering through the efficient use and sharing of the radio spectrum."

  - The FCC and NTIA are collaborating with the NSF on this initiative.
  - https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505788
  - https://www.ntia.doc.gov/blog/2021/ntia-fcc-experts-will-support-national-science-foundation-s-spectrum-innovation-initiative

5

The National Science Foundation articulates how a smart radio system that employs dynamic spectrum access would operate. The NSF, however, acknowledges the complexity of the problem, saying we are still far from being able to actually realize the full-blown scenario it describes. The NSF published this report in 2018. In 2021, we are no closer to realizing this vision than we were in 2018.

To encourage research in this area, the NSF has created a Spectrum Innovation Initiative.

The bottom line is that DSA remains a research topic. Specific instances of spectrum sharing exist, but they are for specific scenarios, such as 4G and 5G devices sharing the same radio channel, or 5G devices sharing unlicensed spectrum with Wi-Fi devices.

National Spectrum Consortium

- https://www.nationalspectrumconsortium.org/
- 400 U.S. companies and academic institutions that work with government, including DOD, on spectrum and spectrum-enabled technologies.
- Oct 2021 announcement of Partnering to Advance Trusted and Holistic Spectrum Solutions (PATHSS) Task Group that will investigate spectrum sharing approaches.
- Creates forum for industry and DOD to exchange sensitive and classified information.

https://www.nationalspectrumconsortium.org/wp-content/uploads/2021/10/PATHSS-Announcement-Press-Release_10.26.pdf

6

According to the National Spectrum Consortium, "The National Spectrum Consortium is a research and development organization that incubates new technologies to revolutionize the way in which spectrum is utilized. Their technologists, engineers, scientists, manufacturers, and program managers work with their counterparts in government to solve the toughest problems facing the nation with regard to spectrum and spectrum-enabled technologies, providing the DoD and other customers with spectrum superiority."

DOD RFI on Dynamic Spectrum Sharing

- In 2020, DOD had RFI[1] for dynamic spectrum sharing
  - "What are other innovative ideas as to how 5G can share spectrum with high-powered airborne, ground-based and ship-based radar operations in the 3100-3550MHz spectrum band?"
  - "How can spectrum modernization, including spectrum Information Technology (IT) modernization and automation, help facilitate faster spectrum sharing?"
  - "How could revenue be shared with DoD under a DSS leasing agreement or any type of leasing agreement?"
- Implication: DOD wanted more than CBRS
- No details available about what DOD might be envisioning
- 70 responses to RFI
- Any such sharing will take years to specify, design, test, deploy
- Rysavy: "DoD's Proposed 5G Spectrum Sharing Fraught with Problems," Oct. 2020. https://rysavyresearch.files.wordpress.com/2020/10/2020-10-problems-dod-5g-spectrum-sharing.pdf

[1] https://beta.sam.gov/opp/f88ac11e80bb4e5b8ebb0a30b703eccf/view

7

In 2020, the Department of Defense (DOD) issued a request for information (RFI) on dynamic spectrum sharing, with specific questions about how spectrum sharing might operate in the future between industry and DOD. The frequency range DOD targeted was 3100–3550 MHz, critical mid-band frequencies for expansion of 5G networks.

The RFI caused some confusion because the term DSS already refers to a specific 5G capability by which LTE and 5G devices can share the same radio channel. Instead, DOD was applying the term more generally and along the lines of Dynamic Spectrum Access (DSA).

The RFI implies that DOD is seeking solutions beyond the types of approaches available today, including CBRS. In early 2021, DOD made the RFI responses available, some 70 submissions. None provided a magic bullet for facilitating spectrum sharing between different types of systems, such as 5G and military systems.

In contrast, many of the responses articulated multiple approaches by which DOD could share its frequencies for commercial 5G networks and its own 5G network.

Different Scenarios for DOD Sharing

1. DOD shares spectrum for DOD 5G networks and commercial networks

2. DOD shares spectrum for military systems and commercial networks

- Completely different solutions
- FirstNet approach addresses first scenario
- CBRS or successor approaches address second scenario

The DOD RFI asked two types of questions. One was on how a DOD 5G network could share spectrum with commercial networks. The other was how DOD military systems could share spectrum with commercial networks.

The two scenarios are completely different and result in different solutions. For example, a FirstNet approach would address the first scenario whereas CBRS or a successor approach would address the second.

FirstNet Approach

- Successful sharing for public safety
- AT&T uses public-safety spectrum, 700 MHz Band 14, and its own spectrum
- Offers broadband service for public safety and consumers
- Public safety has higher-priority use

9

Multiple DOD RFI respondents advocated a FirstNet model by which DOD could have a secure 5G network for its own operations, using both commercial and DOD spectrum, while making the DOD spectrum (for instance, 3100–3450 MHz) available for commercial networks.

FirstNet, built by AT&T, is a nationwide, high-speed broadband LTE network for first responders and the extended public safety community.

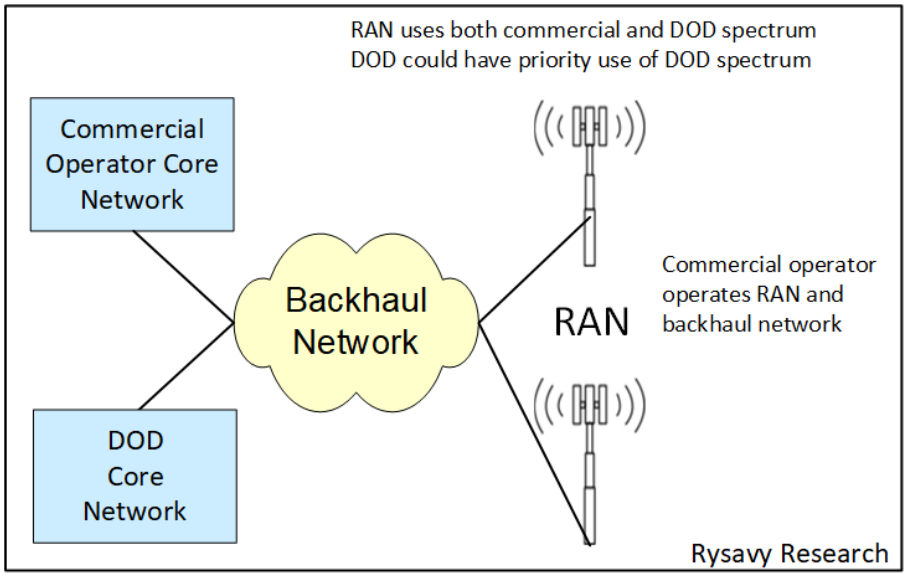
Along with commercial frequencies, FirstNet uses the D-Block in the 700 MHz band, also called Band 14 (758–763 MHz / 788–793 MHz). These low-band frequencies have excellent coverage and building penetration characteristics. Although commercial customers on AT&T can also use the D-Block frequencies, FirstNet users have priority and in emergencies, can completely pre-empt commercial users in the band.

The FirstNet core network is separate from the AT&T core network. The architecture constitutes a RAN sharing approach because the same radio access network supports two different networks.

A FirstNet approach could support DOD spectrum sharing between a DOD 5G network and commercial use of these same frequencies.

See more information about FirstNet at:
https://www.firstnet.com/resources/knowledge-center/what-is-firstnet.html.

Possible Operator/DOD RAN Sharing



10

The figure shows a hypothetical approach for providing DOD a secure 5G network for its own purposes, using a RAN sharing approach similar to FirstNet. A commercial cellular operator would operate a RAN both in DOD locations and in other locations, using both DOD spectrum (for example 3.1–3.45 GHz) and commercial 5G spectrum. In DOD locations, or even all locations, DOD could have priority access to its spectrum. Priority access can mean DOD data packets have higher priority in transmission over commercial data packets, or in emergency situations, commercial usage of DOD spectrum could be completely pre-empted.

The commercial operator would operate the backhaul network, connecting RAN traffic to either the commercial operator core network or the DOD core network. The DOD core network could be managed by DOD and be physically separate, or it could be virtualized within a commercial network. Many technology options are available today to support this type of architecture.

Technologies for DOD 5G Network

- Available Technologies
  - Virtualization
  - Network Slicing
  - Open RAN
  - RAN Sharing
    - Multi-operator Core Network (MOCN)
    - Multi-operator RAN Network (MORAN)
  - Multi-Access Edge Computing (MEC)
  - Micro-segmentation
- Unavailable Technologies
  - Enhanced CBRS operating in "real-time"
  - Next generation incumbent avoidance
  - Cognitive radio
  - True "dynamic spectrum access"

- ➢ Start test-bed experimentation now
- ➢ Don't delay spectrum already in the pipeline

11

In the case of DOD having a secure 5G network for its own purposes, many different technologies exist today to realize this vision, including virtualization, network slicing, Open RAN, RAN sharing, multi-access edge computing, and micro-segmentation. These technologies provide powerful building blocks with which a commercial operator could partner with DOD to provide 5G service, using a combination of commercial and DOD spectrum. For example, with network slicing, an operator could provide a portion of its network capacity customized for DOD with appropriate quality-of-service and security features. For DOD applications, the network slice would function as a private network.

Although technologies exist for DOD to readily obtain a 5G network for its applications, technologies for more sophisticated spectrum sharing between commercial 5G networks and military systems do not exist. These include technologies such as an enhanced version of CBRS operating in "real-time," an incumbent avoidance capability that would replace the CBRS Environmental Sensing Capability, use of cognitive radios, and true dynamic spectrum access.

Wholesale Model

- Contracted entity deploys network using DOD spectrum
- "Leases" capacity to other operators
- Rysavy analysis: 5G technology does not support "wholesale" model
- Carrier aggregation needed for successful 5G
  - Lower bands for control and uplink
  - Mid-band and mmWave for capacity in forward link
  - https://www.ericsson.com/en/ran/carrier-aggregation

12

One idea proposed to DOD is a wholesale network model for 5G using DOD spectrum. With this approach, a commercial contracted entity would build a new 5G network using DOD spectrum and would then lease capacity to other operators. This entity could be an existing wireless operator or new company. As Rysavy analysis shows, however, 5G technology today does not support this model. Based on DOD spectrum, this wholesale network would just employ mid-band frequencies. As effective as mid-band frequencies are for a powerful blend of coverage, capacity, and high throughputs, the frequencies are still challenging with respect to propagation and in-building coverage.

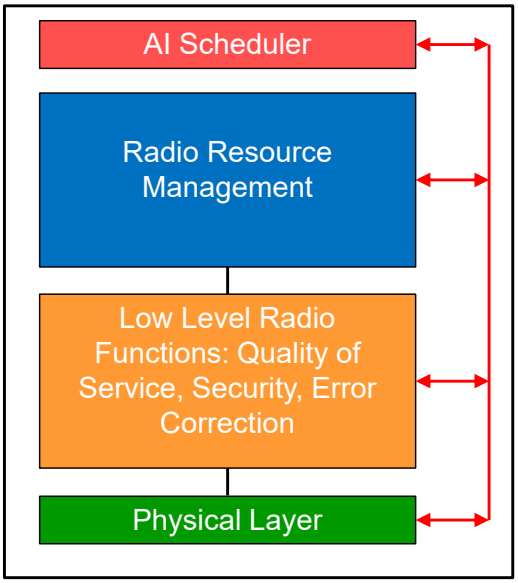
Commercial operators are relying on carrier aggregation to combine mid-band operation with low bands that can carry control signals and uplink connections. Only with such carrier aggregation, will operators be able to deliver a reliable service. Because carrier aggregation combines radio channels at a low level of the protocol stack, it only functions when an operator has direct access to the radio bands, and it would not function if the operator was leasing capacity from a separate network.

The alternative would be for users to roam from a commercial network onto the wholesale network. But unless the wholesale network also had lower bands in its network, the user experience would be degraded once on the wholesale network. In addition, if users on the commercial network were taking advantage of edge-computing services, those would not be readily available on the wholesale network.

Possible 6G AI Solution for Sharing

- AI contemplated by researchers for 6G scheduler
- Scheduler determines who transmits when
- Logical place to place dynamic spectrum sharing capability
- One of many potential sharing approaches for 6G

IEEE, *Artificial-Intelligence-Enabled Air Interface for 6G: Solutions, Challenges, and Standardization Impacts*, Oct 2020. https://ieeexplore.ieee.org/document/9247527



13

AI will be increasingly used in wireless networks, including 5G, for a multitude of purposes, such as for augmented security, best real-time allocation of radio resources, intelligent edge services, and fault mitigation. The Open RAN architecture facilitates AI integration by having well-defined interfaces for management functions.

Future wireless networks, such as 6G, will also implement AI, so that lower-level radio functions, such as packet scheduling, can take into account a vast amount of real-time information about the network and users. The IEEE article hypothesizes how such AI integration could be implemented in 6G. This AI capability in the scheduler would facilitate implementation of dynamic spectrum sharing and begins to realize the vision of true cognitive radios.

The point is that the industry is years away from implementing dynamic spectrum access and now is the time to do the necessary research. Cellular generations operate on a ten-year cycle, with the first third of the time spent on research, the next third on defining requirements, and the final third on developing detailed specifications for actual deployment. We are now in the first third of that ten-year cycle for 6G, a perfect time to perform the research that could result in advanced spectrum sharing defined directly within the standard.

Conclusion on Advanced Spectrum Sharing

- DSA remains a research project.
- No technology exists today for DSS between military and commercial 5G networks
- Multiple good options to provide DOD a secure 5G network using DOD spectrum
- Spectrum sharing will grow but realistic expectations needed
- NTIA/DOD IIC a first step for evolving CBRS and could support other bands in the future
- 6G toward the end of this decade a realistic timeframe for future advanced sharing
- 5G success in near term depends on dedicated spectrum or simple solutions

Appendix

Rysavy Research on Spectrum Sharing

- *5G Mid-Band Spectrum Deployment*
  - https://rysavyresearch.files.wordpress.com/2021/02/2021-02-5g-mid-band-spectrum-deployment.pdf
- *DoD's Proposed 5G Spectrum Sharing Fraught with Problems*
  - https://www.fiercewireless.com/wireless/industry-voices-rysavy-dod-s-proposed-5g-spectrum-sharing-fraught-problems
- *Bad Idea of Nationalized 5G Network Put to Rest*
  - https://www.fiercewireless.com/wireless/industry-voices-rysavy-bad-idea-a-nationalized-5g-network-put-to-rest
- *Scary Experimentation at 3.5 GHz*
  - https://hightechforum.org/scary-experimentation-3-5-ghz/

Abbreviations

- AWS Advanced Wireless Service
- CBRS Citizens Broadband Radio Service
- CBSD Citizens Broadband Radio Service Device
- DPA Dynamic Protection Area
- DSA Dynamic Spectrum Access
- DSS Dynamic Spectrum Sharing
- ESC Environmental Sensing Capability
- GHz Gigahertz
- Hz Hertz
- IIC Incumbent Informing Capability
- LAA Licensed Assisted Access
- LTE Long Term Evolution
- MEC Multi-Access Edge Computing
- MOCN Multi-Operator Core Network
- MORAN Multi-Operator RAN
- NPRM Notice of Proposed Rulemaking
- NR New Radio
- NR-U New Radio Unlicensed
- NTIA National Telecommunications and Information Administration
- RAN Radio Access Network
- RFI Request for Information