Dynamic Spectrum Alliance Limited
3855 SW 153rd Drive
Beaverton, OR 97003
United States
http://www.dynamicspectrumalliance.org

October 28, 2022

The Swedish Post and Telecommunications Board (PTS)
Box 6101
102 32 Stockholm
Sweden

Re: Spectrum Strategy

Dear Sir/Madam,

The Dynamic Spectrum Alliance (DSA)[1] respectfully submits these comments in response to the Swedish Post and Telecommunications Board (PTS) public consultation on its "Spectrum Strategy," which seeks input on its efforts to promote spectrum investment, technology development and innovation, and efficient use of spectrum, while maximizing for Sweden the societal benefits of spectrum over time.

The DSA applauds PTS for reviewing and updating its Spectrum Strategy. We agree with the principles PTS has identified, including the importance of creating conditions for diverse spectrum access and the need for innovative techniques for sharing spectrum to ensure sufficient spectrum is available today and in the future.

In support of these principles, DSA recommends that PTS include in its Spectrum Strategy the use of new spectrum management tools that allow multiple technologies, services, and deployment types to share and maximize efficient use of frequencies. In addition to considering lower power and/or local licensing approaches to enable sharing, we recommend that PTS leverage dynamic shared access systems to maximize operational flexibility for new services and maximize spectrum efficiency. DSA believes that providing additional spectrum access options through use of new spectrum management tools, such as dynamic shared access systems, will help meet future mobile data traffic demands, benefit competition, create conditions for innovation, and spur more rapid deployments of wireless networks and services.

As PTS may be aware, several DSA members currently operate automated dynamic spectrum management systems on a commercial basis in the TV White Space, 3 GHz, and 6 GHz bands. Our members have significant insight into their operational capabilities and benefits as they enable the introduction of new services, including broadband mobile and fixed networks, local and private use cases, and applications. The success of these automated spectrum management systems has been notable - both

[1] The DSA is a global, cross-industry, not for profit organization advocating for laws, regulations, and economic best practices that will lead to more efficient utilization of spectrum, fostering innovation and affordable connectivity for all. Our membership spans multinationals, small-and medium-sized enterprises, as well as academic, research and other organizations from around the world all working to create innovative solutions that will benefit consumers and businesses alike by making spectrum abundant through dynamic spectrum sharing. A full list of DSA members is available on the DSA's website at www.dynamicspectrumalliance.org/members

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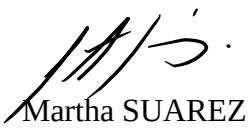
in terms of their ability to increase spectrum efficiency by enabling new services while successfully protecting incumbents as well as their ability to increase spectrum access options for a wide range of innovative, competitive services.

We are available to discuss these comments and provide any additional information as PTS considers options for implementing such systems in Sweden.

Respectfully submitted,



Martha SUAREZ
President
Dynamic Spectrum Alliance

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DSA
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DSA COMMENTS

I. Introduction to the DSA and Automated Spectrum Management Systems

Today we have the technical ability to automate frequency coordination and thereby lower transaction costs, use spectrum more efficiently, speed time-to-market for new services, protect incumbents from interference with greater certainty, and generally expand the supply of wireless connectivity that is fast becoming, like electricity, a critical input for most other industries and economic activity.

To maximize the efficient use of spectrum and provide a variety of access options, the DSA recommends that regulators worldwide implement automated shared access systems as well as innovative licensing frameworks. In the whitepaper entitled "Automated Frequency Coordination - An established tool for modern spectrum management,"[2] The DSA makes the case that the use of databases to coordinate spectrum assignments has evolved significantly since its first introduction, but at its heart, it is nothing new. The basic steps are the same as in a manual coordination process or where a regulator assesses the opportunities for local licensing on a case-by-case basis. However, what is new includes:

(1) Surging consumer demand for wireless connectivity and hence the need to intensively share underutilized frequency bands;
(2) Significant improvements in the computation power to efficiently and rapidly run advanced propagation analysis and coordinate devices and users in near real-time; and
(3) More agile wireless equipment that can interact directly with dynamic frequency coordination databases.

Automated spectrum management systems, such as those developed for the TV White Spaces (TVWS), the 3.5 GHz Citizens Broadband Radio Service (CBRS), and 6 GHz bands are, at their core, very similar. Technical and service rules for operations in each band are converted into algorithms, which are used together with information provided as part of a database query, a list of available channels and the maximum power available on each available channel for that location is provided directly back to a device seeking to access the band.

The DSA anticipates that regulatory authorities worldwide will need to rely increasingly on automated spectrum management systems to handle surging demand for wireless connectivity by sharing underutilized frequency bands. Significant improvements in computation power are enabling more efficient and rapid advanced propagation analysis capability, which in turn enables coordination of devices and users in near real-time. In addition, more agile wireless equipment is

[2] Available at http://dynamicspectrumalliance.org/wp-content/uploads/2019/03/DSA_DB-Report_Final_03122019.pdf

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being developed that can interact directly with dynamic frequency coordination databases, increasing opportunities for even greater efficiency and scale.

The following sections will describe three such automated spectrum management systems that have been developed in the United States and can be adapted to meet the objectives identified by PTS for Sweden's citizens and economy.

A) Automated Spectrum Sharing in the U.S. 3.5 GHz CBRS Band

One example of a successful implementation of an automated shared access system and novel licensing framework is the 3.5 GHz CBRS band in the United States. Authorized by the Federal Communications Commission (FCC) in January 2020, CBRS has been a shining example of the myriad benefits of automated spectrum sharing.

Under the CBRS regulatory framework, the spectrum access system (SAS) coordinates CBRS frequency use (3550-3700 MHz) and manages coexistence among the three tiers of access:

1) Incumbent (e.g., navy radar and commercial fixed satellite services);
2) Priority access licensed (PAL); and
3) General authorized access (GAA).

The environmental sensing capability (ESC) network detects incumbent naval radar use of the band and alerts the SAS to move new terrestrial commercial operations to non-interfering channels. The SAS also interfaces with the FCC's Universal Licensing System (ULS) to obtain information about fixed satellite service (FSS) incumbents and grandfathered fixed wireless systems. Using this information, the SAS is able to calculate aggregate interference from new commercial users to incumbents and enforce protection of these systems. In the nearly three years of commercial operational experience, no incumbents have reported interference from new CBRS users, demonstrating the effectiveness of SAS management of the band.

Commercial users in the CBRS band have multiple options for accessing this 150 MHz of spectrum:

- Acquisition of a PAL in the FCC's 2020 CBRS auction where use-or-share rights for county-based licenses were offered;
- Use of the GAA tier, which does not require an individual license to operate, but does require use of certified equipment and connectivity to a SAS to receive a spectrum grant for operations with a particular transmit power and antenna orientation at a specific location and height; or
- Leased rights from a PAL license holder.

Based on the type of device (fixed or personal/ portable) and its coordinates, information about the transmitter's location and operating parameters and the technical rules adopted to protect incumbents and/or adjacent users from harmful interference, the SAS calculation engine determines the list of available channels at the PAL and/or GAA device location and its maximum permissible radiated power.

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As described above, the SAS not only coordinates protection of incumbent users from new commercial operations, but also manages the assignment of frequencies to PAL and GAA users, protection of PAL operations, and co-existence among GAA users to maximize spectrum efficiency and provide deterministic access for all users. The automated SAS process provides near real-time management of the CBRS band, speeding time-to-market while minimizing uncertainty and administrative burdens.

Through this automation of shared spectrum, a whole host of new services have emerged. In addition to densification of the nationwide public mobile networks, and use of these frequencies by rural wireless Internet service providers (WISPs), a wide variety of private networks are also using the CBRS band. From business to leisure, hundreds of smart office, airport and stadium private networks have been deployed using CBRS as the result of having access to spectrum without the need for an individual license. In fact, today there are over 280,000 CBRS cell sites deployed across the United States with the vast majority using the GAA tier.

Examples of such private wireless network deployments using the CBRS GAA tier include:

Energy management:
https://www.fiercewireless.com/private-wireless/schneider-electric-adds-private-wireless-smart-factories

Retail:
https://www.druidsoftware.com/2019/11/15/cbrs-ongo-at-american-dream-entertainment-retail-complex-nj-usa/

Military logistics:
https://www.fiercewireless.com/private-wireless/federated-demo-dod-highlights-benefits-shared-spectrum

Municipal government:
https://www.fiercewireless.com/private-wireless/motorola-and-harris-county-build-private-lte-network

https://www.fiercewireless.com/private-wireless/cox-launches-cbrs-pilot-city-las-vegas

Transportation:
https://www.fiercewireless.com/wireless/boingo-deploys-trial-cbrs-network-at-dallas-love-field-airport

Education:
https://www.csrwire.com/press_releases/747561-private-wireless-helps-schools-close-digital-divide

https://www.fiercewireless.com/private-wireless/fort-worth-isd-builds-sustainable-cbrs-network

https://www.fiercewireless.com/private-wireless/samsung-amdocs-deploy-private-cbrs-network-howard-university

Entertainment:
https://inbuildingtech.com/venues/connectivity-wireless-jma-stadium-cbrs/

Hospitality:
https://www.thefastmode.com/technology-solutions/24585-airspan-networks-deploys-5g-cbrs-private-network-for-hospitality-industry

Manufacturing warehouse/supply chain:
https://www.fiercewireless.com/private-wireless/calchip-connect-emerges-key-player-private-wireless

https://www.fiercewireless.com/private-wireless/mxd-adds-second-private-wireless-network

Agriculture:
https://www.fiercewireless.com/private-wireless/three-day-deployment-makes-tractors-autonomous

https://enterpriseiotinsights.com/20220607/smart-farm/how-robot-tractors-and-a-private-network-came-together-at-a-smart-vineyard

B. Automated Frequency Coordination of Licence-exempt Use of the 6 GHz Band

Another notable example of automated spectrum sharing is the 6 GHz Band, where the FCC as well as numerous other regulators worldwide are enabling licence-exempt WLAN/RLAN use on a shared basis with incumbent services using the following approach:

1) Allowing 1200 MHz (5925-7125 MHz) of the 6 GHz Band for licence-exempt use; and

2) Authorizing the three categories of licence-exempt devices:

(i) Very Low Power (VLP) devices

(ii) Low Power Indoor (LPI) devices, and

(iii) Standard Power (SP) devices that can operate both outdoors and indoors under the coordination of an automated database management system, known as the Automated Frequency Coordinator (AFC).

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Countries worldwide are actively deploying LPI and VLP devices on a licence-exempt, shared basis in the 6 GHz band, leveraging wider channel availability (up to 160 MHz with Wi-Fi 6) to increase spectrum efficiency while maintaining the ability to share spectrum with incumbents and other licence-exempt deployments. In the future, Wi-Fi 7 will be able to accommodate 320 MHz channels, which will further improve latency, throughput, reliability, and quality of service.

For SP and outdoor operations, AFC systems have been designed to provide channel availability information to licence-exempt devices, while ensuring that incumbent systems, including fixed point-to-point microwave links, are protected from interference. When an authorized and authenticated device queries an AFC for spectrum availability, the AFC assesses which incumbent receivers have the potential to receive excess energy from the licence-exempt device based on its location and potential transmit power. The AFC calculates the maximum transmit power for that device's location on each 6 GHz channel and provides a list of options for the device to select. The device must check in with the AFC daily to determine if any changes to incumbent use of the band have occurred that would alter the channel and transmit power options available to it.

Building on the experience and lessons learned from the use of SAS in the CBRS band, several DSA members have developed AFC systems for the 6 GHz Band and have applied to become AFC system operators in the United States. It is expected that the FCC will certify a number of AFC system operators and permit standard power licence-exempt devices to begin using the 6 GHz band in early 2023. DSA anticipates that many of these same AFC system developers will also seek to operate in countries, such as Canada, Brazil, Korea, and Saudi Arabia, that are in the process of finalizing their regulations for licence-exempt access to the 6 GHz Band, including use of an AFC to manage standard power devices.

C. TV White Spaces

A third example of an automated spectrum management system in operation in the United States is in the broadcast television White Spaces (TVWS) where automated spectrum management systems facilitate licence-exempt access to vacant TV band channels. Rules governing database-coordinated access to TVWS were finalized first in 2010 by the FCC but have been adopted by a growing list of countries since then. TVWS database systems ingest incumbent licensing data, including geolocation and operating parameters, and calculate vacant channel availability, as well as allowed power levels, providing a list of available frequencies and permissible transmit powers to White Space devices. In the United States this incumbent protection data includes "reservations" of scheduled activity provided via an online portal by licensed wireless microphones, which typically operate intermittently (for example, at major public events). In this sense, the TVWS system manages three-tiers of sharing, where licensed Program Making & Special Events (PMSE) users (microphones) have priority access in relation to licence-exempt devices.

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II. Innovative Licensing Frameworks Together with Automated Frequency Management

A. Tiered Licensing

When considering these different licensing approaches to foster the development of new broadband networks and services, DSA encourages regulators to consider a tiered framework that will provide multiple spectrum access options for different types of operators and users. A three-tier or two-tier framework could be adopted depending on the frequency band and its incumbent situation. In bands where incumbents are operating, those operations could continue in the top tier on a protected basis, while new entrants in one or more lower tiers may operate so long as they protect the top tier. A three-tiered approach could be adopted as follows:

> Tier 1 – Incumbent users. Users operating in the band that have the highest priority in accessing spectrum. Their access must be guaranteed at all times during their operation so their radio equipment does not need to be aware of other operations sharing the band.
>
> Tier 2 – Licensed new users. New entrant users that require a degree of certainty in accessing spectrum. In order to ensure that the band can be shared with this tier of new users, it is fundamental that the operation of incumbent services is well understood (for example, they operate only in certain areas) and is predictable (for example, they operate at certain times or there is a way to know when spectrum needs to be vacated). If such information is not accurate enough or it is not available, then access to the band for Tier 2 users might be greatly reduced or not possible at all.
>
> Tier 3 – Opportunistic users. New entrant users that can access spectrum on an licence-exempt or licensed by rule basis. These users may not need access to spectrum over a larger geographic area and/or are operating indoors or on a campus or may be operating in more remote areas where spectrum usage will not be as competitive. In many cases, such networks are deployed in very remote areas where spectrum is largely unused and the risk of interference to higher tier users is negligible. There might be other cases where there is sufficient spectrum available and the envisioned applications allow QoS flexibility, for example because the band would mainly be used to provide additional capacity to networks using other anchor frequencies. In such cases, it is conceivable to have a third tier of users with minimal regulatory barriers and no need for interference protection from other Tier 3 users.

In theory, a tiered spectrum sharing model can be applied to any band. In addition, it is also possible to combine a tiered licensing approach with streamlined secondary market rights. For example, the new license conditions might include the right for the license holder to lease the spectrum to other users – whether on a geographic basis (partitioning) or by sub-dividing the spectrum (disaggregating). Such a secondary market can drive innovation, allow new technology to be deployed by leased spectrum users, and support various sectors, such as enterprise networks and industrial uses.

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B. Use-It-Or-Share-It Policies

In addition to tiered licensing, the DSA also recommends that regulators consider implementing a "use-it-or-share-it" policy for bands that are licensed to mobile network operators. Conceptually, use-it-or-share-it rules authorize opportunistic access to licensed spectrum that is locally unused or underutilized. Until the spectrum is actually put to use in a local area, it should be available for non-interfering use by networks and devices. Licensees lose no rights whatsoever. By way of example, in 2016 the FCC authorized opportunistic access by GAA users to unused PAL spectrum in the 3.5 GHz CBRS band. Opportunistic use of unused PAL spectrum is controlled by the SAS, which requires that GAA users must periodically check with the database to renew permission to continue operating. This is one of the key reasons for the success of CBRS.

A general use-it-or-share-it authorization has a number of affirmative benefits. First, opportunistic access reduces spectrum warehousing in areas where the economics are least attractive for large service providers. It might increase access for operators that are interested in deploying, but who lack needed spectrum access in that local area. Second, opportunistic access further encourages secondary market transactions by facilitating price discovery on both the supply and demand side. For licensees, it will both identify users interested in a potential lease or partition and provide information on the potential value (i.e., how much is my spectrum worth?). For users, opportunistic use is an opportunity to test the local market and to determine the value of a more secure, longer-term lease or partition agreement (i.e., how much am I willing to pay for spectrum?). Third, opportunistic access will lower barriers to entry for innovative new use cases by parties that at least initially either cannot afford or do not believe they need to pay for exclusive use and interference protection. The option to deploy, at least initially, without committing to the cost of a long-term lease or license could be particularly useful for small providers and industries.

C. Automated Shared Spectrum Management

The DSA strongly believes that wireless connectivity plays a growing and critical role in the digital transformation of industry and society and that such connectivity can be delivered by a range of different market players – from traditional mobile network operators using licensed spectrum, to enterprise users deploying license-exempt technologies, to other private wireless network operators relying on secondary market or other shared access opportunities.

A key market and technology trend that is common across these different approaches is the use of automation, cloud-computing, and machine learning to increase spectrum efficiency and access. Applying cloud-computing capabilities to spectrum management enables more predictable quality of service, better congestion avoidance, and improved coordination. Benefits of automated spectrum sharing technology include:

- Increasing spectrum efficiency and density of usage (e.g., permitting re-use of frequencies to support both indoor and wide area operations in same geographic area and/or enabling more closely spaced deployments)
- Enabling regulators to process license applications at a speed and scale not possible with manual processing

- Supporting a seamless transition from automated license applications to 'full' automated dynamic spectrum access (e.g., with an ongoing machine-to-machine update and reporting process)
- Enabling flexibility of spectrum use in keeping with changing demand across different classes of users and business models (e.g., some business models require only periodic, rather than consistent access to spectrum)
- Facilitating diverse private network deployments at scale by enabling license applications to be made by third-party automated cloud-based services on behalf of a licensee (machine-to-machine interfaces)
- Collecting timely, real-world data on noise floor, propagation, spectrum usage, and interference reports
- Interfacing directly with regulators' licensing databases and other services, easing access, management, and support of offline analysis objectives
- Simplifying regulatory evolution and innovation by:
    - Using same interface for updating databases to support introduction of new regulations
    - Upgrading entire ecosystem at once, simplifying the transition to new technologies and regulations
    - Enabling regulatory customization by location / time / frequency.

As PTS states in its Spectrum Strategy, in the future all frequency bands will likely need to become shared bands. In anticipation of this eventuality, the DSA foresees that regulators will need to rely on automated spectrum management systems to handle surging demand for wireless connectivity by sharing underutilized frequency bands. Significant improvements in computation power are enabling more efficient and rapid advanced propagation analysis capability, which in turn enables coordination of devices and users in near real-time. In addition, more agile wireless equipment is being developed that can interact directly with dynamic frequency coordination databases, increasing opportunities for even greater efficiency and scale. The DSA therefore recommends that PTS include in its Spectrum Strategy the use of automated spectrum management systems to assist with its efforts to maximize the utility of all frequency bands.

III. Conclusion

The DSA appreciates the opportunity to provide input on the PTS Spectrum Strategy. We believe that the use of innovative licensing frameworks, spectrum sharing, and automated sharing technology can help PTS to reach its goals of ensuring spectrum is used efficiently and effectively, maximizing gains for users as well as the Swedish economy, and facilitating spectrum access by a variety of entities and use cases.