INCUMBENT INFORMING CAPABILITY (IIC) FOR TIME-BASED SPECTRUM SHARING

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Abstract:

As the President's principal advisor on the regulation of the telecommunications industry, and policies relating to the Nation's economic and technological advancement, the National Telecommunications and Information Administration (NTIA), U.S. Department of Commerce programs and policymaking focus largely on protecting federal spectrum-based capabilities while expanding the availability of spectrum for all users. Managing core federal spectrum programs effectively and efficiently, identifying innovative approaches to increase spectrum access and sharing opportunities, and ensuring that the Internet remains an engine for continued economic growth, which promotes a 21st century Internet economy and expands broadband Internet access in America are a driving force for NTIA policy decisions. A key pillar of this policy is to increase spectrum access for all users through improved cooperation and collaboration between Federal and non-Federal spectrum stakeholders. This paper describes an Incumbent Informing Capability (IIC) for Time-Based Sharing, an innovative way to increase opportunistic spectrum access collaboratively, securely, and dynamically within spectrum allocations principally used by the federal government.

The IIC is a mechanism for more reliably informing “new entrants” in a shared spectrum band when incumbent federal systems are operating in close proximity and thus need to be protected. New entrant access to the spectrum would be controlled through an enhanced, near-real-time Spectrum Coordination System (SCS). The IIC could replace extra layers of sharing techniques such as the environmental sensing capability (ESC), which presently is required by the Federal Communications Commission (FCC) for the Citizen Broadband Radio Service (CBRS) in the 3550-3700 MHz band.

IIC has several potential benefits including support for mid-band spectrum sharing, reduced dependence on environmental sensing, more secure and reliable operations, and improved incumbent control of real-time spectrum usage information. Mid-band spectrum (between 1 GHz and 10 GHz)[1] is valuable for broadband mobile wireless (*e.g.*, 5G) communications because of its favorable propagation characteristics combined with potential for large individual channel bandwidth.

This paper describes the concept for the IIC solution including operational needs and proposed business processes. It outlines how the IIC could be employed to enable spectrum sharing in the CBRS 3550-3650 MHz band with potential for application to other bands in the future. Successful implementation of IIC will require interdisciplinary collaboration across institutions to apply AI/machine learning, secure distributed processing and data storage, and automated aggregate interference analysis. We expect the capability to evolve over time toward a dynamic spectrum sharing paradigm in selected bands where "everyone informs", building on work demonstrated in the DARPA Spectrum Collaboration Challenge (SC2) that can more fully optimize the use of spectrum. The work is relevant to US global leadership in 5G and beyond, inspiring innovation and further research into advanced dynamic spectrum sharing.

[1] Dept. of Commerce and NTIA, *Second Annual Report on the Status of Spectrum Repurposing*, at 1 (Sept. 2020).

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1. Introduction

Given the demand for commercial wireless services and the amount of spectrum used by federal agencies, wireless carriers often inquire about how much spectrum agencies need, locations where the spectrum used, and the times when spectrum might be available for commercial access. But how do you answer those questions reliably and rapidly? The simplest solution may be to have the agencies provide the data themselves, through a real-time, secure, and automated database. That's the core proposal of a new dynamic spectrum-sharing concept that the National Telecommunications and Information Administration (NTIA) is pioneering with the Department of Defense (DOD).

Dubbed Incumbent Informing Capability (IIC), the concept is a time- and location-based sharing approach that would enable DOD and other federal spectrum users to submit information, reliably and securely, about when and where they would be employing certain frequencies. This information then would be fed into a spectrum coordinating system (SCS) to temporarily modify the operations of the other lower priority users sharing the impacted bands.[2] The goal is to enable more efficient, secure, and reliable spectrum sharing between 5G networks and the incumbent federal radars and could be scaled to other spectrum bands.

2. Background

NTIA's Spectrum Management program, managed through its Office of Spectrum Management (OSM), ensures that electromagnetic spectrum is used efficiently and effectively to enable Federal agencies to perform their missions, while supporting the commercial sector's development of next generation wireless services and encouraging American leadership in commerce. OSM carries out the President's authority to assign spectrum resources to radio stations belonging to and operated by the United States.[3] The federal agencies rely on the radio spectrum to execute numerous congressionally mandated missions, ranging from national defense, homeland security, and law enforcement to ensuring aeronautical and marine safety, conducting space travel, scientific research, and accurately predicting the weather. The agencies could not provide these vital

[2] The SAS is currently defined pursuant to Part 96.53 of the FCC Rules and provides information to operators on the permissible channels or frequencies at their location and radiated power levels, among other requirements.

[3] *See* 47 U.S.C. §305(a); 47 C.F.R. §300.1.

government services without radio frequency assignments, which OSM is responsible for managing.

OSM, in coordination with our co-regulator - the FCC, has the additional responsibility to increase spectrum access for licensed and unlicensed commercial use in accordance with the Spectrum Pipeline Act of 2015[4] and the MOBILE NOW Act of 2018[5] while furthering U.S. leadership and economic growth driven by advancements in associated technologies. OSM works closely with the FCC to coordinate spectrum use, identify and reallocate both federal and non-federal spectrum bands to accommodate commercial wireless services, update spectrum-related telecommunications policies, and develop long-range spectrum management plans. To execute these responsibilities, NTIA depends on significant collaboration with pertinent Federal agencies and key private-sector stakeholders.

The concept of sharing spectrum in this fashion is not novel. It is already practiced by the 3 GHz Citizens Broadband Radio Service (CBRS), the TV White Spaces Database, Dynamic Frequency Selection (DFS) in the 5 GHz UNI Bands and the recently authorized Automatic Frequency Control (AFC) in the 6 GHz band. The CBRS and DFS rely on sensing whereas the TV White Spaces and AFC rely upon database access of known incumbent services. Each of these spectrum sharing techniques is adapted to and optimized for a specific band. As long ago as 1998, the NTIA was supportive of sharing, as it stated in a seminal report:

> "A trend toward sharing of federal and nonfederal bands is evident. Parochial interests will be overtaken by technological advances and it will no longer be practical or cost effective to sustain an exclusive allocation, except in situations involving safety and national security. Thus, planning must be open to technological advances and the associated progression leading to increased sharing of frequency bands between two sectors."[6]

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[4] *See* Middle Class Tax Relief and Job Creation Act of 2012, Pub. L. No. 112-96, Title VI, Subtitle G, 126 Stat. 245-55 (Feb. 22, 2012); Spectrum Pipeline Act of 2015, Pub. L. No. 114-74, Title X, 129 Stat. 621-24 (Nov. 2, 2015).

[5] MOBILE NOW Act § 603. It additionally precluded the already identified frequencies of 1695-1710 MHz, 1755-1780 MHz, 2155-2180 MHz, and 3550-3700 MHz from satisfying the 255 megahertz requirement. *Id.*

[6] *See* NTIA SP 91-23, "U.S. Spectrum Management Policy: Agenda for the Future" (Sept. 3, 1998).

With the OSM Vision Statement of "anytime anywhere access to spectrum for all users", the organization fulfills this vision statement with 3 priorities:

- Implement methods and technology to support an enduring process for spectrum access.
- Automate spectrum management processes to increase security, transparency, and access to accurate and authoritative data (i.e., modernization).
- Pursue spectrum management workforce development initiatives (e.g., selection, training, classification, recognition, and retention).

3. Incumbent Informing Capability Concept Overview

This IIC concept further achieves the priority of creating an enduring process for spectrum access. Even though NTIA is required by law to prioritize exclusive use when feasible,[7] sharing may be used instead when relocation of federal systems would take too long or cost too much. In addition, because spectrum is a limited resource and everyone's spectrum access requirements are increasing, relying exclusively on system relocation is not sustainable. Spectrum sharing is a necessary tool to meet repurposing goals and to ensure all users have sufficient spectrum access.

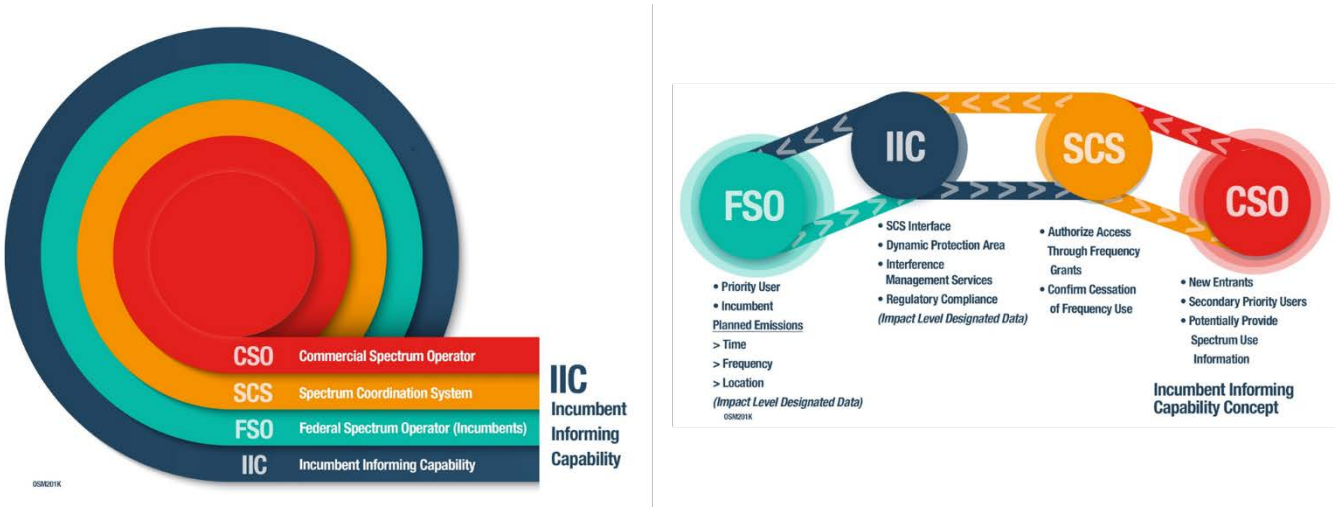

Figure 1 Incumbent Informing Capability Concept

[7] 47 U.S.C. §923(j)(1) provides: "Relocation prioritized over sharing. In general. In evaluating a band of frequencies for possible reallocation for exclusive non-Federal use or shared use, the NTIA shall give priority to options involving reallocation of the band for exclusive non-Federal use and shall choose options involving shared use only when it determines, in consultation with the Director of the Office of Management and Budget, that relocation of a Federal entity from the band is not feasible because of technical or cost constraints."

The IIC is a mechanism for more reliably and securely managing interference between "incumbent" federal users and "new entrant" commercial operators sharing spectrum in a given band. The approach leverages the fact that, in some instances, federal use of spectrum is episodic and potentially amenable to scheduling. Federal users would provide data on when they actually would use the spectrum – perhaps even just before using the spectrum. That data would be used to grant access to nearby commercial users when permissible to use that shared spectrum. This is an innovative spectrum management mechanism, and it could become a critical linchpin for NTIA's federal spectrum management.

The IIC will use a multi-phased development approach to enable a federally operated automated spectrum sharing mechanism to enhance spectrum sharing among federal incumbents and new non-federal operators (and theoretically provides the technology to enable sharing with new federal users in certain bands). Ultimately, the IIC could be expanded to any number of federal bands where scheduling is appropriate. The concept is illustrated in Figure 1. IIC information consists of four primary components depicted in Figure 1:

- The Federal Spectrum Operator (FSO) refers to the protected incumbent with priority access and whose operations are intermittent.
- The IIC is the mechanism responsible for informing the Spectrum Coordination System (SCS) component of imminent incumbent operations.
- The SCS is the component responsible for managing the Commercial Spectrum Operator's access to the shared spectrum. (For the CBRS band this may be the existing Spectrum Access Systems (SAS).)
- The Commercial Spectrum Operator (CSO) component refers to the new entrant (non-federal) secondary user.

4. IIC Operations and Processes

4.1 IIC Operational Needs

A foundational principal for the IIC is that federal incumbent users require unencumbered, primary access to spectrum to test, train, and operate to achieve their missions. To accomplish this, NTIA, in collaboration with the DoD, is identifying operational needs as a foundational principal for

enabling the IIC concept. These operational needs provide guidance as we design the IIC, and we expect these needs will evolve and grow as the IIC is developed.

4.1.1 Federal Operational Security

The IIC must maintain Federal operational security while providing data for the commercial users. This explains why IIC should be a federalized system. Sensitive federal incumbent information (i.e., operating time, frequency, location, etc.) must be protected at interfaces where access is available to commercial systems and users. To support this operational need, new security classification guidance may need to be established, identified, or updated to address IIC data handling. The appropriate network classification to house IIC and the methodologies for interfacing with the SCS and ultimately non-federal users will need to be identified.

4.1.2 Spectrum Access Functionality

The spectrum access function of the IIC concept is known as the Spectrum Coordination System (SCS), and its function is to authorize new entrant, secondary access to the spectrum on a time-selective basis. NTIA anticipates cooperating with the FCC on determining how the SCS will be operated. When an SCS receives notification from the IIC that a particular area (specifically, a "Dynamic Protection Area" or "DPA") needs protection on certain frequencies, the SCS activates that DPA on those frequencies to protect federal systems from interference. Additionally, the SCS and IIC need a mutual level of operational timescale (*e.g.*, if the IIC provides data on a second-by-second timescale, the SCS should be equivalently responsive). We anticipate that over time more automation will be introduced which will lead to shorter timescales.

4.1.3 Interference Reporting and Resolution Mechanisms

A robust design of the IIC must take account of the possibility that harmful interference may arise under certain circumstances; the IIC must provide a mechanism for reporting and resolving interference in a timely manner. To that end, the IIC will employ data analytic tools and an accessible dashboard that will foster transparency on interference issues. This can require coordination with the Federal Communication Commission's Enforcement Bureau. Interference resolution timelines are to be determined; however, we reasonably expect the interference resolution period to decrease as more automation is introduced into the system, leading to the potential for near real-time interference resolution, especially in simple cases.

4.1.4 Consistency with Applicable Regulations

FCC and NTIA regulations should be incorporated into IIC operations. More importantly, regulations must be synchronized with the capabilities as the IIC and SCS technologies evolve over time (i.e., FCC and NTIA regulations must facilitate, not impede, technological maturation over time). Fundamentally, automation of the business processes of the regulations is an objective need over time.

4.1.5 Dynamic Protection Area (DPA) Analysis

The IIC should provide Dynamic Protection Area (DPA) analysis, definition, and control. A DPA is defined as a geographic area where nearby commercial operators may be instructed by an SCS to modify their emissions to protect nearby incumbent operators.[8] An activated DPA must be protected from harmful interference from commercial operations.[9] DPA engineering models and algorithms will be developed and implemented as part of IIC. Further research into the engineering model development is critical, including how harmful interference is calculated, and the suitability of propagation models. Additionally, further study is required to determine how DPAs are treated from a regulatory perspective. Federal missions and spectrum usage are not static and the DPAs must evolve to accommodate new federal operations and the regulations for bands implementing IIC must address this requirement.

4.1.6 Incumbent Spectrum Use Information

The IIC must provide secure and reliable information about current and past federal incumbent users. The IIC will archive spectrum use data and be capable of providing authoritative data regarding past Federal incumbent use. Accurate projections of future use will require information from the federal agencies about their planned use as well as planned system upgrades and new spectrum dependent missions. The IIC can also archive information about commercial spectrum demand, based on spectrum access granted.

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[8] *See* Letter from Paige Atkins, Assoc. Administrator, OSM, NTIA, to Julius Knapp, Chief, OET, FCC and Don Stockdale, Chief, WTB, FCC (May 17, 2018), https://www.ntia.doc.gov/files/ntia/publications/ntia_3.5_ghz_band_dpa_letter_-_gn_dkt_no._17-258-05172018.pdf.

[9] A detailed description of how DPAs are protected in the CBRS band is provided in Wireless Innovation Forum *Requirements for Commercial Operation in the U.S. 3550-3700 MHz Citizens Broadband Radio Service Band* Document WINNF-TS-0112 Version V1.9.1 (March 11, 2020).

4.2 IIC Business Processes to Enable Spectrum Sharing

To properly govern interactions between IIC administrators, operators, and users, a system of business processes must be established to ensure efficient operation, system/network security, adherence to regulatory rules, and appropriate tracking and documentation of IIC operations. Part of the initial IIC development will focus on creating these business processes to support the IIC concept. The Incumbent Informing Capability requires business processes for administering the IIC such that Federal Spectrum Operators (FSO), SCS administrators and Commercial Spectrum Operators (CSO) can share spectrum efficiently. We recognize that the business process needed to enable spectrum sharing are subject to change given the early stage of IIC development and the likely differing spectrum management requirements for specific bands. We also recognize that IIC will need to be housed on a secure network and protocols and mechanisms for exchanging information with commercial SCSs will need to be determined to meet all information security and handling requirements. Accordingly, the following IIC business processes – Use Notification, Interference Resolution, Regulatory Compliance, and Network Fail Safe – represent those currently identified and may not be the entirety of what ultimately is required.

4.2.1 FSO Current/Planned Spectrum Use Notification

The IIC concept depends on FSOs notifying the IIC of the current and/or planned frequency occupancy information. The mechanism for providing this information can be a system requiring human to device/system interaction or an automated notification without a human in the loop. For example, an incumbent transmitter may send an automated secure message to the IIC when it becomes operational in lieu of providing earlier scheduling information. The specific format for spectrum use notification and mechanism for transfer is to be determined but the information format developed under the DARPA Spectrum Collaboration Challenge (SC2) program is one candidate format.

4.2.2 Interference Resolution

It is important to establish an IIC business process to resolve interference in real time (*i.e.*, while the incumbent operations are underway) to prevent impacts to vital federal operations. The process must establish a mechanism for contacting the non-incumbent users and providing sufficient information regarding the harmful interference for the non-incumbent to immediately identify the potential source and remedy the interference. Necessarily, part of the business process for IIC will

be to identify conditions for the SCS to limit non-incumbent access to the spectrum and establish the interfaces to the SCS that will enable this capability.

4.2.3 Regulatory Compliance

Establishment of an IIC business process that reflects NTIA and FCC rules consistent with IIC implementation is a critical element for effective spectrum sharing. It is also important that the rules be written to capture the policy requirements and still allow flexibility in development of software solutions to fulfil those requirements. Narrowly written fixed rules may limit evolution and creativity in the development of innovative software solutions. One concept that has been suggested is the use of a handbook or reference book that describes current specific IIC implementation and operation and would be incorporated by reference from the NTIA and FCC Rules. This may be a way to provide flexibility because the handbook could have a review cycle as the implementation is evolved over time. Moreover, the FCC and NTIA would avoid the need to generate rule changes that would be a burden on their processes and license holders or potentially constrain the federal agencies from modifying their current operations to meet changing mission requirements.

4.2.4 Network/System Fail Safe Process

Finally, the establishment of an IIC business process to protect the network/system from intentional and unintentional disruption. These business processes will support orderly and auditable access and interactions between users and the IIC. When appropriate, access may also be restrictive or limited to prevent users from accidentally shutting down the entire network during their interactions. Additionally, the system must be designed to protect incumbent federal operations in the event of a network failure.

5. Possible Future: Everyone Informs

IIC is another step on the path to future real-time dynamic spectrum sharing paradigm we call "Everyone Informs". This concept builds on results demonstrated under the DARPA Spectrum Collaboration Challenge (SC2) project.[10] On SC2 "competitors … develop(ed) a new wireless

[10] https://www.darpa.mil/news-events/2019-10-24

paradigm in which radio networks … autonomously collaborate and reason about how to share the RF spectrum, thereby avoiding interference and jointly exploiting opportunities to achieve the most efficient use of the available spectrum. SC2 teams … develop(ed) these breakthrough capabilities by taking advantage of recent advances in artificial intelligence (AI) and machine learning, and the expanding capacities of software-defined radios."[11]

We imagine a possible future where the technology demonstrated under SC2 allows for maximizing spectrum sharing by having all users share information about what they are detecting in a band and what their emissions are/will be – not just federal incumbent users. SC2 showed that this information can be used to optimize the efficiency of spectrum use across heterogeneous uses of the spectrum.

For SC2 the incumbent periodically shared 3 pieces of information about sensed interference via a "backchannel" known as the Collaborative Intelligent Radio Network (CIRN):

- Current undesired signal power
- Permitted undesired power (the threshold)
- Center frequency and bandwidth over which undesired signal power was measured

Collaboration messages were passed across the CIRN between the networks sharing the spectrum using a standard: the CIRN Interaction Language (CIL). Multiple possible implementations for the CIRN are possible: radio network is connected to the Internet; Disconnected operations – low rate satellite communications link, HF, etc. We contemplate the possibility of the IIC leveraging the CIL or something like it.

Additionally, like the concept for IIC, incumbents and competitors could provide information about their past/current/planned use of spectrum via the CIRN:

- Frequency ranges recently used
- Frequency ranges for planned emissions in the near future
- Interference observed
- Current loading and priority

[11] https://www.darpa.mil/program/spectrum-collaboration-challenge

We might imagine a future with different classes of incumbents based in part on the information they are able/willing to share: e.g., provide: 1. interference detection flag; 2. Channel power measurements; 3. 1 & 2 plus geolocation data, including antenna pointing.

DARPA has identified a number of technical and policy challenges that are areas for further research at the boundary between technical and policy domains. These include:

- Incentivizing dynamic but fair sharing
- Identification of which incumbent uses are good candidates for this type of sharing and which should be excluded.
- Generalization of the SAS/SCS concept to sharing with various commercial uses
- Compliance and truthfulness in good faith collaboration

6. Conclusion: IIC - A Potential Platform for Spectrum Sharing

The NTIA vision for IIC is that it evolves to become a "uniform standardized platform" for spectrum sharing across multiple bands. NTIA expects that IIC will be deployed over the next few years to support mid-band spectrum sharing predominately between federal systems and broadband wireless carriers using 4G and 5G technology. NTIA anticipates that IIC will evolve to become a federalized system run and administered by NTIA. IIC is expected to be a long-term project with iterations that will ultimately allow federal agencies to populate and update in real-time a database with frequency, location, and time-of-use information for systems they deploy in the U.S.

The first steps of this effort is updating the previously developed CBRS portal to a DOD scheduler for deployment at 11 participating CBRS test ranges and identifying the data collection and security requirements and considerations. If successful, NTIA will next evaluate expanding IIC functionality to other 5G mid-band spectrum and ultimately transition the capability to an NTIA operation, allowing us to potentially apply IIC to all federal operations in other bands.

IIC could permit easier and quicker spectrum access for commercial wireless services and open the door to innovative, real-time automation. Moving complex federal systems to different spectrum bands has been laborious, time-consuming, and expensive – and eventually there will be no place left to move. The IIC, however, could securely and reliably expedite spectrum repurposing, demonstrating that innovation can continue to solve difficult spectrum challenges.