Before the
DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Washington, DC 20230

In the Matter of	)	
	)	
Development of a National Spectrum Strategy	)	Docket No. 230308-0068
	)	

COMMENTS OF NOKIA

David Bartlett
Amit Mukhopadhyay
Jeffrey Marks
Grace Koh

Nokia
1200 G Street, NW
8th Floor
Washington, DC 20005

April 17, 2023

© 2023 Nokia

Table of Contents

© 2023 Nokia

Before the
DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Washington, DC 20230

In the Matter of	)	
	)	
Development of a National Spectrum Strategy	)	Docket No. 230308-0068
	)	

COMMENTS OF NOKIA

Nokia submits these comments to the National Telecommunications and Information Administration ("NTIA") in response to its Request for Comments ("RFC") on developing and implementing a National Spectrum Strategy. A comprehensive strategy on spectrum is urgently needed and is essential to ensuring the United States remains the global spectrum innovation leader and advancing our national and economic security. Common goals and guideposts among Federal government and commercial users are necessary to lead the nation in the desired direction. Our response is provided to help NTIA shape the future of not only the telecommunication industry and Federal government operations but also of the broader society and economy.

© 2023 Nokia

1 Executive Summary

Nokia fully supports NTIA's effort to develop and implement a National Spectrum Strategy for the United States. Nokia agrees that it is critical that the United States establishes strategies without delay to bolster our nation's leadership. Spectrum will be the lifeblood not only for commercial communications services but also for U.S. competitiveness. As a leading vendor of edge wireless equipment to both commercial and U.S. government stakeholders, Nokia is well-positioned to be a valuable resource to NTIA in this proceeding.

Continued availability of spectrum for 5G will lay the foundation for the successful evolution to 5G-Advanced (5G-Adv) and 6G. The nation must find ways to ensure a steady supply of spectrum in different frequency ranges – low, medium, and high bands. Most critical in the short term, we support ongoing efforts to allow commercial use of lower 3 GHz spectrum for 5G and 5G-Adv.

For 6G, which will begin deployments toward the end of this decade, it is most critical to ensure new commercial mobile allocations in mid-band spectrum in the 7-15 GHz frequency range because of the balance between capacity and coverage this spectrum range can deliver. It is challenging to carve out spectrum in this frequency range due to the existence of many federal incumbent systems. However, every effort must be made to make the most efficient use of this spectrum. Ideally, new spectrum for 6G should be exclusively licensed and not burdened with ongoing sharing obligations. If that is impractical within the time frame for initial deployment, however, we should carefully consider managed sharing with minimal technical restrictions.

One key challenge in this respect is the lack of available information regarding Federal spectrum usage. From the FCC table of allocations, we know the services that are allocated in certain

© 2023 Nokia

parts of the spectrum, but we have very limited information on actual usage. It is imperative that we create a national spectrum database that maintains this information. It is equally important that the conversation between commercial and federal users continues and becomes richer – allowing for advance planning and strategy development for the important next generation services (both commercial and Federal) that will use the spectrum.

In short:

- 6G will be ready for deployment before the end of the decade, but we need to act now to meet domestic demand and keep pace with the pace of innovation among our global partners and rivals.
- The U.S. should strive to open up to 2 GHz of new spectrum in 7-15 GHz range for commercial use to maintain U.S. technology leadership and meet domestic user demand.
- A national database on spectrum usage (including detailed technical information on use) will be essential to make the most informed decisions regarding our national spectrum strategy.

Spectrum will not just enable next generation wireless technologies; it will also fuel critical growth in the nation's economy and security for decades to come.

© 2023 Nokia

2 Introduction

The wireless communications industry has brought unprecedented benefits to humankind and its impact is expected to grow exponentially with the roll out of 6G. While today's networks mostly enable human-to-human communications, networks of the future will connect the physical, digital and biological worlds. These connections will bring tremendous growth in productivity, while increasing safety, security, sustainability, inclusiveness and digital equity. This critical connectivity will create jobs and improve the quality of life for millions of people in America and around the globe. Even as today's most advanced 5G networks are delivering the highest performance technically feasible at present, developments in many adjacent fields (e.g., Artificial Intelligence/Machine Learning, semiconductors, material science, etc.) will make even loftier goals achievable in the future.

We expect 6G to be in its nascent stage of deployment towards the end of this decade and on a firmer footing in the 2030s. However, the evolution of 6G will not accelerate until some basic conditions are met. Spectrum is the lifeblood of wireless broadband mobile telecommunication and the most promising 6G advances may remain unfulfilled without adequate and appropriate spectrum allocations. We need to act now to ensure that the right type and amount of spectrum is available in the near term as well as toward the end of the 2020s and beyond.

Countries around the world continue defining their positions for WRC-23 including the bands to be studied for IMT-2030/6G. Ideally, NTIA will define a national spectrum roadmap for 6G in advance of this event, to solidify U.S. leadership in this key forum that decides forward-looking global spectrum policy. Harmonized spectrum allocations across the globe create economies of scale, driving down costs and benefitting U.S. spectrum users.

© 2023 Nokia

3 Pillar #1: A Spectrum Pipeline to Ensure U.S. Leadership in Spectrum-Based Technologies

3.1 Future Spectrum Requirements

Q1: What are projected future spectrum requirements of the services or missions of concern to you in the short (less than 3 years), medium (3-6 years) and long (7-10 years) term? What are the spectrum requirements for next-generation networks and emerging technologies and standards under development (*e.g.*, 5G Advanced, 6G, Wi-Fi 8)? Are there additional or different requirements you can identify as needed to support future government capabilities? What are the use cases and anticipated high-level technical specifications (*e.g.*, power, target data rates) that drive these requirements? How much, if at all, should our strategy by informed by work being performed within recognized standards-setting bodies (*e.g.*, 3GPP, IEEE), international agencies (*e.g.*, ITU), and non-U.S. regulators or policymakers (*e.g.*, the European Union)? What relationship (if any) should our strategy have to the work of these entities? Are there spectrum bands supporting legacy technology (*e.g.*, 3G, GSM, CDMA, etc.) that can be repurposed to support newer technologies for federal or non-federal use?

3.1.1 Most Pressing Spectrum Needs

Spectrum in different frequency ranges – low, medium, and high – is critical for the success of 6G. While lower spectrum bands are conducive for providing wide area coverage, the higher-band spectrum is needed for delivering capacity. Availability of complementary frequency ranges (low, medium, and high) ensures that both capacity and coverage requirements are satisfied.

In Nokia's substantial experience deploying previous generations of technologies, leveraging existing network site infrastructure with new spectrum is important for network planning and cost efficiency. Reuse of existing infrastructure also contributes greatly to environmental sustainability.

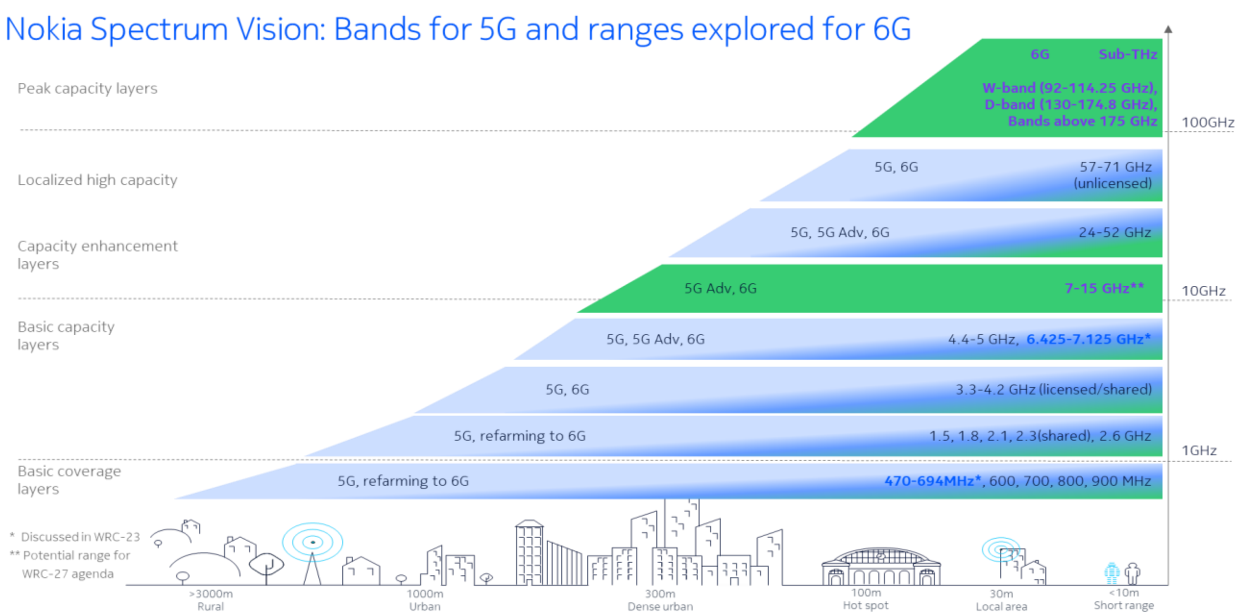
Nokia strongly supports the ongoing effort to allocate new spectrum for commercial use in the lower 3 GHz band (3.1-3.45 GHz) for 5G and 5G-Adv. In the longer term, identifying mid-band spectrum in 7-15 GHz frequency range will be critical for 6G because of the balance between capacity and coverage it can deliver.

Significant 6G research is also ongoing with sub-THz spectrum (commonly referred to 100 – 1000 GHz), which can complement mid-band frequencies, but cannot replace the 7-15 GHz

© 2023 Nokia

spectrum. Sub-THz spectrum is expected to be useful for applications like sensing and wireless backhaul, but it is not efficient for delivering capacity and coverage in wide area networks due to inherent limitations in the propagation characteristics of this very high frequency spectrum range.

Nokia's more comprehensive vision for future spectrum requirements is depicted in the graphic below. We expect 5G-Adv to be deployed in the short term (less than 3 years), 6G to begin deploying in the mid-term (3-6 years) and we expect 6G to be firmly established in 7-10 years.



The spectrum needs depicted above are not exclusively for commercial services. 6G applications will enhance the ability of government users as well. Most of the applications envisioned for 6G (e.g., XR, digital twins, high-precision positioning and sensing, etc.) will be equally applicable to government use cases. These applications should be considered crucial for maintaining U.S. supremacy at home and abroad. Here are a few examples:

© 2023 Nokia

- XR can help simulate risky environments and get troops battlefield ready without putting lives at risk; it can also increase situational awareness in disaster rescue operations by providing important information that is not directly in line of sight.
- Digital Twins (DTs) can help commanders in war rooms batter manage the troops engaged in field operation; DTs can also be immensely helpful in delivering aid after natural disasters.
- High-precision positioning and sensing can keep troops or first responders safe in dangerous situations; these capabilities can also be used to help run mission critical rescue operations following natural disasters.

3.1.2 Spectrum Needs for Leading Edge and Next Generation Use Cases

Today's 5G networks can deliver many use cases that were considered very challenging only a few years ago. Several key future use cases are described below that will rely on further technology developments to 5G-Adv and 6G. These use cases can become realizable in practice because of the new capabilities being brought forward by next generation wireless technologies expected in the next 5-10 years.

For each of the use cases, we have provided a brief description, some example applications, as well as some key characteristics to get a feel for how the use cases are delivered. Furthermore, we have provided some typical network KPIs. Please note that new KPIs are emerging beyond the traditional ones (throughput, latency, jitter, error rate etc.). These include reliability, positioning accuracy, minimum number of simultaneous traffic streams required to deliver the experience, etc. Since these are emerging use cases, we have provided estimated values rather than providing very specific numbers.

© 2023 Nokia

Immersive Experiences

- Description: Dynamic interaction among people, things, and environments through lifelike 3D rendering
- Example applications:
  - Personalized education, training
  - Specific seats in concerts, sports venues
- Key characteristics:
  - 3D rendering of objects
  - Ability to seamlessly interact with the environment
- KPIs
  - Throughput per stream: multi-Gbps
  - Number of streams: 100s
  - Latency and jitter: <20 ms

Multi-sensory Communications

- Description: Experiencing touch (including the feelings of temperature, pressure, texture) as well as smell and taste in a more distant future
- Example applications:
  - Remote work, Virtual meetings
  - Travel and tourism
- Key characteristics:
  - 3D rendering of people and environment
  - Emulation of touch and interaction
  - Multi-sensory experiences
- KPIs
  - Throughput per stream: multi-Gbps
  - Number of streams: 100s to 1000s
  - Latency and jitter: <20 ms
  - Synchronization across streams: <10ms

High Resolution Mapping and Digital Twinning

- Description: Sense, detect, locate, identify, and image targets during remote operation, thus improving situational awareness, and enabling better allocation of for physical resources including preventive maintenance
- Example applications:
  - Manufacturing
  - Smart cities
- Key characteristics:
  - 3D sensing and rendering of environment
  - Simultaneous Location and Mapping
  - Real time updates
- KPIs

© 2023 Nokia

- Throughput per stream (Bidirectional): Multi-Gbps
- Number of streams: 1000s
- Latency and jitter: < 10 ms

Robot and Cobot Operations

- Description: Humans working collaboratively with robots to achieve outcomes that are challenging to be done by robots alone
- Example applications:
  - Bespoke manufacturing
  - Industry 5.0 applications
- Key characteristics:
  - High precision positioning
  - Sensing
  - Many-to-many communications
- KPIs
  - Throughput: Multi-Gbps
  - Latency: <10 ms
  - Number of streams: 100s
  - Reliability: Seven 9s
  - Positioning accuracy: < 1 cm
  - Sensing accuracy: >99%

Other Applications

There are many other applications emerging as key use cases for wireless technologies but their KPIs are still in the process of evolving. Some high-level examples include:

- Universal Connectivity/Digital Equity: While most of the population is connected via wireless networks, there are significant geographic areas that are not covered, primarily due to reasons of economic viability. It is expected that with the evolution of technology in adjacent technologies (e.g., cheaper launch of LEO satellites, improved steerability of drones and balloons etc.) non-terrestrial networks will become more practical for deployment and universal wireless coverage will render digital inequality a thing of the past.
- Sustainability: The wireless industry is an essential component of the nation’s sustainability journey. From sensors to control systems to more efficient operating protocols, sustainability

© 2023 Nokia

use cases will be driven by application of communication technologies that will require additional spectrum.

3.1.3 Collaboration with Other Agencies and Standards Development Organizations (SDOs)

In today's highly interconnected world, the United States must be actively engaged in global technology policy developments to ensure its continued leadership in spectrum strategy development and implementation. While 5G-Adv work is well underway at 3GPP, key activities on 6G standards development are ongoing in multiple arenas around the world. Several of these organizations are listed below:

This is only a small sample of organizations involved in early 6G work. There are many countries (e.g., Finland, Germany, Sweden, UK, Japan, South Korea, India, among others) that are making early investments in 6G research and development. It is critically important to work closely with like-minded nations and develop a robust ecosystem that will benefit from trust, transparency, and economies of scale.

© 2023 Nokia

3.1.4 Repurposing of Spectrum Bands Supporting Legacy Technology (*e.g.*, 3G, GSM, CDMA, etc.)

The repurposing of spectrum (i.e., "refarming") is already being done in the commercial communications industry. Spectrum formerly used for CDMA or GSM has been reallocated towards use of W-CDMA, LTE, or 5G. In some cases, even non-IMT spectrum (e.g., for broadcast, WiMax, etc.) has been repurposed. Generally, repurposing of spectrum is a good practice. It allows reuse of sites and related infrastructure while making better use of the spectrum, since next generation technologies are characterized by higher spectrum efficiency and higher performance.

However, it is important to keep in mind that the amount of spectrum needed for older mobile communications technologies is fairly small compared to today's needs and future requirements. Additionally, channel bandwidths used in previous technologies are much smaller, making reuse more challenging (e.g., innovative solutions like carrier aggregation could be necessary).

Repurposing spectrum from one type of service to another (e.g., radar to telecommunications) is much more challenging than, for example, repurposing for a generational upgrade of the same service. However, such repurposing for a new service must be seriously considered to optimize spectrum efficiency. One major challenge is disparity in lifecycles. While equipment in some industries may remain in service for multiple decades (or even half a century or more), some other industries have equipment lifespans of a decade or less. Additionally, disparate services may be enabling very different user bases with diverse functional requirements. As challenging as repurposing may be, it must continue to be a spectrum priority.

Furthermore, failure to upgrade equipment to newer technologies is no excuse for making inefficient use of spectrum. There are many examples of past generations of equipment relying on lower quality and cheaper components, thereby assuming the risk that adjacent bands would remain

© 2023 Nokia

dormant. But even in cases where leading edge technologies were deployed, such spectrum users should be expected to reassess and upgrade over time. Transmitter and receiver technologies are rapidly evolving (and improving) and anyone that uses spectrum, whether in the same band or in adjacent bands, must keep pace with the most efficient spectrum advancements in the industry. Radio altimeter users' interference concerns have made headlines regarding potential emissions from several hundred MHz away simply because their own receivers have not kept pace with recent developments that "see" emissions into bands far outside their own allocated spectrum. While this is important and safety and security are Nokia's top priorities, efficient use of spectrum is the responsibility of all spectrum users – new entrants and incumbents alike. It is critical that NTIA exercises authority in leading federal agencies to promote spectrum efficiency.

3.2 Amount of Needed Spectrum

Q2: Describe why the amount of spectrum now available will be insufficient to deliver current or future services or capabilities of concern to stakeholders. We are particularly interested in any information on the utilization of existing spectrum resources (including in historically underserved or disconnected communities such as rural areas and Tribal lands) or technical specifications for minimum bandwidths for future services or capabilities. As discussed in greater detail in Pillar #3, are there options available for increasing spectrum access in addition to or instead of repurposing spectrum (i.e., improving the technological capabilities of deployed systems, increasing or improving infrastructure build outs)?

3.2.1 Insufficiency of Currently Allocated Spectrum

Currently allocated spectrum for commercial mobile use is insufficient and will have to be supplemented by additional spectrum for three main reasons:

- Data traffic is expected to grow significantly in the coming years, continuing to put stress on networks in population centers.

© 2023 Nokia

- Next generation applications (e.g., XR, digital twins, etc.) will consume far more bandwidth than today's most capacity-demanding traffic (video).
- Channel bandwidths of next generation technologies are expected to be much wider, in order to deliver higher performance.

Traffic is not uniform across all geographies. Demand for spectrum is closely related to the number of simultaneous users (and the type of application). Thus, we observe extremely high-capacity demand in population centers (especially during certain hours of the day) and relatively low demand in rural areas. To offset this imbalance with a fixed amount of spectrum, the network is much denser in population centers compared to rural areas – higher demand is being addressed by higher densification.

However, network densification comes at a high price – both for initial capital expenses and ongoing operating expenses. Furthermore, in many cases, additional densification is virtually impossible due to lack of real estate and can have a negative impact on environmental sustainability. Difficulty in siting new infrastructure is particularly acute in highly populated city centers, where demand is also typically the highest.

As mentioned above, the next generation applications (XR, digital twins, etc.) will drive tremendous growth in data demand. Many networks in large cities are running at their capacity limits during peak hours. Additional spectrum will be necessary to accommodate future demand – both for increased use of current applications as well as to accommodate newer applications.

3.2.2 Utilization of Existing Spectrum Resources

While it is relatively easy to assess spectrum utilization by commercial operators, it is much more challenging to assess spectrum utilization by federal agencies. The FCC allocation table only

© 2023 Nokia

mentions the services *allocated* to certain frequencies; but the *actual utilization* data for these federal allocations is extremely difficult to discern. There is a critical need for access to this information so that new and different approaches to higher utilization may be investigated – including leveraging geographical and temporal domains.

3.2.3 Options for Increasing Spectrum Access Beyond Repurposing Spectrum

The commercial telecommunications industry is leading the efforts in efficient spectrum usage. Spectral efficiency per channel is approaching theoretical limits and recent advancements have been more in the spatial domain (i.e., higher order MIMO technology). The only other option remaining is physical site densification which comes with other costly challenges mentioned above.

It is imperative that all users of spectrum contribute to the most efficient use of this scarce resource. This includes transmitting and receiving in-band radio signals within specific limits and minimizing out-of-band transmission and reception with respect to adjacent bands.

The commercial wireless industry has done a remarkable job of building infrastructure in population centers and more rural areas, using the above principles. While there may be opportunities of further densification, this substantial heritage of sustained investment has had a positive impact on closing the digital divide. However, we must be conscious of the impact of densification on network costs and environmental impact.

3.3 Spectrum Bands

Q3: What spectrum bands should be studied for potential repurposing for the services or missions of interest or concern to you over the short, medium, and long term? Why should opening or expanding access to those bands be a national priority. For each band identified, what are some anticipated concerns? Are there spectrum access models (*e.g.*, low-power unlicensed, dynamic sharing) that would either expedite the timeline or streamline the process for repurposing the band?

© 2023 Nokia

3.3.1 Spectrum Bands for Study for Potential Repurposing

The United States has spent considerable effort investigating lower 3 the GHz band for commercial 5G use. Nokia agrees that it is imperative that a substantial part of the 3.1-3.45 GHz spectrum band is made available for commercial use, even if that requires a spectrum sharing approach. That said, even if sharing is required, relocating the most challenging services is recommended to facilitate optimal 5G and 6G deployments. Leadership in 6G, however, will require repurposing far more midband spectrum than is available in the lower-3 GHz range. Therefore, we urge new commercial allocations of additional spectrum for 6G in the 7-24 GHz range, with an emphasis on the lower part of the spectrum (i.e., 7-15 GHz).

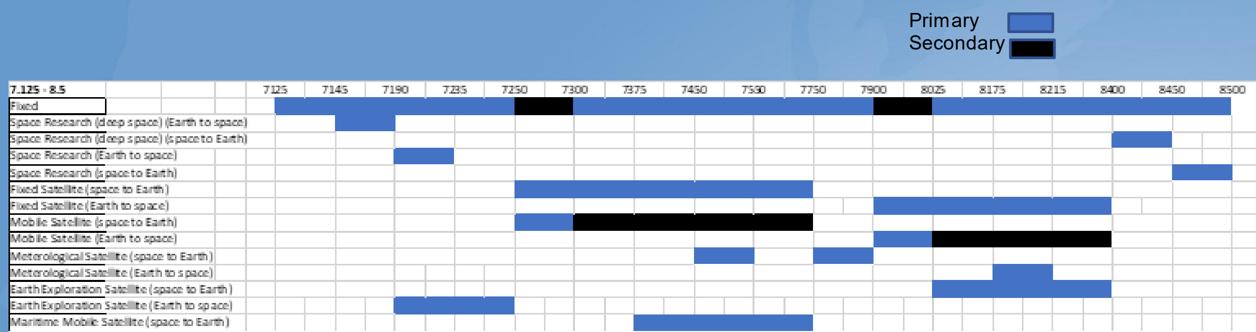
Spectrum in the 7-15 GHz range is desirable because it is closer in its propagation characteristics to spectrum that has already been deployed for 5G and earlier generations. It will allow maximum re-use of existing infrastructure thereby reducing deployment costs. In fact, spectrum in the 7-8 GHz range would provide maximum benefit as higher element antennas with beam forming capabilities may be able to closely replicate coverage areas of C-band (3.7-4.2 GHz) deployments.

Spectrum in 15-24 GHz should also be explored, although it is less desirable than the lower mid-band ranges discussed above. This spectrum is closer to mmWave spectrum (e.g., 24 GHz – 100 GHz) in its propagation characteristics and is not well suited for wide area coverage. Because there are several federal allocations in the 15-24 GHz range, it will require a thorough investigation to determine how to make that spectrum available for commercial use – preferably through exclusively licensed usage or through sharing with minimal technical constraints.

The charts below capture FCC spectrum allocations for different users, which is reproduced from a report by the Technological Advisory Council (TAC). The real challenge is to assess the actual usage of these spectrum bands.

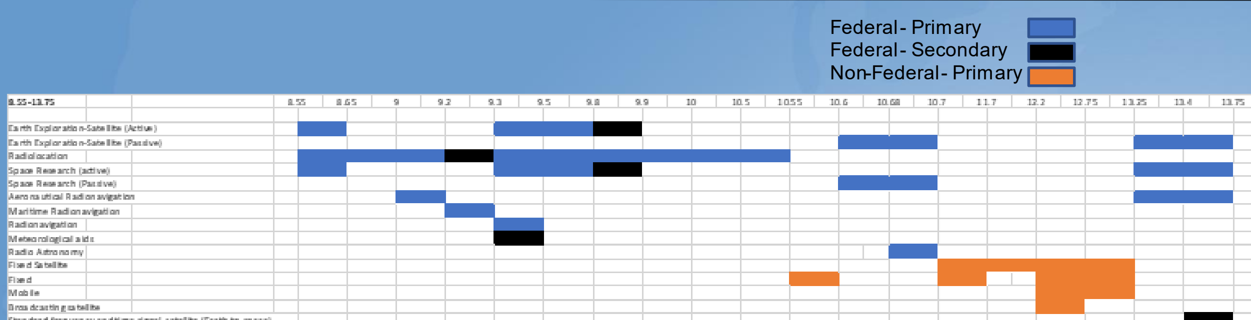
© 2023 Nokia

7.125 – 8.5 GHz Federal allocation



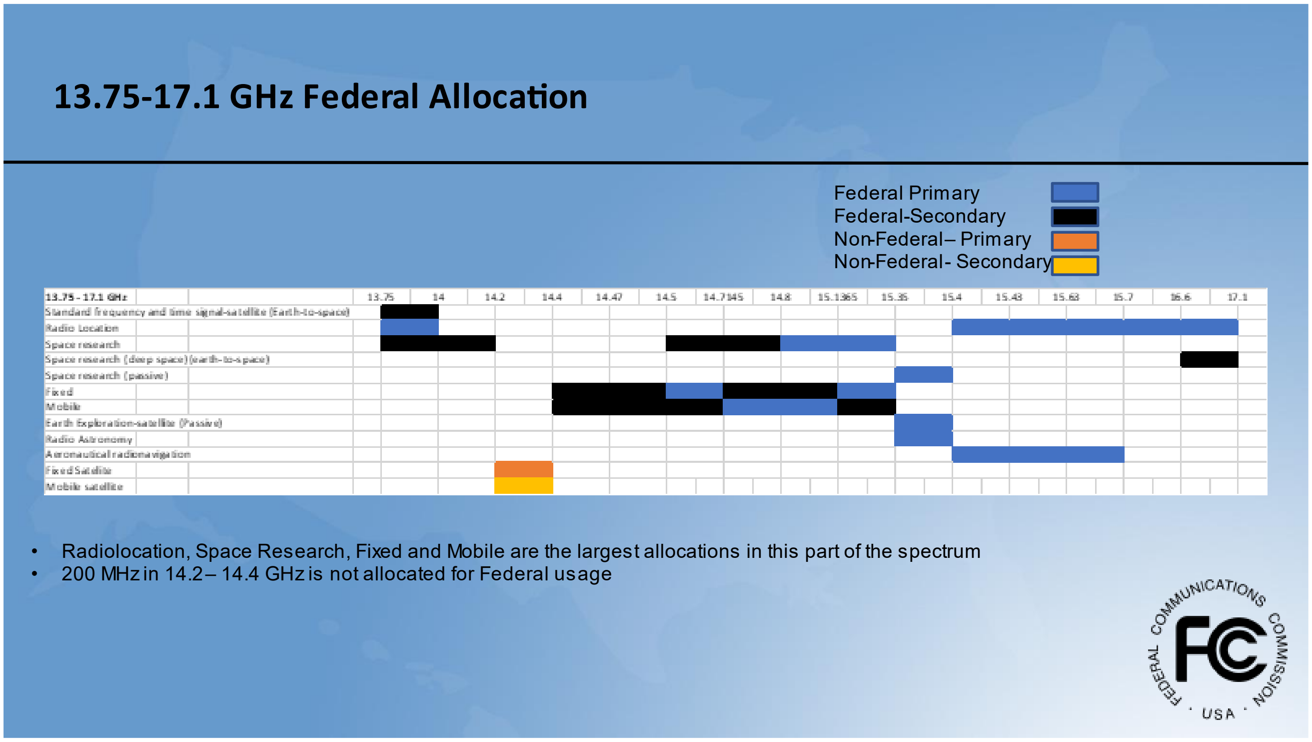
- Fixed, Fixed Satellite and Mobile Satellite are the largest current allocations and will be the biggest challenge for 6G usage
- Approximately 20% of Fixed use is by DoD, and satellite allocation also includes DoD operations (Source Commscope)
- Other allocations may not be that critical because they may not be “ubiquitous”
- Some applications may need protection from 6G

8.55 – 13.75 GHz Federal allocation



- Radiolocation is the single largest allocation in this part of the spectrum
- ~2500 MHz in 10.7– 13.25 GHz is allocated for Non-Federal use
- There is relatively low usage around 13 GHz and experimental license is available (Source Qualcomm)

© 2023 Nokia



It should be noted that some applications may be inherently challenging to share (e.g., radio navigation due to its ubiquitous use over the entire country) while other applications (e.g., Fixed Service with its well-defined, limited service area) may be more amenable to sharing. Also, like services tend to coexist more easily. Thus, it would be desirable to explore packing similar services in the same or adjacent bands, thereby freeing up spectrum for use by other services. A more comprehensive accounting of actual federal spectrum usage is needed for analysis of currently allocated spectrum to explore how to make the overall spectrum use more efficient for all users.

3.3.2 Recommended Spectrum Bands as National priority

Based on current industry analysis, at least 500 MHz of spectrum per commercial operator will be necessary in the 7-15 GHz spectrum band to meet demand. Given that typically four commercial operators have licenses in most major markets in the United States, this will amount to

 © 2023 Nokia

freeing up a total of 2 GHz spectrum in 7-15 GHz range. Specifically, the following are identified as the most promising bands in the 7-15 GHz range:

- 7.125 – 8.5 GHz, because of its proximity to 3.7-3.98 GHz spectrum already deployed, while 5.9 – 7.1 GHz has already been allocated to unlicensed usage.
- 10.7-13.25 GHz, because this range appears to have limited federal usage.
- 14-15.35 GHz, because this range already has mostly fixed/mobile allocation, predominantly for federal usage.

Opening a total of 2 GHz spectrum from the above ranges should be a national priority to ensure the United States remains the technology leader in this space.

3.3.3 Spectrum Access Models to Facilitate Repurposing

Nokia urges that robust mobile broadband services are best provided with access to full-power technical service rules and exclusive geographic licensing. Identifying spectrum that meets or approaches this goal is worth a longer time horizon and makes it desirable to begin the process as early as possible.

Unlicensed low power usage will not meet the strong performance and high reliability requirements of critical applications. Operators will be hesitant to invest in spectrum if they cannot be sure that they can use it when they need it to meet demand. This has been clearly demonstrated in the disparate auctions results of CBRS vs. C-band spectrum.

Dynamic sharing should be considered as the last option, only to be considered when exclusive licensing is not possible in a timely manner. Mechanisms for dynamic sharing are evolving. In the lower 3 GHz range, different techniques are being explored and it will take years before they reach market maturity. However, this approach should be considered, particularly given the fact that

© 2023 Nokia

freeing up spectrum completely from incumbent users is impractical in the foreseeable future. If sharing is the only option for making new spectrum available for commercial use, it should be considered while minimizing any restrictions (e.g., low power) on spectrum usage for the new commercial entrants.

As a final matter, to the extent that early entry by new services can be facilitated through low power, dynamic sharing, or other sharing mechanism, Nokia favors such approaches as long as the timeline for incumbent relocation is clear. Offering early access to the lowest 100 MHz of the C-Band at auction is an example of creative spectrum policy that provided substantial value as relocation of incumbent operations was ongoing.

3.4 Factors for Identifying Spectrum

Q4: What factors should be considered in identifying spectrum for the pipeline? Should the Strategy promote diverse spectrum access opportunities including widespread, intensive, and low-cost access to spectrum-based services for consumers? Should the Strategy promote next-generation products and services in historically underserved or disconnected communities such as rural areas and Tribal lands? Should the Strategy prioritize for repurposing spectrum bands that are internationally harmonized and that can lead to economies of scale in network equipment and devices? How should the Strategy balance these goals with factors such as potential transition costs for a given band or the availability of alternative spectrum resources for incumbent users? How should the Strategy balance these goals against critical government missions? How should the Strategy assess efficient spectrum use and the potential for sharing? What is an ideal timeline framework suitable for identifying and repurposing spectrum in order to be responsive to rapid changes in technology, from introduction of a pipeline to actual deployment of systems?

A national spectrum strategy should consider a diverse set of priorities, including:

- **Similar services in same/adjacent spectrum**: Packing similar services in the same/adjacent spectrum leads to better spectrum utilization. These services require similar types of spectrum, generally have similar spectrum usage characteristics, and often use similar equipment

© 2023 Nokia

components. Examples could be different types of satellite-based services in the same direction (i.e., uplink or downlink).

- **Technologies with comparable lifecycles in same/adjacent spectrum**: Technology for certain services evolve much faster than others (e.g., commercial telecommunication vs. federal radars). Allocating services that have disparate lifecycles in the same or even adjacent bands may not be the best approach as the longer lifecycle service will hold back advancement in the shorter lifecycle service.
- **Diverse needs of communities**: Population centers need more capacity whereas rural areas and tribal lands typically need better coverage. Capacity demand in population centers may be supplemented by higher band spectrum while rural areas and tribal lands need lower band spectrum for wide area coverage.
- **International harmonization**: Economies of scale is a key driver for keeping costs low. Our national spectrum strategy should evolve in synchronization with our allies around the globe to take advantage of diverse perspectives and innovative developments.
- **Mission critical use and the speed/cost of migration**: The importance of preserving mission critical use cannot be over-emphasized. But these uses must evolve with time; otherwise, we could fall behind in our mission critical capabilities as well as hamper the introduction of leading edge commercial services. The speed/cost of migration of incumbent services is indeed a factor, but it is critical that evolution of such mission critical services be included in any forward-looking national spectrum strategy. Sharing of spectrum for mission critical use and commercial use may drive faster technological advancement.
- **The National Spectrum Strategy should be based on a 10-year equipment lifecycle**: The timeline for identifying and repurposing spectrum should ideally be driven by the lifecycle of

© 2023 Nokia

the fastest-evolving spectrum user. The commercial telecommunication industry goes through a generational change approximately every 10 years. Our national spectrum strategy should adopt a methodology that the spectrum pipeline looks ahead at least 10 years and starts working on repurposing necessary spectrum ahead of time. Many incumbent users need a long lead time to adapt, and some users may need an even longer runway to make the spectrum available.

3.5 Spectrum Access Management

Q5: Spectrum access underpins cutting-edge technology that serves important national purposes and government missions. Are there changes the government should make to its current spectrum management processes to better promote important national goals in the short, medium, and long term without jeopardizing current government missions?

In addition to the current spectrum auction regime that involves multiple year timeframes and large geographical areas, there may be opportunities for short term spectrum access for smaller geographical areas in high demand. This may be accomplished in several ways:

- **Local licensing**: The U.S. government may allocate spectrum over small geographical areas (e.g., of the size of a typical enterprise campus or a venue like a large stadium) and allow bids for a smaller timeframe (e.g., a year or less). While it is important to ensure that there is sufficient wide-area licensed spectrum for carriers to meet demand for nationwide 5G and 6G, incorporating spectrum for Industry 4.0 and 5.0, industrial and enterprise use cases, is key to U.S. global competitiveness. This form of local licensing is being experimented in some European countries (e.g., Germany, UK etc.) and is triggering exclusive enterprise use of spectrum for their specific requirements, driving industrial automation.

© 2023 Nokia

- **Spectrum trading/Secondary markets**: This is a mechanism that allows users to gain access to spectrum that was not originally available to them but is currently being underused by the licensee. It provides a market mechanism for licensees to reorganize their spectrum for optimized use. If this trading is done in a dynamic fashion with the right economic incentives, the market will drive the most efficient use of spectrum. Web3 distributed ledger/ blockchain (BC) technology can be utilized to reduce transaction costs in the novel spectrum administration and management concepts like local licensing, sharing and leasing, through automatization of business-to-business complex multi-step workflows in contracting and data exchange. The flexibility and scalability introduced into regulation and spectrum management lower barriers to entry and enables new entrants to access local spectrum timely with lower transaction cost based on their specific business needs.

3.6 Spectrum Sharing

Q6: For purposes of the Strategy, we propose to define "spectrum sharing" as optimized utilization of a band of spectrum by two or more users that includes shared use in frequency, time, and/or location domains, which can be static or dynamic. To implement the most effective sharing arrangement, in some situations incumbent users may need to vacate, compress or repack some portion of their systems or current use to enable optimum utilization while ensuring no harmful interference is caused among the spectrum users. Is this how spectrum sharing would be defined? If not, please provide a definition or principles that define spectrum sharing. What technologies, innovations or processes are currently available to facilitate spectrum sharing as it should be defined? What additional research and development may be required to advance potential new spectrum sharing models or regimes, who should conduct such research and development, and how should it be funded?

Spectrum sharing can be implemented using any or all of the following four domains: frequency, time, geography, and power. The efficacy of the mechanism is driven by many factors, including nature of the service and technical capabilities of equipment. The basic guiding principle of sharing should be that diverse users of the spectrum should be able to operate with minimal

© 2023 Nokia

restrictions within the predefined constraints of spectrum sharing. The primary spectrum sharing regimes are described below:

- **Light licensing** (e.g., 6GHz AFC): This is a static approach where users register specifications of their proposed usage at particular locations and a database determines whether to allow such location and if so, if any restrictions are to be imposed.
- **Priority-based database approach** (e.g., CBRS): Lower priority users are granted spectrum only when higher priority users are not using it in a geographical area. This may involve relocation or power restrictions to allow modified service by the non-priority user rather than full cessation of operations.
- **Geography/time-based sharing** (e.g., AMBIT): Certain geographic areas are reserved for protecting incumbent usage. These areas may be earmarked as Periodic Usage Areas (PUAs) where incumbent and other usage may be preplanned while other areas are designated as Coordinated Planning Areas (CPAs) where the incumbent can become active any time without alerting other users ahead of time. Geography-based sharing can also facilitate terrestrial service sharing with non-geostationary satellite services, especially by avoiding areas around earth stations.
- **Managed dynamic spectrum sharing** (candidate in Emerging Mid-Band Radar Spectrum Sharing (EMBRSS)): This is for future study and implementation. Usage of spectrum between incumbent and others may be managed dynamically using a combination of time, frequency, geography and power domains in order to mitigate interference concerns. Non-incumbent equipment and/or a separate management system will detect/predict incumbent usage and proactively turn on mitigation mechanisms. Nokia is currently engaged with the National Spectrum Consortium and the Department of Defense to ensure that incumbent radar and 5G

© 2023 Nokia

networks operating can co-exist seamlessly in shared spectrum by controlling the behavior in real time of the 5G system when the incumbent radar is present. Nokia uses RIC and Multi-access Edge Computing (MEC) capabilities to deliver radio network programmability and AI/ML across the Open RAN ecosystem to expose radar interference detection and mitigation capabilities via an O-RAN interface developed by the O-RAN Alliance.

- **AI/ML-based cognitive radios**: This is also for future research and implementation. Taking advantage of emerging AI/ML-based techniques, non-incumbent users will be able sense when an incumbent is using the spectrum and initiate interference mitigation measures. Complementarily, the incumbent can also adjust its use of spectrum and/or have the capability of ignoring interference from known sources and yet make full use of spectrum.

Significant research and development is required to develop the last two approaches mentioned above. A strong cooperation between industry and federal users is needed for mutual success. Nokia recommends that the U.S. Government develop funding opportunities to promote these technologies. Nokia respectfully suggests that a supervisory body is needed to oversee the joint work.

3.7 Pros and Cons of Spectrum Sharing Approaches

Q7: What are the use cases, benefits, and hinderances of each of the following spectrum access approaches: exclusive-use licensing; predefined sharing (static or predefined sharing of locations, frequency, time); and dynamic sharing (real-time or near real-time access, often with secondary use rights)? Are these approaches mutually exclusive (*i.e.*, under what circumstances could a non-federal, exclusive-use licensee in a band share with government users, from a non-federal user point of view)? Have previous efforts to facilitate sharing, whether statically or dynamically, proven successful in promoting more intensive spectrum use while protecting incumbents? Please provide ideas or techniques for how to identify the potential for and protect against interference that incumbents in adjacent bands may experience when repurposing spectrum.

© 2023 Nokia

The use cases, benefits and hindrances of various sharing approaches are described below:

- **Exclusive-use licensing**: This is the most desirable way to allocate spectrum for commercial use as licensees are confident that they can use it whenever they need it, and they are in full control of how to make the most efficient use of this part of the spectrum. Such confidence also promotes the very large investment in infrastructure deployment required to provide maximum service to all communities. The market does not like uncertainty and the guarantee of availability makes investors confident in investing large sums of money in spectrum and infrastructure.
- **Pre-defined sharing**: This type of sharing is reasonable when incumbents have limited geographical and/or temporal use of spectrum. The challenge is that non-incumbents can be burdened with onerous restrictions on how, where and when they may be able to use the spectrum. We are seeing various issues with deployment by non-incumbents when onerous sharing criteria are involved (e.g., CBRS – low power leading to poor coverage, AMBIT – sites being rejected from large markets where licensees have invested heavily, etc.)
- **Dynamic sharing**: In theory, this is a very useful way to share. There are two fundamental challenges: (1) the licensees do not know whether they will be able to use the spectrum when they need it – this may lead to poor user experience; and (2) the mechanisms for dynamic sharing are in a very nascent stage – much R&D work is needed to make it practical and commercially viable. Also, a common understanding of "fairness of sharing" needs to be built into the mechanism, which may be fundamentally challenging.

© 2023 Nokia

Previous efforts of sharing spectrum while protecting incumbents have been only partially successful, as mentioned above in the examples of CBRS and AMBIT. While protection of incumbents has been very successful, the intensity of spectrum usage could have been improved with some further refinements of the techniques used. We must learn the lessons from the previous efforts and improve our techniques going forward.

In the future, protection of adjacent bands in sharing should continue to be rather straight forward, based on work already done by the FCC with respect to transmitter and receiver standards. Transmitters need to limit out-of-band emissions and receivers need to reject out-of-band emissions. Different types of users and equipment across boundaries need to respect each other's requirements in the best interest of both parties. What will make a real difference is finding better ways of using spectrum, taking advantage geographical and temporal dimensions and reducing the level of restrictions imposed on non-incumbent users (e.g., separation distances, power restrictions etc.).

3.8 Incentives and Policies

Q8: What incentives or policies may encourage or facilitate the pursuit of more robust federal and non-federal spectrum sharing arrangements, including in mid-band and other high priority/demand spectrum? For example, does the current process for reimbursement of relocation or sharing costs adequately incentivize the study or analysis of spectrum frequencies for potential repurposing? Are there market-based, system-performance based or other approaches that would make it easier for federal agencies to share or make spectrum available while maintaining federal missions? At the same time, what mechanisms should be considered to meet some of the current and future federal mission requirements by enabling new spectrum access opportunities in non-federal bands, including on an "as needed" or opportunistic basis?

NTIA has long led the government's evaluation of federal spectrum usage and facilitated the introduction of new services into historically federal-only bands, and its chief tool for doing so is the Spectrum Relocation Fund ("SRF" or the "Fund"). In concept, the SRF is a good incentive for exploring ways in which federal spectrum users can improve their systems and release spectrum for

© 2023 Nokia

either shared use with, or exclusive use by, commercial entities. The 2012 statutory revisions expanded the use of the Fund beyond cost recovery for transitioning spectrum; the Fund now also supports research and analysis of alternate technologies and exploration of potential sharing solutions.

Nokia suggests that NTIA could use the Fund to develop and expand the Incumbent Informing Capability to increase the information flow between commercial and federal users. The IIC would increase and systematize information sharing between federal and commercial spectrum users. NTIA should also be able to use the Fund to frame studies that might lead to modernizing legacy technologies in the federal government, with the goal of reducing their spectrum footprints.

However, the Fund is limited in size and cannot cover all the potential proposals submitted by agencies; Congress should consider replenishing the SRF, for example, by allocating a small percentage of every spectrum auction (regardless of whether federal spectrum has been transitioned for the auction). Congress could also authorize similar funds in other agency budgets, mandating that spectrum efficiency become not only an NTIA priority but a priority for the whole of government. In short, increased authorization and appropriation is needed to allow NTIA to coordinate more comprehensive consideration of federal-commercial spectrum usage.

Nokia also supports Congress making the SRF more flexible, allowing agencies to fundamentally overhaul how they perform certain services – full modernization rather than a transition to a "comparable capability." Such upgrades could both improve the U.S. capabilities in areas such as war fighting, meteorology, etc., while also increasing the efficiency of spectrum utilization for all commercial and federal services. Additionally, the SRF cannot contribute to freeing up more spectrum for unlicensed use. Under the Commercial Spectrum Enhancement Act, the transitioned spectrum must raise 110 percent of the federal incumbent's estimated relocation costs.

© 2023 Nokia

Nokia recognizes that these are actions that can only be taken by Congress, but until such action, the Administration should consider how it can make the most of the budgetary tools available toward supporting research, analysis, and planning for increased federal-commercial spectrum sharing and re-allocation of federal spectrum.

3.9 Comparing U.S. Spectrum Governance Model with Other Nations

Q9: How do allocations and varying spectrum access and governance models in the U.S. compare with actions in other nations, especially those vying to lead in terrestrial and space-based communications and technologies? How should the U.S. think about international harmonization and allocation disparities in developing the National Spectrum Strategy?

Spectrum allocations should respond to the needs of the nation and its strategic plans. The United States has had a mixed set of results in this matter. We trail many other nations in mid-band spectrum while we lead and spearhead the efforts of taking novel approaches at making spectrum available.

The United States has been behind other nations with respect to the availability of mobile broadband spectrum that combines wide area coverage and capacity, essential for the consolidation and evolution of 5G. Other countries have more spectrum allocated in prime frequency ranges for 5G, such as 3-4 GHz range. Also, European, Middle Eastern and African countries have the possibility of using the upper 6 GHz band (6.4-7.1 GHz) for this purpose, while the U.S. does not. Therefore, considering that the U.S. strives to lead in 5G and 6G, there is a need for a forward looking and transparent process for the allocation of spectrum for mobile broadband in appropriate amount and frequency range.

The United States has been driving and leading the developments on innovative spectrum access worldwide. CBRS with the implementation of a SAS and the AFC to be operational at the 6

© 2023 Nokia

GHz band are examples of this leadership. The multi-stakeholder groups for development of best practices and standards relative to spectrum usage and sharing have been an important pillar for the innovation in the use of spectrum in the U.S.

A best practice example would be from our neighbor to the north. The process put in place by ISED in Canada related to issue of potential interference to aviation radio altimeters operating in the 4.2-4.4 GHz due to 5G operating in the adjacent band (3450-3980 MHz) points to a good direction with respect to transparency. While there is room for improvements in the process, ISED participated actively in a working group involving the interested stakeholders, including receiving technical inputs from the aviation authority, the aviation industry, and the mobile industry, and shared their own technical assessment in detail for open discussion. This led to a resolution acceptable by all parties.

A governance model leveraging multi-stakeholder groups, and involving Federal and non-Federal stakeholders as well as international allies, is advised for the enhancement in the use of spectrum. Economies of scale is a key driver for keeping costs low. Our national spectrum strategy should evolve in synchronization with our allies around the globe to take advantage of diverse perspectives and innovative developments.

© 2023 Nokia

4 Pillar #2: Long-Term Spectrum Planning

4.1 Stakeholder Groups

Q1: Who are the groups or categories of affected stakeholders with interests in the development of the National Spectrum Strategy and participating in a long-term spectrum-planning process? How do we best ensure that all stakeholders can participate in a long-term spectrum planning process in order to facilitate transparency to the greatest extent possible, ensure efficient and effective use of the nation's spectrum resources?

All users of spectrum are stakeholders. Users of spectrum (e.g., including, but not limited to, the federal government, enterprises, network equipment vendors, and commercial service providers) along with regulatory authorities (e.g., FCC and NTIA) and public interest groups (for example, representing consumers) should form the core stakeholder group.

4.2 Timeline for a Long-Term Process

Q2: What type of timeline would be defined as a "long-term" process? What are key factors to consider and what are the key inputs to a long-term planning process? What data are required for planning purposes? Do we need data on spectrum utilization by incumbent users, including adjacent band users, and, if so, how should we collect such data and what metrics should we use in assessing utilization? Do we need information from standards setting bodies and, if so, what information would be helpful and how should we obtain such information? What is the appropriate time horizon for long-term spectrum planning and how often should we revisit or reassess our prior findings and determinations? How do we balance periodic review and reassessment of our spectrum priorities with providing regulatory certainty to protect investment-backed expectations of existing spectrum users? How can federal and non-federal stakeholders best work together?

4.2.1 Key Factors to Determine the Timeline for Long-Term Planning

As a rule of thumb, a 10-year period should be considered as the horizon for the long-term spectrum planning process. As discussed above, the commercial mobile industry typically advances to the next generation of technology and equipment on this 10-year timeline, which is faster than

© 2023 Nokia

other technology platforms that may have lifecycles measured in multiple decades. Nokia respectfully suggests that NTIA develop and revisit its spectrum strategy based on this shorter 10-year duration rather than hold back innovation for technologies that are slower to evolve.

More specifically, there are three main factors to be considered that leads Nokia, on balance, to recommend this 10-year planning timeline:

- **Development lifecycle of standards for next generation technology:** It takes years to develop standards for certain technologies using the nation's spectrum assets. For example, 3GPP-based commercial communication networks standards develop a new generation approximately every 10 years. Technologies using unlicensed spectrum (e.g., WiFi) typically have a shorter development cycle. These lead times for evolution of commercial technologies are relatively short compared to many technologies used by government and other industries. Certain standards evolution for some other industries (e.g., aviation) may take decades.
- **Equipment lifecycle**: Once equipment is operational, it may be in service for a few years or a few decades. There is a need to be cognizant of lifecycles of various equipment – especially those critical to national security and those that require very high initial investments.
- **Lead time to clear spectrum**: Gaining access to spectrum by moving/re-arranging incumbents and completing the process of auction is a challenging process. As more and more spectrum-hungry applications emerge, this will become even more challenging. This is particularly true because demand from different industries is typically high for the same part of the spectrum.

© 2023 Nokia

4.2.2 Information from Standards Bodies Offer Key Data

Standards bodies are good sources for a preview of future spectrum needs. However, that information must be supplemented by expert opinion from different parts of the industry, academia and government agencies.

There is also an acute need for accurate assessment of current spectrum usage by the federal government, including the technical parameters of actual use. Without the proper knowledge of present data, future projections will not stand on solid ground.

4.2.3 Time Horizon for Planning and Revisiting the Spectrum Strategy

As discussed above, Nokia suggests that the timeline for spectrum planning is 10 years into the future. It is recommended that this 10-year plan is reviewed every 5 years, given that the lifecycle of technology keeps getting shorter over time.

4.3 **Stakeholder engagement**

Q3: How can federal and non-federal stakeholders best engage in productive and ongoing dialogue regarding spectrum allocation and authorization, repurposing, sharing, and coordination? Learning from prior experiences, what can be done to improve federal/non-federal spectrum coordination, compatibility, and interference protection assessments to avoid unnecessary delays resulting from non-consensus?

A major hurdle to productive engagement is the lack of information about federal use of spectrum. While FCC spectrum allocation charts capture spectrum *assignments* (i.e., the right to use the spectrum), the real information needed is how much of that allocated spectrum is actually being used, and when used, for how long and in which geography. Without this basic information, any spectrum sharing solution will be sub-optimal.

© 2023 Nokia

There is an urgent need to create a database that includes the technical details of federal spectrum usage. Understandably, some of this information may not be publicly disclosed, but the information must be properly documented for efficient access by authorized personnel. A high degree of collaboration among NTIA, FCC, and DoD and other interested agencies (NASA and NOAA are examples of agencies that rely on spectrum allocations) is essential for this exercise to succeed.

Another matter of key importance is the dissemination of information regarding DoD's (and other relevant agencies') technology evolution roadmap that can potentially free up spectrum currently held by the U.S. Government. It is critically important to share information about the spectrum need specifications of next generation equipment employed by federal users so that the overall use of the spectrum can be optimized.

4.4 Additional Spectrum-Focused Activities

Q5: Are additional spectrum-focused engagements beyond those already established today (e.g., FCC's Technical Advisory Committee (TAC),2 NTIA's Commerce Spectrum Management Advisory Committee (CSMAC),3 and NTIA's annual Spectrum Policy Symposium) needed to improve trust, transparency, and communication among the federal government, industry, and other stakeholders (including Tribal Nations) and why? What would be the scope of such engagements, how would they be structured, and why would establishing new engagements be preferable to expanding the use of existing models? If existing models are sufficient, how (if needed) should FCC and NTIA maximize their usefulness or leverage their contributions to enhance and improve coordination?

Nokia respectfully suggests that the examples provided – TAC, CSMAC, and the Annual Symposium – are valuable engagements but they are limited in what they can accomplish. The result of the TAC and CSMAC are industry recommendations to the government, whereas the Annual Symposium includes both government and industry proposals and panels, but is only one day. What is needed are more sustained "nuts and bolts" exchanges that include NTIA, the government agencies

© 2023 Nokia

that actually use spectrum (DoD, NASA, etc.), and industry. It may be desirable for the government to require an application process by industry participants to allow a greater exchange of potentially sensitive government information related to spectrum use.

The collaboration framework for spectrum sharing in 3.1-3.45 GHz between DoD, NTIA, FCC and commercial entities is working well. The industry stakeholder group, the Partnering to Advance Trusted and Holistic Spectrum Solutions (PATHSS), has been formed in the Regulator Workgroup in National Spectrum Consortium. However, there is always room for improvement.

It is crucial that DoD and the commercial industry are engaged as true partners and carry out a dialogue focused on creating efficiencies within DoD's spectrum holdings. Spectrum sharing collaboration between DoD and commercial services is extremely challenging, given the sensitive nature of the information that may need to be exchanged. But industry experts from both sides need to be involved in creating innovative solutions.

The PATHSS model needs to be assessed for possible further enhancement so that experts have access to the right information and can engage in open, technical dialogue in a classified environment. Currently, this effort is led by DoD but an equal partnership with NTIA and the FCC may lead to a more coherent approach.

4.5 Spectrum Authorization Approaches

Q6: In considering spectrum authorization broadly (i.e., to include both licensed and unlicensed models as well as federal frequency assignments), what approaches (e.g., rationalization of spectrum bands or so-called "neighborhoods") may optimize the effectiveness of U.S. spectrum allocations? Are there any specific spectrum bands or ranges to be looked at that have high potential for expanding and optimizing access? Which, if any, of these spectrum bands or ranges should be prioritized for study and potential repurposing? Conversely, are there any bands or ranges that would not be appropriate for access expansion? What, if any, metrics are ideal for measuring the intensity of spectrum utilization by incumbents in candidate bands?

© 2023 Nokia

4.5.1 Rationalization of Spectrum Bands and Bands with High Potential

It is generally recommended that a national spectrum strategy seek to cluster similar services around similar spectrum bands. Mobile communications – whether over licensed or unlicensed spectrum – have very similar spectrum needs. Similarly, fixed terrestrial services for commercial use are not fundamentally different from fixed terrestrial services for federal use. The same applies to federal/commercial mobile or satellite services.

Having said that, there are obviously special needs that have to be considered. Security/reliability equipment lifecycle needs of federal use may be significantly more stringent than those for commercial use. In-band and out-of-band emission restrictions may have to be more strictly imposed for certain users than others.

As mentioned above, the most critical bands for study in the immediate future are the 3.1-3.45 GHz and 7-15 GHz bands (preferably in the lower part of these range). There is significant interest with sub-THz spectrum (approximately 100 GHz – 1 THz) in the context of future 6G standards. While this spectrum range should be made available for research and experiments, there is less urgency to study this spectrum for widescale commercial use in the next 6-8 years.

4.5.2 Metrics for Assessing Spectrum Usage

A common metric for assessing spectrum usage across various users will require a broad dialogue among key stakeholders. The usages of some applications are routinely assessed as provided in the examples below:

- Mobile broadband service: Operators deploy spectrum to meet local traffic demand. Network measurement data can be used to assess how much traffic is carried over individual spectrum

© 2023 Nokia

bands (i.e., carriers). Overall usage can be measured in terms of traffic per unit geographical area, per unit time, and per unit amount of spectrum.

- Fixed service: Terrestrial point-to-point links are deployed in a geographical area to carry traffic. Often, the number of links per unit geographic area is used as a metric for assessing intensity of spectrum usage. It is also possible to measure the traffic carried over those links per unit time.
- Satellite service: Spectrum usage intensity can be measured referring to the volume of traffic per unit geographical area per unit time.

Measuring most other services, especially for federal incumbent usage, is much more challenging. The use of spectrum for DoD's radar operations, GPS navigation systems, NASA's space research, etc., cannot be measured in simple quantitative terms. At the same time, the national importance of many of these applications is significant and is difficult to assessed through simple scientific or economic statistical data.

It is highly important, however, to focus on developing the metrics. The ultimate goal is to assess whether spectrum allocated to a given user is being utilized in the most efficient way possible. There are many mission-critical uses of federal incumbents that may not be broadly understood by the larger scientific/engineering community, who may be clamoring for release of spectrum perceived to be "underused".

To alleviate these uncertainties and promote mutual trust among diverse communities of spectrum users, Nokia suggests that NTIA convene a workshop involving all relevant parties to develop new ideas. This may lead to the formation of a group that can undertake the task of developing spectrum usage metric that would be acceptable to stakeholders.

© 2023 Nokia

4.6 Spectrum Workforce

Q7: What is needed to develop, strengthen, and diversify the spectrum workforce to ensure an enduring, capable and inclusive workforce to carry out the long-term plans (including specifically in rural and Tribal communities)?

In Nokia's experience, there is an acute need for greater expertise and training in all areas of spectrum research, development, and related services. For the foreseeable future, the U.S. market will require a mix of increased domestic capacity as well as continued support globally to meet substantial near-term demand for wireless equipment components. It is important to build U.S. domestic workforce capacity, but not be so restrictive as to impede near-term U.S. commercial deployments. Nokia therefore encourages NTIA to consider funding projects, including advanced radio technologies, cloud and RAN infrastructure, and AI/ML knowledge and skills, which require (and can spur) an increased U.S. high-tech workforce as well as the global workforce that supports U.S. deployments. Such projects are necessary to drive the demand for increasing the capacity of the spectrum workforce.

To meet the goal of increasing domestic R&D and high-tech manufacturing expertise, Nokia believes that the U.S. government should review its immigration procedures and policy to address near-term workforce challenges. Green cards and H-1B visas, which are typical instruments used by technology companies to fill their employment ranks, often are in short supply. The U.S. government should consider how its immigration policies could better support the goal of maintaining global leadership in technology development and innovation.

© 2023 Nokia

5 Pillar # 3: – Unprecedented Spectrum Access and Management Through Technology

5.1 Innovations in Spectrum Management Models

Q1: What innovations and next-generation capabilities for spectrum management models (including both licensed and unlicensed) are being explored today and are expected in the future to expand and improve spectrum access (and what are the anticipated timelines for delivery)?

Please refer to our response in section 3.5 (Spectrum Access Management). Many of the technology underlying next-generation spectrum access models are quite mature, such as Block Chain/Digital Ledger.

5.2 Policies for Innovative Spectrum Use

Q2: What policies should the National Spectrum Strategy identify to enable development of new and innovative uses of spectrum?

Nokia encourages the Administration to put policies in place that encourage a baseline level of performance of receivers, both for new entrants as well as potential upgrades for incumbent services. The mobile industry has consistently demonstrated that it is very much motivated to create and adhere to its standards with respect to receiver interference immunity performance. Other industries using spectrum will also likely have their own incentives to meet technical requirements in order to function efficiently. It would be helpful for the FCC and/or the NTIA to form and lead an industry forum involving all relevant parties (both federal and non-federal) to agree upon a common set of requirements and a roadmap for receiver performance parameters. This multi-stakeholder group should drive the interests of all parties, so a range of interests are considered in advance of new spectrum allocations and new service deployments. A timely example is currently operational in

© 2023 Nokia

PATHSS where stakeholders from the commercial industry and federal agencies are collaborating to explore coexistence of different services in the 3.1-3.45 GHz spectrum band.

5.3 **Role of Government in Promoting New Techniques**

Q3: What role, if any, should the government play in promoting research into, investment in, and development of technological advancements in spectrum management, spectrum dependent technologies, and infrastructure? What role, if any, should the government play in participating in standards development, supporting the use of network architectures, and promoting tools such as artificial intelligence and machine learning for spectrum coordination or interference protections? What technologies are available to ensure appropriate interference protection for incumbents in adjacent bands? What spectrum management capabilities/tools would enable advanced modeling and more robust and quicker implementation of spectrum sharing that satisfies the needs of nonfederal interests while maintaining the spectrum access necessary to satisfy current and future mission requirements and operations of federal entities? How can data-collection capabilities or other resources, such as testbeds, be leveraged (including those on Tribal lands and with Tribal governments)?

5.3.1 Role of Government

Industry-led voluntary approaches should be the fundamental building block for developing new technology. Government-led policy directives and guidance could be beneficial when paired with these industry-led approaches. Nokia does not believe the government needs to be involved directly in developing standards or new technologies, although incentives will certainly encourage advancements. Playing an active role in bringing stakeholders together will be very helpful. At the same time, there should be consequences of using outdated equipment that limits maximization of spectrum utilization (e.g., decades-old altimeters in airplanes). It would also be desirable to provide federal entities incentives for upgrading equipment on a shortened refresh cycle not only to increase spectrum efficiency but to improve performance of mission.

© 2023 Nokia

5.3.2 Technologies for Interference Protection in Adjacent Bands

The commercial mobile industry is leading the way for protecting users in adjacent bands. Transmitters manage their out-of-band emissions very strictly and receivers reject signals from adjacent bands with equal adeptness. Other industries using spectrum bands adjacent to commercial mobile should take advantage of the maturity in commercial industry and set pace for their own industries. As an example, the aviation industry can leverage advancements in receivers in commercial mobile equipment and use relevant components in their altimeters.

5.3.3 Models/Tools for Spectrum Management

Several promising tools/models for better spectrum management between federal and non-federal users are being investigated in PATHSS. The three main techniques are described below:

- **Dynamic Spectrum Management:** This is a stand-alone system that is aware of different user's spectrum needs and acts as an arbitrator to allocate spectrum dynamically (in time, frequency, geography and power domains) based on predefined guidelines.
- **Active RAN**: Commercial systems sense the presence of federal usage and adjust their emissions to avoid interference.
- **Federal mitigation**: Federal systems are aware of commercial usage and leverage the prior knowledge to operate within the constraints.

5.4 Role of the IIC

Q4: NTIA is pursuing a time-based spectrum sharing solution called the incumbent informing capability (IIC) to support spectrum sharing between federal and non-federal users.4 What are some recommendations for developing an enduring, scalable mechanism for managing shared spectrum access using the IIC or other similar mechanism, with the goal of increasing the efficiency of spectrum use? What challenges

 © 2023 Nokia

do non-federal users foresee with potentially having limited access to classified or other sensitive data on federal spectrum uses and operations as part of the IIC or similar capabilities, and what recommendations do users have for ways to mitigate these challenges? What are the costs and complexities associated with automating information on spectrum use?

5.4.1 Applicability of IIC

In principle, IIC is a very commendable way of sharing spectrum between federal and commercial users. In many federal applications, spectrum is not used 24X7 over an entire geographical area. There are often great opportunities to share spectrum across both geographical and temporal domains. While an early incarnation of this technique was observed with SAS in CBRS, there is a lot of room for improvement based on the learnings from that experience.

Non-federal users do not need access to sensitive classified information. The only thing they need is the ability to use the spectrum most effectively. If we can develop a system that will develop trust between federal and non-federal users that spectrum is being allocated for the optimum use by both parties, that should cross the main hurdle. In the process of developing the IIC system, there should be transparency about how the system is allocating spectrum for different users.

© 2023 Nokia

6 Conclusion

Nokia thanks the NTIA for the opportunity to comment in this proceeding and looks forward to continuing to work with the U.S. Government to develop and implement a National Spectrum Strategy for the United States.

Respectfully submitted,

Nokia

/David Bartlett/

David Bartlett
Amit Mukhopadhyay
Jeffrey Marks
Grace Koh

Nokia
1200 G Street, NW
8th Floor
Washington, DC 20005

April 17, 2023

© 2023 Nokia