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Request for Information on the National Spectrum Research and Development Plan

Ericsson

Ericsson Response: Request for Information on the National Spectrum Research and Development Plan

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Introduction

As a leading global mobile networks vendor, and a clear leader in the United States, Ericsson appreciates the initiative of the US Government in creating this opportunity to respond to the request for information on the nation's R&D plan for spectrum.

Our response to the RFI will be guided by our perspective as a mobile network vendor: we view spectrum as the critical means to an end, which is the successful deployment of competitive nationwide scale networks. As we continue to expand the reach of 5G into so many spheres of society and industry and prepare to transition to the next generation, a comprehensive approach to identifying a spectrum pipeline for mobile services remains important.

The key to successful deployment in any spectrum band is competitive and cost-effective performance in terms of capacity, coverage, service continuity, and quality of experience. The service expectations of end users, the operators' customers, are the same regardless of spectrum band or operational mode or regulation and will only get higher. Since the introduction of digital cellular communication technologies in the early 90s, traffic on commercial mobile networks has grown exponentially. This growth is aided by a value chain which benefits from a virtuous cycle that encompasses regulators, technology developers, service providers, and end-users.[1] Digital communication has enormous benefits for economic productivity in a variety of sectors of society and industry. The humble mobile telephone network has evolved into an extension of the Internet, spanning economic sectors such as entertainment, industry, telecommunications, finance. Mobile technologies are well along the way in assuming critical functions that impact public safety,

[1] The term "technology developers" includes participants such as chipset vendors, equipment providers, hyperscale cloud providers, and application or content developers. Service providers likewise includes connectivity providers and application service providers such as media distribution companies, web services, telecommunications operators, etc.

peacekeeping, utilities, automation, and transportation. Our business and that of the mobile telecommunications industry in much of the world depends on the regulatory and policy mechanisms that can free up spectrum for mobile services.

Demand for mobile services grows unabated, and more spectrum is needed in the UHF and centimetric ranges between 3.1-8.5 GHz in the nearer term in the 5G era, and within the 7-15 GHz ranges in the longer term to secure success in the 6G era and beyond. We expect that radio spectrum will be made available under a variety of regulatory regimes, including ones that require sharing, and in a variety of bands that preferably are concentrated mostly in the centimetric wave bands below 8.5 GHz, but also include suitable bands extending beyond 8.5 GHz into the millimeter wave regions. Indeed, there is academic interest in studying even sub-THz spectrum above 100 GHz; fundamental technologies and use cases must however mature further.

Successful deployment in a band validates the business case of our operator customers for deploying in it, and their investment in spectrum licenses and in equipment. It also means good business for us as a network vendor, and our own investment into technology, products, and services to support the deployment. The same holds true for the terminal side. In addition, end user demand is satisfied with the right expectations. At the same time, successful deployment translates into high utilization of precious spectrum, which is a scarce national resource. Thus, there is alignment of incentives among the end user, the operator, the network vendors, terminal vendors, and the government, which is a clear start for ultimate success.

1 Q1: Strategies for conducting spectrum research

Innovation in spectrum sharing technologies is driven by conflicting demands placed on spectrum by multiple services, all of which have availed of greenfield spectrum in the past. It is natural that the search for spectrum for mobile services will seek bargains from other services already assigned to a band of interest, often to federal users. The NTIA National Spectrum Strategy (NSS) prescribes consideration of dynamic spectrum sharing to improve the efficiency of use of spectrum among wireless networks and other services. A definition for dynamic spectrum sharing appears at the end of this paper.

Ideally, the sharing regime should maintain the performance of licensed spectrum with full-power and wide-area coverage, offer global scale to products, and follow standardized solutions. The presence of mobile networks in a band will involve some interference to other services sharing the band; co-existence studies should reach reasonable accommodation on the noise rise to those users. If necessary, sharing must include a plan to upgrade those users with poor receiver immunity specifications. At a high level, research should address the requirements to be met by all services.

We assume that the primary motivation behind sharing is to provide shared access to spectrum to commercial mobile networks and one other or more Radio Service(s), e.g. commercial mobile network and satellite, fixed services, earth exploration/space services, radiolocation, or radionavigation. Often, sharing of spectrum may involve granting priority to one service or the other and may require protection of one or more services separated by frequency, space, or time of use. This is the essence of the dynamic behavior sought.

In our view, a fundamental challenge is how we may maximize network performance subject to those constraints without compromising the mission of other services that may be interfered by network operation. This challenge will be answered differently in the shorter term and longer term.

1.1 Near-term Approach: The Mobile Network is already very capable

One of the first actions to support spectrum R&D decision making is the necessity to quantify current spectrum usage to determine the extent to which the spectrum is being used through surveys and/or analyses. R&D plans should consider whether incumbents plan to upgrade or can be upgraded and ensure that incumbent systems use commercial partners and standards where possible. Spectrum R&D should also consider investing in and promoting incumbent technology advancements in spectrum utilization as appropriate. Assessments should also examine the possibility of improving cost-effective spectrum access by existing services by looking at the potential of band segmentation or relocation.

Ericsson recommends R&D decisions that incorporate the capabilities of mobile technologies to the utmost. 5G NR has been developed with a host of features that can be configured and repurposed in novel ways to build efficient solutions that can be deployed quickly. One strength of mobile technologies is the ability to operate over multiple bands using dual connectivity or carrier aggregation. Combining shared spectrum with one or more exclusively licensed bands is a quick way of implementing services by offering the network a way of gracefully accepting degraded capacity without outage to customers. Transmit power control, antenna tilt adjustments, or powering off sectors or sites allows higher priority users protection through coordination. Many of these features may be implemented without changes to mobile standards and with a cost that the industry is willing to assume.

As an immediate step, the spectrum R&D plan should expediently consider the reduction of Dynamic Protection Areas in CBRS band and Cooperative Planning Areas in the AMBIT band with better methods for coordination with incumbent systems.

1.2 Long term approach: Innovative spectrum sharing solutions

In the longer term, basic academic and industrial research can be matured to the point where its outcomes can be adopted in standards, be industrialized into viable products, and eventually deployed. We hope that the shorter-term solutions will provide a solid foundation for later advances. This incremental approach has served mobile networks very well.

We foresee exciting possibilities for research. We believe that spectrum sharing modes and the technologies to enable sharing go hand in hand. In terms of spectrum, we look forward to new sharing modes that blur the differences in performance between shared and unshared spectrum and offer the benefits of both. New information sharing mechanisms between the network and the other services can be developed. Revolutionary changes to the network's higher and lower layers, including transmit and receive techniques can be adopted.

1.3 Sharing Conditions

We believe the pressing need is for sharing spectrum between a network and an incumbent system under specific conditions. The industry seeks to prioritize operation with high power. Spectrum sharing becomes necessary when previously allocated services cannot be relocated or decommissioned. Consequently, there are inevitable constraints on the network to protect the incumbent, compared to exclusive licensing of the same spectrum. In our view, a fundamental challenge is how to maximize network performance subject to those constraints.

Ideally, the sharing regime should maintain the performance of licensed spectrum with full-power and wide-area coverage, offer global scale to products, and follow standardized solutions. At a high level, research should address the requirements to be met by all services with a level of information sharing that engenders trust and confidence between the participants in a sharing regime.

1.4 US research and development funding

At Ericsson, we have generally had distinct approaches to government-funded research and to government-funded development. We are very comfortable with collaborative research, where the open exchange of ideas is an existential need. We provide funding and equipment to a number of US research programs and university collaborations. We may consider programs where we receive small amounts of funding for our own research in the future.

We are cautious about funding for development, where we focus on building competitive products on a global scale. We thrive in open competitive markets, and indeed we are the clear leader in the US. We are wary of funding for development potentially creating product subsidies and market distortion.

1.5 US research organization

We are very encouraged by the resurgence of investment in wireless research in the US, which we view as highly overlapping with spectrum research. In the big picture, we do not see a need to fundamentally change the way research is organized in the US. Our position is to find opportunities which match our interests and engage with them on their own terms.

Ericsson is highly active in the US research community with the broad goal of energizing research towards 6G and beyond. To that end we have multiple strategic engagements with government, academia and industry that all build towards that goal. We have a number of ongoing bilateral university research collaborations, including UT Austin, MIT, Stanford, NYU, UC Berkeley, Rutgers, and most recently Princeton. We are partners in several NSF programs, where we provide funding and equipment: NSF RINGS program, the NSF FuSe program, and its follow-up in planning, FuSe2; and PAWR, where we provide network equipment to the ARA and AERPAW testbeds. We are participating in several project proposals under the DoD MEC hub program. We are part of a team that won an award for an Open RAN testing lab from the NTIA Public Wireless Supply Chain Innovation Fund. We served on the advisory board of the DARPA spectrum sharing challenge. We are very active in ATIS NGA, including leadership positions and contributions to many activities.

1.6 Spectrum research and standards

Along with its renewed interest in wireless and spectrum, the US Government has also highlighted the need for increased participation in standards. The National Standards Strategy for critical and emerging technology was issued in 2023, with communications and networking technologies listed first among eight focus areas. It follows naturally that one desired outcome of spectrum R&D is to influence future standards. The work towards 6G is in its early stages in bodies such as ITU-R and 3GPP, with full specifications expected around 2028 and first deployments around 2030. While standards evolve over several releases within a mobile generation, including 6G, there is some urgency to engage in spectrum R&D now to reach actionable results that can impact future standards in a few years.

2 Q2: Recommended priority areas for spectrum R&D

2.1 Spectrum Utility

This is not just a measure of how many services can be allocated in the same frequency band but must include an economic understanding of associated business models for network services and of incentives for investment under various options for utilizing spectrum.

2.2 Automatic and rapid interference mitigation

When spectrum sharing is considered, studies will have to consider dependencies that cannot be codified in a single systematic solution. Instead, unique sharing criteria will need to be researched and developed. In general, sharing will depend on a framework that requires two major facilities:

1. Information exchange interfaces that can provide situational awareness of the environment based on location, time, frequency band, and transmission characteristics of any signal relative to the impacted receivers. Information exchange can be slow, such as from geolocation-aided policy servers, or fast, such as with sensors located at the network edge.
2. Functional ability to alter the behavior of one radio service in order to share spectrum with another radio service, and additionally to mitigate the effects of mutual interference.

2.3 Modeling for coexistence analysis

Every use case is unique and the quality of information about another radio service will determine the effectiveness of the methods possible. Information sharing between stakeholders is critical. Co-existence studies should reach reasonable accommodation on the noise rise to each service and consider upgrading those users that have poor receiver immunity. Studies should aim to maximize spectral efficiency and ensure that spectrum is used to its highest degree by all stakeholders.

2.4 Sharing Scenarios

Many bands will require sharing with satellite communications. The graphics in **Error! Reference source not found.** illustrate typical approaches to sharing that may be employed in a variety of binary sharing scenarios; often, the sharing needed is based on mere geographic separation of services. Temporal adaptivity may be considered under rare circumstances.[2]

Some sharing situations of interest involve compatibility with fixed services or radiolocation. It is noteworthy that radiolocation alone among the above examples is where real-time agility in dynamic adaptation of spectrum use by the mobile network may be imagined. Notification

[2] Consider combating the effects of temporal propagation changes that may occur due to atmospheric changes that alter long signal paths, e.g. through ducting.

between such radars and mobile systems is a recommended priority area for advancing the art and for implementation in a testbed.

Research should clearly identify all situations that benefit from dynamic spectrum sharing and then whether real-time dynamic adaptation in networks offers a cost-effective method of sharing spectrum at scale. In the case of terrestrial radar, the network may be designed to adapt to the cadence and duty cycle of some classes of radars. In the case of mobile radar platforms, dynamic approaches may need to adapt to radar platform mobility as well. Research should consider the practicality of homogeneous behavior in equipment versus whether adaptation will have many flavors. Lastly, studies should adopt a mission-oriented systems approach to network design and develop interference mitigation strategies to provide reliable connectivity.

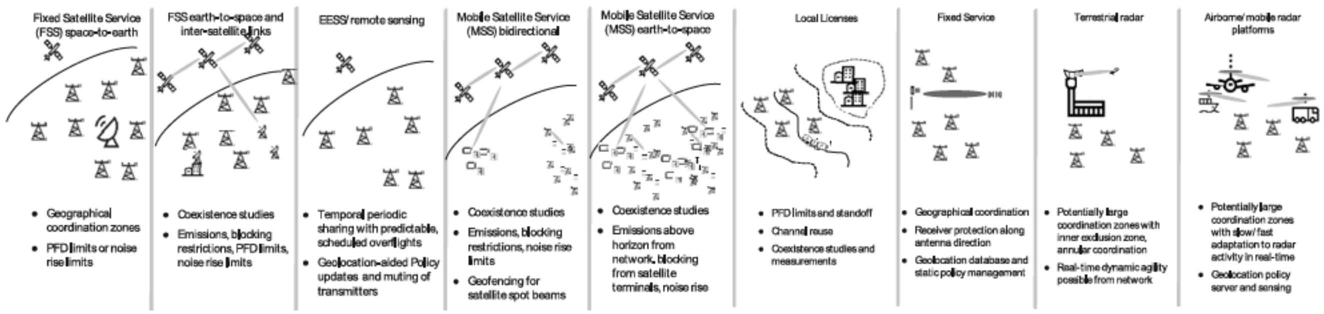

Figure 1 Sharing spectrum in diverse situations with potential mitigation approaches; the provided scenarios are representative and not comprehensive.

3 Q3: Grand challenge problems for spectrum R&D

Ericsson supports grand challenges focused on dynamic spectrum sharing between a mobile network and several types of incumbent systems. The demand for spectrum is increasing and, in some cases, dynamic spectrum sharing could permit balanced access to spectrum by the incumbent and mobile networks. In a multi-year challenge, the degree of difficulty could be ratcheted up every year. For instance, better modeling of the dynamism of the incumbent system could be considered. Understanding the relationship between the granularity of information exchange between the services and the corresponding performance benefit is key to the ultimate success of spectrum sharing.[3]

We see such a grand challenge as one important component in an overall concerted effort on spectrum research, as exemplified by our partnerships and collaborations in an earlier section.

Below are a few topics that can be investigated, e.g. in an NSF program, relating to spectrum and sharing in particular.

3.1 First Step: Network Management and dynamic spectrum sharing

Network management is most efficient in a steady state and needs relatively stable resource availability. Network management is also most effective over time frames that can maintain

[3] We note that information exchange was a part of SC2 but wasn't quite developed.

stability by moving users to stable alternative resources, reallocating policies across use cases, and accepting degraded performance without compromising service continuity. Fast-varying reconfiguration of resources may keep the network in an inefficient transient state.

Network management is currently designed to optimize performance given available resources. Sharing resources can vary in time more or less quickly. One research topic is to investigate how to evolve network management to be able to provide stable and effective operation with time-varying resources.

3.2 Further Efforts: Time dynamic sharing

In the case of periodic or intermittent dynamic incumbent activity, agility is needed in response while protecting the incumbent. The degree of dynamism of spectrum occupancy by the incumbent may be caused by physical motion, e.g. airborne or maritime radar and by its signal occupancy in time, frequency, or space, e.g. rotating radar beam.

Consider an airborne radar, with a sweep cycle of the order of seconds and a narrow beamwidth of a few degrees out of 360. A ground location is in the main lobe of the beam for the order of, say 100 ms out of 10 s. Given a rough timing of the incoming beam, and a safety window of e.g. 1 s, the network could operate there for 90% of the cycle. Carrier aggregation with one carrier in the shared band and one in a band exclusive to the network can maintain continuity of service with the exclusive carrier during the 1 s window.[4] In contrast, precise timing of the incoming beam for simultaneous operation on the shared carrier would require enormous complexity for little additional gain and no applicability in most bands.

Effective management of radio resources in wireless networks is best done with local action for rapid response and long-distance external information interfaces for policy and license management. This has the benefit of design aligned with the global market. External information interfaces can provide semantic data on imminent events and protection requirements that instruct local mitigation measures. Research should hew to those principles, thereby ensuring empowerment and autonomy of the network.

3.3 Incumbent physical motion

In the case of low earth orbiting satellites and mobile radar platforms like airborne radar, the motion of the platforms is relatively irrelevant at the time scale of the network, e.g. an airplane with a radar moves across 10 cm in the duration of a 5G NR scheduling slot. However, the lack of full-duplex capability can make detection of radar challenging at the base station in TDD bands. Antenna down-tilting reduces observability at or above the horizon. UE based sensing should be studied in the context of near- and long-term solutions. Satellites can move relative to the earth's surface as well but usually do so in a predictable and periodic manner.

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[4] Here we ignore the movement of the plane, which is very slow compared to the beam sweep. The speed of the plane affects the length of the radar event, which is of the order of 100's of seconds.

3.4 Modeling

While empirical propagation models are a great tool for understanding the potential of sharing, a statistical model does not match reality. Bias often occurs from risk-averse requirements and absence of customized modeling. These phenomena should be studied.

Research can consider how situational modeling of the observed environment can be blended with tools like ray tracing. Such techniques show great promise in considering actual performance in the field and can be subject to adaptive modeling and simulation. Additionally, it is important to model traffic in mobile networks realistically, recognizing the reality of sparse use of network resources as opposed to continuous loading of a channel with energy and its relation to interference.

3.5 Sensing

Sensing of interference is possible in situations where a service is capable of monitoring use of spectrum by another service. There are two possible approaches. Operation of services like radar may be amenable to sensing within the mobile network deployments; these abilities are a great fit for 6G integrated sensing functions. Receivers for satellite transmission might benefit from monitoring detectable increases in noise level at the site of their antennas. In the former case, systems should aim to get real-time notification from sensors integrated into network components or by sensor functionality that can interface with the RAN spectrum management function. Integrated sensors in base stations and user equipment are appealing for the reuse of the network components. External sensors may be near-term solution before the 6G timeframe. A sensing function like the ESC in CBRS would need time to convey information about measured interference that is worthy of network reconfiguration; action would be decidedly less agile in those cases. Research should also consider security implications of the use of sensors; mere sensing of energy at the network can be exploited by malicious actors.

4 Q4: Spectrum R&D accelerators

4.1 Data Management

The US Government should recreate an improved spectrum dashboard that clarifies actual use of spectrum bands wherever regulated radio services are in operation. Public data sets should be made available, including information about equipment in service, allowing for embargo of sensitive information.

4.2 Spectrum Competitions and Challenges

The Spectrum Challenges culminating in SC2 were an excellent approach to “gamification” of research efforts with the Colosseum testbed as a platform for comparative evaluation. The approach does have limitations; however, it is worth looking at rapid evaluation of competing approaches tuned to well-designed objectives.

4.3 Testbeds for Spectrum R&D

In addition to our support for the PAWR program mentioned earlier, we also support the OpenAirInterface Software Alliance (OSA) and serve on its board. Open-source stacks such as OAI allow researchers to delve deep into and modify network stacks at will. Testbeds that employ software defined radios show great promise but tend to be expensive to construct and operate.

Flexibility and visibility can also make it difficult to add complex functionality to testbeds. In PAWR, it has been a struggle to incorporate advanced beamforming and antenna arrays with flexible MIMO functionality. The Colosseum channel emulator also does not support large arrays. In-line emulation in digital twin environments offers good potential in conjunction with ray-tracing and advanced modeling as mentioned earlier.

In our opinion, it is better to aim testbeds towards the future, focusing on key experimental capabilities that facilitate the advancement of spectrum research, with all the flexibility and observability needed. A testbed focusing on current technology would have a hard time keeping up even with current commercial deployments.

We offer the following recommendations for future spectrum testbeds:

- Aim new testbeds towards the future, focusing on key experimental capabilities that facilitate the advancement of spectrum research. Dedicate new funding to focus on specific features that advance spectrum research.
- Reuse existing testbed infrastructure and strengthen its remote access capability. Proliferation of testbeds would dilute effort and slow progress.
- Build a new channel emulator that can scale with array size and number of nodes, relying on ray tracing techniques and digital twins of arrays.
- Adopt a common data model with detailed meta-data with associated software tools to facilitate usage by researchers in off-line experiments. Facilitate data collection with offline processing, rather than complete networks with real-time processing.

5 Q5: Immediate and near-term federal activities

The R&D plan should not stop the government from establishing a clear pipeline for spectrum availability for 5G and eventually for 6G. Apart from spectrum in the lower 3 GHz band, 7.125-8.5 GHz, and 12.7-15.35 GHz,[5] the government should also commit to examining the potential of the 4.4-4.94 GHz band. Near term activities are further detailed in Section 1.1.

6 Q6: Process to refine and enhance R&D plan

We recommend forming a committee composed from Industry, Academia, and Government representatives to review and further adjust the R&D plan. We emphasize the necessity to have industry involved.

7 Definition: Dynamic Spectrum Sharing

Dynamic Spectrum Sharing is the ability of two or more radio services operating across the same frequency range to adapt efficient utilization of that range in time, frequency, or space such that they can each provide their intended service in a cost-effective manner with minimal performance degradation or interference caused to other services in the range.

[5] This includes the recent FCC intentions to allot 12.7-13.25 GHz and potential spectrum in the 14 GHz range.

8 Conclusions

We reiterate that while the RFI addresses research and development, actions towards meeting immediate spectrum needs of the national telecommunication infrastructure should not be paused in anticipation of research outcomes. Academic work develops fundamental expertise, while testbeds expose possibilities that may be considered within standardized solutions.

Ericsson is a leader in its industry and devotes a substantial number of resources to R&D. Our expertise will be critical as the US considers new ways to access spectrum to meet traffic demand. The mobile industry depends on adequate spectrum availability to support cost-effective connectivity for all, including national imperatives around reliable public safety services and critical use cases supporting automation across major societal and industrial sectors. Securing a clear spectrum strategy that creates a pipeline of bands is an economic and national security imperative.

We have organized our recommendations into immediate, shorter term, and longer-term steps, and provided more details about the longer term, where R&D can be more ambitious and open ended. We expect shorter term solutions to be as simple as possible, exploiting the advanced features that already exist within mobile standards. Ericsson is committed to support the advancement of spectrum sharing as one solution to ensure a consistent and reliable access to spectrum.

ABBREVIATIONS

Abbrev.	Description	Abbrev.	Description
AERPAW	Aerial Experimentation and Research Platform for Advanced Wireless	NR	New Radio
AMBIT	America's Mid-Band Initiative Team (3.45-3.55 GHz)	NSS	National Spectrum Strategy
ARA	**A**gricultural and Ru**ra**l Communities	O-RAN	Open Radio Access network
CBRS	Citizens Broadband Radio Service	OAI	Open Air Interface
CISE	Computer and Information Science and Engineering	OSA	OpenAirInterface Software Alliance
DARPA	Defense Advanced Research Projects Agency	PAWR	Platforms for Advanced Wireless Research
EESS	Earth Exploration and Space Services	PFD	Power Flux Density
ESC	Environmental Sensing Component	R&D	Research and Development
FSS	Fixed Satellite Services	RF	Radio Frequency
FuSe	Future of Semiconductors	RFI	Request for Information
MIMO	Multi-Input Multi-Output (antenna)	RINGS	Resilient Intelligent Next Generation Systems
MSS	Mobile Satellite Service	SC2	Spectrum Challenge 2