Spectrum Sharing Approach: Turkey Model Proposal

Submitted: 14 March 2023
Reviewed: 30 May 2023
Revised: 14 June 2023
Accepted: 17 June 2023

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Article submitted to peer blind review

DOI: https://doi.org/10.26512/lstr.v16i1.47566

Abstract

[Purpose] Spectrum is a scarce and valuable national resource. With 5G, it is predicted that the demand for spectrum will increase gradually. In order to overcome the increasing data traffic problem and connection needs, the spectrum should be used as efficiently as possible. This paper aims to develop a new perspective on spectrum management in Turkey, and the applicability of spectrum sharing applications in Turkey has been investigated. Suggestions were made regarding the changes that can be made in the current legislation.

[**Methodology/Approach/Design]** Within this study, interviews were held with the three leading mobile operators in Turkey through focus group discussion, and evaluations were made about the approach of Turkey's mobile communication sector to the subject. In addition, innovative spectrum management practices in Europe and United States (US) regarding the emerging spectrum sharing approach were examined. The current practices of European countries were presented in the semi-structured interview via e-mail.

[Findings] This paper provides opinions of Turkish leading mobile operators about spectrum sharing, current EU and US practices, and necessary changes in Turkish legislation to enable spectrum sharing. A new perspective on spectrum management in Turkey has been developed, and the applicability of spectrum sharing applications in Turkey has been investigated. Suggestions were made regarding the changes that can be made in the current legislation.

[Practical Implications] What outcomes and implications for practice, applications and consequences are identified? How will the article impact on society, business, or enterprise? What changes to practice should be made as a result of this research? What is the legal or economic impact?

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[Originality/Value] This paper fulfills the need for originality and presents new knowledge about spectrum sharing in Turkey's telecommunication sector.

Keywords: Spectrum Sharing. License Shared Access. Telecommunications. 5G.

INTRODUCTION

Spectrum is a scarce and valuable national resource. With 5G, it is predicted that the demand for spectrum will increase gradually. The spectrum should be used as efficiently as possible to overcome the increasing data traffic problem and connection needs. With current spectrum allocation methods, accessing the spectrum under 6 GHz is challenging, which is vital for 5G. The importance of supporting the increase in data traffic has been demonstrated in various studies in the literature. For example, the British regulatory administration The Office of Communications (OFCOM) has suggested that if the spectrum planned to be allocated to mobile broadband services in the UK by 2030 is allocated as planned, mobile data traffic will increase 71 times. If this allocation is not realized, it can increase by a maximum of 30 times (Ofcom, 2016). Depending on not providing enough spectrum to the mobile operators, this situation can be interpreted as being deprived of the economy associated with the spectrum.

To overcome these spectrum scarcity problems and meet the spectrum demands of future applications, it is necessary to develop and use innovative spectrum access technologies and adopt new regulations and institutional frameworks that can maximize the effectiveness of these technologies (Park et al., 2014).

The increasing use of radio-based technologies by society and the opportunities for social development provided by these technologies underline the importance of radio frequency spectrum and national spectrum management. The advancement of technology necessitates various modern spectrum applications increasing the demand for limited resources. Increasing demand requires efficient use of spectrum and implementation of effective spectrum management processes (Peha, 2009).

SPECTRUM MANAGEMENT APPROACHES FROM PAST TO PRESENT

The ‘command and control’ approach, the traditional spectrum management approach, has recently been adopted by spectrum regulators as the only management style (Prasad and Sridhar, 2013). According to this approach,

the use of most bands is allocated to certain technologies and services, preventing the bands from changing hands in secondary markets. This method is effective in situations and times with few users and low-frequency usage. The emergence of new technologies and the use of the traditional approach, together with the changes in user demands, have limited the effective and efficient use of spectrum, which is the main principle of spectrum management, and it has become necessary to remove the restrictions on the use of spectrum. Otherwise, there will be a slowdown in technological innovations in the electronic communication sector and inefficient spectrum use. In this context, it is recommended to reduce the role of the regulatory authority and encourage the licensee to decide how the spectrum will be used (Prasad and Sridhar, 2013).

Towards the end of the 20th century, spectrum access and spectrum access conditions began to be regulated. The regulatory intervention has been seen as crucial to tackling the problem of interference due to the increasing number and variety of radio-based services (Durantini and Martino, 2013). Over time, three main generations of radio spectrum management have evolved. On the contrary, rather than a complete separation between the generations in question, their application provides benefits in meeting the various needs of various technologies and services. Table I (Massaro, 2017) lists some critical differences between the three generations. As seen in the table, there are some critical differences between the three generations regarding policy objectives and regulatory approaches, particularly regarding allocation procedures and spectrum access.

	First Generation	***Second Generation***	***Third Generation***
Policy Objectives	Avoid from Interference International Harmonisation	Efficient Allocation (Static Efficiency)	Innovation and Investment (Dynamic Efficiency)
Regulatory Approaches	First Come, First Served Beauty Pageant Approach	Market-based Tenders Secondary Trade	Technology-Based Leasing License Exempt
Spectrum Access	Individual Exclusive Access	Individual Exclusive Access	Individual Shared Access

Table 1 - Overview of Spectrum Management Generations

The first-generation spectrum management approach (administrative approach) aims to minimize the risk of interference and to use the radio spectrum in an internationally harmonized manner. The use of an internationally harmonized spectrum has been encouraged from the beginning of spectrum regulations to take advantage of the benefits brought by the standardization of technologies and economies of scale in device production (RSPG, 2014). This regime is administratively based and provides limited central planning and regulatory decision-making flexibility.

The primary policy objective of the second-generation spectrum management approach (market-based approach) is to increase static efficiency and guarantee a more efficient radio spectrum allocation. This regulatory approach to the radio spectrum has shifted its axis towards meeting market needs rather than focusing on central planning. Spectrum usage rights have started to be allocated through auctions, and licenses have been awarded by tender procedure between competing candidates. In this approach, the bidder who bids the highest monetary amount generally gets the license. The most important advantage of the auction procedures is that the licenses are allocated to the highest bidder users, and these users are expected to be the users who give the highest value to the spectrum (Cave and Doyle, 2007).

The third-generation spectrum management (technology-based approach) focuses on technological development, unlike previous generations. According to this approach, it is necessary to develop and use innovative spectrum access technologies and adopt new regulations and institutional frameworks that can maximize the effectiveness of these technologies. In particular, policymakers and regulators in the EU and the US are working on new spectrum sharing regulations that will allow joint access on a licensed basis.

This study examined the change in spectrum management paradigms from past to present, and new approaches adopted in spectrum management have been revealed. Then, interviews were held with the experts of the three leading mobile operators in Turkey through focus group discussion, and evaluations were made about the sector's approach to the subject. In addition, a semi-structured interview was conducted via research and e-mail to have information about European countries' current spectrum sharing practices.

Within the scope of the studies above, a new perspective has been developed in spectrum management in Turkey. Suggestions were made regarding the changes that can be made in the current legislation. In addition, as an additional suggestion, the basic scheme of the technical infrastructure that will enable spectrum sharing applications has been created, and the working logic has been explained.

SPECTRUM SHARING

What is Spectrum Sharing?

Spectrum sharing is the simultaneous use or joint use of a fixed radio frequency resource by several independent users in a given geographic area.

In spectrum sharing, users with different access priorities share a common resource, the spectrum, in a predefined hierarchy. Spectrum sharing allows heterogeneous wireless networks to coexist and dynamically access the same spectrum resource (Zou, 2017). In spectrum sharing, a heterogeneous mix of wireless systems consisting of different access priorities, quality of service (QoS) requirements, and transmission characteristics must coexist without causing harmful interference to each other.

Overview of Spectrum Sharing Practices and Regulations

Determining radio frequency bands suitable for spectrum sharing in the EU is one of the main objectives of the Radio Spectrum Policy Program (RSPP) (EC, 2012). In the EU, two alternative sharing approaches are encouraged: Collective Use of Spectrum (CUS) and LSA (License Shared Access). The main difference between these two approaches is the type of authorization applied. Service providers are subject to a general authorization type under the CUS approach and an individual authorization type under the LSA approach (RSPG, 2011). The spectrum can be used without obtaining an individual license in the general authorization type. Everyone can access a certain spectrum band as long as compliance with predefined conditions is guaranteed. However, no protection against interference can be claimed, and users are not asked to coordinate themselves.

In the US, to ensure more efficient use of spectrum and to provide sufficient spectrum to support the increase in wireless data traffic, the FCC (Federal Communications Commission) launched the 3.5 GHz Citizens Broadband Radio Service (CBRS) service, paving the way for nationwide dynamic spectrum sharing (FCC, 2019).

Spectrum Sharing in Turkey

In the second paragraph of Article 40 of the Electronic Communications Law numbered 5809 of Turkey, titled "Spectrum monitoring and control", it is stated that "The institution shall ensure that the allocated frequency, when necessary, for the effective and efficient use of frequencies with spectrum management, including spectrum planning, frequency allocation and registration, and pricing. It is authorized to make the regulations required by the spectrum trade, including the repurchase and resale of the spectrum, as well as the monitoring and inspection of the spectrum by regulation." Although it has been

stated that the Information and Communication Technologies Authority (ICTA) is authorized to make the necessary regulations regarding spectrum trading, there is no provision in the law regarding spectrum sharing.

Beyond that, regarding spectrum sharing, in the National Broadband Strategy and Action Plan (2017-2020) (UAB, 2017), it is stated that "In areas where three operators do not see commercially profitable to prevent repetitive investments and to prevent waste of resources, coverage of divided highways, highways, tunnels, conventional train lines, high-speed train lines, and base stations to be established in settlements with a population of less than 10 thousand have been made compulsory to be used by active network sharing. In other words, three operators will be able to serve their subscribers at the same time on a single base station in these areas."

In addition, in action step No. 7, titled "Effective and Efficient Use of Spectrum":

> "9. Regulatory framework and related infrastructure regarding authorization principles that enable spectrum sharing and trade will be prepared.
> First, tradable resources will be identified, and the rights and obligations related to these resources will be determined.
> To what extent the spectrum trading can take place (whether it will be possible to use the frequency by dividing it in terms of quantity and/or time and/or geography).
> A separate regulation will be prepared that regulates the procedures and principles regarding the methods by which spectrum trading can be carried out (lease and/or transfer) and the rights and obligations of the transferor/lessor and the transferee/lessor of the usage right within the scope of these procedures.
> In spectrum trading and sharing, frequencies can be made available to other operators voluntarily."

Apart from this, there is no similar example to the EU and US practices mentioned above for spectrum sharing in Turkey.

The Importance of Spectrum Sharing in 5G

With 5G, billions of machine-type M2M (machine-to-machine) devices are expected to enter our lives for tasks such as detecting, collecting, and transmitting data. Unlike traditional human-to-human-H2H communication, M2M communication has features such as low mobility, infrequent transmission, and low data size. Considering the irregular and corrupted data transmission traffic patterns and spectrum scarcity, setting up a private network and allocating spectrum for M2M communication needs is a very cost-inefficient approach. An alternative solution to this problem is to integrate existing H2H networks and M2M networks and enable them to share underutilized spectrum resources (Zhou

et al., 2020). This new spectrum sharing approach will meet the needs of 5G networks.

5G technology, whose standardization studies are still ongoing, will have advanced features to meet various connection needs, such as high data capacity, high data rate, low latency, high reliability, multiple device connections, mobility, and low energy consumption compared to existing network technologies (ITU-R, 2015). To meet these connectivity needs, 5G networks are expected to be highly heterogeneous, including both macro and small cells, MIMO-Multiple-Input Multiple-Output technology, and high-capacity backhaul carriers (ITU-R, 2015). The heterogeneity of 5G networks is particularly supported in frequency bands above 1 GHz and below 6 GHz (5G Obsevatory, 2021).

On the other hand, low-frequency bands have propagation properties that can support applications that require robust performance. However, high-frequency bands allow higher data capacity to be transmitted even over short distances. High bandwidth and global harmonization are the two main reasons that make high-frequency bands attractive. High-frequency bands, especially in the millimeter wave range between 20 and 300 GHz, provide contiguous and wide bandwidths to support connectivity needs such as high data rate, low latency, and high capacity in certain areas with very high traffic demand (5GAmericas, 2019). The width of the blocks in the higher frequency bands is at least 100 MHz, while the width of the spectrum blocks in the lower bands is usually 5-10 MHz. In addition, high-frequency bands offer some opportunities for global harmonization. These contribute to the economies of scale in device manufacturing, reduction of device complexity, and reduction of out-of-bounds interference problems.

It is difficult to find an adjacent spectrum for mobile broadband services in the sub-6 GHz spectrum. The sub-6 GHz spectrum is quite crowded as it is used for various general and commercial uses, including mobile broadband services. The sub-6 GHz spectrum used for mobile broadband services is not globally harmonized (ITU-R, 2012). However, the availability of the spectrum in question and the amount of bandwidth differs between bands and countries. Spectrum fragmentation may prevent 5G from meeting the connectivity needs of certain use cases. In such cases, where the spectrum is highly fragmented, re-farming is no longer an appropriate solution (Cave and Doyle, 2007). Unloading existing uses across the spectrum results in an unreasonably costly and time-consuming process, contrary to expectations (Khun-Jush and Bender, 2012). At the same time, some studies show that some parts of the sub-6 GHz spectrum are underutilized (Kim et al., 2020). Policymakers and authorities prefer new spectrum sharing regulations as an alternative to spectrum re-farming as a

potentially effective way to access spectrum below 6 GHz in a timely manner (Simon Forge, 2012).

RESEARCH METHOD

Data Collection Method

In this study, focus group interviews were conducted using a semi-structured interview technique to determine their approaches and intentions on spectrum sharing with three leading mobile operators based in Turkey about spectrum sharing as a qualitative research method. One interview was conducted for each operator. Interviews were held online due to the Covid-19 pandemic conditions. In terms of sample selection, the operators interviewed within this study cover one hundred percent of the Turkish mobile communication sector according to their market shares. The selected operators are technology companies operating in Turkey, with a long-established history, providing individuals and businesses with all telecommunications technologies, including fixed, mobile, and content services.

Analysis of Interviews

The notes of the interviews with the operators were analyzed by a coding method using the qualitative research analysis software NVivo. In this context, various codes were created for certain expressions that emerged in the interviews, and analysis was carried out on these codes.

The code index used in the interviews is given below:

- Paying Attention to Competitive Matters
- Service Quality Obligations
- The Need for Regulation
- Unlocking Access to New Frequency Bands
- On A Voluntary Basis
- "Exclusive Licensing"
- Infrastructure Management at ICTA
- Measures to Prevent Harmful Interference
- Vertical Sectors Should Not Be Allocated Frequencies
- Spectrum Sharing is Available at 3.5 GHz
- Spectrum Sharing is Not Suitable at 3.5 GHz
- Cautious Approach to "Club Use" at 26 GHz
- Data Privacy Considerations
- Creation of Incentive Mechanisms
- Sharing at 60 GHz is Convenient
- Sharing at 60 GHz is Not Suitable

- Must Be "Light Licensing" at 60 GHz
- A Complementary Solution
- Control and Inspection Challenges
- Requirement of Technical Infrastructure
- Sharing is Available in the 2300 MHz Band
- Sharing in the 2300 MHz Band is not Suitable
- 2300 MHz Band Should Be Given to a Single Operator
- Use or Lease Method is on a Voluntary Basis
- Clear Definition of Sanctions
- Spectrum Scarcity Does Not Exist.

A total of 7 questions were asked to the operators to get their opinions on spectrum sharing. Firstly, we asked operators: "1. What is your overview of spectrum sharing? Do you see a deficiency or need in this area in Turkey? What are the reasons for the missing points? (Weakness in demands of operators, the reluctance of existing public users, lack of technical infrastructure…)."

The answers given by the operators are analyzed on an operator basis, and the points that all three operators agree on these questions are listed below:

- Spectrum sharing should be implemented on a commercial voluntary basis, not as an obligation.
- The lack of regulation in the current situation.

In addition, they stated that all three operators are warmly interested in additional spectrum allocations, that the frequency bands of two operators should be allocated to the operators as "exclusive" and that frequencies should not be allocated to other stakeholders in vertical sectors. They also mentioned the necessity of clearly defining the measures and sanctions to prevent harmful interference.

Secondly, we asked operators: "2. Do you find it necessary to make regulations regarding spectrum sharing?". All three operators emphasize the lack of legislation, and one operator said that spectrum sharing could be considered, if necessary, regulations are made. Also, one operator said that they see that ICTA has not yet used its authority to make secondary regulations in the law. ICTA is expected to make this regulation.

Thirdly we asked the operators that "3. Are there any issues regarding spectrum sharing in your plans? Do you have a sharing model suggestion?".

When the answers to the question were analyzed, one operator stated that one operator could not make any plans without the regulatory framework. It would

not be appropriate for the other two operators to allocate frequencies to other stakeholders in the vertical sector.

In the other question; "4. What is your expectation from the regulatory body when regulations regarding spectrum sharing are made?" The issue was addressed from the answers given by three operators to the question:

- The terms of the regulation on spectrum sharing and the sanctions in case of non-compliance should be clear.
- It is necessary to determine the measures that can eliminate harmful interference.
- ICTA has not yet exercised the authority to make regulations on this issue, which was given to ICTA by the Electronic Communications Law.
- It should be considered in regulations regarding other service quality and coverage obligations when making regulations.

Regarding frequency bands, we asked that; "5. Which frequency bands would you prefer when the spectrum-sharing regulations are made? How would your request be in case of spectrum sharing with existing public users (Licensed Shared Access etc.) in the 2300 -2400 MHz frequency band?"

Three operators gave different answers to the question. While one operator mentioned that the available spectrum in the band should be divided into at most two operators, the other operator mentioned that the band should be shared equally among all three operators. The other operator conveyed that the band should not be allocated to mobile operators.

The other question is "What are your opinions on a usage scenario such as the Czech Republic application that provides control of the effective use of the spectrum with prior notification in frequency bands (5GHz, 60 GHz) that are exempt from frequency allocation?"

Three operators gave different answers to the issue also. While one operator mentioned the subject of "exclusive licensing", the other operator stated that they might consider using the band by making the necessary amendment to the current regulation. The other operator indicated that they did not intend to use the band.

Another question to the operators was "6. What are your opinions on 5G and Spectrum Sharing? What is your opinion on the interoperator 'spectrum pool' approach using 'network slicing' for the 3.5 GHz band, as in Finland?"

When we asked the question, operators had different approaches from each other. While one operator found the Finnish example logical, the other two operators were more cautious about sharing. This issue is also seen in the pie chart (Figure 1) taken from the NVivo qualitative analysis program regarding the questions' answers. Another prominent issue is the concern of operators' data privacy issues in case of sharing.

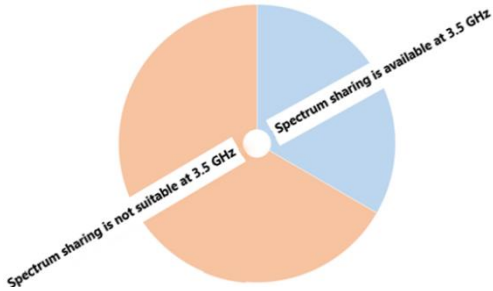

Figure 1 - Operator's Opinions on the 3.5 GHz Band

In another question regarding 5G frequency bands, we asked that: "What is your opinion on the 'use or rent' approach or 'club use' approach, as in the Italian approach in the 26 GHz frequency band?"

When we asked the question, one of the operators stated that it could be implemented if the regulation was certain and the necessary infrastructure was ready, while the other operator approached the application positively. The other operator, on the other hand, approached the application negatively. Another issue that emerged from the answers is that the mandatory situation in the "use or rent" method is inappropriate for the operators.

In the other question, we asked that: "c. What are your opinions on the LAA approach in the 6 GHz and 60 GHz bands?" One operator responded positively to the question, but a little more technical work is required to use it without a license (with light licensing). In contrast, the other operator stated that it could be a complementary solution for them, and the other operator did not think of sharing in this band. The pie chart created with the NVivo program according to the answers is given in Figure 2. The graph shows the three operators' approaches to the question differently.

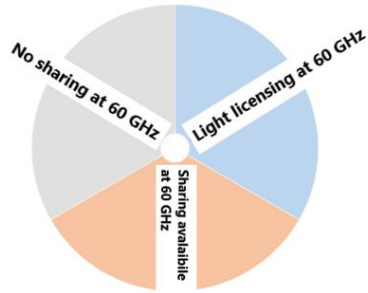

Figure 2 - Operator's Opinions on the 60 GHz Band

When the codes of the operator's interviews s are analyzed in general, the most cited by the operators in terms of spectrum sharing are:

- Paying attention to the issues related to the competition when making regulations about spectrum sharing,
- Considering the existing service quality obligations,
- The need for a regulation on spectrum sharing,
- Positive evaluation of access to new additional frequency bands with spectrum sharing,
- Spectrum sharing is not a necessity but on a commercial, voluntary basis, and this may not be attractive to operators since it is a necessity in methods such as "use or rent",
- They prefer to use the spectrum as "exclusive" rather than shared use,
- The control of the technical infrastructure that is likely to be established regarding spectrum sharing should be in the ICTA,
- Clearly determining the measures to prevent interference in the regulation to be made,
- Not allocating frequencies to vertical sectors such as production, business, logistics, agriculture, mining, and health, except for the mobile communication sector,
- While making regulations regarding spectrum sharing, the issues of bringing incentive mechanisms.

In addition, it has been observed that there are differences in the answers to the questions. For example, one operator thought the coverage quality would increase in sharing spectrum in a certain frequency band. In contrast, the other

operator believed that the coverage quality would decrease in case of sharing in the same band, so it would be necessary to install more base stations. In this sense, these differences in operator opinions may be due to the commercial concerns of the operators. For example, it is evaluated that the opinions of an operator who needs additional spectrum more and an operator who does not need spectrum differ.

Analysis of Interviews based on Operators

Operator X

When the interview codes with the X operator are analyzed in general, as seen in Figure 3, it is understood that the codes close to the center are mentioned more frequently in the interview. Accordingly, the X operator is summarized as follows:

- Spectrum sharing can be a complementary solution, not an essential solution for them,
- They always base their original planning on "exclusive licensing",
- Measures to prevent sanctions and interference should be clearly defined.

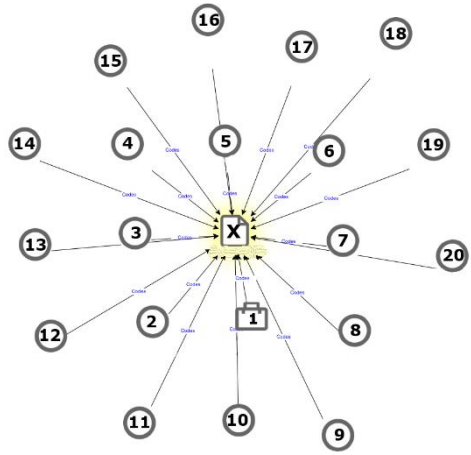

Figure 3 - Analysis of the Interview with Operator X

Definitions of numbers in Figure 3:

1. Clear Explanation of Sanctions
2. 2300 MHz Band Should Be Given to a Single Operator
3. "Exclusive Licensing"
4. Infrastructure Management at ICTA
5. Service Quality Obligations
6. The Need for Regulation
7. A Complementary Solution
8. Measures to Prevent Harmful Interference
9. Cautious Approach to "Club Use" at 26 GHz
10. Paying Attention to Competitive Matters
11. Requirement of Technical Infrastructure
12. Spectrum Scarcity Does Not Exist
13. Data Privacy Considerations
14. Control and Inspection Challenges
15. On a Voluntary Basis
16. Use or Lease Method is on a Voluntary Basis
17. Creation of Incentive Mechanisms
18. Unlocking Access to New Frequency Bands
19. Must be "Light Licensing" at 60 GHz
20. Spectrum Sharing is Not Suitable at 3.5 GHz.

Operator Y

The codes of the interview with the Y operator are analyzed in Figure 4. Codes close to the center were mentioned more frequently in the discussion. Accordingly, the Y operator is summarized as follows:

- Since they see spectrum sharing as the opening of new frequency bands for mobile communication, they approach spectrum sharing positively,
- It is necessary to pay attention to the issues related to competition while making the regulation,
- The control and auditing difficulties experienced in spectrum sharing applications.

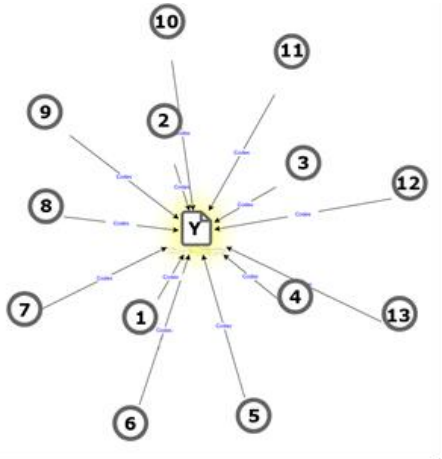

Figure 4 - Analysis of the Interview with Operator Y

Definitions of numbers in Figure 4:

1. Paying Attention to Competitive Matters
2. Control and Inspection Challenges
3. Infrastructure Management at ICTA
4. Unlocking Access to New Frequency Bands
5. Vertical Sectors Should Not Be Allocated Frequencies
6. The Need for Regulation
7. Data Privacy Considerations
8. Service Quality Obligations
9. On a Voluntary Basis
10. Sharing at 60 GHz is Convenient
11. Spectrum Sharing is Available at 3.5 GHz
12. Sharing is Available in the 2300 MHz Band
13. Measures to Prevent Harmful Interference.

Operator Z

The codes of the interview with the Z operator are analyzed in Figure 5. Codes close to the center were mentioned more frequently in the discussion. Accordingly, the Z operator is summarized as:

- Frequencies should not be allocated to vertical sectors other than mobile operators,

- They stated that "exclusive licensing" is their primary approach rather than sharing the spectrum. Apart from this, other codes of the interview with the Z operator are given in Figure 5.

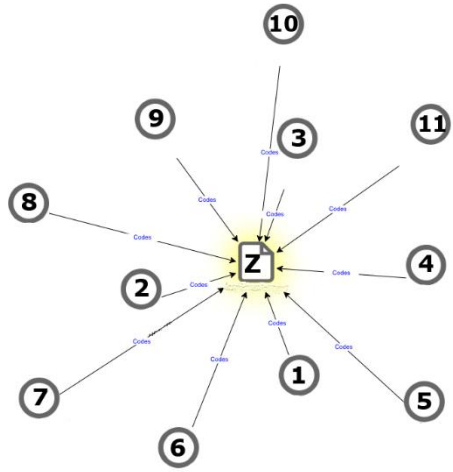

Figure 5 - Analysis of the Interview with Operator Z

Definitions of numbers in Figure 5:

1. "Exclusive Licensing"
2. Sharing in the 2300 MHz Band is Not Suitable
3. Sharing at 60 GHz is Not Suitable
4. Vertical Sectors Should Not Be Allocated Frequencies
5. Spectrum Sharing is Not Suitable at 3.5 GHz
6. Paying Attention to Competitive Matters
7. Infrastructure Management at ICTA
8. On a Voluntary Basis
9. The Need for Regulation
10. Service Quality Obligations
11. Cautious Approach to "Club Use" at 26 GHz.

International Interview Study on Spectrum Sharing

A number of inquiries were directed to country administrations through the Independent Regulators Group (IRG) about spectrum sharing. Responses were received from 15 countries to the questions sent by e-mail. Although the questions asked to the country administrations and the operators were similar, questions were asked to country administrations to understand the more concise regulatory

framework. The countries that answered the questions are Austria, Belgium, Croatia, Czechia, Finland, Hungary, Italy, Malta, Latvia, Norway, the United Kingdom, Serbia, Slovakia, Slovenia, and Spain.

An overall assessment of the responses shows that most of the responding countries have regulations in the field of spectrum sharing. In many of the countries that answered the questions, it is seen that various laws and regulations regulate these regulations. To summarize:

- In some countries, such as Hungary and Spain, it has been observed that there are regulations regarding spectrum trading instead of spectrum sharing.
- In Slovenia and Italy, it is stated that there is a "case-by-case" based spectrum sharing approach in 5G tender processes.
- Slovakia has adopted the "spectrum pool" approach in the 5G tender. In the spectrum pool approach, a certain number of operators can use certain spectrum ranges from a common spectrum pool where the other operator does not.
- Latvia, Belgium, Croatia, Czechia, Malta, Slovakia, and Serbia, on the other hand, stated that there is no regulation on spectrum sharing in their countries. Still, Belgium and Serbia noted that they are considering making regulations in the future.
- In addition, Norway has stated that sharing opportunities at 2.3 GHz and 26 GHz are under evaluation.
- In Austria, it was stated that spectrum sharing is not explicitly allowed in cities with high competition, such as Vienna, Graz, and Linz.
- In Finland, it was stated that dynamic spectrum sharing was implemented in the 1427-1518 MHz band.
- Due to its highly advanced applications and regulations, we can consider the United Kingdom as one of the countries that best implements spectrum sharing.

In addition, all countries with spectrum sharing stated that their agreements are subject to the administration's approval before sharing.

SUGGESTIONS

Suggestions within the Scope of Operator Interviews

In this section, the issues in the interviews with the operators are compared with the applications abroad, and various results are tried to be reached. In this context:

- Although all three operators talk about their reservations about competition violations that may occur in the case of spectrum sharing, it is possible to overcome these reservations with various commitments to be made by the sharing parties, as seen in the Danish example (Danish Competition and Consumer Authority, 2012). Apart from this, ICTA should not allow transactions that significantly reduce effective competition in the relevant market regarding spectrum sharing.
- The weakness of the obligations regarding the service quality expressed by all three operators will be eliminated by the measures that can be determined by the sharing conditions.
- Overcoming the interference problems expressed by all three operators will only be possible if the technical infrastructure to be established is well-designed and the sanctions to be applied are clearly defined.
- Although some operators have reservations that sharing at 3.5 GHz is not economically and technically appropriate, it is clear that establishing a shared network at 3.5 GHz has benefits in terms of both reducing costs and increasing data transmission capacity in rural areas, as can be seen from the examples of Finland and Denmark. (RSPG, 2021). For this reason, it is considered that the sharing practices applied in Norway, Denmark, and Finland can also be applied in Turkey.
- As another issue, some operators have reservations about the "use or rent" method. It is thought that if this model, which is believed to be applied especially in the 26 GHz frequency band, is applied as in the example of Italy and Slovenia, the use of inactive spectrum can be prevented. Signals in the 26 GHz frequency band are attenuated at short distances due to the nature of the propagation in the high-frequency band. Therefore, it is not possible for any operator to provide nationwide coverage in this frequency band. In this context, it is considered that the use of the part other than the part allocated to it in the mentioned frequency band by the other operator in places where the frequency is not used will be a valuable method to prevent the use of inactive spectrum.

- Regarding the 2300 MHz frequency band, it is considered that the LSA approach applied in Europe can also be applied in Turkey. Considering the current military use of the band in Turkey, it is evaluated that a database-based spectrum sharing system to be designed, and the use of the band by mobile operators in areas where there is no military use can prevent the use of idle spectrum. In this context, although the database-centered technical infrastructure to be established for the realization of this system is managed by third-party private companies in the American approach, it is considered that it would be appropriate for the infrastructure to be established in Turkey to be governed by the ICTA in line with the opinions of the operators.

In this context, it is recommended to install the technical infrastructure given in Figure 6 basic scheme within the body of ICTA.

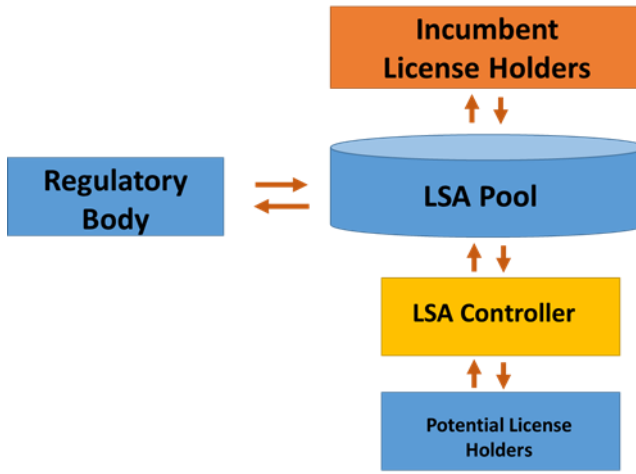

Figure 6 - Technical Infrastructure for Spectrum Sharing

In Figure 6, the LSA pool represents the LSA license database. License information includes which frequency band can be used in which location and with which technical parameters. On the other hand, the LSA controller provides access authorization by passing certain authorization filters to potential users who want to access the LSA database in question. Due to the regulatory authority's continued access to the information in the LSA repository, which licenses can be made available is under the control of the regulatory authority.

It is considered that the use of the 60 GHz frequency band, together with a web interface to be established as in the Czech Republic, within the framework of the "light licensing" (notification mandatory) approach, by vertical sectors other than mobile operators, may be beneficial in terms of effective and efficient use of the spectrum.

To make a general assessment, it has become a necessity to replace the 'command and control' approach, which is the traditional approach in spectrum management, with market-based and then technology-based approaches, within the framework of the principle of effective and efficient use of spectrum with the increase in frequency use, the emergence of new technologies and changes in user demands. In this context, it is considered that the role of the regulatory authority in spectrum allocations should be reduced, and the authorization holder should be encouraged to decide how the spectrum will be used and to determine the value of the spectrum with market-based and technology-based approaches.

Recommendations for Lack of Legislation

It is considered that the issues related to spectrum sharing in EU regulations should be included in electronic communications legislation and practices. It is considered that the following regulatory changes can be made to bring the spectrum sharing in Turkey closer to the practices within the scope of EU and world examples and to ensure that it is carried out in accordance with the EU legislation.

The following new article could be added to the Spectrum Management Regulation in order to facilitate spectrum sharing:

> "ARTICLE X: (1) Frequencies that can be shared within the scope of spectrum sharing applications by operators shall be determined by the Authority. The provision related to spectrum sharing should be included in the relevant Regulation. Within the scope of this article, the regulation regarding which frequency bands can be shared under what conditions can be made through a new ICTA Board Decision specified below. It is necessary for the new Board Decision to include the frequency bands for spectrum sharing-based services and the minimum bandwidths subject to sharing, and for the said Board Decision to be updated when necessary."

New Authority Decision:

> "Electronic Communication Services, Frequency Bands, and Minimum Bandwidths Subject to Spectrum Sharing
> The following frequency bands can be shared by operators within the scope of spectrum sharing applications. In line with the principle of effective and efficient spectrum utilization, the integrity of channels

> assigned to an operator shall be preserved in spectrum sharing applications, depending on the nature of the service.
> Electronic Communication Service Frequency Band(s) Minimum Bandwidth:
> Cellular Systems 2300 MHz To be determined
> Cellular Systems 3.5 GHz To be determined
> GSM 26 GHz To be determined
> Point-to-Point 60 GHz To be determined"

It is necessary for the new Authority Decision to determine the framework and scope of spectrum sharing-related matters.

Additionally, similar amendments should be made in the Authorization Regulation as well.

It is considered that a separate regulation regulating the procedures and principles regarding spectrum sharing should enter into force. Within the scope of the regulation mentioned above, to what extent can spectrum sharing be realized (whether it will be possible to use the frequency by dividing it in terms of quantity and time and/or geography); The methods by which spectrum sharing can be carried out (rental and transfer, network sharing) and the rights and obligations of the shareholder and the shared user within the scope of these procedures should be clearly determined.

In addition, it is considered that the sanctions to be imposed by the ICTA should clearly be included in the regulation mentioned above.

Recommendations for Technical Infrastructure

Establishing a technical infrastructure, as shown in Figure 6 for spectrum sharing will ensure transparency in the market and inform consumers. Within the scope of the infrastructure, it is considered that information on whom the spectrum sharing parties are, their authorizations, the dates when the application will come into effect and expire, if any, the geographical area, the type and amount of shared frequencies can be kept. This way, market transparency will be ensured, and the consumers will be informed about which operators they will receive service from.

CONCLUSION

Spectrum is a scarce and valuable national resource. With 5G, it is predicted that the demand for spectrum will increase gradually. In order to overcome the increasing data traffic problem, the spectrum should be used as efficiently as possible. Promoting dynamic efficiency has become a worldwide public policy priority. As stated in the reports of international organizations such as the OECD, a growing telecommunications sector not only provides direct

economic and social growth but also indirectly contributes to the development of other industries such as transportation, trade, and construction industries.

With the traditional spectrum management approach, it is not possible to take advantage of the opportunities offered by the spectrum. To realize this vision and meet the spectrum demands of future applications, it is necessary to develop and use innovative spectrum access technologies and adopt new regulations and institutional frameworks that can maximize the effectiveness of these technologies. For this purpose, the concept of dynamic spectrum access and spectrum sharing between wireless systems has emerged. Spectrum sharing is the simultaneous use or joint use of a fixed radio frequency resource by several independent users in a given geographic area.

Within the scope of this study, the importance of the spectrum and the social and economic benefits to be provided when the spectrum is used effectively and efficiently has been investigated. The perspective, suggestions, and reservations of the mobile communication sector in Turkey towards the spectrum sharing approach were analyzed through focus group discussions. Focus group interviews were carried out in the form of semi-structured interviews, and the pre-prepared question set was conveyed to the operators before the interviews for the operators to make a preliminary preparation. In the interviews, the general opinions of the operators on spectrum sharing and their opinions on various frequency bands were taken. The interviews were analyzed using various coding techniques through the NVivo qualitative research program. The current spectrum management approaches applied in Europe, and the USA have been examined by conducting semi-structured interviews via document scanning and e-mail.

Then, the approaches of the mobile operators in Turkey, with the policies in Europe and the USA regarding spectrum sharing, were evaluated together recommendations were made regarding some regulatory changes and the technical infrastructure requirements of the Spectrum Sharing System (Figure 6), which are considered to have economic and social benefits in their implementation in Turkey.

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