TDRA | هيئة تنظيم الاتصالات والحكومة الرقمية
TELECOMMUNICATIONS AND DIGITAL GOVERNMENT REGULATORY AUTHORITY

Spectrum Management in the next decade: Towards Increased Agility

A White Paper by TDRA
2023

Agility in Spectrum Management

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1. Executive Summary

This TDRA “Spectrum Agility” White Paper presents a future-looking perspective on an agile and sustainable spectrum management regime for the next decade in the UAE. TDRA, by enhancing its spectrum management system and implementing the best available spectrum management solutions, promotes further industry development in line with UAE Digital Government Strategy and objectives. The White Paper considers more efficient and effective use of advanced, data driven spectrum management solutions generally and their potential impact for the UAE.

TDRA has a mission to make spectrum available for innovative wireless services, as they play a major role in the significant transitions in which the UAE is engaged. In its endeavour to contribute to its objectives, TDRA cooperates and collaborates with all its strategic partners.

This White Paper is intended for all stakeholders interested in future wireless opportunities and the evolution towards agile spectrum management systems. It provides insights into the driving forces for change and possible approaches to reaching the UAE’s digital goals. The following driving forces are explored:

- Digital policy goals and strategic drivers of the UAE
- Wireless technology opportunities and developments
- Spectrum management solutions developments
- UAE specific agility in spectrum management scenarios.

Increasingly, development requires ubiquitous connectivity. Alongside this “connectivity and capacity when required” offering, advanced, flexible and software driven radios (with cognitive capabilities) are expected to develop further so as to be a viable industrial technology, allowing devices to themselves choose the most appropriate frequency band and technology for communications.

There is a need for networks to meet sustainability targets, ensuring higher consumption efficiency. 5G, whilst delivering a lower watts per bit consumption, consumes more energy than previous networks, suggesting that 6G may need to make further improvements in power efficiency.

Wireless technology developments, as well as user expectations to be able to access the required spectrum quickly and with minimal administrative burden, invite regulators to ensure that their regulatory frameworks and approaches are fit for purpose. Agility, as defined in this white paper, will aid regulators in this regard in that systems will be better able to handle changing requirements.

The future scenarios TDRA has explored focus on the degree of development of maturity and technology factors. The extent of development in process autonomy and agility in the next decade will depend on:

- Wireless technologies opportunities, in particular dynamic autonomous sharing and AI application at network management level;
- Progress of AI in spectrum management solutions; and

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- The scope of institutional policy decisions in SMS requiring policy defined intervention.

To explore the changeovers towards Agility 2031, TDRA presents a series of initiatives based on extensive research related to the following objectives:

- “Users as part of the ecosystem”
- “Promoting AI”
- “Enhanced Automation/Autonomy”

The high level approach to this project is shown below in Figure 1.

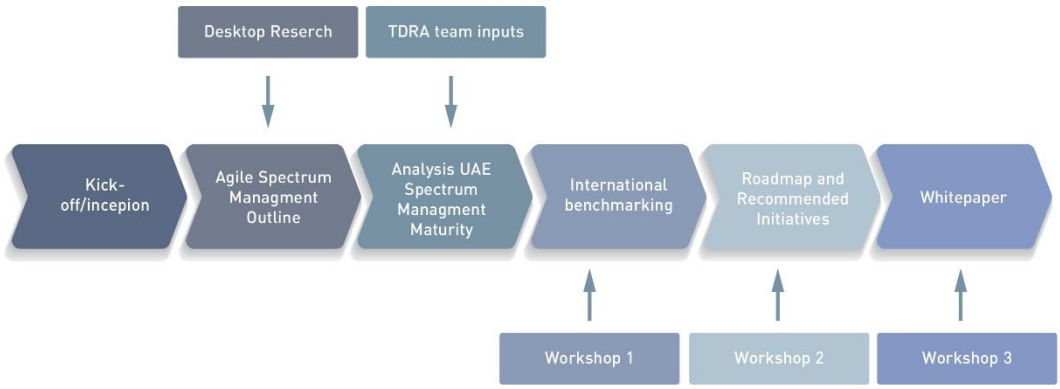

Figure 1 – Project approach.

2. Purpose of White Paper

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3. The UAE Digital Government Strategy, Foresight, Scenarios, and Spectrum Agility Implications

The UAE intends to take advantage, in a proactive way, of advanced and emerging digital technologies. It aims to deliver the best digital services to its society, industry and government in a future-oriented, inclusive, and sustainable manner, making it a priority to take into account the future needs of users and customers[1].

The digital future goes beyond phones, towards global connectivity, enhanced industrial processes, smarter cities and sustainable climate targets[2]. Inclusion, resiliency, user involvement, openness and proactiveness require a strong, efficiently and dynamically managed, world class, wireless connectivity infrastructure. The implications in terms of radio spectrum policy, management and access are far-reaching, as the radio spectrum provides the support for always more numerous digital applications.

The Telecommunications Regulatory Authority (TRA) was established as the Government Agency in charge of telecommunications and radio spectrum management in 2004. It became the Telecommunications and Digital Regulatory Authority (TDRA) in 2020 with the inclusion of Digital Government objectives. Its mission is to:

> "… strive to be a leading organisation in the ICT sector in United Arab Emirates, committed to maintaining positive competition to protect the interests of the subscribers, and promoting electronic transformation of the federal agencies and their services, by relying on national competencies to apply the best international standards and practices in supervision of the sector´s and to encourage innovation and investment" [3].

Its Telecommunication Sector is in charge of Spectrum Management, Regulatory Affairs, and Technology Development.

In 2022, TDRA has engaged in an in-depth "Spectrum Agility" research effort which aims at aligning its mission, policies, spectrum management systems and procedures with a 2031 Vision, in support of the UAE National Digital Government Visions, Strategies, and Policies.

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[1] UAE, 2022. The UAE Digital Government Strategy 2025. Available at: https://u.ae/en/about-the-uae/digital-uae/uae-national-digital-government-strategy

[2] UAE, 2020. 2020: Towards the next 50. Available at: https://u.ae/en/about-the-uae/the-uae-government/2020-towards-the-next-50

[3] TDRA, 2022. About TDRA. Available at: https://tdra.gov.ae/en/About

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TDRA refers to the 50 years (Centennial Plan) UAE vision and foresight[4]. It relies on the UAE scenario building methodology and future shaping tools[5][6]. To conceive this White Paper, TDRA has performed an extensive scientific and policy literature research effort, conducted a wide regional and international survey of radio spectrum regulators policies and practices, and consulted vendors and subject matter experts.

The 'We the UAE 2031' vision[7], published in November 2022, builds upon the previous foresight exercises and presents "…four pillars that cover all sectors including the society, economy, diplomacy and ecosystem:

1. Forward Society - achieving the prosperity of society by enhancing the capabilities of the citizens to maximise their effective contribution in all sectors
2. Forward Economy – reflecting the UAE's belief in the importance of human capital as the main driver of the next 10-year development plan
3. Forward Diplomacy - consolidating the pivotal role and influence of the UAE based on respect for human values
4. Forward Ecosystem - enhancing the government performance and the UAE's infrastructure and its development according to the latest technological methods, including the development of digital infrastructure."

Of particular relevance for this TDRA White Paper is Pillar 4, the "Forward Ecosystem", which emphasises the performance of UAE Government entities. Notably also, the "Forward Diplomacy" pillar emphasises the increasing international influence of the UAE. International influence is at play in technology innovation, as well as in the very lively and highly internationalised area of spectrum management, with so many technology and regulatory issues debated in regional and international fora, in particular the ITU.

As the Government agency in charge of radio spectrum management, alongside other wide ranging telecommunications tasks, TDRA has a proven record of excellency in the performance of its missions, recognised on a global level by the

[4] UAE, 2022. UAE Centennial 2071. Available at: https://u.ae/en/about-the-uae/strategies-initiatives-and-awards/strategies-plans-and-visions/innovation-and-future-shaping/uae-centennial-2071

[5] MOCA, 2019. Shaping the Future. Available at: https://www.moca.gov.ae/en/area-of-focus/future-foresight

[6] MOCA. Scenario Planning Toolkit. Available at: https://www.moca.gov.ae/docs/default-source/default-document-library/scenario-planning--toolkits/scenario-planning--toolkits.pdf?sfvrsn=2

[7] UAE, 2022. 'We the UAE 2031' Vision. Available at: https://u.ae/en/about-the-uae/strategies-initiatives-and-awards/strategies-plans-and-visions/innovation-and-future-shaping/we-the-uae-2031-vision

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award of the top level 'G5' rating in the ITU Generations of Regulation framework[8] in 2022.

As another example of TDRA involvement in current digital developments is the UAE Pass. The UAE Pass provides a national digital identification that allows individuals to identify themselves with a single sign-on, enabling access to a range of government services (including spectrum authorisations). For TDRA, this also acts as an online or smartphone-based authorisation portal and facilitates validation of spectrum authorisations by enforcement agencies.

At the dawn of 2023, spectrum management is facing new technological developments and the correlated regulatory adjustments. This can be summarised in a future looking approach to spectrum access as:

- "Anywhere spectrum agility", agile access to the required radio spectrum resources at any time; and
- "Forward looking agility", agility in providing the radio spectrum to accommodate technology and service evolutions over time.

TDRA has a mission to make spectrum available for innovative wireless services as they play a major role in the significant transitions in which the UAE is engaged. In its endeavour to contribute to its objectives, TDRA cooperates and collaborates with all its strategic partners.

In dealing with foresight in highly innovative digital environments, the UAE adopts a foresight and scenario approach, as illustrated by the UAE Government publications[9][10].

Within the global international and UAE economic and digital policy context, this "Agility in Spectrum Management" White Paper is based on a comprehensive research project which has included forward looking scientific and technological analyses, a benchmarking exercise of spectrum management practices and numerous interviews with stakeholders in the UAE, regionally and internationally. As a result, this White Paper presents scenarios of wireless technologies and service evolution over the next decade, as well as of evolutions in spectrum management systems and solutions. This comprehensive research effort results in a developed vision that will allow TDRA to transition in the next decade to the most appropriate spectrum management platforms to contribute to the objectives of the UAE economy and society.

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[8] ITU, 2022. Policy & Regulatory Frameworks. Available at: https://www.itu.int/en/ITU-D/Regulatory-Market/Pages/Policy-&-Regulatory-Frameworks.aspx

[9] UAE Ministry of Cabinet Affairs, 2020. Publications. Available at: https://www.moca.gov.ae/en/publications

[10] MOCA. Scenario Planning Toolkit. Available at: https://www.moca.gov.ae/docs/default-source/default-document-library/scenario-planning--toolkits/scenario-planning--toolkits.pdf?sfvrsn=2

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4. The TDRA Strategic Vision: Towards always more Agile Spectrum Management Systems

Demand for spectrum continues to grow alongside economic growth in the UAE. The TDRA "Spectrum Agility" project has assessed this current situation within the UAE and TDRA and how this compares to other countries and regulators globally, as well as TDRA's aspirations with regards to implementing an agile spectrum management system. Through the project work, the comparison with other regulators has allowed identification of a realistic target for TDRA in terms of future spectrum agility (as characterised by the highest agility level in the spectrum management maturity assessment metrics).

4.1. Current Approach to Authorizing Spectrum Use

TDRA's current spectrum management tool dates from 2008 (which itself is an update of the original 2005 system). It has been subject to many updates since then. Key aspects of the original specification and subsequent development were minimal wait times for applicants and good visibility for management of the status of applications. TDRA, and the UAE government generally, places great emphasis on customer experience. As such, its systems and processes are designed to make authorisation applications as straightforward for stakeholders as possible.

The TDRA provides an authorisation portal on its web site for users to apply for spectrum use as demand dictates (noting that some spectrum usage is also authorised through general authorisations or exemptions). It is also possible to modify, renew and cancel authorisations via the TDRA web site and all spectrum authorisations are now electronic.

The UAE telecommunications sector is characterised as a duopoly with two main licensees: e& by Etisalat and du. There are also sector specific licensees which hold licences for specific services. To provide public telecommunications services within the UAE, applicants need to obtain a telecommunications licence. Private networks do not require a telecommunications licence but do require a spectrum authorisation to be able to make use of the radio spectrum, noting that trading and leasing of spectrum are not permitted within the UAE[11].

4.2. Agile Spectrum Management

Against this current situation background of spectrum management within the UAE, and based on research of industry, regulatory and academic developments, 'agile' spectrum management can be characterised as follows:

- The system should be flexible, enabling the automatic selection of a frequency based on certain system inputs;
- The system should be user friendly, accepting multiple input types, e.g., single, batch, automated, and pre-configured;
- The system should be able to easily integrate into any spectrum monitoring/sensing solution;

[11] Under article 50 of the UAE Telecommunications Law, entities have to obtain an authorisation directly from TDRA in order to make use of the spectrum.

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- The system should be able to easily integrate into any IT system (e.g., finance, type approval) used by spectrum regulators;
- The system should minimise application and authorisation times towards zero (considering both application completion times and application processing times, i.e. the inputs from both the applicant and TDRA colleagues) and reduce human intervention;
- The system should be live, intelligent and data driven; and
- The system should take advantage of advanced technologies such as artificial intelligence and distributed ledger systems.

Specifically:

Agility in spectrum management has been defined as “the ability to meet evolving user needs in a user-friendly and timely manner. It touches upon the flexibility of spectrum management systems to accommodate all possibilities and requirements, bringing the time from application to BiU (bringing into use) ideally to zero, with minimal or no human intervention. This also applies to the way we provide frequencies for emerging technologies and services”

A set of spectrum management maturity assessment metrics has been developed alongside the agility definition, as laid out in Table 1 below, based around a number of attributes with varying levels of automation and interaction. For each attribute, a possible value between 1 and 4 is possible, where 4 represents the most agile state and 1 the least. Based on the research and benchmarking work conducted, level 4 in all attributes is considered to be a reasonable and achievable aim for TDRA.

There are numerous external factors that exist outside of this definition. Some of these are global and beyond the reach of regulators at an individual level, for example changes to the Radio Regulations resulting from WRC resolutions. Others result from national priorities, for example due to data privacy and national security concerns, and can impact the achievable agility of a country’s spectrum management approach.

However, the continued policy of TDRA is to establish a strong relationship with its users to understand future needs, allowing it to meet them with an agile, user-friendly and flexible spectrum management system which integrates with all necessary data and processes.

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Attribute	Level 1	Level 2	Level 3	Level 4
Spectrum Database (authorisations and technical parameters)	Basic/Excel	Off the shelf tool (SMS4DC)	Self-developed or dedicated, customised COTS[12] tool (to meet applicant's requirements)	Live, dynamic, configurable and flexible
Technical Analysis Tools (Software)	Basic/Excel	Off the shelf tool (SEAMCAT)	Self-developed or dedicated, customised COTS tool (to meet regulator's requirements)	Live (operational values), dynamic, customisable, configurable and flexible, e.g. ANFR AR[13] fixed link tool
Customer application process	Paper/letter/email/ phone	Online form (electronic submission)	Online portal (automatic submission)	Smart portal with virtual assistant
Spectrum occupancy data	Measurement campaigns	Fixed and mobile monitoring stations	Dynamic and mesh sensors	Integration of monitoring sensors to live database
Spectrum occupancy shared online	No visibility beyond NFAT/NFP	Published band plans	Searchable licence database	Full, live visibility for target bands
Assignment	Manual/paper	Electronic assignment	Automated assignment	Real time/live assignment
Authorisation Duration Flexibility	Fixed period	Fixed period with flexibility to review	Totally flexible	Live, on the go

Table 1 - Spectrum management maturity assessment metrics

[12] COTS, Commercial Off-the-shelf

[13] AR, Augmented Reality

5. Benchmarking

Input from regulators around the world was sought to both validate the approach taken and determine currently deployed agile developments.

The benchmarking analysis found that TDRA ranks highly in most of the maturity assessment metrics considered, and when compared to many of the world's advanced regulators. Opportunities for development for TDRA exist in aspects such as technical analysis tools and making spectrum occupancy information available to entities outside of TDRA.

The benchmark analysis shows that Private Mobile Radio (PMR), Programme Making and Spectrum Events (PMSE), Dynamic Spectrum Access (DSA) and application processing are the services/processes most associated with 'agile' spectrum management technologies (for example, AI and the use of mesh sensors). The use of DSA schemes is most associated with sharing between mobile and other services, although some regulators also associate this with RLAN, broadcasting, PMSE and satellite.

5.1. Summary

The current approach to spectrum management within TDRA has been considered, reaching the conclusion that TDRA already operates in a mature manner, i.e. the application process is straightforward and readily accessible, and analysis and assignment is conducted in a technologically advanced and fast manner.

Through consideration of TDRA's approach to spectrum management, and consideration of the current and future technology capability, spectrum agility has been defined, along with a set of assessment metrics. The benchmarking exercise found that TDRA's approach is broadly similar or slightly more advanced than many of the other regulators in many of the aspects considered.

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6. Driving Forces and Evolutions in Spectrum Management for Wireless Technologies and Services

Major innovations in wireless technologies and services, as well as advances in spectrum management solutions, are expected in the next decade. How regulators ensure they manage spectrum effectively in the face of these developing industries will be determined by the interplay and adjustment of both factors.

On the one hand, innovations in wireless technologies and services will require changes in the spectrum demands of innovative services, and possibly evolutions in frequency allocations and authorisations. This might represent changes in the scale of demand, but also in the nature of the required spectrum. For example, new technologies may require spectrum in different locations, over different time periods and in different quantities. These can be described as push factors, in that new spectrum usage will force spectrum management approaches to adapt.

On the other hand, developments in spectrum management solutions, i.e., the solutions that spectrum management organisations use in managing the spectrum, will also change the way that spectrum use is authorised. Developments in the capabilities of management solutions, either self-developed by regulators or introduced by industry or academia, will allow spectrum to be authorised in new innovative ways. These can be described as pull factors in that regulators draw by themselves to new more agile methods.

This TDRA “Spectrum Agility” White Paper explores how the push and pull factors interact, and the implications for the handling of user requirements and satisfaction which are a central focus for TDRA.

6.1. Technology Developments and Changing User Requirements

A wide array of innovative wireless technologies and services are on the horizon for 2031. These are expected to affect operators, regulators, industry and the public in general. To know how the spectrum regulator can best serve its customers, this White Paper explores in detail the changing wireless technologies and service landscape within which it will operate.

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A survey of wireless technologies visions from the ITU[14], equipment vendors (e.g. Nokia[15], Ericsson[16] and Huawei[17]) and research institutions projects (NSF NextG Research[18] and the EU HEXA-X Research project[19]) was conducted. The main expected evolutions in the mid-term are the following:

- The developing capabilities of 6G;
- The growing demand for localised spectrum usage, both for PMSE type applications and for private networks (industries, local entities, referred to as “verticals”);
- The need for improved connectivity to and in homes (through Wi-Fi and expansion of fixed wireless access), ‘not spots’ (increasingly being addressed through satellite constellations, particularly non-geostationary, NGSO, low earth orbits, LEO) and things (Internet of Things, IoT);
- The integration of multiple network topologies for enhanced coverage and service (3D networks);
- The development of networks as a service (NaaS) and on demand access to spectrum;
- The growing importance of the sustainability and carbon footprint of ICT.
- The importance of, cybersecurity, trustworthiness, and resilience in networks; and
- The growing role that cognitive radio could have in spectrum access and monitoring.

Many of the identified developments have implications for network management and are primarily of interest for operators, but many are also relevant to radio spectrum management, in particular the challenging but promising nature of cognitive radios.

[14] IEEE ComSoc, 2022. Excerpts of ITU-R preliminary draft new Report: FUTURE TECHNOLOGY TRENDS OF TERRESTRIAL IMT SYSTEMS TOWARDS 2030 AND BEYOND. Available at: https://techblog.comsoc.org/2022/02/27/excerpts-of-itu-r-preliminary-draft-new-report-future-technology-trends-of-terrestrial-imt-systems-towards-2030-and-beyond/

[15] Nokia, 2021. Network evolution towards the 6G era. Available at: https://www.nokia.com/blog/network-evolution-towards-the-6g-era/

[16] Ericsson, 2022. Future technologies for an intelligent society. Available at: https://www.ericsson.com/en/future-technologies

[17] Huawei, 2022. Communications Network 2030. Available at: https://www.huawei.com/en/giv/communications-network-2030

[18] NSF, 2022. IEEE Next G Summit Plenary (An Overview of NSF’s Support for NextG Research) Alex Sprintson, NSF. Available at: https://www.youtube.com/watch?v=B6_ywxYHzAM

[19] HEXA-X, 2022. A flagship for 6G vision and intelligent fabric of technology enablers connecting human, physical, and digital worlds. Available at: https://hexa-x.eu

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6.1.1. Cognitive Radios

Cognitive radios can dynamically select the best available frequency by detecting which would provide the best performance whilst ensuring protection of incumbent users. The pace of development of cognitive radios will be a major factor in the evolution of radio spectrum usage and management. The use of cognitive radios could allow for a decentralised management system if devices are able to conduct the sensing and decision aspects themselves and could potentially allow for more opportunistic access to spectrum for users. Of course, devices themselves are likely to be more complex and expensive than non-cognitive radios, as devices will need to be capable of operating over multiple frequency bands, and ultimately support the use of different bandwidths and modulation schemes. In addition, devices will need to be capable of sensing spectrum occupancy, or at least be able to seek this information from alternative sources, and be sufficiently intelligent to analyse the information to determine a suitable transmission arrangement. As such it is likely that the use of cognitive radios will not, in the short term at least, be appropriate for all services.

There are several regulatory approaches that provide similar outcomes to cognitive radios, for example TVWS (TV White Spaces), CBRS (Citizens Broadband Radio Service) or AFC (Automatic Frequency Coordination).

6.1.2. Sustainability Targets

In 2017, the UAE launched its 'Energy Strategy 2050'[20], which aims to increase the contribution of clean energy in the total energy mix from 25% to 50% and reduce the carbon footprint of power generation by 70%, thus saving AED 700 billion by 2050. It also seeks to increase the consumption efficiency of individuals and corporations by 40%.

To comply with the UAE objectives of a 40% increase in energy consumption efficiency, further advances in network technologies are required. The requirements for 6G are still under development, but these may present an opportunity to better meet sustainability targets. For example, the European initiative Hexa-X has set targets for 6G in terms of sustainability[21]:

- Enabling carbon emissions reductions of more than 30% using 6G;
- More than 30% reduction for the Total Cost Ownership (TCO), including energy fees; and
- More than 90% reduction in energy consumption per bit.

[20] UAE, 2022. UAE Energy Strategy 2050. Available at: https://u.ae/en/about-the-uae/strategies-initiatives-and-awards/federal-governments-strategies-and-plans/uae-energy-strategy-2050

[21] Hexa-X, 2020. Deliverable D1.2 Expanded 6G vision, use cases and societal values. Available at: https://hexa-x.eu/wp-content/uploads/2022/04/Hexa-X_D1.2_Edited.pdf

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6.1.3. UAE Expectations of Spectrum Management Processes

Within the UAE, it is a requirement that government services in general be available to citizens in a straightforward way that is appropriate for them. Specifically, this means that services are required to be available online, having easy to use interfaces with minimal burden to users. One of the ways this is characterised within the current TDRA spectrum management system is in the number of clicks required to submit a spectrum application. Significant development work has been undertaken to minimise the number of clicks required. One of TDRA's main KPIs is that of waiting time for spectrum authorisations. Some services are fully automated, for example authorisation renewals, whereas others require intervention from TDRA staff to process the application.

The requirement to make access to spectrum as quick as possible means that continued effort to minimise the authorisation delay will be required. In addition, the developments identified with regards to ad-hoc and flexible demand for spectrum make it clear that TDRA's approach to spectrum management will need to cater for this aspect as well.

6.1.4. Summary

Several developing trends within the wireless telecommunications industry have been identified. The first trend is that of developments in IMT (International Mobile Telecommunications) technology: 5G is now widely being deployed globally, but 6G is on the horizon, and with it will come new spectrum requirements and network topologies. Alongside developments in IMT comes the growing demand for localised spectrum access in the form of private networks, or verticals, and increased demand for PMSE equipment at events.

A further development regards the need for ubiquitous connectivity. Connectivity to end users is increasingly foreseen to be delivered from space by LEO and MEO satellites, instead of the more common mobile or fixed terrestrial networks. Where terrestrial connectivity does exist, moves to implement FWA and improved Wi-Fi connectivity serve to improve the experience for end users. Connectivity is also increasingly required by devices and things for applications such as location tracking. This connectivity can be provided by a number of different IoT networks.

Developments in networks themselves are also expected. For example, integrated networks are foreseen to offer better connectivity through the use of different layers, e.g. traditional macro base stations, small cells, HAPS and satellites. Further, it is expected that end users will be able to purchase networks as a service, accessing network capacity only when required. Alongside this "connectivity and capacity when required" offering, cognitive radios are expected to develop further so as to be a viable industrial technology, allowing devices to themselves choose the most appropriate frequency band and technology for communications.
There is a need for networks to meet sustainability targets, ensuring higher consumption efficiency. 5G, whilst delivering a lower watts per bit consumption,

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consumes more energy than previous networks, suggesting that 6G may need to make further improvements in power efficiency.
All of these developments, as well as developing user expectations to be able to access the required spectrum quickly and with minimal administrative burden, invite regulators to ensure that their regulatory frameworks and approaches are fit for purpose and capable of dealing with the latest developments. Agility, as defined in this white paper, will aid regulators in this regard in that systems will be better able to handle changing requirements.

6.2. Spectrum Management Solution Opportunities and the Developing Capabilities of Regulators

As the requirement for access to spectrum develops, so too do the approaches and solutions that regulators use to manage the spectrum. This section considers the developments that have been identified and that allow regulators to manage spectrum in more agile and innovative ways.

6.2.1. Alternative Spectrum Licensing and Authorisation Models[22]

Traditionally, spectrum authorisations have tended to be based around three premises:

- Spectrum licences (as is often used for mobile licences);
- Site or transmitter licences (authorising the use of a specific frequency at a specific location, noting that this includes licensed shared access); or
- General authorisations and licence exemptions (whereby no individual licence is required so long as equipment complies with certain usage criteria).

Increasingly however, other less conventional licensing and authorisation schemes are being implemented.

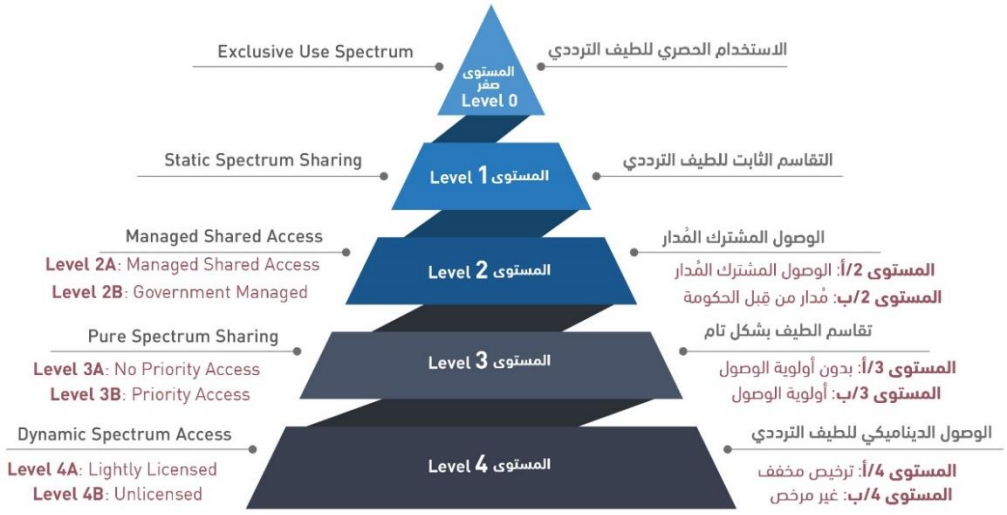

Figure 2 - Five levels of spectrum sharing models. Reproduced from Pucker, 2020.

22 In this section, referring to common international practices, “licensing” and “authorisation” are generically and indifferently applied to spectrum.

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One of the first alternative models is local licensing, whereby spectrum is still block assigned, i.e., frequencies are assigned, but for a specific area rather than an entire region or country. In many countries, this type of approach is used to authorise verticals. For example, 10 of the 27 European Union Member States had implemented local licensing schemes (mainly in 3.6GHz spectrum) as of March 2022. These local licensing schemes often remain administrative in nature but do facilitate a more flexible way of authorising spectrum for certain uses.

Another alternative model is light licensing, whereby users of equipment are required to register with the regulator to access the spectrum, but an individual licence is not necessarily required.

6.2.2. Spectrum Sharing Regimes

Spectrum sharing ranks high on the agenda of some spectrum policy makers as a potential "agile" solution to address excess demand for spectrum. Growing demand for spectrum is resulting in high levels of congestion in certain spectrum bands and areas of the world. In some cases, sharing between users can help to increase the spectrum efficiency of the bands in question. Similarly, access to specific bands, for example as required by IMT (International Mobile Telecommunications), can result in challenging incumbency scenarios that are, in some cases, best addressed through sharing.

Sharing technologies are already commercially available in some countries, with dynamic spectrum access (DSA) represented by CBRS (Citizens Broadband Radio Service, representing time-based sharing) and AFC (Automated Frequency Coordination, representing location-based sharing). However, the growing demand for spectrum suggests that further network sharing technologies and approaches may be required in the future, depending on the issue to be addressed and the physical characteristics of the frequency bands.

Sharing regimes such as CBRS make use of sensing to facilitate sharing, noting that there is a move within the US to move away from sensing-based systems, instead making use of 'Incumbent Informant Capability'[23] (IIC) to notify users in lower tiers when incumbents require access to spectrum. Other regimes such as AFC make use of centralized databases to coordinate usage. These regimes can be specific to certain contexts, or they could be viewed as building blocks which may be useful for sharing regimes in other contexts and bands. For instance, a CBRS type approach could be used in the context of PMSE when there is a need to protect an incumbent user. However, the implementation of such sharing regimes can be complex and costly, meaning regulators are often hesitant to commit to such regimes until demand is evident.

[23] NTIA, 2020. Incumbent Informing Capability (IIC) For Time-Based Spectrum Sharing. Available at: https://www.ntia.doc.gov/files/ntia/publications/iic_for_time-based_spectrum_sharing.pdf

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Changing the use of a frequency band begins at the ITU, with new allocations secured by a specific service in the Radio Regulations. This allocation is then entered into national frequency allocation tables (NFAT), with access to the band then determined by the regulator. The choice of access regime for a band is dependent on several factors, for example the presence of incumbent users, user needs (both existing and new), device characteristics and commercial viability.

In the case of some bands, for example maritime radars in the C-Band in the US, the cost to “refarm” (move to different frequencies) existing users (maritime radar) and put in place the necessary new equipment, was considered excessive. Instead, it was determined that the cost and complexity involved in developing the CBRS sharing approach (and not migrating maritime radar users) was viable given the huge benefit that access to C-Band spectrum for 5G would bring.

An important component for moving towards spectrum agility in the UAE would be implementing feasible spectrum sharing. Table 2 below shows an indicative timeline for the developments required:

Time Period	Developments
2024-26	AI-ready policy rules combine with sensors and cognitive radio to make greater levels of sharing, automated spectrum access and frequency assignment within single technology and service areas possible
2026-31	AI extends to sharing and decision-making across all technology and service areas
2031+	It is also feasible that in future a common sharing approach applicable to all shared spectrum bands could be developed. In this instance, a single tool would be able to manage sharing by all users, without regulators having to put in place dedicated systems for each.

Table 2 - Indicative spectrum sharing timeline.

6.2.3. Increased Intelligence and Agility in Databases

Spectrum Management Systems (SMS) are at the core of solutions in making spectrum available to users. Staff at national regulators interact with the SMS in granting authorisations (for example through collection of user demand information and analysis of any requests) and applicants interact with the system in order to provide the relevant information.

One area where developments may come into play in the shorter term is that of more developed and automated spectrum management systems. For example, certain SMS vendors already offer semi-automated processing of licence requests, and countries contacted through the benchmarking exercise verified that a number of services are now subject to automatic authorisations.

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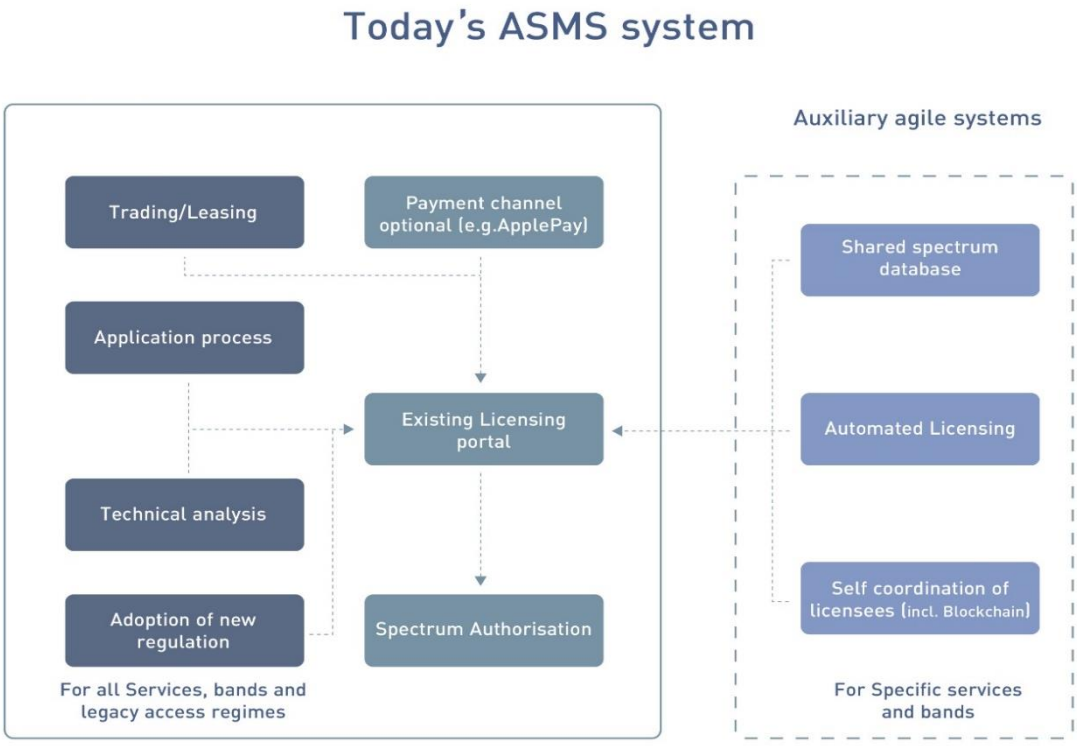
Further integration of these, and extension of the processes used to other services, is likely to continue.

Furthermore, greater levels of intelligence may be possible within the SMS, offering users a more personalised experience. For example, users logging into accounts on an authorisation portal could be guided towards actions related to their existing authorisations, for example renewal, or be initially guided towards relevant authorisation applications. Whilst not common amongst the benchmarked regulators, a number had identified that work in this area was ongoing, particularly with regards to improving customer experience without impacting upon the ability of regulators to collect the necessary information.

Beyond simply greater levels of automation, it could also be expected that SMS themselves will become more flexible and dynamic. Spectrum management systems today rely heavily on centralised licensing databases, interacting with various other systems including application portals, technical analysis tools and finance and type approval portals. A generalised system diagram for the current current spectrum management tools is shown below.



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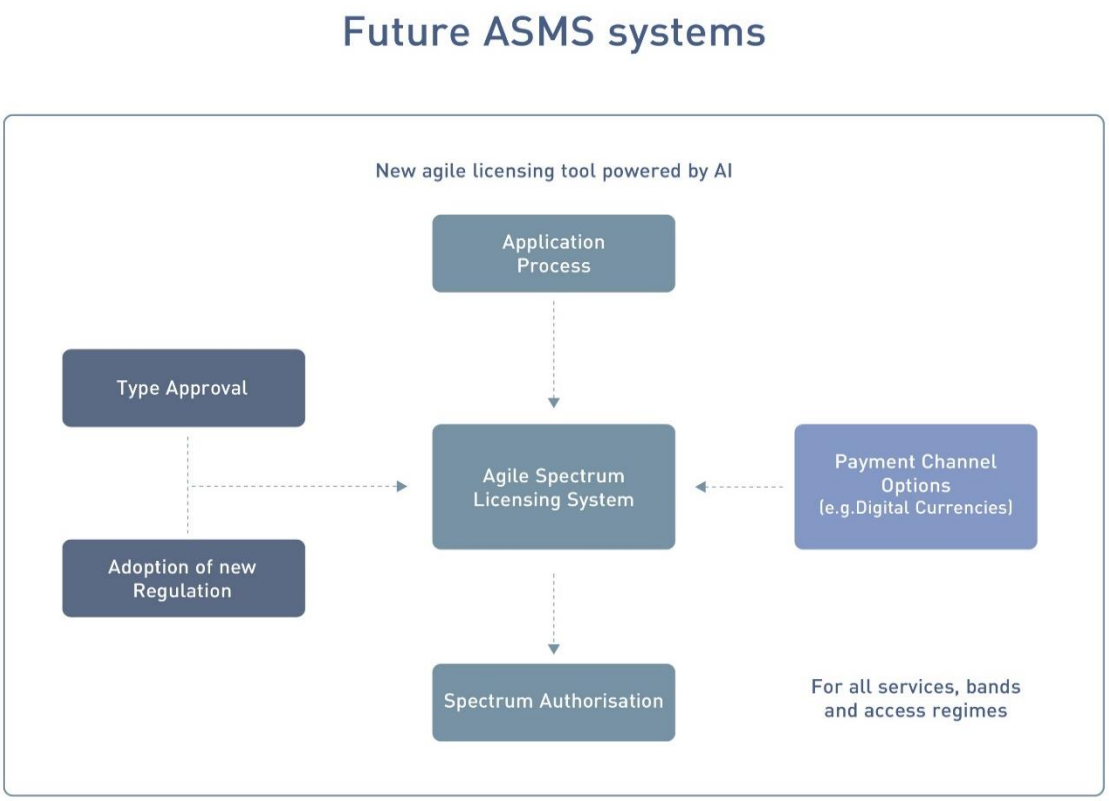

***Figure 3 – Current and future spectrum management systems*.**

On the horizon for these is an integration into a single solution. Such a system would not feature dedicated auxiliary tools to handle 'agile' parts of the spectrum management approach, but rather all services, bands and access regimes would be handled in a centralised tool, alongside more traditional legacy access regimes. The tool would be sufficiently intelligent to consider applications under the appropriate access regime, interacting with other systems as needed. Such a system would be better able to deliver the sort of spectrum management agility represented by the higher levels of the assessment metrics that have been defined.

Greater integration of SMS with other tools is also likely to be beneficial to both regulator and end user experience of systems. For example, direct integration of the SMS with monitoring data could facilitate immediate licence authorisations by allowing automated and more accurate interference potential calculations, especially for applications such as PMSE.

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6.2.4. Artificial Intelligence

Artificial intelligence, AI, is typically taken to mean the ability of machines and computers to augment data processing methods and speed to an advanced level beyond human capabilities. Many sources include in the definition the ability to be able to learn, problem solve, or at least deduct rules, as opposed to the more traditional input-output approach historically taken by computers and machines. Instead, AI systems can perceive and analyse their environment and act accordingly to maximise the chances of success. An application is machine learning, whereby AI systems are trained using large datasets to be able to identify the most successful outcomes.

Artificial intelligence in spectrum management is not yet mature. For example, the ITU considers artificial intelligence as important in several aspects of spectrum management[24] but its publications regarding the application of artificial intelligence in spectrum management pertain mostly to cognitive radio.

We consider that AI can be applied beyond general spectrum management aspects but also to more practical and IT-related elements, for instance smart assistants could be used to help applicants making applications for spectrum use to navigate the portal and automatically recognise user profiles and provide personalised guidance to users.

Research in artificial intelligence is expected to play a role in managing dynamic spectrum access systems. Arguably, using the above definitions of AI, techniques such as CBRS and AFC (considered previously in the White Paper) already illustrate artificial intelligence as they take account of environmental conditions, learning as they go, to maximise the chances of success in spectrum authorisations. Research suggests that AI could be suitable in the management of DSA (Dynamic Spectrum Access) as, once trained, AI-based DSA schemes should be able to process new data easily and be able to deal with the complex and fast changing nature of wireless signals that humans and traditional equipment may find challenging[25]. A further usage of AI in DSA could be to price spectrum based on the levels of instantaneous demand, such that spectrum pricing is able to change in real time, in theory helping to maximise the levels of spectral efficiency that can be obtained.

One aspect of spectrum management that could definitely benefit from artificial intelligence is that of monitoring. The role that artificial intelligence could have in processing the vast amounts of monitoring data, and making this available to

[24] ITU, 2022. AI will make radiocommunications smarter. Available at: https://www.itu.int/en/action/ai/emerging-radio-technologies/Pages/default.aspx

[25] Y.-C. Liang, 2020. Dynamic Spectrum Management, Signals and Communication Technology. https://doi.org/10.1007/978-981-15-0776-2_6

authorisation systems, could be highly useful[26]. AI's proven ability for pattern recognition could be of particular use in identifying signals which, when coupled with a dense network of sensors, could enable real time spectrum occupancy measurements.

Regulators around the world are beginning to implement automated licensing systems (typically focussed on PMR, PMSE, fixed links and maritime and aeronautical), but these are based on well-defined and understood assignment algorithms. The extension of AI to systems where higher levels of policy decision making are required in assignment (e.g., refarming, satellite) or for security and defence considerations, is considered significantly more difficult.

A further area where AI may prove useful is in identifying the impact of changes to the ITU Radio Regulations, as updated at World Radio Conferences (WRC). Currently, the process of updating national frequency allocation tables (NFAT) requires identifying what changes have been made to the services allowed to access each frequency range. This can be a manual and time-consuming process following WRC. It is quite possible that AI is able in the short term to identify the relevant changes in the Radio Regulations and update the NFAT in a shorter timescale and with fewer errors than a human.

Artificial intelligence to recognise potentially successful satellite ITU filings is also worthy of consideration. Based on a TDRA staff suggestion, this requires either a machine learning approach, based on successful satellite filings to date, or the development of an algorithm to determine likely probability of success.

6.2.5. Blockchain and Secure Cooperative Assignment Procedures

A blockchain is a decentralised ledger of information, shared across several so-called nodes. It is not currently widely deployed in spectrum management systems but blockchain or other secure cooperative assignment procedures may be considered a promising solution to solve some of the future challenges related to data verification.

[26] Telecommunication Engineering Centre, 2021. AI in Spectrum Management. Available at: https://www.tec.gov.in/pdf/Studypaper/AI_in_Spectrum_management.pdf

It is very difficult for users to falsify the information as each node (computer) holds a complete copy of the information, and transactions (changes to the information) are verified prior to adoption into the blockchain. Five key benefits of blockchains are considered below[27]:

- Decentralisation, i.e., no one party is responsible for the information;
- Transparency, i.e., the history of transactions leading to the current state is visible to all users;
- Immutability, i.e., it is difficult to change the information;
- Availability, i.e., the blockchain is replicated across many nodes, offering large amounts of redundancy; and
- Security, i.e., all entries in the ledger are cryptographically signed.

Between them, these key features can eliminate the need for a trusted entity responsible for the administration of many spectrum management aspects and allow for better visibility of spectrum occupancy, particularly if the blockchain can be updated in (near) real time.

Opening the blockchain to all users has the drawback that more complex verification mechanisms and blockchain nodes are required but removes administrative burden from the regulator.

Whilst there are several foreseen benefits and use cases related to the usage of blockchain in spectrum management, there are also a number of potential drawbacks. Firstly, the processing power required to validate blockchain transactions is potentially a limiting factor in their applicability. Many devices that could use the imagined blockchains are likely to be mobile in nature and hence battery powered. The battery drain that will be generated by the requirement to validate transactions could potentially prove prohibitive. Similarly, validating transactions will also require additional communication between nodes or devices accessing spectrum and the other blockchain nodes. This could require additional spectrum resources, thereby reducing the efficiency of the system. The validation also requires time. As such, blockchain as a real time spectrum authorisation or management system may be limited.

There are promising use cases for blockchain, but its limitations must be understood. At best, it provides a decentralised, potentially near real time spectrum management tool that can help to incentivise users to share spectrum more effectively and efficiently. At worst, it is an inefficient way to replicate what regulators already have. ANFR's successful implementation of a blockchain for self-coordination of frequencies between PMSE users demonstrates that for specific cases, blockchain can provide useful benefits. However, most regulators remain unconvinced of the benefits of deploying a blockchain in spectrum management more generally. Other, more simple, secure cooperative assignment procedures could be explored.

[27] Martin BH Weiss et al., 2019. On the Applications of Blockchain to Spectrum Management. IEEE Transactions on Cognitive Communications and Networking.

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6.2.6. Payments in Digital Currencies (UAE 2019-20 Project Aber)

The UAE launched in 2019 Project Aber, a Central Bank Digital Currency (CBDC) intended to explore domestic and cross-border payments through a distributed payment system. The project found significant efficiency improvements and transaction cost savings when using a centralised payment system[28]. In November 2020, the deployment of a CBDC in UAE was deemed feasible, pending further studies. In particular, CBDCs face significant regulatory challenges requiring careful consideration, for example privacy concerns, consumer protection, and anti-money laundering rules[29]. CBDCs have already been launched in a significant number of countries.

Through the research, digital currencies such as CBDC were found to have some benefits in certain scenarios, although mainly due to the complementary nature of CBDCs and blockchains, allowing for example smart contracts. Regulators contacted through the benchmarking exercise saw that the use of digital currencies, whether private or CBDC, was a matter for a nation's central bank rather than the organisation responsible for spectrum management.

6.2.7. Summary

Developments in spectrum management solutions are expected to be significant. Currently, spectrum management solutions and regulatory approaches tend to be fragmented, with a dedicated system and approach handling access to most bands and services, and standalone auxiliary tools and approaches for the more specific access regimes.

Developments in spectrum management solutions and technologies, such as AI and secure cooperative assignment procedures, are expected to allow a better integration of the various aspects of the SMS, and development of more agile and flexible tools. An ultimate aim would be for a single agile tool to be sufficiently intelligent and flexible to be able to authorise all services and spectrum as required.
Such a system could then feasibly implement new authorisation and regulatory approaches and sharing regimes as required (without the need to implement a dedicated new system), as well as possibly determining pricing dynamically if required. It is possible to provide a better service to customers through, for example, smart assistants to guide applicants through the application process, automated authorisations and analysis based on operational parameters rather than worst case values. A spectrum sharing framework perspective for the UAE will act as a catalyst for new spectrum access regimes combined with dynamic databases.

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[28] Central Band of the UAE, 2020. CBUAE and SAMA Issue Report on Results of Joint Digital Currency Project "Aber". Available at: https://www.centralbank.ae/media/nigd2put/cbuae-and-sama-issue-report-on-results-of-joint-digital-currency-project-aber_en.pdf

[29] Atlantic Council, 2022. Central Bank Digital Currency Tracker. Available at: https://www.atlanticcouncil.org/cbdctracker/

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7. TDRA 2031: Roadmap, Scenarios, and Timeline for the Evolution of Smart Spectrum Management Systems

The TDRA 2022 “Spectrum Agility” project has extensively researched wireless technology opportunities and the evolution of spectrum management solutions, the agility benefits they provide, and their implementation among entities in charge of spectrum management around the world.

Agility factors, technologies and spectrum management solutions will evolve in a non-linear and not fully predictable way over the next decade. There are notable uncertainties in their timeline. It is therefore necessary in this White Paper, in accordance with the UAE recommended scenario approach[30], to consider more than one possible path in the development of agile models. Answering the question “*how can spectrum management be fit for purpose and enable excellent experience for customers and spectrum users in the UAE?*”, is best assessed through three scenarios, and a discussion of the initiatives TDRA itself needs to take to achieve its agility goals.

The future scenarios TDRA has explored have focussed on the degree of development of maturity and technology factors. The extent of developments in process autonomy and agility in the next decade will depend on:

- Wireless technologies opportunities, in particular dynamic autonomous sharing and AI application at network management level;
- Progress of AI in spectrum management solutions; and
- The scope of institutional policy decisions in SMS requiring policy defined intervention.

[30] Scenario planning toolkit, UAE Government guide, 2019

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Based on the comprehensive international comparisons and benchmarking TDRA has performed, considering the future network technology opportunities, and the improvements in SMS spectrum management solutions, TDRA considers 3 key paths to agility scenarios over the 2023-2031 period:

Agility Scenario	Description	Path to Agility	Outcome
A. Trend towards incremental agility	Step-by-step improved agility in spectrum management	Evolutionary adoption of new agile processes including some additional intelligence	Incremental maturity level
B. Leap towards full agility conditions	Full Agility conditions	Generalised adoption of all fully agile processes to be conceived and developed	Fully agile maturity ("dream" reference scenario)
C. Objective based approach: The Road to 2031	Significantly enhanced agility in spectrum management	- Adoption of new agile processes - TDRA future-oriented initiatives	Quantum progress in maturity level

Table 3 - Spectrum management development scenarios for the 2023-2031 period.

7.1. Scenario A: Trend towards Incremental Agility

The benchmarking exercise conducted in the TDRA Spectrum Agility project has found somewhat cautious expectations from regulators around the world regarding the possibility of quick and substantial further advances in spectrum management automation in the foreseeable future. Spectrum management automation might take place, but only progressively, as illustrated in Figure 4.

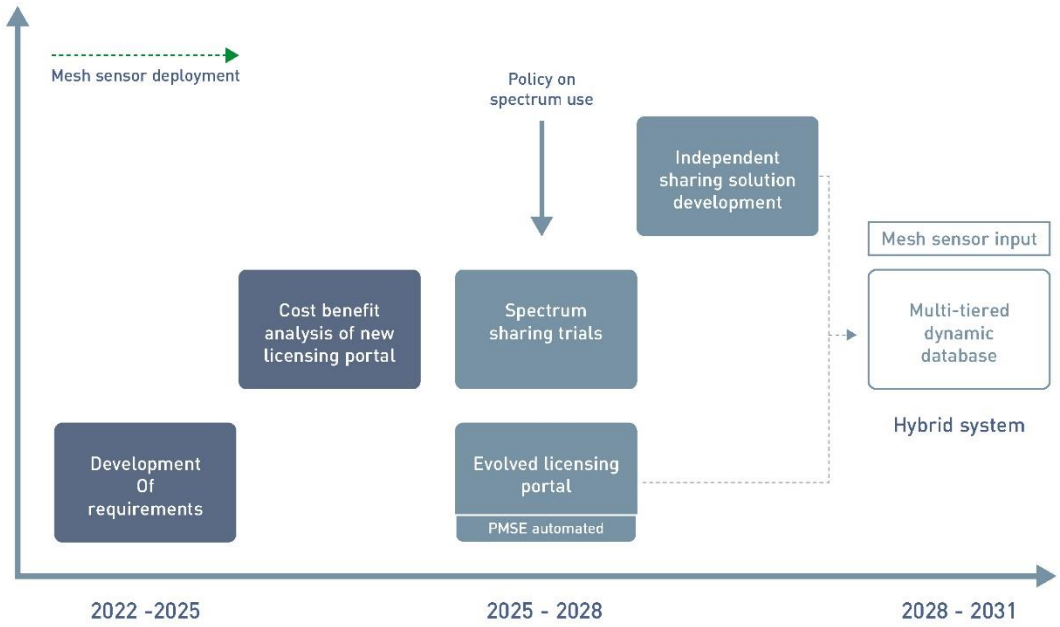

Figure 4 - Example spectrum management development roadmap for Scenario A.

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In this baseline scenario, live databases will take time to be set up and be fully operational. Sharing will be limited by prevalent claims of exclusive rights by incumbents, the complexity and relatively slow pace of development of effective cognitive radios, and the limited spectrum bands open to this innovation. Blockchain and cooperative frequency assignment will be limited to few services where relatively basic requirements can be handled by the users themselves. This does not mean that Agility will not improve in the next few years, but it will progress in an incremental, evolutionary way.

7.2. Scenario B: Leap towards Full Agility Conditions

Fully autonomous spectrum management is considered as a goal worth considering, but on an indeterminate horizon by the community of radio spectrum stakeholders and regulators. This fascinating perspective is often referred to in radio spectrum management circles as a “dream” or even a “fantasy”. Figure 5 describes such a hypothetical path towards “fully agile automation”.

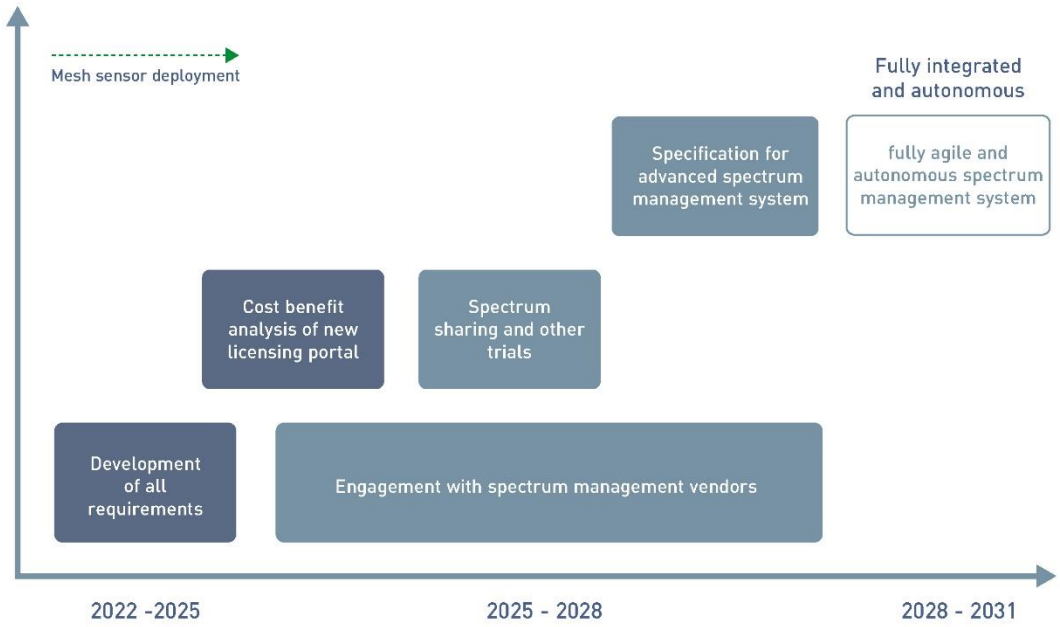

Figure 5 - Example spectrum management development roadmap for Scenario B.

The possibility of perfectly accurate cognitive radios combining with super powerful AI to make possible real-time, fully autonomous and optimally efficient spectrum allocation, assignment, authorisation and management across extensive frequency bands is explored in testbeds research projects conducted mostly in the United States by DARPA and the NSF.

According to the TDRA survey of stakeholders, the generally accepted expert opinion is that there still will be limitations on what spectrum management solutions can achieve in terms of autonomous spectrum assignment and authorisation. Beyond the lab, in real-life conditions, a combination of technical and policy considerations is in play for spectrum authorisation for many

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services. Dynamic spectrum access is already widely in use for determinate technologies and services but is far from extending beyond service allocations and covering the whole radio spectrum. Competition conditions, security and defence issues, can benefit from AI analysis, but they will not easily fit into autonomous systems, however smart they are.

Although they provide a useful reference vision, the conditions for the advent of such a fully autonomous spectrum management solution will not be ready by 2031. Interestingly, though, this provides a glimpse at what radio spectrum management might comprehensively look like someday. It allows some useful metrics of the gap between where we are, the practical realities of the wireless ecosystem demands, developments, spectrum management solutions, and what we can ambitiously but reasonably aim at. It defines a space, a framework, within which to define initiatives that will be implemented to achieve the best possible outcomes in an objective based approach until 2031.

7.3. Scenario C: Objective Based Approach: The Road to 2031

Facing the realities at the beginning of 2023, it turns out that the road to 2031 for the TDRA Agility timeline will result from a combination of technology and spectrum management solution opportunities, reinforced by TDRA's own initiatives and developments, contributing to the UAE "2031 Ecosystem" digital objectives wherever spectrum management is implied.

The selected major initiatives TDRA is taking to speed up the journey on the Agility highways to escalate the maturity level of spectrum management regime, involves, but is not limited to, the following considerations:

- The degree of systemic, dynamic integration of the application, authorisation, monitoring process;
- The implementation of live and dynamic databases;
- The use of Blockchain and secure cooperative procedures for self-organisation of spectrum assignments;
- The extent of single decision-direct assignments, verticals, FWA which increase the burden of tasks of the regulator; and
- The extension of sharing approaches (advanced sensing, integration of databases and sensing, dynamic access).

The table below describes the objectives pursued by TDRA on its path towards a high agility and autonomy maturity level.

Objective	Description
1. Users	Users as part of the agile, real-time, spectrum management system
2. Promoting AI	Promoting AI in the ASMS process anticipating and fulfilling user needs
3. Enhanced automation/ autonomy	Enhanced automation/autonomy for Agility implementation: roadmap Towards 2031

Table 4 - Description of the objectives associated with Scenario C.

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The objectives of this changeover process are the following.

7.3.1. Objective 1: Users as Part of the Agile, Real-time, Spectrum Management System

In line with the UAE Digital objectives, TDRA aims to achieve high user satisfaction, which is part of its charter. The “Spectrum Agility” research project, in its definition of agility and flexibility, has led to consider users as part the spectrum management system itself. Indeed, the role of TDRA does not stop once an authorisation has been issued to a user. TDRA is required to ensure continued interference free operation for the duration of the authorisation, and allow users to flexibly modify, renew or cancel their authorisations when needed.

A potential application of this concept lies in managing users’ frequencies in real time to ensure higher levels of service and spectral efficiency. Live usage and authorisations can take place. For example, if a frequency at a given location can be useful for another applicant, TDRA could (under certain conditions) modify the authorisation of an incumbent user to dynamically clear space for the new applicant. This could be described as ‘live spectrum management’.

As another implementation of the “user as part of the spectrum management system”, it may be possible to provide users dynamically (under certain conditions) with expedited authorisations for usage of spectrum. If users are registered with TDRA and equipment is fully type approved and connected to TDRA’s systems, it could be possible to automate parts of the authorisation process with minimal human intervention.

Currently authorisations in the UAE are for a single year, but an application of the sort of real time and connected system considered could be to authorise usage for much shorter durations, e.g. a number of minutes, if required. This could also facilitate charging for spectrum access dynamically. For example, users could be charged once devices are switched on until they are switched off, with the frequency automatically selected by TDRA’s database on behalf of the device. This would also give TDRA better visibility of spectrum usage and device ownership.

It could also be possible to define priority levels for users such that if concurrent access is required, those with a higher priority are ensured access. This is akin to the approach used in CBRS for example.

Actually, it could be possible to define spectrum management in 5 dimensions: x, y, z (i.e., coordinates), time and frequency. For some services, it is likely to be possible to further automate and make almost autonomous, most, if not all, aspects of an authorisation. However, for some services, the level of complexity is such that automation will not be possible for all aspects in the short term, for example those that require significant amounts of coordination. Certain aspects, for example technical analysis or exchange of information, could potentially be automated.

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The main objective in this scenario is to enhance the level of system autonomy in the authorisation process.

7.3.2. Objective 2: Promoting AI in the ASMS process: Anticipating and Fulfilling User Needs

In this TDRA Objective, AI intervenes as a major Agility factor at each step of the spectrum management process.

Application of AI at	Description
1. Application submission	This is an AI assistant that could potentially offer support in completing the application autonomously as an interactive online solution. Elementary AI, with data in the hundreds, closer to an evolving expert system, will help identify the user and its needs in an always more precise manner. User profiles could be used as part of the application portal to help offer a more personalised service to applicants. It could also be possible to pre-calculate and publish the available fixed link channels in each area, for example to make applications easier for users.
2. Application processing and authorisation	Autonomous processing of with the objective of no human intervention to include RF predictions, technical analysis, calculations, collaborative authorisation processes, getting closer to automated assignment decisions in many cases. As more data is generated and higher resolution needed to enable/support spectrum authorisation, evolved algorithms will play a pivotal role, allowing a level 2 AI.
3. Monitoring process	The monitoring stage, which includes preventive monitoring, deals with lots of measurement data incoming from a range of sensors (e.g. mesh sensors). The data will need to quickly be processed, interpreted and presented in a meaningful way to support live authorisations. Thus, a Level 3 Advanced AI application would be needed.

Table 5 - Development levels for AI.

This 3-step spectrum management process can constantly and robustly evolve over time. However, within an advanced dynamic spectrum management solution, possibly including sharing provisions, the 3 steps can be integrated in a system with feedback and loops. This would represent the most promising application of AI in the future.

Furthermore, once more data on spectrum usage can be collected, AI could contribute to policy making and improve cost effectiveness. This is being considered in 6G with the increased use of ML and AI.

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7.3.3. Objective 3: Enhanced Automation/Autonomy for Agility Implementation: Roadmap Towards 2031

Spectrum management regimes in future will increasing be more agile, this means enhanced levels of automation/autonomy beyond what is available today.

Evolution from today's systems to future systems is based on certain developments currently arising, notably more intelligence in data processing, more automation and autonomy of spectrum management processes, and an increase in the use of dynamic spectrum access systems across different bands and services. Figure 6 shows the transition and initiatives from today's systems to future systems.

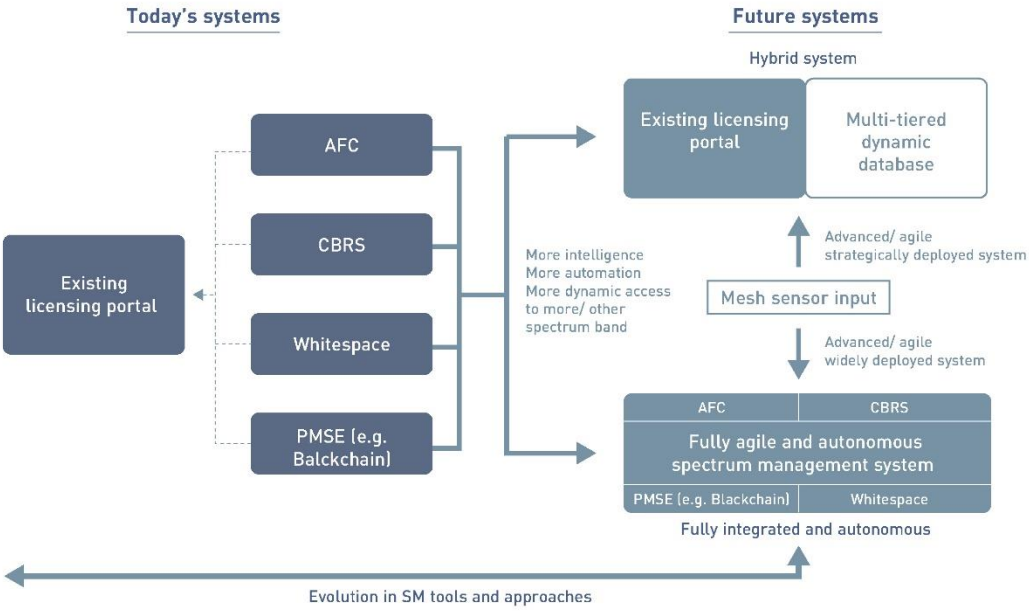

Figure 6 - Current and future spectrum management systems.

7.4. TDRA Initiatives and the ITU Framework

The international table of frequency allocations evolves step by step, following the ITU conferences quadrennial calendar. Agility is on the horizon, but the path towards it conforms to a strict institutional framework. Cognitive approaches, however, if applied across technologies and services, have potentially wide-ranging international implications. ITU procedures might have to change in the future to allow for more flexibility/agility. In terms of spectrum management solutions though, something can be achieved.

The ITU spectrum management handbook was last updated in 2015 and refers to computer systems and automation. It does not refer to more futuristic elements such as the use of AI or more intelligence incorporated into spectrum management. It might be useful, through the findings from this study, for the ITU to consider an update to their spectrum management handbook and consider future initiatives and spectrum management capabilities over the next decade.

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Whilst changes at an ITU level are beyond the scope of this White Paper, there are some considerations around the potential limitations on flexibility and agility that could be achieved for some aspects due to the requirement to comply with the ITU regulatory framework. As the ITU cycle requires a number of actions and requires consensus based decision making, changes to the framework can potentially require significant amounts of effort and time to enter into national implementations. Previously, there have been a number of suggestions regarding changes to the ITU process, but to date none have been found suitable. Thus, where decisions need to be made, the possible extent and pace of automated agility processes implementation is still limited.

7.5. The Road to 2031: UAE Digital Objectives and TDRA Initiatives

In its endeavour to foster Agility in spectrum management, TDRA conforms to a rigorous management approach which:

- Focuses on outcomes;
- Achieves high impacts;
- Supports experimentation on networked collaboration;
- Follows adaptive resource allocations;
- Opens knowledge flow in a disruptive, innovative and transformational manner; and
- Focuses on engagement and co-creation.

This will need to be a realistic manifesto of spectrum management evolution so that TDRA is able to implement the initiatives in a timely and cost effective manner.

To reinforce the opportunities offered by technologies and the progress in spectrum management solutions, and to explore the changeovers towards Agility 2031, TDRA considers the following initiatives:

Initiatives Related to the "Users" Objective

- **Personalised procedures** with AI to guide users
- A **more open spectrum**: Expand sharing to facilitate user access
- Empower users with **secure collaborative assignment** procedures whenever possible

Initiatives Related to the "Promoting AI" Objective

- Extensive research into 'Algorithm based' spectrum application, authorisations, and monitoring

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Initiatives Related to the "Enhanced Automation/Autonomy" Objective

- Define efficient workflows combining automation and policy orientations, including priority and emergency communications
- Extend research efforts to enhance spectrum efficiency and sustainability in spectrum management with UAE Research institutions, vendors, international partners

These initiatives are intended to complement the opportunities offered by new wireless technologies and spectrum management solutions to speed up the path towards agility in radio spectrum management.

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8. Timeline and Benefits of Implementing an Agile SMS

TDRA intends to initiate a programme of activities to implement an agile SMS over the next 9 years based on the objectives and initiatives discussed in this White Paper. The following timeline sets out the main time ranges in which TDRA will implement its plan.

2023

In the already implemented first stage 2022-23, TDRA baseline SMS compares favourably to international spectrum management standards, as demonstrated by the TDRA's ranking in the ICT global competitiveness indicators and indices, thus already engaged in evolutionary process.

2024-26

In the next stage, TDRA implements supply driven evolutions on the horizon, AI, advanced spectrum sharing approaches.

2026-31

In the third stage, TDRA mixes supply trends with its own initiative-driven approach, defined in accordance with the UAE Vision 2031 and the TDRA strategic objectives.

TDRA will keep track of the evolution towards an agile spectrum management system through the development of dedicated agility objectives, focusing on inclusion, users as part of the ecosystem, AI developments at the service of spectrum application, authorisation and monitoring, and the progress of automation towards autonomous processes in spectrum management systems.

Furthermore, a programme of this nature needs to demonstrate a clear set of benefits to justify pursuing the work plan and to ensure maximum value is delivered to TDRA from a future SMS. The following are some of the main benefits that would arise:

- **Customer Happiness** - an enhancement in customer satisfaction with their dealings with TDRA resulting from, for example, easier applications or faster authorisation timescales;
- **Spectrum Efficiency** - an improvement in the spectral efficiency achieved by services operating in the UAE;
- **Flexibility** - an improvement in TDRA's ability to offer flexibility to users, for example with regards to access to different bands or under different conditions; and
- **TDRA Capability** - an improvement in TDRA's ability to perform its spectrum management functions, for example an ability to process a greater number of applications in less time.

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