5G Americas Response

to Department of Defense Request for Information on 5G

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Contents

Executive Summary

5G Americas welcomes the Department's inquiry into how to accelerate 5G deployment, including on how to expedite the repurposing of more mid-band spectrum for commercial broadband. 5G Americas appreciates DoD's interest in deploying 5G for its own uses, and appends information on DSS, in the event DoD is seeking to transition use of 4G on its installations to 5G. 5G Americas also appends information on network slicing.

Globally, the mid-band range of 3.3 – 4.2 GHz has been the focus of other countries' 5G deployments. 5G Americas is pleased that over the summer the Department joined the White House announcement that 3.45- 3.55 GHz would be made available for commercial use across the continental United States. It is critical that this 100 MHz not be included in any new type of shared network operated by DOD or a novel vendor. Rather, the Department should move forward on clearing systems from 3.45 – 3.55 GHz so the band can be auctioned for exclusive full-power commercial use in 2021. To compete internationally in the 5G era, the U.S. must repurpose spectrum expeditiously. Accordingly, as part of the repurposing review. the Department, NTIA and other federal users should use commercial standards for sharing and compatibility studies,

Congress provided in the 2012 Spectrum Act: *In evaluating a band of frequencies for possible reallocation for exclusive non-Federal use or shared use, the NTIA shall give priority to options involving reallocation of the band for exclusive non-Federal use and shall choose options involving shared use only when it determines, in consultation with the Director of the Office of Management and Budget, that relocation of a Federal entity from the band is not feasible because of technical or cost constraints.* That policy should govern federal actions with respect to this inquiry. Only where relocation of a federal system is not feasible should the Department consider any form of spectrum sharing. When the statutory criteria is met, any form of sharing should be accomplished through proven commercial methods, such as with experienced, competitive spectrum access database managers selected from the private sector based on rigorous criteria. 5G deployment is critical to U.S. economic, technological, industrial and military leadership. Commercial access to more mid-band spectrum is crucial. The mobile industry is ready to work with the Department to realize our shared national goal of leading in 5G.

Recommendations

- DoD should focus on clearing 3450- 3550 MHz towards the goal of auctions next year for exclusive, licensed full-powered commercial broadband, and not consider this 100 MHz in any part of a shared network operated by DoD or a vendor.
- DoD should continue to review 3100-3450 MHz for commercial repurposing, since this range has international support and corresponds with the mid-band being harmonized around the world for 5G.
- DoD and NTIA should work with industry stakeholders to establish Incumbent Informing Capability (IIC) requirements and development timelines.
- DoD and NITA should work collaboratively with industry on modeling and simulation efforts to help all stakeholders develop compatibility approaches that make spectrum available as soon as possible.

Introduction

5G Americas, the voice for 5G and LTE in the Americas, is a trade association the Board of Governors of which includes AT&T, Cable & Wireless Communications, Ciena, Cisco, Commscope, Crown Castle, Ericsson, Intel, Mavenir, Nokia, Qualcomm, Samsung, Shaw, T-Mobile USA, Telefónica, and WOM. Currently chaired by Igal Elbaz of AT&T, 5G Americas has a broad membership of leading wireless operators and vendors of 5G software, core, radio access network equipment, and other key wireless infrastructure comprising the 5G ecosystem. 5G Americas facilitates and advocates for the advancement and transformation of LTE, 5G and beyond throughout the Americas.

5G Americas is pleased to submit this white paper in response to the Department of Defense's Request for Information on Spectrum Sharing for 5G. This a critical discussion at this point in our nation's deployment of 5G. 5G Americas is Market Representative Partner of 3GPP, a global initiative uniting seven telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), known as "Organizational Partners", and that provides their members with a stable environment to produce the reports and specifications that define 3GPP technologies.

The Department refers to the term "Dynamic Spectrum Sharing" (DSS) in its Request for Information (RFI). Within 3GPP, DSS has a meaning applicable to private sector commercial networks. In a recent White Paper on *Global 5G: Rise of a Transformational Technology* [1], 5G Americas and Rysavy Research notes that as operators seek to introduce new cellular technology generations, they have re-farmed their spectrum in discrete blocks to serve the next technology generation as consumer device mix changes. However, manual spectrum re-farming creates an operational burden because it requires careful planning, coordination, and execution to avoid degradation in end-user performance [2].

DSS technology introduces 5G faster and more efficiently compared to static spectrum re-farming, while also leveraging pooling gains by operating two technologies in the same spectrum band. In other words, with DSS, the same radio channel can support both LTE and 5G, facilitating the rollout of 5G in existing cellular bands. Additionally, DSS improves spectrum use by reducing the effect of having a spectrum block tied up to a technology that is lightly loaded. DSS achieves this result by enabling dynamic allocation of radio resources as required by that particular generation of cellular technology, such as LTE and 5G. In terms of system performance, DSS does not improve spectral efficiency; rather, it increases spectrum utilization when possible.

Despite its ability to allow an operator to simultaneously serve legacy customers and customers adopting the next generation of cellular technology, DSS does result in some loss of capacity, including voice. This is due to the additional overhead of having two radio access technologies operating in the same spectrum block [3]. DSS can only be implemented for channel bandwidths of at least 10+10MHz. DSS requires LTE and New Radio (NR) schedulers to communicate with each other to adequately coordinate resource allocation. As a result, LTE and NR baseband hardware need to be collocated with low latency. Radio hardware should also support RF sharing between LTE and NR.

Ultimately, 5G Americas assumes that the Department's use of DSS was intended to mean more general dynamic spectrum access (DSA) rather than 3GPP's understanding of DSS. Such DSS would have little relevance for facilitating sharing federal spectrum between government radar and commercial users. Indeed, no commercial spectrum sharing technology exists today for 5G that would allow it to interoperate with DoD systems in the lower 3 GHz band [4]. AS noted above, DSS was designed to enable a radio channel to support both 4G LTE and 5G, not both radar and 5G. Moreover, the standard for DSS took years to develop [4].

Accordingly, in this White Paper 5G Americas will generally refer to sharing technology encapsulated in the acronym DSA except where the Department implies DSS in 3GPP's context from Section I of the RFI. In the event that the Department is interested in DSS for use in its own installations for moving personnel or systems off of LTE to 5G, 5G Americas includes an Appendix on DSS in this White Paper.

DOD Owning and Operating Independent Networks For Its 5G Operations

5G Americas welcomes the Department's interest in implementing 5G technology for its own operations. The Department and its service branches can benefit from the global scale of 5G by adopting 5G networks at its installations. 5G offers a broad ecosystem of vendors and use cases that will simplify DoD's adoption of 5G networks. A key factor facilitating the widescale adoption of 5G wireless solutions by the private sector is commercial access to sufficient amounts of spectrum. Spectrum harmonizing is also key to achieving cost-efficient and competitive industrial devices.

5G Americas has often noted that the "gold standard" for repurposing is cleared spectrum, with the federal systems relocated to other bands, so that the spectrum can be exclusively licensed to commercial entities through auction. Congress said as much in the 2012 Spectrum Act [5]. Congress directed NTIA, in "evaluating a band of frequencies for possible reallocation for exclusive non-Federal use or shared use," to "give priority to options involving reallocation of the band for exclusive non-Federal use and shall choose options involving shared use only when it determines, in consultation with the Director of the Office of Management and Budget, that relocation of a Federal entity from the band is not feasible because of technical or cost constraints [6]." In its recently adopted Report and Order on the 3.45 – 3.55 GHz band the Federal Communications Commission (FCC), states, "Spectrum that has been cleared to the greatest extent possible provides maximum flexibility in future uses, ensuring intensive and efficient use of that spectrum going forward. Spectrum encumbrances, on the other hand, constrain the potential of future uses of that spectrum, deter investment in the band, and undermine the public interest benefits of the relicensing process [7]."

5G Americas urges the Department and NTIA to continue to look for where agencies' systems can be relocated out of bands suitable for commercial mobile broadband, particularly in the mid-band spectrum which has become the globally harmonized range for 5G (particularly in the range 3GPP calls 'Band 77', 3.3 – 4.2 GHz). Indeed, by the conclusion of last year's World Radiocommunications Conference hosted by the United Nations' International Telecommunication Union (ITU), 76 countries from each of the three ITU regions, including our own, identified 3.3 – 3.4 GHz for mobile. 3GPP has specifications for the operation of both LTE and 5G NR covering 3.3 – 3.55 GHz, and there are already significant deployments worldwide along with the required ecosystem to enable those deployments. Seventy percent of the world's mobile operators (nearly 140 operators around the globe) are investing their 5G deployments in this range. The 3300 – 3400 MHz band is also included in existing frequency arrangements harmonized in our regional Commission on International Telecommunications (CITEL) [8], a part of the Organization of American States, as well as at the ITU [9]. 3.4 – 3.55 GHz is already allocated globally to mobile in all three ITU regions, whereas the United States the band is allocated to radar. By maximizing commercial access to the entire lower 3 GHz band, the Department will allow its users and other federal agencies to benefit from global 5G economies in the band.

Some have construed the Department's RFI as an attempt by the DOD to run a national public 5G network. 5G Americas does not read the RFI in that manner and appreciates the Department's clarification of its intent in recent public statements [10]. Were the RFI to have called for such a proposal, 5G Americas would have urged the Department not to depart from the current model of competing commercial networks. As the Department understands, the U.S. has led in 4G and now 5G because it has chosen the free market competitive network model.

5G Americas continues to urge, particularly in the mid-band, the Department and NTIA to continuously review which spectrum bands can be cleared for exclusive, commercial use in adequate contiguous blocks to support 5G, particularly in the mid-band. DSA should be adopted by the Department and operated by experienced and competitive private sector database managers, to maximize commercial access to shared spectrum, only where DOD systems cannot be relocated due to national security reasons. A competitive model for selecting database managers to operate any DSA spectrum access database allows all variants as long as the networks are coordinated.

Development and implementation of a dynamic sharing arrangement takes considerable time. Based on past experiences, there is a need to create a process for sharing information between the DOD and the commercial interests. Citizens Broadband Radio Service (CBRS) is a spectrum sharing arrangement very specific to a certain band. It could be difficult to export the technology to other markets, and possibly other bands. Technologies that are unique to a specific model do not enjoy market scale and efficiencies, which may impede the success of the sharing arrangement.

5G Americas recognizes the particular national security concerns with the Department operating its own 5G private networks. Additionally, it cautions that the history of spectrum policy is replete with particular users wanting their own dedicated spectrum, such as the utilities or public safety. As displayed by the FCC's recent 4.9 GHz proposal, spectrum dedicated to particular users is not always used with maximum efficiency. The CBRS auction, with its smaller geographic county licenses and 10 MHz blocks, was expected to result in many new entrants, particularly enterprises, holding licenses for their own dedicated use. 5G will be very important to enterprise verticals for advanced manufacturing and automated vehicle platooning, as well as smart cities. The vast majority of the CBRS licenses went to commercial communications providers with few exceptions.

With this recent example in mind, 5G Americas urges the Department to be open to the provision of 5G solutions by the private sector to meet its needs, where that can be done consistent with national security as the Department does with satellite communications and other communications.

Technologies to Make Additional Mid-Band Spectrum Available Faster

In addition to DSS and DSA, network slicing is another private sector technology that would benefit the Department by allowing it to access slices of commercial spectrum dedicated for its particular mission critical needs. In *Global 5G: Rise of a Transformational Technology*, 5G Americas and Rysavy Research explain that not only do 5G networks include a new radio (NR) and core, but thanks to virtualization, these networks can also present multiple "faces" for different use cases using an architectural approach called "network slicing" as first defined in 3GPP Release 15 [11]. This architecture allows an operator to provide multiple services with different performance characteristics. Each network slice operates as an independent, virtualized version of the network designed to serve a defined business purpose or customer. Thus, each slice consists of all network resources required to address the specific need. The network slice is the only network the application customer sees for a given application. The slices not subscribed to by the customer are invisible and inaccessible. The advantage of this architecture is that the operator can create isolated, fine-tuned slices for specific use cases.

More detailed information on network slicing is included in the Appendix.

Network slicing would therefore allow a carrier to deliver to DOD's branches or their installations the 5G services they desire while that carrier simultaneously serves other customers' needs. For instance, on a military base, DOD could operate its own network, but continue to enable 5G services to military users through a network slice provided by a commercial operator, as the military users left the base. The Department can bring its own encryption and other Quality of Service (QoS) requirements and apply them to the slice provided by the commercial operator.

However, the industry needs more mid-band spectrum to simultaneously and robustly serve the Department's and other customers' 5G needs through network slices, and win the race to 5G.

In addition to Network Slicing, the Department should continue to explore Incumbent Informing Capability (IIC) to improve on Enhanced Sensing Capability (ESC) for spectrum access database operations to increase commercial access to 3.55 – 3.65 GHz. Implementation of IIC could improve *time to market* for commercial operators in bands shared with federal users. IIC is more generalized than ESC so it could be applied to other bands where the Department can share but cannot relocate systems. NTIA and DOD should work with industry stakeholders to establish IIC requirements and development timelines.

5G Americas is pleased that the Department requested $98 Million from the recently concluded CBRS auction proceeds to revisit the CBRS rules and possibly reduce the protection zones around the incumbent government radar in the band. In addition to IIC and other means to right-size the protection zones, 5G Americas hopes the Department, NTIA, and the FCC can revisit the power levels of commercial services in CBRS to allow higher-power, standardized 5G operations. Such high-powered operations would allow more continuity of operations with similar components and antenna configurations. Ultimately, 5G antennas can tune across the entire 530 MHz range, reducing costs for consumers of 5G. Higher powered CBRS devices would expand the use case that could be deployed in the CBRS band.

Returning to the concept of 3GPP's DSS, it is worth reminding the Department that today 5G standards do not support a mode of operation in which a user obtains bandwidth from two different networks simultaneously [4]. In DSS, the same operator is deploying both 4G and 5G in the same spectrum. Different bands of spectrum from different operators are not aggregated. The alternative of breaking the connection with a commercial provider and roaming onto a DoD network would also be a poor solution for multiple reasons, including the likely less robust operation of the DoD network. Additionally, the wholesale network would likely not support the multiple valued-added services being planned for commercial 5G networks, such as edge computing [4].

How to Make 3.1 – 3.55 GHz Available for Commercial 5G Access Faster

5G Americas appreciates the Department's decision to make 3.45 – 3.55 GHz commercially available throughout the continental United States (CONUS) since that band is squarely within the globally harmonized range for 5G. The 3.45 – 3.55 GHz band should be auctioned as soon as possible next year for mutually-exclusive licensed use, and should not be part of any network the Department accesses in CONUS for its own use. The Department and NTIA already conducted an extensive analysis, as required by Mobile Now, to determine this 100 MHz could be made available to the industry with few restrictions. U.S. operators, already deploying and planning for mid-band broadband with CBRS and C-Band can readily add this spectrum to their service offerings to enhance 5G capabilities. Considering any other use of this specific frequency band, such as for a DoD shared network, will needlessly diminish U.S. 5G capabilities.

Furthermore, the 100 MHz within the 3.45 to 3.55 GHz range, relative to all mid-band spectrum available today, represents only 14% of mid-band spectrum available today for commercial use in the U.S. A new government-controlled network based on this spectrum alone would simply not have enough capacity to make a difference and would be a huge distraction for the industry [4].

It is also critical to continue making the lower 3.1 – 3.45 GHz range available for commercial access. Spectrum on the order of 150 MHz is needed in this mid-band range This spectrum should be licensed and auctioned in a suitable timeframe. Spectrum that cannot be cleared to allow sufficient access similar to the rules in 3700 – 3980 MHz should be shared.

The 3.3 – 4.2 GHz range has become the globally harmonized range because of its combination of coverage and capacity. Some countries are considering hundreds of MHz per carrier. The 530 MHz in the 3.5 GHz range may be a strong start, but will not result in 200 MHz or 400 MHz per U.S. carrier. As Commissioner O'Rielly stated when adopting the 3.45-3.55 GHz band decision recently, not only do wireless providers seek 100 MHz blocks of mid-band for their own 5G deployments, but "cable providers are actively seeking wireless opportunities, industrial uses and other private networks are being deployed, and the Internet of Things will require extensive network connectivity, and that's just a handful of plausible uses and services. Not to mention, we need to ensure there are spectrum resources for future technology generations. Make no mistake, the spectrum pipeline cannot be left empty [12]."

Other Spectrum Bands that Can be Made Available for Commercial Access

In its RFI, the Department asks what other spectrum bands assigned to DOD can be made available for commercial access. 5G Americas endorses Commissioner O'Rielly's stance that the spectrum pipeline cannot remain empty and commends the Department's attention to the 7 – 8.5 GHz band. Earlier this year, the mobile industry raised the possibility of this federal mid-band range being repurposed for commercial use. This band falls within the "mid-band" range of the FCC's inquiry that commenced several years ago. An industry report found that based on what information is publicly available on federal users in the band, 7/8 GHz is lightly-used, relative to other mid-band ranges [13]. Moreover, commercial users in 6 GHz are similar to the federal users in 7 – 8.5 GHz, which permits easy coordination of mobile operations (particularly the number of fixed microwave users). The 7/8 GHz range falls within the range that Congress directed the Administration in the Mobile Now Act to review for possible repurposing for commercial broadband [14] [15].

The 7 – 8.5 GHz band should be considered for flexible use and it is recommended that dialog between NTIA, FCC, and commercial interests begin quickly. Based on the history of spectrum repurposing in the U.S., identifying, clearing, or establishing an appropriate spectrum sharing framework takes many years (for example, witness CBRS). Therefore, it is imperative to continue identifying a pipeline of suitable spectrum to address the capacity demands for 5G.

5G Americas has had a long-standing interest in 1300 – 1350 MHz and 1780 – 1830 MHz for repurposing for commercial mobile use [16]. The 1780 – 1830 MHz band is adjacent to the 1755 – 1780 MHz band that the federal government repurposed from Department of Defense use almost a decade ago and resulted in the highest amount of spectrum auction proceeds in U.S. history (over $40 billion) when paired with 25 MHz of Advanced Wireless Services spectrum in the 2 GHz band. The 1780 – 1830 MHz band is allocated in all three global ITU regions for mobile services and included in 3GPP's band plan as Band 3. Making that band available for commercial access would enable U.S. industry to ultimately leverage global economies of scale to the benefit of U.S. users.

Half a decade ago, 5G Americas noted in comments to the FCC that the 1300 – 1350 MHz band was a priority band for repurposing [17]. Five years ago, efforts were underway to study if agency operations might be made spectrally and operationally more efficient through the transition to multi-function phased array radar. The Federal Aviation Administration (FAA) and the National Oceanographic and Atmospheric Administration (NOAA) sponsored studies to evaluate the feasibility of replacing existing primary radar systems with phased array radars, including for air route surveillance radar (ARSR) in the 1300 – 1390 MHz band [18].

In its second annual report on the *Ten-Year Plan*, the NTIA had the band under consideration for possible sharing and/or relocation following President Obama's 2010 directive identifying 500 MHz of spectrum for mobile broadband. Specifically, NTIA noted, "the PPSG listed the 1300 – 1370 MHz band to study for sharing and the 1370 – 1390 MHz band for potential relocation. Sharing the entire 90 megahertz across these two bands may achieve greater benefits; however, there are differences in use of the 1300 – 1370 MHz and the 1370 – 1390 MHz bands that the PPSG must take into account if they prioritize these two bands as one for the next band to study for sharing [19]". The 1300 – 1370 MHz sub-band contains 70 MHz that could be paired with the 70 MHz in 1780 – 1850 MHz for mobile broadband.

Five years ago, the industry and NTIA were studying new sharing technologies for 1780 – 1850 MHz that could also have been applied in the 1300 – 1350 MHz band. Advanced Antenna Systems and other 5G capabilities have further improved the ability of commercial broadband to share spectrum [20]. As a result, previous analysis could be leveraged to expedite commercial access because these bands have been reviewed previously by the U.S. government for repurposing.

Millimeter wave spectrum continues to hold promise for 5G densification in urban centers and for enterprise applications. 5G Americas thanks the Department for its earlier decision to share the 37 – 37.6 GHz band, but requests that the Department work with the FCC and industry to finalize a sharing framework for the Shared Access Licenses. Today, the FCC's Part 30 rules for flexible use in the millimeter wave spectrum provide that:

> *(a) The 37–37.6 GHz band will be available for site-based registrations on a coordinated basis with co-equal eligible Federal entities.*
>
> *(b) Any non–Federal entity meeting the eligibility requirements of § 30.3 may operate equipment that complies with the technical rules of this part pursuant to a Shared Access License.*

(c) Licensees in the 37–37.6 GHz band must register their individual base stations and access points prior to placing them in operation.

Equipment exists today that covers the 37-40 GHz band, but there is not a clear process for applying for a Shared Access license. The situation is a cautionary tale that new sharing regimes between federal spectrum and commercial users inherently take time to establish and be implemented in the market. Imposing any new sharing framework in the globally-harmonized mid-band would be a strategic disadvantage to the U.S. in the race to 5G. China's 5G networks are not using any form of spectrum sharing. The way to compete in this race is with proven methodology [4]. The 37 GHz band is also part of 3GPP's Band 260. As the Department is aware, the broader band of 37 – 43.5 GHz was identified globally at last year's World Radiocommunication Conference for International Mobile Telecommunications (IMT) for administrations wishing to implement broadband in the range [21]. Hence, improving the licensing process to expedite and maximize commercial access to 37 – 37.6 GHz would allow U.S. industry to leverage global economies of scale, to our consumers and businesses' benefit.

Data Standards to Accelerate Spectrum Repurposing

5G Americas agrees that a common set of more accurate, real-world assumptions and parameters for sharing studies agreed between NTIA, DOD, other federal users, and the FCC would accelerate spectrum repurposing and maximize commercial access, while still protecting federal systems. A common set of agreed parameters for sharing studies based on a realistic system, including robust simulations with a high number of iterations, would give parties comfort that repurposing decisions would protect incumbents from harmful interference.

5G Americas urges DOD and NTIA to use propagation models and other parameters for sharing studies based on 3GPP and other commercial standards such as COST 231, and technology advances, including Advanced Antenna Systems that incorporate massive MIMO (multiple input multiple output) and beamforming capabilities. 3GPP standards and COST 231 reflect rigorous global debate among competing vendors and other stakeholders – deliberations in which DOD and the FCC take part. 5G Americas hopes the Department's Data Strategy will commit to the use of 3GPP and other commercial standards in sharing studies for the possible repurposing of federal bands to commercial use, since the accuracy of the data and the timeliness of technological inputs drive the models' usefulness.

Disagreements within the U.S. on the modeling and simulation parameters for sharing and compatibility studies result in time lost in the global competition to 5G deployment and emerging technologies that rely on 5G (like AI), advanced manufacturing, robotics, and other automated vehicles. To prevent additional delays, 5G Americas recommends that DoD and NITA work collaboratively with industry on modeling and simulation efforts to help all stakeholders develop compatibility approaches that make spectrum available as soon as possible.

Benefits of Private Sector Mutually-Exclusive Spectrum Licenses

The Department raises the prospect of leasing spectrum capacity to the private sector. 5G Americas finds that prospect problematic for several reasons. 5G Americas notes that DOD uses its NTIA assigned spectrum and may not have authority to lease such spectrum. DOD's potential leasing of its assigned spectrum could indicate that it has excess capacity and, instead, should relocate or share if the goal is to increase private sector 5G deployment. The Department should not try to raise fees from the private sector when overall economic benefits would flow from repurposing the spectrum for commercial use. Not only do we need to expedite more spectrum to market, we need to ensure that the spectrum is put to good use. Were the Department to pursue leasing its spectrum, additional inefficiency might arise if the leases are unduly long and more likely than not entered into with contractors with close relations to the Department. In such cases, the lessees could effectively squat, essentially keeping the spectrum from more efficient use in the market.

Were the Department to gain the authority to lease its assigned spectrum for fees then it inherently becomes a competitor to the private sector, but with advantages a privately-owned operator does not have (taxpayer appropriations and access to infrastructure subsidized by the public, distorting the market for spectrum-based advanced services, and undermining innovation by private industry). Attempts at government-initiated wholesale networks in other countries show they are not the most efficient method for maximizing broadband deployment to the public and attendant economic benefits [22] [23]. For example, in India, the government runs its own network for rural broadband and develops its own standard for DSA which drives up deployment costs. Government-initiated wholesale networks in Russia, Mexico and Kenya have been subject to delays, and have not resulted in any net increase of competitive providers reselling the wholesale spectrum [22] [23]. Government-initiated wholesale networks have also led to spectrum fragmentation which ultimately decreases spectrum availability and creates interoperability concerns. As Peter Rysavy has noted, neither the federal government nor the entities reportedly influencing the DoD sharing plan, have any expertise in building cellular networks [4].

For the above reasons, 5G Americas prefers the private sector competitive network model where operators hold licenses acquired through auction. Compared to spectrum leases, licenses give operators the certainty required to invest in network build-out with DOD determined terms, and therefore not maximize the certainty needed for private 5G investment.

Conclusion

5G deployment is a national strategy goal far too important to squander in a lengthy process. 5G deployment is critical to U.S. economic, technology, industrial and military leadership. Historically, repurposing new bands has taken 10 years to deliver commercial access to the spectrum. With so much at stake, we can no longer afford the luxury of a decade. The Department needs to be responsive today, particularly with respect to increased commercial access to the global 5G band. U.S. industry – nor indeed the United States writ large – cannot afford band fragmentation such as we will experience with the lower-power CBRS between two higher powered 5G bands in 3.45-3.55 GHz and the C-Band. U.S. technology innovation must be transportable outside the U.S. Sharing will have to be done on a band-by-band basis given the suite of federal incumbents in each band. This will require allowing the private sector to deploy the latest globally-standardized technology from 3GPP and not having the Department operate a public 5G network through use of either DSS or DSA, or by subleasing assigned spectrum to the industry.

Appendix

Dynamic Spectrum Sharing

From *Global 5G: Rise of a Transformational Technology* (September 2020):

Dynamic Spectrum Sharing (DSS) enables smooth and efficient migration from 4G/LTE to 5G NR by giving both technologies instant access to the same spectrum. DSS design was driven by the following requirements:

- It should be able to release as much of NR's full potential as possible when LTE traffic intensity is low.
- NR should have a minimum impact on LTE latency, coverage, and peak rate, at least when NR traffic load is low.
- All legacy LTE devices should be able to access the network for the deployment to be commercially sound. This implies it is not possible to change the LTE specifications for NR/LTE spectrum sharing.

3GPP Framework for DSS

3GPP did not define one monolithic solution for spectrum sharing, but rather a set of tools that can be used for building a spectrum sharing solution for simultaneous operation of LTE and NR. Some of the 3GPP defined tools serve the exclusive purpose of operating NR and LTE on a common carrier. Other NR configurations, such as various PDCCH mappings or demodulation reference signal (DMRS) positions, are vital for spectrum sharing.

The network node (eNB or gNB) operating in DSS mode rapidly allocates the time/frequency resources for the actual user data transmission between LTE and NR, depending on the number of users and priority of their data packets.

An NR device configured with "LTE CRS rate matching" is aware of the resource elements in the time-frequency grid that carry LTE cell-specific reference signals (CRS) and it does not decode NR data on these resource elements. CRS rate matching is available for the NR data channel when using 15kHz subcarrier spacing. For higher subcarrier spacing, LTE CRS rate matching on resource element level is not feasible, as signals transmitted with different numerologies are not orthogonal and cross subcarrier interference would occur between NR data and interleaved LTE reference signals.

In the uplink ("UL"), LTE applies a 7.5 kHz (half a subcarrier) shift to all its UL transmissions. An NR device operating with FDD and its UL with 15kHz numerology can be configured to apply the same shift. Without a 7.5kHz shift, a frequency guard between LTE and NR UL is needed. The 3GPP standard does not give any more additional specific guidance regarding implementation of efficient spectrum sharing for SA or NSA deployments. Reference 3GPP specifications include: 38.331; 38.214; 38.101; 38.211.

Device Support

Device support is required for DSS. A network implementation must ensure that broadcast transmissions of LTE and NR (PSS, SSS, MIB, SIBs, TRS and CSI-RS) must be positioned so they are supported by a device operating according to that Radio Access Technology (RAT), but invisible to a device operating on other technology.

Methodologies for efficient DSS implementation built on 3GPP framework

Coordinated scheduling at TTI level: NR downlink ("DL") and UL data transmissions are kept separate from LTE data transmissions via coordinated scheduling, which implies that scheduling decisions are taken every millisecond.

Using MBSFN subframe to transmit NR common channels: NR cell in dynamic spectrum sharing configuration may choose to transmit SSB in an LTE multicast-broadcast single-frequency network (MBSFN) subframe which has fewer LTE reference symbols, thereby avoid collision between NR and LTE reference symbols. Other reference symbols of NR can also be transmitted in the MBSFN subframe of LTE.

Transmitting the NR physical control channels: While the 3GPP specification is very flexible where the PDCCH can be transmitted, the mandatory device capability only requires control channel support within the first three OFDM symbols of a slot. To avoid collisions with LTE CRS, the NR PDCCH is mapped to the third, or second and third, OFDM symbol in a slot, depending on the LTE reference signal configuration.

Semi-static rate-matching resource set configuration for Downlink: This functionality enables rate matching around LTE sync and PBCH so that they do not interfere with NR PDSCH. A mandatory feature for capability signaling is to enable the NR UE to perform rate matching for NR PDSCH around semi-statically defined patterns in LTE.

Summary of some key features supporting DSS

1. ***LTE CRS rate matching:*** Ability for NR to map around LTE Cell Specific Reference Signals (CRS):
    - Without CRS rate matching, LTE PDSCH capacity is severely reduced.
2. ***General rate matching:*** Similar to CRS rate matching, but maps NR signal around LTE synchronization signal blocks (SSB) and PBCH.
3. ***Mini Slots:*** Provide solutions for three areas of concern:
    - Allow NR transmission in normal subframes without CRS rate matching.
    - Mini slot (Type B) PDSCH provides alternative to puncturing solution for NR PDSCH broadcasts in Idle and Inactive modes.
    - In conjunction with other DSS enhancements, mini slots can provide one additional NR PDCCH symbol (total of two), which could be needed for increased PDCCH capacity and/or better NR coverage.
4. ***MBSFN subframes:*** Provide almost clear subframes for NR, without risk of collisions with LTE:
    - Extensive use of MBSFN subframes reduces LTE capacity and throughput.
    - Will be used primarily for SSB, PBCH and SIB1 messaging.
5. ***Extended PRBs:*** Additional PRBs available to NR, in guard band of LTE carriers. For reference, extended PRBs provide a 4% to 6% boost to NR capacity:
    - 10MHz NR carrier - 2 additional PRBs.
    - 15MHz NR carrier - 4 additional PRBs.
    - 20 MHz NR carrier - 6 additional PRBs.
6. ***Other features supporting DSS:***
    - Flexible Type A PDSCH – DSS solution without mini slots.
    - 7.5kHz UL shift – avoids the requirement for a guard band between LTE and NR uplink.

- PDCCH in symbol 2 – NR PDCCH immediately follows symbols reserved for LTE PDCCH.
- TRS in symbol 6 and 10 - Tracking Reference Signal maintains LTE/NR phase alignment.
- Flexible CSI-RS placement.

Network Slicing

From Global 5G: Rise of a Transformational Technology (September 2020)

Network slicing is defined in the 3GPP Release 15 specifications. Further enhancements to network slicing occur in successive releases. This architecture allows an operator to provide multiple services with different performance characteristics. Each network slice operates as an independent, virtualized version of the network designed to serve a defined business purpose or customer. Thus, each slice consists of all the network resources required to address the specific need. For a given application, the network slice is the only network it sees. The other slices, to which the customer is not subscribed, are invisible and inaccessible. The advantage of this architecture is that the operator can create isolated, fine-tuned slices for specific use cases.

Slicing can accommodate:

- Requirements on functionality, such as priority, charging, policy control, security, and mobility.
- Performance, including latency, availability, data rates, and reliability.
- Specific users, such as public safety, specific enterprise, roaming, and MVNOs.

GSMA has identified the following industry segments as ones that will benefit from network slicing:

- Augmented Reality and Virtual Reality
- Automotive
- Energy
- Healthcare
- Manufacturing
- Internet of Things
- Public Safety
- Smart Cities

Network Slice identification is done via the Single Network Slice Selection Assistance Information (S-NSSAI), which contains the Slice/Service type (SST). The SST refers to the expected Network Slice behavior in terms of features and services. The NSSAI (Network Slice Selection Assistance Information) is a collection of S-NSSAIs.

Currently, 3GPP allows up to eight S-NSSAIs in the NSSAI to be sent in signaling messages between the mobile device and the network. This means a single UE may be served by at most eight network slices at a time.

3GPP has identified four standardized Slice/Service Types (SSTs) shown in Figure 25.

Figure 25: Standardized Slice/Service Types

Slice/Service type	SST value	Characteristics
eMBB	1	Slice suitable for the handling of 5G enhanced Mobile Broadband.
URLLC	2	Slice suitable for the handling of ultra- reliable low latency communications.
MIoT	3	Slice suitable for the handling of massive IoT.
V2X	4	Slice suitable for the handling of V2X services.

3GPP also defines Network Slice as a Service (NSaaS). NSaaS can be offered by a Communication Service Provider (CSP) to its Communication Service Customer (CSC) in the form of a communication service. NSaaS also allows the CSC to use and optionally manage the network slice instance. CSC can play the role of CSP and offer its own services (e.g. communication services) on top of the network slice instance.

Figure 26: Network Slice as a Service

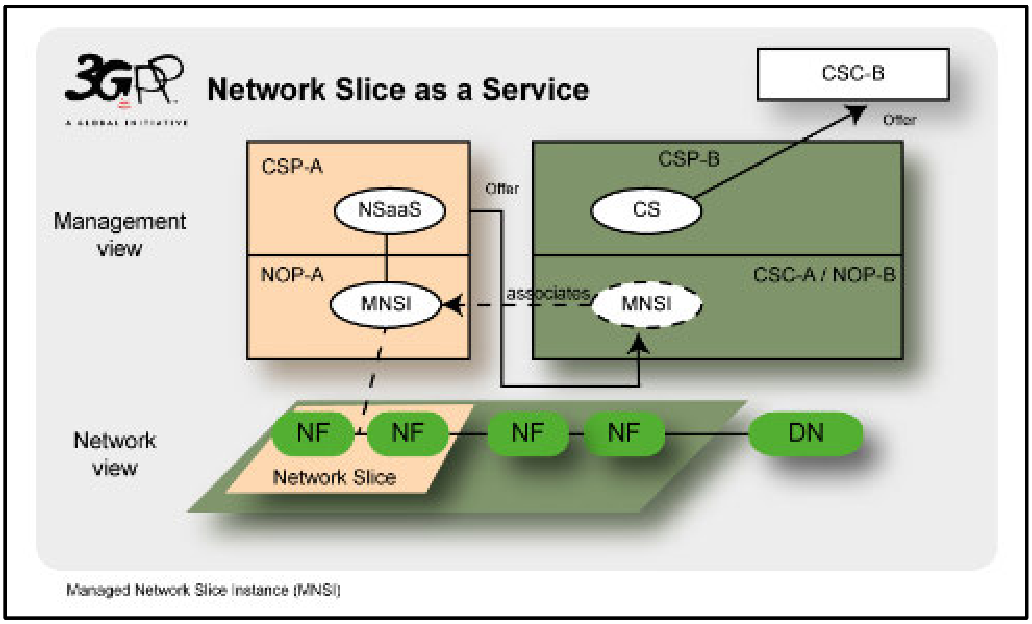
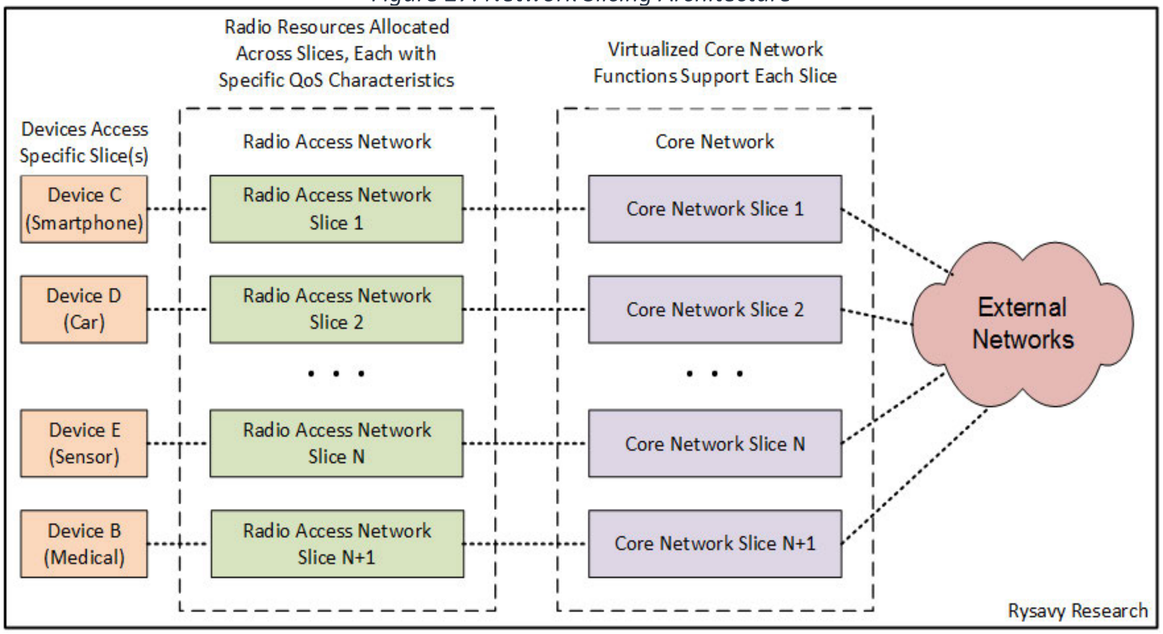


Figure 27 shows the network slicing architecture, with devices having access to only the slice or slices for which they have subscriptions. Each slice has radio resources allocated, with specific QoS characteristics. Within the core network, virtualized core network functions support each slice and provide connections to external networks.

Figure 27: Network Slicing Architecture

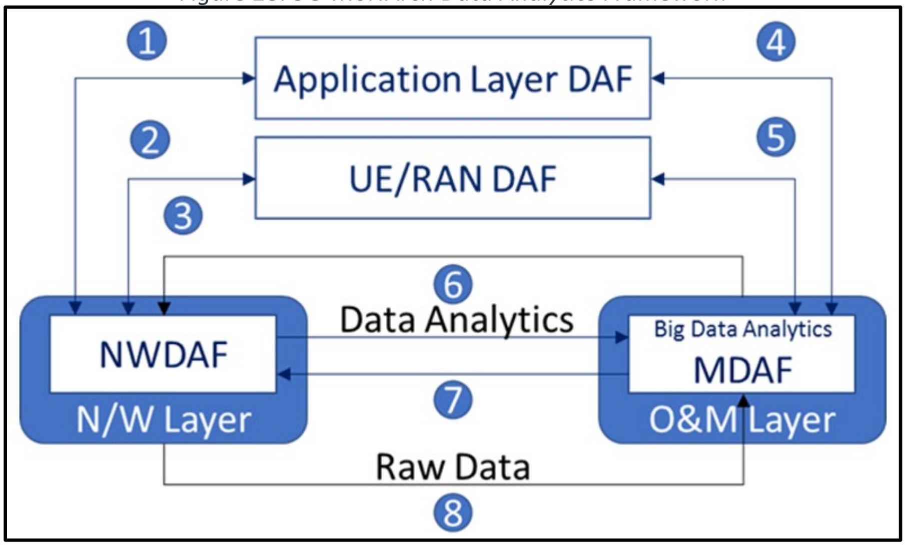


End-to-end data analytics will facilitate advanced network slicing capabilities in 5G networks. In support of such analytics, 3GPP and other organizations have defined a number of capabilities, including 3GPP's Management Data Analytics Services (MDAS). Within this architecture, The Network Data Analytics Function (NWDAF), RAN Data Analytics Function (RAN-DAF), and Management Data Analytics Function (MDAF) collect and provide data analytics for use by other functions, including the Policy Control Function for policy decisions and the Network Slice Selection Function (NSSF) for slice management.

Telemetry data analytics-based statistics from NWDAF and RAN-DAF, combined with artificial intelligence and machine learning, will allow operators to dynamically optimize their networks and automate 5G network slicing management. Network slicing will likely progress from a smaller number of manually configured static slices that evolve to larger numbers of slices dynamically configured for shorter periods of time.

5GPPP MoNArch has developed the "5G Mobile Network Architecture"70 that specifies a detailed management framework for 5G network slicing. Its Integrated Data Analytics Framework employs NWDAF, RAN-DAF, and MDAS. Figure 28 shows the data analytics framework in 5G-MoNArch, including the interaction between the network layer and orchestration-and-management (O&M) layer for data collection and analytics sharing.

Figure 28: 5G-MoNArch Data Analytics Framework



The interfaces in this framework, as explained in the MoNArch architecture document, are as follows:

- ***Interface 1:*** NWDAF interacts with the Analytics Function (AF) via the Network Exposure Function (NEF) using the network (NW) layer Service Based Interface (SBI).
- ***Interface 2:*** N1/N2 interface.
- ***Interface 3:*** The O&M layer configures the Network Function (NF) Profile in the Network Repository Function (NRF), and NWDAF collects the NF capacity information from the NRF.
- ***Interface 4:*** MDAF interacts with application/tenant using the Northbound Interface (NBI).
- ***Interface 5:*** MDAF interacts with the RAN DAF using O&M layer SBI.
- ***Interface 6:*** NWDAF consumes the services provided by MDAF using the crosslayer SBI.
- ***Interface 7:*** MDAF consumes the services provided by MWDAF using the crosslayer SBI.
- ***Interface 8:*** MDAF collects data from NW layer via trace file/monitoring services.

Although managing QoS across multiple slices is complex, a number of factors drive such capability:

- New use cases enabled by 5G, representing significant new business opportunities, will depend on network management and traffic prioritization.
- The virtualization of 5G networks augmented by eventual AI-capabilities will facilitate the necessary network management.
- Small or smaller cells with a smaller number of devices in the coverage area along with greater capacity will simplify RAN QoS management.

Acronyms

3GPP	3rd Generation Partnership Project
4G	Fourth Generation of Broadband Cellular Network Technology
5G	Fifth Generation of Broadband Cellular Network Technology
AF	Analytics Function
AI	Artificial Intelligence
ARSR	Air Route Surveillance Radar
CBRS	Citizens Broadband Radio Service
CITEL	Commission on International Telecommunications
CONUS	Continental United States
CRS	Cell-Specific Reference Signals
CSC	Communication Service Customer
CSI-RS	Channel State Information Reference Signal
CSP	Communication Service Provider
DAF	Data Analytics Function
DL	Downlink
DMRS	Demodulation Reference Signal
DOD	Department of Defense
DSA	Dynamic Spectrum Access
DSS	Dynamic Spectrum Sharing
ESC	Enhanced Sensing Capability
ETSI	European Telecommunications Standards Institute
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FDD	Frequency Division Duplex
GSMA	Global System for Mobile Communications
IIC	Incumbent Informing Capability
IMT	International Mobile Telecommunications
ITU	International Telecommunication Union
LTE	Long-Term Evolution
MBSFN	Multicast-Broadcast Single-Frequency Network
MDAF	Management Data Analytics Function
MDAS	Management Data Analytics Services
MIMO	Multiple Input Multiple Output
MOU	Memorandum of Understanding
MVNO	Mobile Virtual Network Operator
NB	Node-B
NBI	Northbound Interface
NEF	Network Exposure Function
NF	Network Function
NOAA	National Oceanographic and Atmospheric Administration

NR	New Radio
NRF	Network Repository Function
NSA	Non-Standalone
NSaaS	Network Slice as a Service
NSSF	Network Slice Selection Function
NTIA	National Telecommunications and Information Administration
NW	Network
NWDAF	Network Data Analytics Function
OFDM	Orthogonal Frequency Division Multiplexing
PBCH	Physical Broadcast Channel
PDCCH	Physical Downlink Control Channel
PDSCH	Physical Downlink Shared Channel
PPSG	Policy and Plans Steering Group
PRB	Physical Resource Block
PSS	Packet Switch Stream
RAN	Radio Access Network
RAN-DAF	RAN Data Analytics Function
RAT	Radio Access Technology
RF	Radio Frequency
RFI	Request for Information
SA	Standalone
SBI	Service Based Interface
SIB	System Information Block
S-NSSAI	Single Network Slice Selection Assistance Information
SSB	Synchronization Signal Blocks
SST	Slice/Service Type
TRS	Telecommunications Relay Service
TSDSI	Telecommunications Standards Development Society, India
TTA	Telecommunications Technology Association
TTC	Telecommunications Technology Committee
UE	User Experience
UL	Uplink+B44B71B46B46:B72

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Acknowledgments

5G Americas facilitates and advocates for the advancement and transformation of LTE, 5G and beyond throughout the Americas.

5G Americas' Board of Governors members include AT&T, Cable and Wireless, Ciena, Cisco, CommScope, Crown Castle, Ericsson, Intel, Mavenir, Nokia, Qualcomm Incorporated, Samsung, Shaw Communications Inc., T-Mobile USA, Inc., Telefónica and WOM.

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