A 5G AMERICAS WHITE PAPER

THE 6G UPGRADE IN THE 7-8 GHZ SPECTRUM RANGE: COVERAGE, CAPACITY AND TECHNOLOGY

OCT 2024

Contents

Executive Summary

As we prepare to usher in the new era of 6G in the 2030 timeframe, it is essential to make sure that the right spectrum—the lifeblood of any wireless technology—is in place. The spectrum must be available not only in sufficient quantity, but also in the frequency range to ensure commercial success. The industry projects that 400-500 MHz of mid-band spectrum per mobile operator will be necessary for 6G. Assuming there are 3-4 operators in a given market, the minimum spectrum need for a market will be 1.5-2 GHz. Furthermore, this spectrum should be available in the lowest possible frequency range in order to achieve the desired user experience at a reasonable cost point.

This paper illustrates that the new spectrum block at 7.125 – 8.400 GHz is important for 6G radio deployments for providing 10-20 times more capacity and higher data rates while reusing existing base station sites. Advanced beamforming, higher order MIMO configurations in both base stations and user equipment, and higher amount of spectrum are all relevant for boosting radio coverage and capacity on the new spectrum blocks. High power exclusive usage of the new spectrum can provide greatest benefit in terms of radio performance while spectrum sharing scenarios are also considered for flexible and rapid utilization of the new spectrum.

1 Introduction

In the preparation for the World Radiocommunication Conference in 2027 (WRC-27), the ITU has identified the following bands to be studied for 6G: 4.4 – 4.8 GHz, 7.125 – 8.400 GHz and 14.8 -15.35 GHz. The first band (4.4 – 4.8 GHz) is not available in the United States or Canada and the third band (14.8 – 15.35 GHz) is not available in the United States. Thus, the availability of the band at 7.125 – 8.400 GHz is foreseen as important for 6G success in the Americas. Some other countries, including Europe, are also investigating 6.400 – 7.125 GHz band for possible deployment of 6G but the spectrum range is not available in the U.S. or Canada, as it has been allocated for unlicensed use. Therefore, 7.125-8.400 GHz band appears to be emerging as the only globally harmonized band and is sometimes being referred to as the "Golden Band of 6G". The new 6G band will also be complemented by smooth refarming of existing 5G spectrum on FDD, TDD and mmWave bands to 6G. The high-level spectrum view for 6G is show in Figure 1.

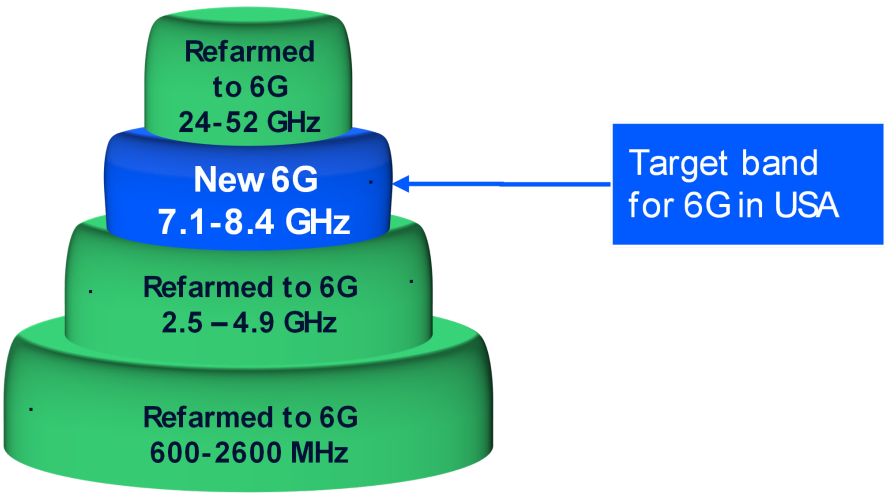

Figure 1: 6G deployment requires new spectrum at 7.1 – 8.4 GHz (Source: 5G Americas member company).

When the transmission frequency increases by a factor of two from 3.5 GHz to 7 GHz, the wavelength gets halved, thus allowing the number of antenna elements that can be accommodated within a given aperture (surface area) to be increased by a factor of four. This increased density of antenna elements enables higher antenna gain, which can partly compensate for the higher pathloss at the higher frequency and allow re-use of existing base station sites for the new band. The higher number of antenna elements combined with more transceivers, new 6G features, Artificial Intelligence (AI) based algorithms, and powerful hardware can make beamforming more advanced, boosting the spectral efficiency and capacity further. It is also expected that the amount of spectrum available in 7 GHz will be four to five times higher compared to spectrum in 3.5 GHz.

The high-level radio targets for the new 7-8 GHz spectrum are illustrated below.

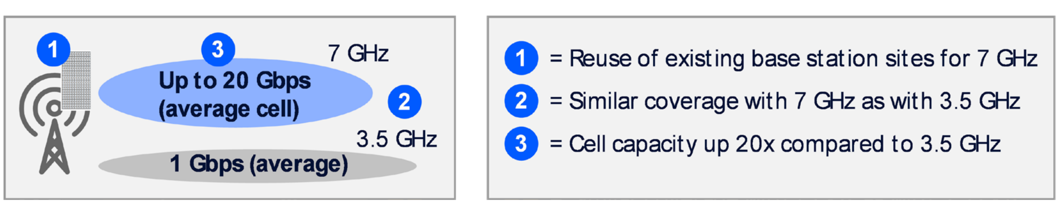

Figure 2: High-level targets for 7.125 – 8.400 GHz spectrum (Source: 5G Americas member

company).

The 7.125-8.4 GHz spectrum range has currently lots of incumbent allocations, mostly comprised of federal users. While some repacking or reallocation may be feasible for certain users, it is quite unlikely that the band will be completely cleared for mobile deployment in the next 5-7 years – the expected deployment time frame for 6G. While exclusively licensed spectrum is the best way to guarantee quality of service for end users, we understand this may be a challenge for this band in the foreseeable future. The only way to gain access to any significant amount of spectrum for 6G may be through spectrum sharing but it is to be kept in mind that full power operation in exclusively licensed spectrum bands is the most cost-efficient way to provide wide area coverage for mobile networks. Any technical sharing conditions that may be introduced in this band must not put undue restrictions on cost-efficient deployment and operations of mobile networks.

The key takeaways from this document are:

1. The 7.125-8.4 GHz spectrum is foreseen as important for 6G success in the Americas for wide area coverage with mobile broadband. It is the only spectrum range in the U.S. and Canada currently synchronized with WRC-27 Agenda Item 1.7. A globally harmonized band is crucial to take advantage of the economy of scale which helps to bring the costs down and thus improves affordability.
2. The entire frequency range (1.275 GHz of spectrum) should be studied for use by mobile operators. Use of this frequency range will be pivotal in reaching the total spectrum requirement of 1.5-2 GHz needed for successful deployment of 6G.
3. Lots of technological advancements are taking place to deliver the expected performance of 6G without needing to add new cell sites. This is extremely important for sustainability as well as lower costs for users.
4. It is understandable that some spectrum sharing may be needed to be in place as it could be challenging to move incumbents to other spectrum bands in the foreseeable future. Any technical constraints towards mobile usage should be kept to a minimum, else the spectrum will not be considered attractive for 6G deployment.

1.1 Emerging future challenges for spectrum allocation

Traffic growth in mobile networks is expected to drive five times more data over the next 5 years. There are various key drivers for this growth:

- Increase of new types of devices (AR glasses)
- Emergence of new use cases (enterprise metaverse)
- Expansion of fixed wireless service for cord-cutters

Additionally, some emerging applications in the 6G era will have high performance requirements, generating very high peak loads. For example:

- Multi-sensory XR
- Drone swarms
- Collaborative robots, etc.

Additionally, some of these applications may put very high requirements on transmission in uplink directions.

At the time of 6G's launch (around 2028-30), it is expected that both 4G and 5G networks will be operational in the U.S, meaning 6G will require brand new spectrum. Studies from Qualcomm and Nokia have indicated that the channel size of 6G will be 400-500 MHz. With 3-4 operators per market, this leads to 1.5-2 GHz spectrum needs at the launch of 6G. Several studies in the industry have also indicated that about 1.5 – 2 GHz of spectrum will be needed for continued successful evolution of mobile networks.[1 2]

The ability to reuse existing cell sites without network performance degradation is a very important consideration in selecting spectrum bands. This relates not only to deployment costs but also to energy savings and sustainability. Given that current 5G deployments are mostly in C-band and below frequencies, the spectrum bands for 6G also need to be as close to these frequencies as possible as propagation characteristics in higher frequency bands are not ideally suitable for wide area deployments.

Since such spectrum is unavailable below 7 GHz, the 7.125 – 8.4 GHz spectrum is essential for mobile operators. Detailed studies need to be undertaken regarding what features can enable capacity and coverage in this spectrum range comparable to such characteristics in 3.5 GHz range.

It should be noted that re-use of 3.5 GHz base station sites, referred also as grid re-use, is essential to minimize initial capital expenses (CapEx) and also ongoing operational expenses (OpEx). Grid re-use is also a key factor in sustainability, which is an important consideration for 6G.

The higher the frequency is compared to 3.5 GHz, the more challenging it is to reuse the grid due to inherent propagation characteristics of spectrum bands. Some of the drawbacks can be overcome by technological advancements but there is a limit to how much can be achieved. As shown in Table 1, performance with 7 GHz can be achieved close to that of 3.5 GHz with higher order MIMO and higher Equivalent Isotropic Radiated Power (EIRP). However, EIRP may not be increased any further (beyond what is proposed in Table 1) due to EMF radiation safety concerns and thus cell-edge performance may degrade significantly when 13 GHz spectrum is used for deployment.

Table 1: Relative cell range comparison – cell-edge performance for 500m ISD (Source: 5G Americas member company).

Relative cell edge performance for urban macro network			
Spectrum	Antenna configuration	Maximum EIRP	Cell-edge throughput
3.5 GHz	64 TRX, 192 AE	81-82 dBm/100 MHz	100% [Baseline]
7 GHz	256 TRX, 1024 AE**	85 dBm/100 MHz*	100% [similar to baseline]
13 GHz	256 TRX, 1024 AE**	85 dBm/100 MHz*	50% [compared to baseline]

*Hypothetical EIRP limits; actual limits may be significantly lower due to regulatory conditions. Most recent 12.7 GHz NPRM proposed 75 dBm/100 MHz and sought comments

** Example configurations only; higher order configurations theoretically possible at 13 GHz with greater complexity and at higher cost points

Furthermore, there is significant government incumbency in this spectrum range and considerable work needs to be done by regulators (e.g., FCC, NTIA, ISED etc.) for clearing and/or sharing between government incumbents and potential commercial users. It is possible that some combinations of packing and relocating and/or coexistence and sharing will be necessary.

The paper is structured as following: Section 2 describes spectrum decisions at World Radiocommunication Conference 23 and how it aligns with regulators' spectrum policies in the United States and Canada. Emerging antenna technologies are covered in Section 3 while their impacts on coverage and capacity are presented in Section 4. Finally, the challenges of incumbent users in 7.125 – 8.4 GHz and possible means of sharing between federal and commercial users are investigated in Section 5.

2 Spectrum decisions in WRC-23 for 6G studies

2.1 WRC-23 resolutions likely impacting 5G-Adv/6G

The conference made the following decisions for the current period:

- Identification of 3.3-3.4 GHz for IMT
- Identifications of Upper 6 GHz band (6.425-7.125 GHz) IMT, not only in EMEA but also per footnote in Mexico, Brazil, and some Asian countries.
  - Recognition of the use of wireless access systems (WAS)/RLAN for some countries is also part of the identification deal.
  - The top 100 MHz (7025-7125 MHz) were identified for IMT for the Asia Pacific region. Potentially, additional countries in Americas and Asia Pacific can join the upper 6 GHz band footnote @ WRC-27, identifying the entire 700 MHz for IMT.

Additionally, the conference also approved study items towards WRC-27 (Agenda Item 1.7) for the following spectrum bands:

- 4400-4800 MHz (only in EMEA and Asia)
- 7125-8400 MHz (global, excluding 7250-7750 MHz in Europe due to use by NATO)
- 14.8-15.35 GHz (global)

Figure 3 illustrates 6G spectrum layers and the outcome of WRC-23.

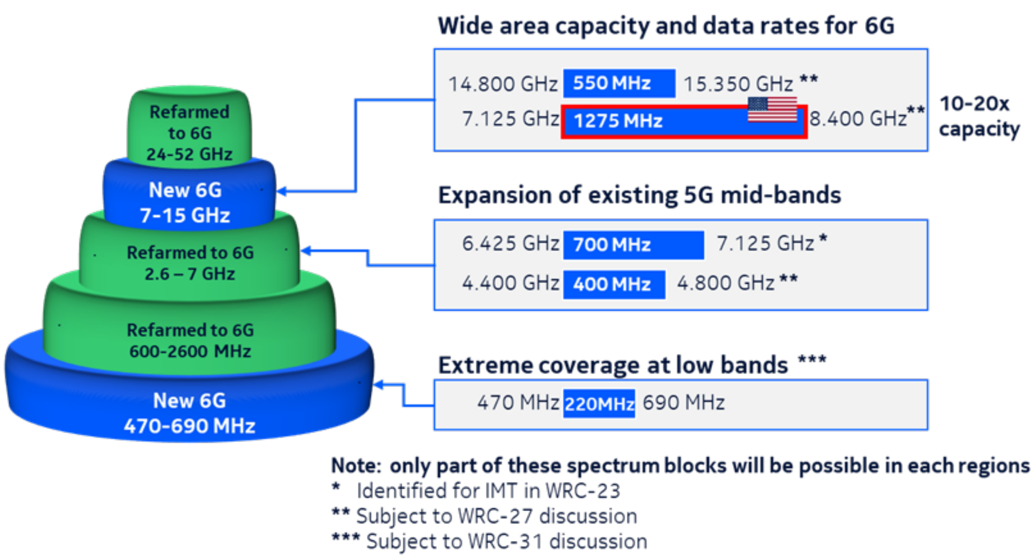

Figure 3: WRC-23 provides good spectrum blocks to be studied for 6G (Source: 5G Americas member company).

The new mid-band spectrum blocks in different regions are shown in Figure 4.

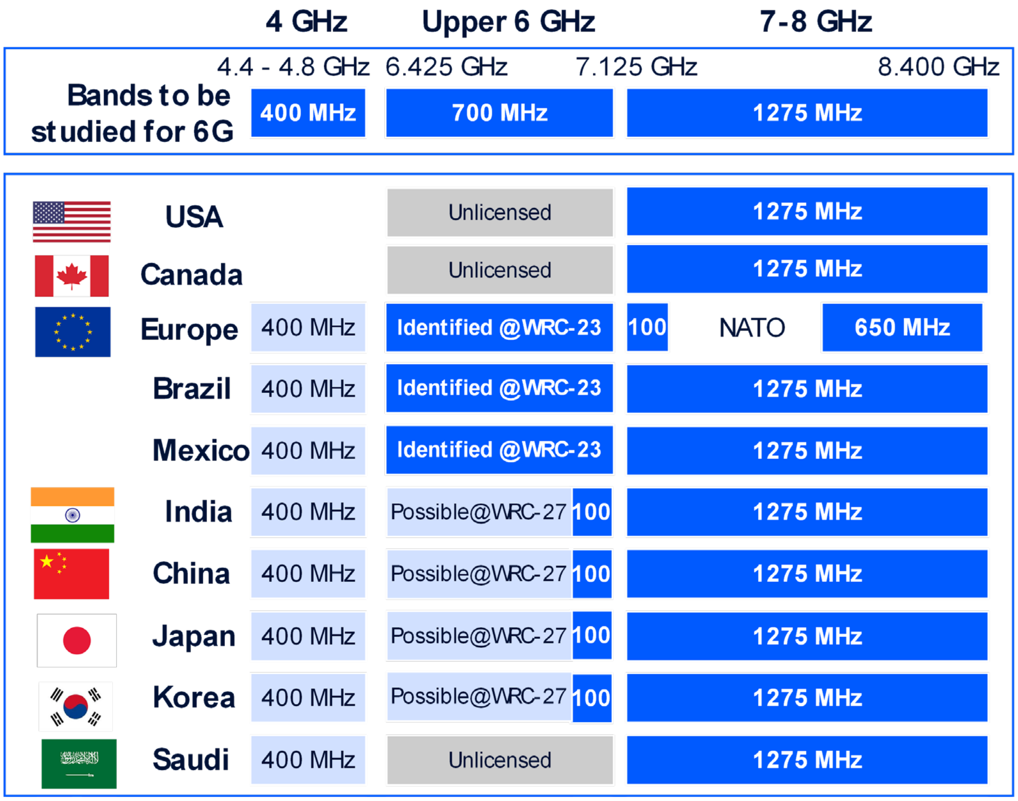

Figure 4: Mid-band 4.4 – 8.4 GHz spectrum in key markets (Source: 5G Americas member company).

2.2 U.S. position at WRC-23 and NSS

The following new bands were proposed by the U.S. delegation (October 31, 2023)[3] at WRC-23 as study item towards WRC-27 for wireless broadband use:

- 3.1-3.3 GHz: The Department of Defense (DoD) determined that sharing is feasible if certain advanced interference mitigation features and a coordination framework to facilitate spectrum sharing are put in place. Additional studies will explore dynamic spectrum sharing and other opportunities for private-sector access in the band, while ensuring DoD and other federal mission capabilities are preserved, with any necessary changes.

- 12.7-13.25 GHz: The FCC is further considering options for flexible use of the 12.7-13.25 GHz band (the “Upper 12 GHz band”), which has in-band and adjacent-band federal operations that may need to be protected.

The NSS proposed (November 14, 2024) these additional bands for further investigation by the U.S. government:

- 7.125 – 8.4 GHz (on a licensed and/or unlicensed basis): A variety of mission-critical federal operations in this band (including Fixed, Fixed Satellite, Mobile, Mobile Satellite, Space Research, Earth Exploration Satellite, and Meteorological Satellite services) that will make it challenging to repurpose portions of the band while protecting incumbent users from harmful interference.

- 37 – 37.6 GHz: Further studied to implement a co-equal, shared-use framework allowing federal and non-federal users to deploy operations in the band.

2.3 Canada position at WRC-23 and Spectrum Outlook

At WRC-23, Canada supported IMT identification throughout Region 2 in 3600-3700 MHz, as well as in 3700-3800 MHz. Regarding WRC-27, Canada supported studies for possible IMT identification in both 7125-8400 MHz and 14.8-15.35 GHz.

In addition, in its latest version of its Spectrum Outlook[4], ISED designated frequency range 3.1-3.45 GHz range in a priority 3 band, noting that this band is currently allocated to the radiolocation service. This means that ISED will start to regularly monitor relevant international developments, particularly those in the U.S. This is an usual step that could potentially lead to future consideration of its use in Canada.

2.4 Common spectrum band between WRC-27 Agenda Item 1.7

A common band harmonized across the globe is crucial for ecosystem development that can leverage the economy of scale. A fragmented set of spectrum creates challenges for global roaming and increases the costs for both equipment manufacturers, network operators, and consumers. However, the only common spectrum range that intersects between WRC-27 Agenda Item 1.7, the U.S. National Spectrum Strategy, and Canada's support of WRC-27 studies, is 7.125 – 8.4 GHz.

It is essential that administrations make every possible attempt to allocate the 7.125 -8.4 GHz for commercial mobile usage, even if it requires some spectrum sharing mechanisms to be implemented between incumbent services and commercial mobile users.

3 Antenna technologies at 7-8 GHz bands

3.1 Main antenna requirements

The size of the antenna element is relative to the wavelength which is inversely proportional to the transmission frequency. When the frequency doubles, the wavelength gets 50% shorter and the antenna element spacing gets 50% smaller, and consequently four times more antenna elements can be supported in the same physical space. When the operating frequency grows from 3.5 GHz to 7 GHz, it is possible to have four times more antenna elements in the same area. The benefit of more antenna elements is higher antenna gain which translates into better coverage, and more accurate beamforming which translates into higher capacity.

Advanced antenna technologies and so called extreme massive Multiple Input Multiple Output (mMIMO) antenna is expected to be the key radio technology for the new 7 – 8 GHz bands in boosting the antenna gain and enabling the reuse of the existing base station sites. Extreme mMIMO refers to the antenna with very large number of antenna elements [5].

Figure 5 illustrates typical sizes of mMIMO antennas at different frequency bands assuming antenna element spacing is half of the wavelength. The typical 3.5 GHz mMIMO antenna has 192 antenna elements and the antenna size is approximately 75 cm x 40 cm. The future 7 GHz antenna can have 768 antenna elements in the same physical size, that is 16 columns and 24 rows of dual polarized antenna elements. Four times more antenna elements can increase the antenna gain in theory by 6 dB from 24-25 dBi to about 30 dBi.

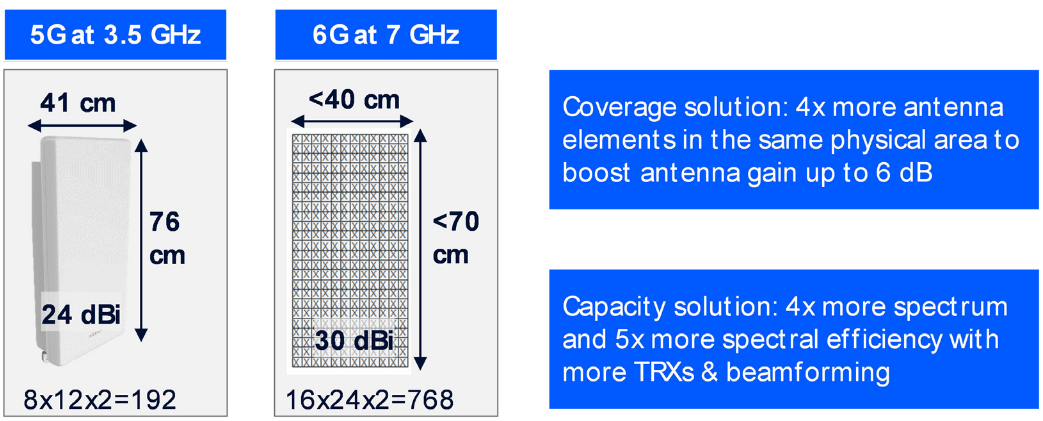

Figure 5: Design targets for 6G antenna at 7 GHz band (Source: 5G Americas member company).

Extreme mMIMO will set tough requirements for the massive MIMO antenna hardware and software in order to provide high radio performance, and to minimize the cost and power consumption. The number of transceivers (TRXs) can be lower than the number of antenna elements. Initially, the number of TRXs could be kept low to develop a hybrid beamforming solution. This solution maximized the antenna gain with several antenna elements while minimizing the complexity with few TRXs. Hybrid beamforming refers to the combination of analog and digital beamforming where large number of antenna elements are first mapped to lower number of TRXs, and then followed by digital beamforming. When the number of TRXs is increased from 128 to 384 or even 768, the complexity will increase dramatically in Radio Frequency (RF), as well as for beamforming. These requirements will put high pressure on the underlying System on Chip (SoC) technologies.

Hybrid beamforming can minimize the antenna complexity with fewer TRXs, but hybrid beamforming brings additional challenges to the antenna implementation: the feeder network and the phase shifters between TRX and antenna elements leads to losses, and decreases the antenna gain. With few TRXs and the need for feeders and shifters, part of the antenna gain may be lost in the feeder network. Therefore, optimizing the hybrid beamforming for large number of antenna elements is one of the key requirements for 6G extreme mMIMO.

4 Expected coverage and capacity enhancements compared to 5G networks

4.1 Capacity

New radio generations have increased radio capacity by using more spectrum and more advanced antennas. 3G used 5 MHz without MIMO, 4G used 20 MHz with 4x4MIMO, and 5G used 100 MHz with mMIMO. The evolution will continue further into 6G by using more spectrum (a target of 400 MHz) and more advanced mMIMO. The evolution of the average cell capacity is shown in Figure 6 and the assumption for cell capacity evolution in Table 2. Figure 6 assumes that phase 1 of 6G brings more capacity because of more spectrum, while phase 2 of 6G will bring the advanced beamforming capabilities which increases the spectral efficiency from the typical 5G level of 10 bps/Hz to the extreme 6G of 50 bps/Hz.

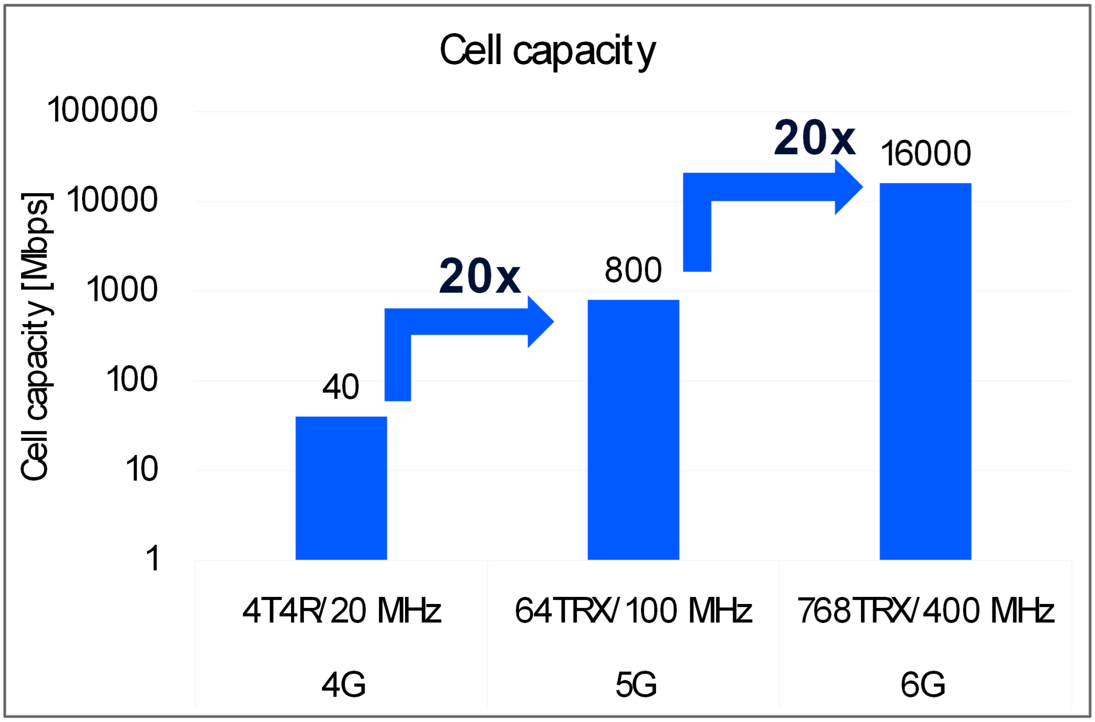

Figure 6: Evolution of average cell capacity (Source: 5G Americas member company).

Table 2: Assumption for the cell capacity evolution (Source: 5G Americas member company).

	Bandwidth	Spectral efficiency	Average cell throughput
4G	20 MHz FDD	2 bps/Hz	0.04 Gbps
5G	100 MHz TDD	10 bps/Hz	0.8 Gbps
6G	400 MHz TDD	50 bps/Hz	16 Gbps

Spectral efficiency can be enhanced with more TRXs, more advanced beamforming in the base stations, and with more antennas in the user equipment (UE). Simulation results are shown in Figure 7. The starting point is 3.5 GHz with 192 antenna elements (AE) and 64TRX using UE with four receive antennas (4RX) and max four co-scheduled UEs in Multiuser-MIMO. The efficiency increases by using 8RX UEs and by doubling the number of antenna elements to 384AE and the number to TRXs to 128. The last step assumes extreme mMIMO antenna with 768AE and 768TRXs. The total improvement in the spectral efficiency is more than four times from 10 bps/Hz to more than 40 bps/Hz. The simulations illustrate that the new antenna solutions can bring a substantial boost in the spectral efficiency towards 50 bps/Hz.

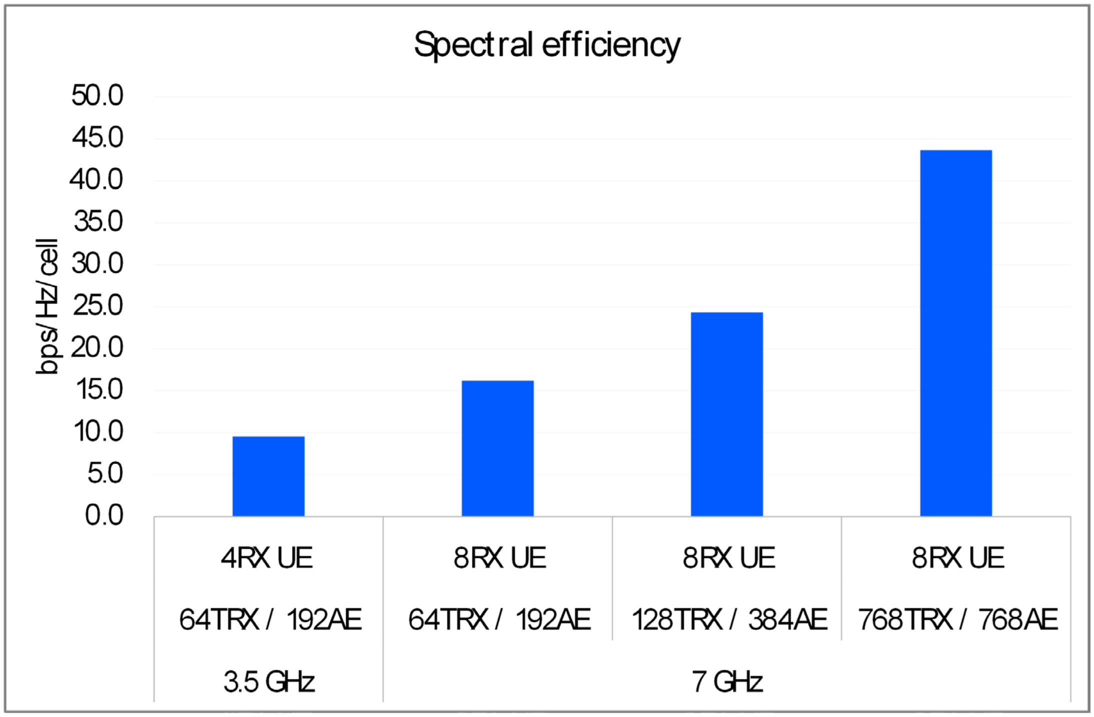

Figure 7: Spectral efficiency simulations (Source: 5G Americas member company).

4.2 Coverage

Base station sites contribute to a large part of operator capital (site acquisition, construction, equipment purchase) and operational (site lease, power, backhaul transport) expenses. Therefore, the ideal target should be to reuse existing sites to the maximum extent and to minimize the number of additional base station sites. The signal propagation is impacted by the transmission frequency and the cell range gets smaller when the spectrum gets higher. The loss in cell size at higher spectrum can be partly compensated by higher antenna gain, which is the solution in 5G with beamforming antenna at 3.5 GHz band. We will continue the same evolution in 6G by using 7-8 GHz spectrum band with higher gain beamforming antenna. The targets are shown in Table 3.

Table 3: Antenna gain assumptions in the cell range estimations (Source: 5G Americas member company).

Technology	Spectrum	Antenna elements	Antenna gain
4G	1.8 – 2.6 GHz	Passive antenna	18 dBi
5G	3.5 GHz	192 AE	24 dBi
6G	7 GHz	768 AE	30 dBi

Higher antenna gain can compensate for the impact of higher path loss (at least in theory) in line-of-sight case but that is not the case for non-line-of-sight. Furthermore, in-building coverage is impacted more severely at higher frequencies. We assume the following Building Entry Loss (BEL) values at different frequencies:

Table 4: Building Entry Loss assumptions at different frequencies (Source: 5G Americas member company).

Spectrum	BEL
1.8 GHz	15 dB
3.5 GHz	20 dB
7 GHz	25 dB

Typical cell ranges are shown in Figure 8 assuming the antenna gains of 18 dBi at 1.8 GHz, 24 dBi at 3.5 GHz and 30 dBi at 7 GHz, and assuming the Okumura-Hata propagation model. We assume the same radio link features and the same maximum path loss in 4G, 5G and in 6G. If there are new innovations in 6G improving the radio performance, there is a potential to have larger cell ranges in 6G than shown below. We can note that 6G on 7 GHz can provide reasonable outdoor cell ranges of more than 1 kilometer. The outdoor cell range at 7 GHz is about 80% of the cell range at 3.5 GHz. 6G at 7 GHz can also provide indoor coverage up to 300 meters in urban areas but it will not be able to provide comparable indoor coverage as lower bands. It may be noted that BEL will be even higher in 13 GHz spectrum thus making the frequency even less useful for indoor coverage. Therefore, 6G refarming to the existing 4G/5G bands will be required to provide coverage matching with 5G.

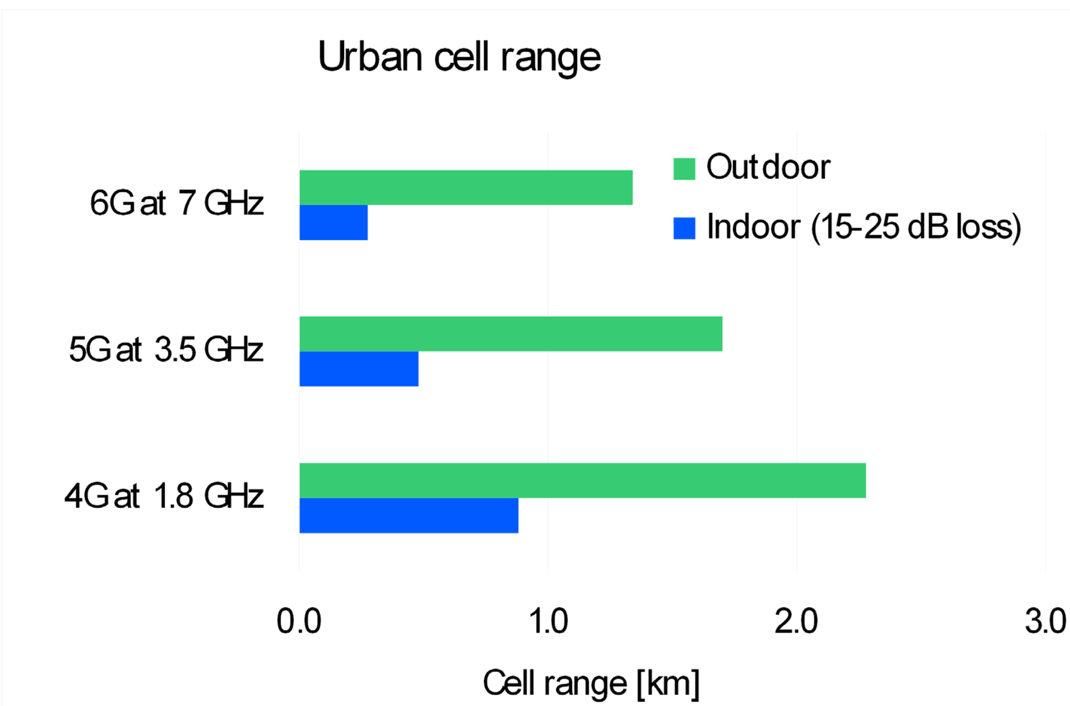

Figure 8: Cell range estimates with Okumura-Hata propagation model (Source: 5G Americas member company).

The propagation studies were verified by the field measurements in the suburban area in Finland. 7 GHz antenna with 768 antenna elements was co-sited with 3.5 GHz antenna with 192 antenna elements, and the signal levels were compared in the drive testing. The results show that 3.5 GHz provides -58 dBm signal level at the distance of 650 meters while 7 GHz provides similar signal level of -60 dBm at the distance of 490 meters. Multiple measurements indicate that 7 GHz can provide approximately 80% of the cell range of 3.5 GHz which matches with the propagation models. These measurements used simple beamforming solution at 7 GHz. Optimization of the beamforming algorithms can increase 7 GHz cell range further. An example measurement is illustrated in Figure 9.

Figure 9: Field measurements in Finland with 7 GHz antenna using 768AE ((Source: 5G Americas member company).

5 Coexistence and spectrum sharing aspects in the 7-8 GHz range

This spectrum range is currently allocated for federal use (both civilian and military) in the U.S. with some minor exceptions. The allocation mostly aligns with international allocation, with minor exceptions.

Figure 10 captures the details:

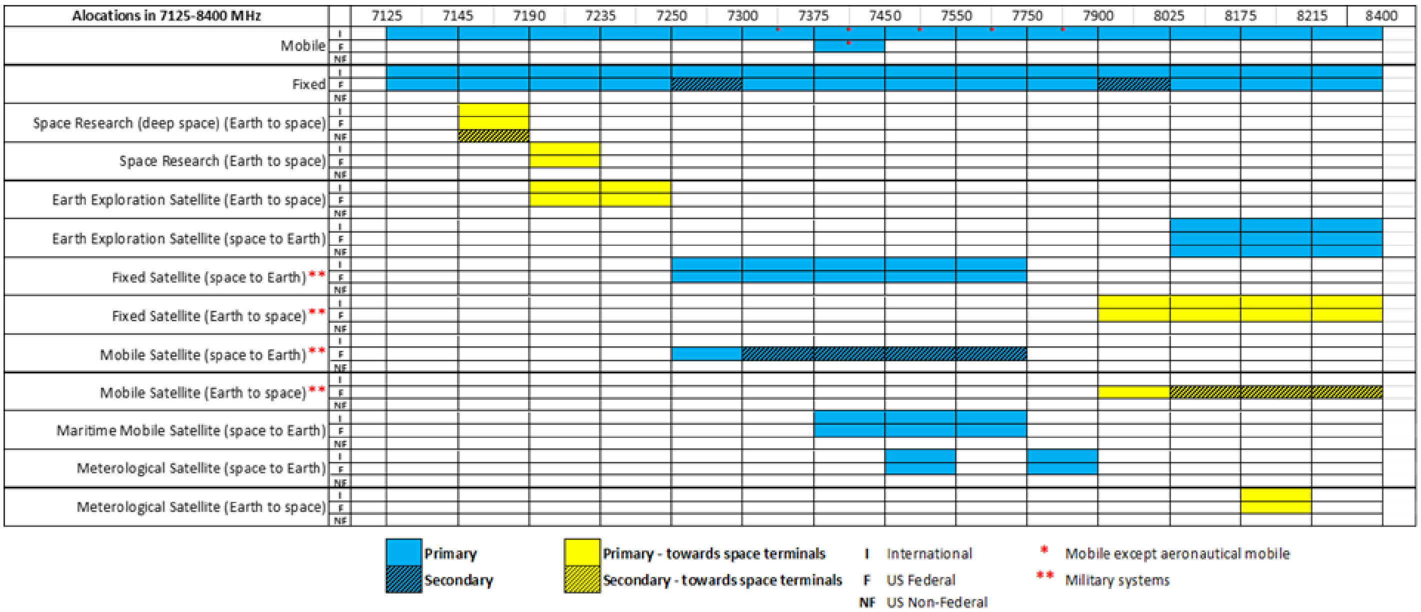

Figure 10: U. S. frequency allocation in the spectrum range 7.125-8.4 GHz (Source: 5G Americas member company).

In Canada, the frequency range 7125-8400 MHz does not currently have a mobile allocation, contrary to the U.S. and international Radio Regulations allocation. However, it does have similar satellite allocations which will allow developing IMT and satellite coexistence throughout ITU Region 2.

As can be observed in Figure 10, there are three main types of services currently allocated in the spectrum range:

1. Terrestrial fixed service
2. Satellite uplink service
3. Satellite downlink service

5.1 Terrestrial fixed service

Fixed services (FS) span the entire spectrum range (7.125 – 8.4 GHz). Based on prior experience in other bands, it is generally very challenging to share spectrum on a dynamic basis if they occupy the same geographic area. Band segmentation, if possible, is a more practical option. Any possibility of coexistence or sharing depends on the density of links.

5.1.1 Current incumbencies

The current incumbency situation in the 7.125 – 8.4 GHz spectrum range is quite complicated:

- The U.S. federal agencies and the Canadian government use of this band is mostly for fixed point-to-point microwave communication systems.
- In the U.S., this includes the Federal Aviation Administration's (FAA) use of this band for fixed point-to-point microwave communications networks to connect remote long-range aeronautical radio-navigation radars to air traffic control centers.
- Approximately 20% of FS use is by the DoD.
- The use of the band for fixed assignments in the 7.125 – 8.5 GHz range has been declining in the U.S. It is expected that relatively shorter length links will be moved to higher frequency bands.

5.1.2 Potential sharing solutions

Spectrum sharing with the incumbents, though very challenging, is not without precedence:

- Similar concept to the 6GHz AFC mechanisms
- Certain separation distances to be maintained by mobile base stations from microwave towers for point-to-point links
- A database-oriented mechanism can estimate potential for interference and allow/reject deployment of base stations
- If the links are mostly in remote areas, this mechanism can pave the way for deploying capacity where it is needed most
- Band splitting will be the ideal situation, particularly if some packing is possible

5.1.3 Uncertainty factors

Several reassignment and repacking may happen in this range for incumbents and new entrants:

- The number and geographical distribution of links is currently unknown. In the U.S., NTIA is expected to provide the data during execution of the NSS Implementation Plan.
- Repacking will likely increase the density of links operating within specific spectrum ranges.
- Some current 6GHz licensed links are contemplating moving up to this band due to concerns about interference from Wi-Fi. FCC may allow some non-federal allocation in this band, thus increasing the density of links in some geographies.
- Unlicensed spectrum may be extended to the lower part of the spectrum (7125 – 7250 MHz).

5.2 Satellite uplink service

Current allocation is spread across two segments: the lower (7145 -7250 MHz) and the upper (7900-8400 MHz) parts of the spectrum range. This type of service has been studied for coexistence in several other bands in the past. It is understood that coexistence, rather than dynamic sharing, is more applicable in this scenario. Stringent requirements are placed on ground-based mobile network equipment on radiation patterns and emitted power.

5.2.1 Current incumbencies

There are space research and deep space research satellites in the lower parts of the spectrum range. These satellites typically have highly sensitive receivers and may need some special treatment.

Satellites for fixed services are in the upper part of the spectrum range and similar coexistence issues have been studied in other bands. There are also some satellites for Mobile Services, but these are mostly allocated for secondary usage and thus of lesser concern.

Finally, there are some meteorological services, but these are relatively few in number.

5.2.2 Potential sharing solutions

Detailed studies need to be performed for determining coexistence conditions. Aggregate interference from a large number of base stations with different orientations and configurations should not cross a protection threshold. There needs to be input on interference threshold, antenna gain and pattern, receiver sensitivity, type of satellite (GSO/NGSO), etc.

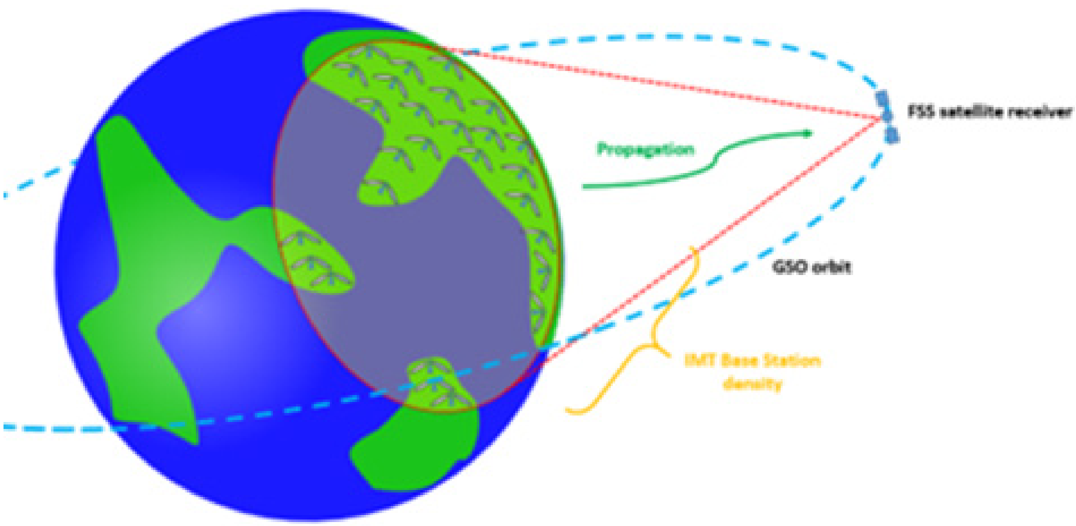

Figure 12: Restrictions on base station emissions (Source: 5G Americas member company).

The following table provides some sample limits on radiated power in vertical directions which could be imposed by administrations for different co-channel satellite systems.

Table 5: Example limits on radiations in different angles above the horizon (Source: 5G Americas member company).

Vertical angle measurement window $\theta_L \leq \theta < \theta_H$ (vertical angle θ above horizon)	*Expected* e.i.r.p. (dBm/MHz) (NOTE 1)
$0° \leq \theta < 5°$	P1
$5° \leq \theta < 10°$	P2
$10° \leq \theta < 15°$	P3
$15° \leq \theta < 20°$	P4
$20° \leq \theta < 30°$	P5
$30° \leq \theta < 60°$	P6
$60° \leq \theta \leq 90°$	P7

NOTE 1: The *expected* e.i.r.p. is defined as the average value of the e.i.r.p., with the averaging being performed

- over horizontal angles between –180° to +180°, and the IMT base station beamforming in a specific direction within its steering range,
- over different beamforming directions within the IMT base station steering range, and
- over the specified vertical angle measurement window ($\theta_L \leq \theta < \theta_H$).

5.2.3 Uncertainty factors

The number of space stations and their current usage is mostly unknown. Some of them are linked with downlink services (including military applications). There is a heavy dependency on NTIA and other government agencies to make available the spectrum usage information so that feasibility of sharing can be properly assessed.

5.3 Satellite downlink service

Allocation mostly in the middle part of the range (7250-7750 MHz) and in upper part (8025-8400 MHz), with the latter being unique in the sense that it is the only non-governmental allocation in the entire spectrum range. There is a small number of EESS Earth Stations in the upper part (including non-governmental) where coexistence may be suitable. The central part is the most challenging and will require dynamic spectrum management schemes. It may be noted that even though there is some mobile satellite service (MSS) allocation in the range, it is mostly secondary in nature, and this is the only allocation which deviates from international allocation for Region 2.

5.3.1 Current incumbencies

Current incumbencies are mostly related to defense and maritime services:

- Federal agencies in the U.S. operate the Defense Satellite Communications Systems (DSCS) series of geostationary satellites in this frequency band. U.S. federal agencies also operate the Wideband Gapfiller Satellite (WGS) in this band. Fixed Satellite Service (FSS) uses 7.25 – 7.75 GHz as downlink and 7.9 – 8.4 GHz as uplink; this includes support for both DSCS and WGS.
- DSCS provides the United States with military communications to support globally distributed military users. As of 14 September 2021, six DSCS-III satellites were still operational.
- WGS is an international system, with Australia, Canada, Denmark, Luxembourg, the Netherlands, and New Zealand also investing in the satellite constellation. An eleventh satellite was set to be completed by 2023.

5.3.2 Potential sharing solutions

Solutions will likely involve coexistence with the only exception possibly being maritime services:

- A limited number of earth stations for FSS are likely spread over vast geographical areas. Maintaining appropriate separation distances between these installations and 5G base stations should be possible (as in 3.45-3.55 GHz).
- Maritime service terminals are likely located around the coast, mostly concentrated around ports. Separation distances should also be a feasible option. Some dynamic sharing (SAS-type) may also be possible as the entire spectrum range may not be used all the time.
- Meteorological and Earth and Environment Sensing (EES) satellites are likely relatively few in numbers and they use a relatively small part of spectrum.

5.3.3 Uncertainty factors

Significant uncertainties remain due to the uses by the DoD.

- It is not known how many earth stations are there and where they are located. Furthermore, EES in 8025-8400 MHz is the only allocation that allows non-federal use in the U.S.
- Ports are often surrounded by high population density areas (New York, Washington, Los Angeles, etc.) where capacity demand will be high.

It is unclear how much MSS is used. If the beams are used mostly in remote areas, then the situation may be manageable but otherwise, the service will cause a challenge. Frequency separation or dynamic allocation may be the only options.

Conclusion

The 7.125-8.4 GHz spectrum is foreseen as important for 6G success in the Americas for wide area coverage with mobile broadband, especially in the context of emerging 6G technology to be deployed in the 2028-30 timeframe. It is the only spectrum range in the U.S. and Canada currently synchronized with a WRC-27 Agenda Item. A globally harmonized band is essential for leveraging the economy of scale which will help to bring the costs down and thus improve affordability of the nascent technology.

The entire frequency range (1.275 GHz) should be studied for use by mobile operators. Use of this frequency range will be pivotal in reaching the total spectrum requirement of 1.5-2 GHz needed for successful commercial launch of 6G.

Major advancements in antenna configuration and beamforming are expected in the near future that may allow networks to deliver the expected performance of 6G without needing to add significantly more new cell sites. This is extremely important for sustainability as well as lower costs for users.

It is understandable that some spectrum sharing may be needed to be in place as it could be challenging to move incumbents to other spectrum bands in the foreseeable future. Simple coexistence solutions may be enough for initial evaluation to access a part of the spectrum range whereas more sophisticated sharing may be necessary to gain access to the entire range. Any technical constraints towards mobile usage should be kept to a minimum, else the spectrum will not be considered attractive for commercial deployment.

ACTION: Agent-based Cyber Threat Intelligence and Operation

AI: Artificial Intelligence

ATIS: Alliance for Telecommunications Industry Solutions

CHIPS: Creating Helpful Incentives to Produce Semiconductors for America

CUBiC: Center for Ubiquitous Connectivity

DARPA: Defense Advanced Research Projects Agency

DL: Downlink

DoD: Department of Defense

FCC: Federal Communications Commission

GSMA: Global Mobile Supplier Association

ICAS: Integrated Communications and Sensing

IMT: International Mobile Telecommunications

IoT: Internet of Things

ISAC: Referred to as integrated sensing and communication

ITU: International Telecommunication Union

JCAS: Joint Communications and Sensing

MEC: Multi-Access Edge Computing

MIMO: Multiple input multiple output

MRSS: Multi-Resolution Spectrum Sensing

NIST: National Institute of Standards and Technology

NSC: National Security Council

NSF: National Science Foundation

NSS: National Spectrum Strategy

NTIA: National Telecommunications and Information Administration

OSTP: Office of Science and Technology Policy

PPP: Public private partnership

RAN: Radio Access Network

RF: Radio Frequency

RFI: Request for Information

RINGS: Resilient and Intelligent Next-Generation Systems

SDO: Standards development organizations

SRC: Semiconductor research corporation

TPR: Technical Performance Requirements

TTC: Telecommunication Technology Committee (Japan)

UE: User Equipment

UL: Up Link

URLLC: Ultra-reliable low-latency communications

U.S.: United States

XR: eXtended Reality

Acknowledgments

5G Americas' Mission Statement: 5G Americas facilitates and advocates for the advancement of 5G and beyond toward 6G throughout the Americas.

5G Americas' Board of Governors members include Airspan Networks, Antel, AT&T, Ciena, Cisco, Crown Castle, Ericsson, Liberty Latin America, Mavenir, Nokia, Qualcomm Incorporated, Rogers Communications, Samsung, T-Mobile USA, Inc., and Telefónica.

5G Americas would like to recognize the significant project leadership and important contributions of group leaders Harri Holma, Senior Advisor – Technology Leadership and Amit Mukhopadhyay, Principal Standardization Leader, Nokia along with many representatives from member companies on 5G Americas' Board of Governors who participated in the development of this white paper.

Endnotes

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