WRC-19 and 5G Spectrum Planning

Rob Frieden
Pioneers Chair and Professor of Telecommunications and Law
Penn State University
102 Carnegie Building
University Park, Pennsylvania 16802
(814) 863-7996; rmf5@psu.edu
web site: http://www.personal.psu.edu/faculty/r/m/rmf5/

ABSTRACT

This paper predicts the likely outcome of spectrum planning work on fifth generation wireless ("5G") services at the 2019 World Administrative Conference ("WRC-19"). It considers whether the United States delegation to the conference embraced old lessons about International Telecommunication Union ("ITU") spectrum management and emerging ones generated by the new technologies and services 5G will offer, as well as growing national security and industrial policy concerns.

Well before WRC-19, carriers in many nations have begun to offer wireless services using the 5G label. These carriers have acted in advance of finalized spectrum allocation decisions and risk rolling out services on frequencies that may not match a future global consensus. This paper identifies opportunities and benefits in an expedited, unilateral approach, but also notes the potential for significant threats and costs, particularly in light of known, but apparently ignored, or forgotten lessons about global and national spectrum planning.

At WRC-15, the United States largely failed to secure consensus support for expanding global spectrum allocations to include more bandwidth near existing allocations in the Ultra High Frequency band and at extremely high, single and double digit GigaHertz frequencies. This paper considers whether changes in WRC-19 preparations by the United States delegation and in the attitudes of delegations from other nations will support expedited consideration of 5G frequency allocations throughout the usable radio spectrum.

The paper concludes that determining whether the United States achieved success depends in large part on one's understanding of the pace, nature, procedures and goals of the ITU spectrum planning process. Observers, including FCC commissioners of both political parties, have complained about flaws in the ITU administrative process that contributed to the absence of efforts to expedite rollout of 5G services and other national objectives. Proponents of the process support the ITU as methodical, thorough, consensus driven and conflict avoiding. WRC-19 will likely generate the same inconsistent evaluations.

I. Introduction

Despite the lack of final and uniform spectrum allocations for the fifth generation of wireless radio ("5G"), carriers, equipment manufacturers and government officials in some nations have expedited the rollout of new wireless services, network equipment and user handsets (European Parliament, 2019) (Kastrenakes, 2019) (GSMA, (2018). Wireless carriers have undertaken an aggressive marketing campaign based on the assumption that they can accrue commercial success and enhance their reputations as innovators and early adopter of future services, such as the Internet of Things (AT&T, 2019) (Verizon, n.d.).

Wireless carriers appear willing to take risks to achieve upside benefits, despite the potential for significant costs as well as less than optimal provisioning of new services, particularly on new frequencies identified by the ITU as candidate expansion bands. Already, unresolved spectrum sharing issues point to the likelihood of protracted conflicts between perennial opponents, such as government users versus private operators [1], terrestrial

[1] "Traditionally, spectrum sharing generally has allowed commercial users to gain new access to bands where they previously had limited or no access at all. Most often, Federal agencies are the incumbents that are required to "make room" for the new entrants. If we continue on this path, however, it will lead to significantly constrained access for Federal agencies with missions that are critical to the health and safety of the American people. While we may uncover incremental ways for agencies to use the spectrum they have more efficiently, these opportunities are finite and will only become more so if the uni-directional sharing trend continues" (NTIA, 2018).

versus space users [2] and television broadcasters versus mobile telecommunications carriers. [3] New conflicts have arisen between ventures with plans to offer 5G complementary services via low earth orbiting satellites and older incumbent carriers operating in higher orbits (Kadyrov, 2017).

Carriers executing 5G plans, in advance of consensus at the ITU, also foreclose prospects for consumer use of a single handset throughout the world. If WRC-19 and subsequent conferences cannot generate a uniform global spectrum allocation plan, then handset manufacturers will have to offer different versions of the same design operating on different nationally allocated frequency bands.[4] The prospect for adding additional chip sets to support more frequency bands may be possible, but already 5G prototypes appear to generate more heat and deplete batteries faster than previous models (Amadeo, 2019) (Horwitz, 2018). Consumers will not like diminished 5G performance, particularly in light

---

[2] "Four years ago, when regulators gathered for the World Radiocommunication Conference, the satellite industry was united on one primary issue: stopping cellular companies from taking C-band spectrum away from satellite operators.

This fall when the International Telecommunication Union's next WRC begins, the satellite industry will have its attention divided on multiple fronts ranging from new rules for smallsats to losing satellite airwaves to 5G cellular networks, creating a fear that efforts could be spread too thin to give each topic the attention it needs. (Henry, 2019).

[3] "Successive WRCs have agreed to make substantial changes to the status of the UHF band, changing the band from an exclusive primary allocation to broadcast services to designating parts of the UHF band as co-primary between broadcast and mobile services. The WRCs have further identified that the mobile services would be based upon IMT standards, and this has been followed by decisions of national and regional administrations to clear broadcasting from those bands in favour of mobile broadband. In some parts of the world, these successive encroachments have already led to a reduction of broadcasting services available, despite continued demand for access to TV services by the public. The WBU-TC believes that any further such re-allocation would lead to a reduction in services available, possibly fatally weakening the terrestrial TV offering in some countries" (World Broadcasting Unions, p.4 2018).

[4] "Europe also wants to designate 26 GHz, the lower portion of Ka-band (which stretches from 26 to 40 GHz) for 5G . . . though the United States, Japan and South Korea feel differently . . . desir[ing] to use 28 GHz for 5" (Henry, 2017).

of extensive marketing promising faster transmission speeds, less latency and overall an enhanced user experience. The absence of consensus on 5G spectrum allocations presents the prospect for heavier handsets, potentially higher consumer cost and the same sort of inconvenience and uncertainty about real or potential handset incompatibility.

The United States failed to secure consensus support at WRC-15 for some of its top priorities to expand global spectrum allocations for 5G, including more bandwidth near existing allocations in the Ultra High Frequency ("UHF") band and at extremely high frequencies in both single and double digit GigaHertz ("GHz") bands (Frieden, 2019). FCC Commissioners of both political parties expressed extreme displeasure with the pace and outcomes of ITU conferences. [5] Similar disappointment at the refusal to expedite the rollout of 5G at all frequency bands may likely occur at WRC-19, because of emerging national security and industrial policy issues having little , if anything, to do with optimizing use of radio spectrum.

Most nations are content with a methodical, multi-year spectrum planning process that emphasizes consensus building, conflict avoidance and emphasis on harmonizing spectrum allocations globally (ITU Radio communication Bureau, 2019) (GSMA, 2017). This appreciation for the status quo may come across as cavalier and insensitive to the upside opportunities accruing from streamlined and expedited administrative procedures. The ITU

---

[5] "There is a real possibility that these practices undermined the value of future WRCs and increased the risk that the ITU will become a tool for governments and incumbent spectrum users to halt spectral efficiency and technological progress. Global spectrum harmonization for future services will be difficult, if not impossible, or, at a minimum, be years behind innovation if such practices are allowed to occur. At the same time, global technological leaders, such as the U.S., will continue to innovate outside and without input from the ITU and its many nation states. This will, in turn, make the ITU and the WRC process less relevant." (O'Reilly, 2016).

"Unlike some countries, we do not believe we should spend the next couple of years studying what 5G should be, how it should operate, and how to allocate spectrum, based on those assumptions." (Wheeler, 2016 p.3).

process largely has generated positive outcomes, even though nations only have the power of persuasion available and cannot offer financial incentives as can occur domestically.

The United States placed itself and its stakeholders in the position of needing expedited action at the ITU, because of domestic regulatory initiatives that accelerated the domestic spectrum reallocation process. At WRC-15, the United States sought to expand mobile spectrum by the reallocation of UHF bandwidth, allocated exclusively for broadcast television (FCC, n.d.). Many nations have identified this frequency band as ideal for shared use by wireless carriers and television broadcasters, because digitization makes it possible to reduce the bandwidth broadcasters need on an exclusive basis. This so-called digital dividend made it possible for the FCC and other national regulatory authorities to "repack" the UHF television spectrum allocation thereby expanding spectrum available to meet substantial demand for more frequencies available for use by mobile telecommunications carriers while preserving the terrestrial coverage of incumbent broadcast television stations. [6]

However, few nations had even started the reallocation process before the United States sought to make it the consensus outcome globally at WRC-15. In many nations, incumbent broadcasters continue to bear a public service mission and some stations are still government owned. Few, if any, nations have the incentives and financial resources to implement incentive auctions [7] that pass through substantial funds to television broadcasters

---

[6] "'Repacking'" involves reorganizing television stations in the broadcast television bands so that stations that remain on the air after the incentive auction occupy a smaller portion of the UHF bad, thereby freeing up a portion of that band for new wireless services uses." (FCC, 2016a)

[7] "The broadcast incentive auction itself will comprise two separate but interdependent auctions -- a reverse auction, which will determine the price at which broadcasters will voluntarily relinquish their spectrum usage rights; and a forward auction, which will determine the price companies are willing to pay for flexible use wireless licenses. . . .

In order to be successful, each of the components must work together. Ultimately, the reverse auction requires information about how much bidders are willing to pay for spectrum licenses in the forward auction; and the forward auction requires information regarding what

agreeing to change frequencies to achieve spectrum repacking goals. The FCC reports that UHF incentive auctions freed up 84 megahertz of spectrum (70 MHz for licensed use and 14 MHz for wireless microphones and unlicensed use), generating $10.05 billion for incumbent broadcasters and more than $7 billion to the U.S. Treasury for deficit reduction (FCC, 2017a).

At WRC-19, the United States delegation again will promote 5G spectrum reallocations consistent with a national agenda of maintaining or reclaiming global leadership in markets for 5G services and equipment including handsets and chips. Having seen the quick progress generated by financial incentives for clearing out UHF spectrum, the FCC has under consideration a similar strategy [8] for clearing portions of the C-band, at 3.7-4.2 GHz (space-to-Earth or downlink) paired with the 5.925-6.425 GHz band (Earth-to-space or uplink), currently allocated for fixed satellite services (Eggerton, 2019) (FCC, 2018).

While other nations eventually will support reductions in bandwidth allocated exclusively to both terrestrial broadcasters and satellite operators, this outcome may take years to complete, particularly if other national regulatory authorities cannot or will not create financial incentives for expedited frequency band clearing like the FCC's past financial incentives for UHF television broadcasters and its proposed plan for satellite operators. In any event, the process will not have begun outside the United States before the

spectrum rights were tendered in the reverse auction, and at what price; and each of these depend on efficiently repacking the remaining broadcasters." (FCC, 2017)

[8] "The 5G-centric FCC is definitely going to free up some portion of the C-band (3.7-4.2 GHz) for next-generation wireless, part of a grand plan to free up as much low-, mid- and high-band spectrum as possible, but sought comment on just how to do that, either through a traditional FCC auction or via marketplace mechanisms like deals between carriers and satellite operators as the alliance is proposing, perhaps even cutting cable operators and broadcasters in for a piece of the proceeds" (Eggerton, 2019).

October, 2019 start date for WRC-19. Additionally, the ITU has no official means for endorsing such a financial incentive strategy.

ITU senior management and country delegates continue to ponder how best to satisfy the acute need for more wireless spectrum to accommodate ever growing demand by people, sensors and machines using an inter-governmental forum that historically has pursued global spectrum planning on a multi-year, incremental pace. The ideal solution has proven elusive, because incumbents with preexisting spectrum assignments are predictably reluctant to share with increasing number of stakeholders having new requirements. Adding to the underlying preference for cautious deliberation, the ITU consensus building process emphasizes harmonization and consensus building, largely eschewing calls to close debate and move to a vote.

II. The Spectrum Management Role of International Telecommunication Union

The ITU provides an essential forum for management of radio spectrum, a shared global resource ("res commune") that provides the medium and building blocks for carriage of content across distances (ITU, n.d.). The ITU operates as a specialized agency of the United Nations and constitutes the world's oldest, continuously operating inter-governmental forum for conflict avoidance and resolution in matters related to radio spectrum, satellite orbits, telecommunications standards and the rollout of telecommunications equipment and services in developing nations.

The ITU achieves legitimacy based on the formal agreement among member nations in treaty-level documents. It also develops and records more numerous, non-binding national commitments to consensus decisions, reached through study, negotiations and compromise. Nations of the world relinquish a degree of sovereignty (self-determination) to reach global, or at least regional consensus, on issues that affect the efficiency, cost, reliability and compatibility of telecommunications equipment and services. The ITU's "good offices"

provides a legitimate forum for nations to balance self-interest with shared goals that can generate synergistic benefits, including the elimination or reduction in conflicts, such interfering use of the same frequency, multiple operating standards, incompatible equipment, different frequency allocations for the same service and the inability of networks to interconnect.

Since its creation in 1875, the ITU has generated a record of many successes offset by a few notable failures. An early victory occurred when it and other international, inter-governmental organizations, reached consensus on several remedial measures designed to accelerate maritime emergency response times that could have saved lives in calamities such as the sinking of the Titanic cruise ship [9] (Magoun, 2012). While several ships sailed within range of the Titanic as it was sinking, the lack of a common emergency frequency and its mandatory monitoring on a continuous basis delayed rescue. The ITU established reasonable and readily accepted radio operating rules for maritime operations with an eye toward saving lives and property.

Notable failures to reach closure on uniform "rules of the road" include the proliferation of incompatible operating standards and allocated frequencies. In both instances, equipment manufacturers had to invest in multiple and incompatible product lines rather than accrue scale efficiencies in having only one global standard. While fourth and fifth generation wireless services have fewer incompatible standards, prior generations forced manufacturers and carriers to consider whether and how to provision handsets capable of operating on different frequency bands, using different transmission formats. Even now, AT&T provides service in the United States, using the Group Special Mobile standard

---

[9] "But the sinking of the ocean liner Titanic in 1912 showed the need for further improvements. Just a few months after the tragedy, the 1912 International Radiotelegraph Conference, held in London, agreed on a common wavelength for ships' radio distress signals. Also, every ship was instructed to maintain radio silence at regular intervals, when operators should listen for distress calls." (ITU, Radio p. 2)

promoted by European handset manufacturers and carriers, while Verizon favors an incompatible Code Division Multiple Access standard.

The ITU also has generated concerns that it seeks to expand its substantive wingspan on matters such as cybersecurity, Internet governance, including the sovereign rights of nations to regulate and limit access to content, and compulsory subsidies to sustain companies using legacy technologies, despite the debut of cheaper competitive alternatives. Some nations, including the U.S. have responded to such "mission creep" [10] by refusing to support consensus legitimizing an ITU role instead of leaving such matters to individual nations pursuing bilateral and multilateral goals [11] (Shackelford, Richards, Raymond, Kerr & Kuehn, 2017) (Masnick, 2012). Critics of the ITU also assert that it has attempted to subvert the role of other standard setting organizations, particularly on matters pertaining the Internet, including emerging issues such as Over the Top, video streaming services and the Internet of Things. (McDowell, 2012) (Thomas, Waters & Fontanella-Khan, 2012).

The ITU's role in spectrum management lies primarily in identifying what services should use which frequencies and in issuing recommendations on a wide array of operational matters (Manner, 2003). Optimization of spectrum use requires stakeholders, under the auspices of the ITU, to study the operational characteristics of spectrum as relates to specific

---

[10] "It is no great secret why the ITU has been considering taking these steps into Internet governance. The world is moving quickly to packet-switching and the Internet Protocol, the basic architecture of the Internet. The ITU believes it stands to lose importance as more and more of the world's telecommunications traffic and infrastructure escapes its jurisdiction." (Whitt, 2013 p.761).

[11] "Before the [2012 World Conference on International Telecommunications], ITU leadership made three key promises:
1) No votes would be taken at the WCIT;
2) A new treaty would be adopted only through 'unanimous consensus;'" and
3) Any new treaty would not touch the Internet.

All three promises were resoundingly broken.13 As a result of an 89-55 vote, the ITU now has unprecedented authority over the economics and content of key aspects of the Internet." (McDowell, 2013 pp. 5-6)

service requirements. One primary variable addresses propagational characteristics, i.e., how far a signal typically travels on a specific frequency, or range of frequencies, using a specified amount of signal power. Generally, lower frequencies support comparably longer signal transmissions than higher frequencies. Accordingly, spectrum managers typically allocate lower frequencies for long distance services, with higher frequencies used for services designed to have short transmission signal contours, or which travel through an environment unlikely to block or degrade the signal, e.g., the vacuum of space between satellites and earth.

Signal propagation also impacts spectrum selection based on the number of simultaneous users. For services provided to many, close by users, higher frequencies provide better accommodation, because signals start to degrade (attenuate) after having traveled short distances. This apparent defect promotes reuse of the same frequency by other users located close by. Such frequency reuse enhances the ability of cellular radio networks to accommodate service demands of many nearby users. Similarly, Wi-Fi networks exploit short signal propagation to provide many non-interfering channels to close by users.

The ITU spectrum management process occurs in a sequence of activities: 1) development of an agenda of new allocations and reallocations, first subject to study and analysis; 2) opportunities for national delegations to articulate their position; 3) consensus building and formulation of national commitments, to reduce the number of non-conforming footnotes to specific spectrum allocations by individual nations; 4) formal designation of frequency allocations for one or more specific services; and 5) the eventual registration of radio spectrum uses and satellite orbital locations by the ITU.

The allocation process often specifies a range of frequencies, commonly referred to as a frequency band, such as 88.1-107.9 MegaHertz (“MHz”) for FM commercial and non-commercial radio broadcasting. The ITU also allocates spectrum for shared use by two or

more compatible services, sometimes with each having the same access priority, but in other instances different prioritization establishing a primary, secondary and tertiary right of access and protection from interfering spectrum use. The ITU subsequently keeps track of the spectrum allocation decisions of individual nations and registers both the frequencies used as well as the orbital locations of satellites. On the domestic front, individual nations similarly allocate spectrum, then assign one or more specific uses for the allocation followed by licensing of specific users and registration of the spectrum and orbital slots used.

III. Efforts to Accelerate 5G Rollout in the United States

The United States government has sought to expedite the commercial rollout of 5G service through an aggressive, multifaceted campaign to remove regulatory obstacles (FCC, 2019) (FCC, 2018). The FCC's so-called 5G FAST Plan has four strategic components: 1) accelerating the allocation of more spectrum into the marketplace, with emphasis on extremely high band in the double digit GHz range; 2) updating infrastructure policy to promote a more proactive, rather than reactive posture; 3) reducing regulations at any level of government—including states and municipalities--considered unnecessary and delaying; and 4) framing the need to act quickly to prevent endangering the national security and losing global marketplace leadership for 5G components, handsets and services.

The FCC characterizes its spectrum planning as "forward thinking" with definitive allocations for both licensed and licensed use in three frequency ranges: 1) low-band spectrum that combines existing mobile wireless allocations in the 800-900 MHz bands with new reallocations of frequencies in the 600-700 MHz bands, freed up with the migration from analog to digital television broadcasting and the FCC's incentive auctions to create financial incentives for incumbent television broadcasters to change, share or abandon UHF frequencies; 2) mid-band spectrum in the 2.5 GHz, 3.5 GHz, 3.7-4.2 GHz and 6 GHz bands that collectively could free up as much as 844 MHz of reallocated spectrum for licensed

carriers; and 3) high-band, small cell, millimeter-wave spectrum in the 24 GHz, 28 GHz, 37 GHz, 39 GHz, 47 GHz and 95 GHz bands. The FCC plans on using auctions for licensing use of about 5 GHz of new 5G spectrum, with the addition of up another 2.75 GHz by refarming the 26 and 42 GHz bands to accommodate incumbent satellite and terrestrial incumbent users while permitting new 5G use as well.

FCC initiatives characterized as infrastructure policy reform include efforts to accelerate coordination of federal agency approval of small cell, extremely high frequency use, including sharing of spectrum among private and governmental users. Additionally, the FCC seeks to prevent state and local regulatory agencies, including franchising authorities for cable television, from stalling or demanding unreasonable compensation and free services. The FCC seeks to impose "shot clock" time deadlines for all state and municipal agency consideration of new 5G facilities installation applications.

The FCC also has ongoing several initiatives collectively framed as modernizing outdated regulations to promote 5G backhaul and digital opportunities for all Americans. This category combines a number of proceedings designed to achieve deregulation, or streamlined rules, promote efficient and shorter coordination of shared conduits, access to rights of way and poles and accelerated migration from copper wire telephone service to next generation technologies such as Voice over the Internet Protocol. The FCC also seeks to reduce or eliminate rate regulation for business services including so-called middle mile routes that link local and long haul networks, or provide back haul services from wireless towers to urban data centers. The FCC also includes in its 5G modernization campaign the reclassification of broadband access to remove common carrier, network neutrality requirements as well as prohibiting local exchange and wireless carriers from using Chinese transmission and switching equipment, because of the potential for this infrastructure to contain hidden technology for espionage.

IV. Mixed Results at WRC-15

At WRC-15, the United States 5G agenda included both reallocation of heavily used spectrum by broadcasters and satellite operators. Additionally, the U.S. wanted the nations of the world to commit additional spectrum at extremely high frequencies that in most nations have pre-existing, non-commercial service specifications, but few actual users (NTIA, 2015).

Progress was reached in harmonizing on a global basis use of the 694-790 MHz frequency band for mobile services, where incumbent television broadcasters continue to operate in many nations (ITU, 2015), and in the 1.5 GHz L-band and 3-4 GHz C-band, used by various incumbent satellite operators who already have coordinated shared spectrum use with terrestrial operators (Lowenstein, 2018) (Maniewicz, 2016). The delegates to WRC-15 deferred consideration of more bandwidth in the 470-694 MHz UHF television band until 2023 (ITU, WRC-2015 Resolution 238), thereby focusing WRC-19's 5G emphasis on double digit GHz frequencies (GSMA, 2018) (El-Moghazi et al, 2017) (Belen, M. 2016) (Atarashi et al, (2016) (FCC, 2015).

The U.S. could not speed up the traditional ITU process that runs on an extended timeline, spanning several World Radio Conferences, with a sequence of actions that follow a tried and true course. The ITU starts by inviting submissions from governments about candidate spectrum reallocations, followed by the development of a work plan for studying issues raised such as interference potential when a new service shares the same frequencies with incumbent users and compatibility among multiple types of spectrum users. The process requires patience and thorough consideration of studies submitted by individual nations, or regional, inter-governmental groups, but typically the product of private sector stakeholders such as equipment manufacturers and service providers.

No spectrum decision at a World Radio Conference can take place before considerable prior work conducted by so-called Study Groups, typically organized by frequency band. WRC-15 concluded without having reached a consensus for even studying the feasibility of prospective use in the 27.5-28.35 GHz band already targeted for future 5G allocations in the U.S.

Arguably, the U.S. agenda for WRC-15 achieved many time sensitive goals (FCC, 2015). Former cable television executive Decker Anstrom, the head of the U.S. delegation to WRC-15, emphasized success at a "watershed conference" that approved allocations of "at least several hundred megahertz on a globally recognized basis" (NTIA, 2015a). Similarly, the ITU framed WRC-15 as a successful conference making significant increases in spectrum allocations for mobile services (ITU, 2018). ITU Deputy Director Mario Maniewicz documented an increase in the spectrum allocated for international mobile telecommunications from 230 MHz in 1992-97 to 1886 MHz at WRC-15 (Maniewicz , 2016).

However, several factors contributed to less than ideal outcomes for the United States. Perhaps the most significant one lies in the ever-increasing complexity and number of stakeholders in spectrum planning. The ITU consensus-based decision making does not operate on Internet time and strives to reach compromise among all constituencies. If the number of stakeholder increases, so does the complexity in decision making and the timespan for reaching closure.

5G technology brings many more players into the spectrum planning process including manufacturers of autonomous, self-driving vehicles, financial technology innovators, smart city and highway planners, electronic commerce and the manufacturers of the Internet of Things, including monitors, sensors and data collectors that will use 5G and other spectrum allocations for short distance transmissions. These new players enter a

consensus-driven forum with rather loose rules and procedures lacking specificity on how to reach consensus and what constitutes sufficient closure (ITU, 2012) (Scholl, 2011).

Other factors contribute to the perception of many nations that 5G did not present an acute spectrum planning problem necessitating a change in procedure and pace. The possibility exists that some nations assumed the U.S. interest in speed as having more to do with retaining or regaining global leadership in all aspects of 5G wireless, including markets for equipment and services, rather than a sincere interest in optimizing technology and nudging the ITU into a more proactive posture.

Bear in mind that even in 2019, the ITU still has some lower frequency, 4G wireless agenda items to close and many nations have not yet adopted a strategy for migrating from 4G to 5G technologies and services. For example, only a few nations have identified and auctioned off 5G spectrum and many have yet to complete the narrowing of broadcast television spectrum assignments made possible by digitization. Arguably, the first step to preparing to accommodate massive new demand for 5G services lies in reducing the UHF spectrum allocated for broadcast television, because these frequencies are adjacent to existing assignment for mobile wireless service and nations can accrue a “Digital Dividend” by refarming them for mobile services. The ITU will not address this issue until 2023 (ITU, WRC-15 Resolution 238).

Whether through inertia, the power of incumbent broadcasters to thwart domestic legislative and regulatory efforts to reduce their allocated spectrum, or both, many nations have yet to undertake a straightforward domestic spectrum reallocation in the UHF broadcast television frequency band. U.S. representatives might have come across as cavalier if they characterized the process as both easily executed and immediately necessary. In 2012, the U.S. Congress mandated sharing of auction proceeds to create a strong and lucrative

incentive for incumbent broadcasters to relinquish existing frequency assignments so that the FCC could reallocate portions of the 512-698 MHz range (FCC, n.d.) on an expedited basis.

The FCC needed two years to establish auction rules (FCC, 2014) and more than two additional years to complete the bidding process (FCC, 2016). Now having concluded the process, the FCC has achieved comparatively faster UHF spectrum refarming, albeit on a unilateral basis without parallel action at the ITU and in other individual nations. Having opted to act before the ITU, the U.S. must confront the consequences of delays in subsequent spectrum allocation actions at the ITU and in specific nations, as well as the possibility that future spectrum reallocations will not match the U.S. model. Additionally, some nations my pushback simply because they feel pressured by heavy handed action seeking to "railroad" a nationalist agenda.

For the most part, the FCC, the National Telecommunications and Information Administration ("NTIA"), housed in the Department of Commerce, and the State Department have established a comprehensive, methodical and multi-year process to prepare for ITU conferences. The President appoints the U.S. Delegation head who receives the status of Ambassador. The FCC convenes an advisory committee to provide the Commission with public views and recommendations regarding non-governmental spectrum. NTIA coordinates the Federal government's participation. The State Department also has advisory committees, formulates official contributions to ITU Meetings and coordinates numerous visits with national and regional groups similarly commissioned to prepare for an ITU conference.

The United States government agencies along with private sector delegates need time to develop a single consensus position on the various agenda items for future ITU conferences. This process requires accommodation and compromise between many domestic constituencies, followed by extensive dialog with national delegations, particularly ones from

North, Central and South America. For example, expanding allocations for terrestrial 5G services impacts the rights of incumbent users of spectrum targeted for reallocation, or sharing. Spectrum management does not necessarily constitute a zero-sum game, with specific winners and losers, particularly in light of enhance sharing capabilities achieved through digitization, compression, encryption, encoding, cognitive and software defined radio and other techniques. However, the process of changing the status quo necessitates a give and take between incumbent users and candidates making a strong case for spectrum reallocations.

5G coordination involves an increasing number of spectrum user categories including incumbent and prospective terrestrial and satellite users, as well as different types of users in each category, e.g., mobile versus users in fixed locations and providers of services using satellites operating in the geostationary orbital arc 22,300 miles above earth versus prospective service providers using satellites in orbits closer to earth.

Participants in the WRC-15 planning process and government officials may have discounted the possible harms in uncoordinated, untimely and inconsistent spectrum reallocations. The vast majority of wireless mobile transmissions do not cross national borders and the evolving trend of using extremely high spectrum, supporting even smaller transmission cells, further supports the view that nations can act unilaterally. Additionally, wireless handset manufacturers have managed to produce smartphones that can operate on many different frequency bands, apparently without significantly more cost, weight, or battery drain. Wireless handset manufacturers can achieve interoperability by supporting access to different frequency bands, while different transmission standards, e.g., GSM versus CDMA, typically result in incompatibility and different product lines.

Only with the passage of time will we see the extent of unharmonized spectrum allocations and their impact on the marketplace success of U.S. 5G equipment manufacturers.

On one hand, the FCC's 5G Fast Plan has created incentives for U.S. wireless carriers to make the necessary capital investment in new 5G infrastructure on an expedited basis, to announce 5G service trials and to promote the near-term availability of 5G compatible handsets. On the other hand, as discussed below, unilateral action by the U.S. trigger many harmful consequences including an adverse effect on the future standing of the country at ITU forums as well as the viability of the ITU consensus building.

A. The Role of Industrial Policy and Cybersecurity Concerns

The possibility exists that mixed success at WRC-15 and future conferences result from the onslaught of new complicating issues, rather than some fundamental shortcomings in conference preparations, consultations with other nations, or consensus building at the conference. Unlike any major, new spectrum allocation initiative, 5G raises both traditional coordination and consensus building requirements, as well as new concerns about national security, international trade, real or perceived assessments of marketplace prospects for specific manufacturers of 5G infrastructure and handsets and necessary strategies to retain, reclaim or extend leadership in establishing ITU conference agendas. These issues can further politicize the ITU process and prompt hours of deliberations about matters having little to do with the primary goal of optimizing use of a shared global resource.

In the U.S., advocates for a variety of legislative, regulatory and judicial outcomes, invoke the vulnerability of 5G marketplace success, however defined, because of unfair advantages that handicap U.S.-based stakeholders. These topics can present quite potent distractions and provocations if they become part of the discussion at ITU forums.

The perception that U.S. manufacturers of telecommunications and information processing equipment lag competitors in China and elsewhere has become a rallying cry for aggressive and unprecedented government action. For example, the FCC has refused to authorize a domestic service authorization request by a Chinese carrier (FCC, 2019b) and has

under consideration a number of rules that largely would prevent U.S. carriers from installing Chinese wireless network infrastructure (FCC, 2018b). Additionally, the claimed loss of global leadership over 5G has become a factor in whether the U.S. Justice Department should approve the proposed merger of TMobile and Sprint, two of the four wireless carriers serving the entire U.S. market (TMobile & Sprint, 2019).

Rather than consider the proposed combination using the traditional antitrust market assessments whether horizontal integration would diminish competition and harm consumers, advocates for approval claimed the merged company would help prevent loss of U.S. global 5G market leadership. Apparently, the government agencies have a patriotic duty to help U.S. "national heroes" achieve marketplace success and also protect the nation from the risk of spying and other forms of espionage and cyberterrorism practiced, or endorsed by national governments, such as China, that also happen to have market insurgents, such as Huawei and ZTE.

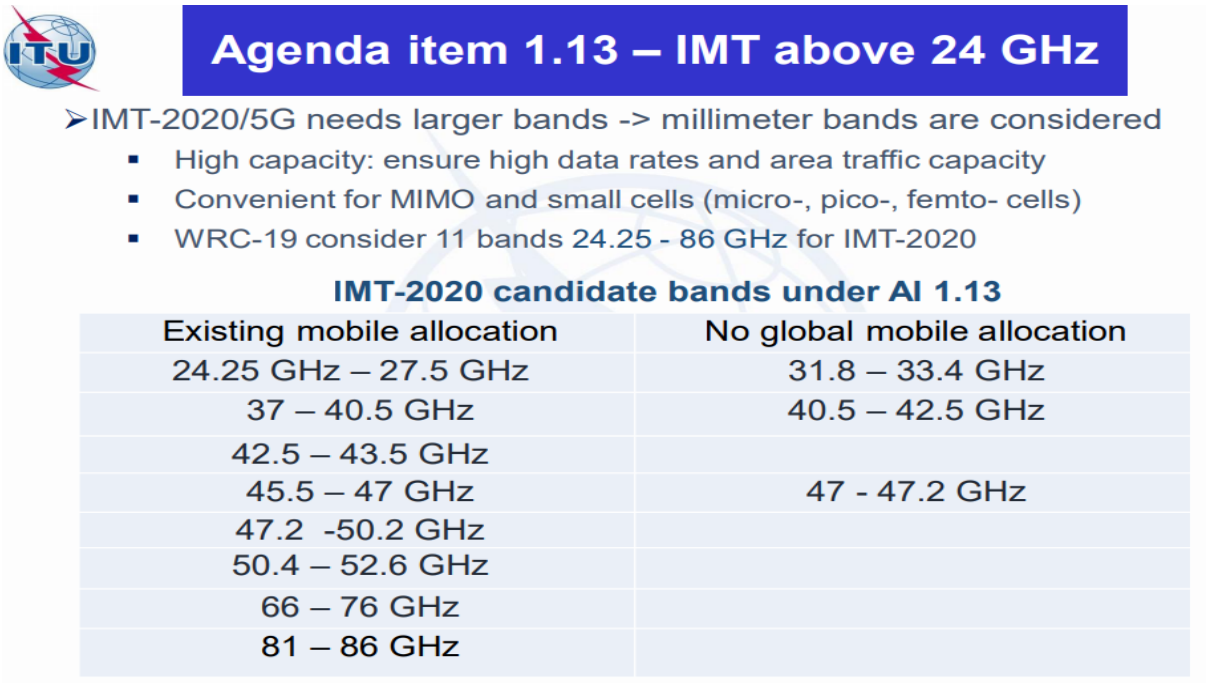
Similarly, aggressive advocacy at international conferences may constitute part of a national strategy to help national heroes regain market share in wireless industries including handsets, chip, modems, switches and other equipment. Over the last few years, U.S. telecommunications companies have lost market share and no longer dominate both the standard setting agenda and market for wireless goods and services. Manufacturers in developing nations have quickly evolved from equipment fabricators, to nimble equipment price cutters, still paying patent royalties to developed country incumbents, to creative innovators using mostly indigenous designs and patents to undercut prices and capture increasing market share.

Standard setting and spectrum allocations for 5G follow parallel courses with the former more likely to involve industry groups rather than inter-governmental forums. Both types increasingly must cope with the added risks of not reaching a consensus, because

irreconcilable differences remain. The more politicized and doctrinal either type of body becomes, the less likely the output will achieve original goals that emphasize consumer welfare, harmonization, efficiency and technological optimization.

V. Prospects for WRC-19 and Beyond

ITU management (ITU Radiocommunications Bureau, 2019a) (World Radiocommunication Conference 2019) (Matas, 2017) (Dine, 2017) and national delegations, including the U.S. (FCC, n.d.) (NTIA, n.d.), extensively prepared for WRC-19 following longstanding procedures. Agenda item 1.13 at WRC-19 will consider a number of 5G candidate frequency bands ranging from 24.25 - 86 GHz covering approximately 33 GHz in total bandwidth.



ITU Radiocommunications Bureau (2019a).

In light of the number of candidate frequency bands and pre-conference articulated disagreement on preferred allocations, as well as perennial disputes between terrestrial and satellite carriers, the U.S. likely will achieve a mixed outcome for its 5G agenda. Ironically, the decision at WRC-15 not to address whether and how to reallocate additional UHF broadcast television spectrum until 2023 (ITU, WRC-2015 Resolution 238), makes it

possible for WRC-19 to concentrate on the high, double-digit GHz bands of particular interest to U.S. carriers.

Despite cautious optimism about U.S. prospects at WRC-19, future delegations may continue to face diminishing returns at ITU conferences, particularly if distracting, politicized and contentious industrial policy and national security matters become more frequent elements in deliberations. [12] To achieve the goals specified by the U.S. government in official submissions to the ITU, interested parties need to consider adopting new strategies with a heightened appreciation that the odds for success have lowered while the preparation and coordination requirements have increased. [13]

This paper has identified many factors that evidence greater complexity and more divergent agendas at ITU inter-governmental forums. The balance of power in terms of leadership in innovation, as well as rollout of new technologies and spectrum use has broadened beyond incumbents in the United States, Europe and Japan. The pace of technological change has increased even as the number of different constituencies and types of innovations have grown. Nations increasingly have their own priorities and timetables for embracing change and new technologies. While this development can help developing nations "leapfrog" and adopt new technology sooner, other nations—developed and

---

[12] "'This conference is unique in that normally we have one — maybe two — what I would classify as the highly politicized agenda items,' Charles Glass, chief of the U.S. National Telecommunications and Information Administration's International Spectrum Policy Division, said May 8 at the Satellite 2019 conference. 'This one has about six, and there are a couple of others hiding out there that could quickly grow to that level'" (Henry 2019).

[13] FCC staff participating in the WRC-15 preparation process and attending the conference identified three troublesome, emerging trends: "Global allocations are increasingly challenging. Identifying spectrum on a regional basis may be more realistic. Incumbent services have a strong voice and show little flexibility in considering spectrum sharing mechanisms" (FCC, 2015).

developing—may have constituencies keen on maintaining exclusive access to a frequency band, using older, but still usable technologies.

Less than robust support for 5G may simply constitute a logical reaction to the cost in migrating to costly next generation networks when existing plant has plenty of usable life and more years of investment amortization to go. Many of the world's mobile wireless users, including police, first responders and the general public, have their service needs currently met using existing frequency bands, long ago allocated, in the Very High Frequency and Ultra High Frequency bands between 100 and 400 MHz.

The route for reaching consensus has become more tortuous leading some national governments more inclined to call for a vote, a rarely pursued option at ITU forums. Nations like the U.S., used to setting the agenda and reaching consensus consistent with national goals, do not welcome instances where each nation casts an equivalent single vote. The U.S. and other, mostly developed nations, were surprised and unprepared when the World Conference on International Telecommunications in 2012 abandoned consensus building and proceeded to a 89 to 53 vote on new International Telecommunication Regulations that would legitimize an Internet governance and policymaking role for the ITU and bolster the sovereign right of nations, such as China and Russia, to monitor, curate, limit access and censor Internet content (Ermert, 2012) (Internet Law Center, 2012) (Pfanner, 2012). To avoid calls to close debate and cast votes and to achieve greater likelihood for timely consensus, the U.S. must consider adjusting its strategy and tactics in light of changed circumstances.

Stakeholders in any national ITU conference preparation forum should recognize the need to resolve disputes well before the time for the start of regional coordination, agenda setting for an ITU conference and conference start dates. Press accounts of WRC-15 and WRC-19 preparation in the U.S. include evidence of unresolved disputes between nationally

licensed terrestrial and satellite carriers as well as between international ventures, such as Intelsat, and domestic carriers. [14] The U.S. government cannot expect to forge consensus internationally if it cannot achieve timely compromise and a single position well before an ITU conference starts.

Additionally, interested parties should recognize that the failure to reach time, pre-conference consensus occurs in many nations and in regional forums, such as the Inter-American Telecommunication Commission ("CITEL"), an entity of the Organization of American States serving nations throughout the Americas (Inter-American Telecommunication Commission, n.d.). Failing consensus and trust building in regional forums, such as CITEL, increase the need to budget and prepare for bi-lateral coordination with individual nations, such as Brazil. [15]

More fundamentally, nations including the U.S., need to understand the risk in the more frequent integration of factors, such as trade and national security concerns, that have little to do with fostering efficient use of spectrum. For example, one can expect China to oppose any U.S. initiative, within the ITU and elsewhere, that would commercially handicap Chinese telecommunications and information ventures. In response to the FCC's consideration whether to prohibit U.S. carriers from installing Chinese equipment (FCC, 2018b), Chinese delegations to ITU conferences might oppose U.S. initiatives as leverage to

---

[14] Within days of WRC-15's November 2nd start date "[s]everal of the world's largest commercial satellite fleet operators on Oct. 22 made an 11th hour attempt to persuade governments not to allow terrestrial broadband networks to use spectrum currently reserved for satellites" (Selding, 2015).

[15] "It makes sense then for the next WRC in 2029 (WRC-19) to adopt protections for either or both planned uses of . . . bands [targeted for international mobile telephony via satellite or terrestrial networks] so the bands can be used on a non-harmful interference basis globally, or at least regionally. . . .

If such actions are not taken internationally, users will have to work on a country-by-country basis to obtain the protections they require for their use of the bands or face potential harmful interference" (Manner, 2018).

secure trade concessions on matters, possibly addressed elsewhere, that have limited, if any, relationship to substantive mission of the ITU.

If trade and national security concerns become more visible and distracting factors in ITU conferences, the ITU Secretariat should appreciate that the legitimacy and utility of its mission may be at risk. Over many years, U.S.-based critics of the ITU have characterized its management as biased and intent on "mission creep" into such areas as cybersecurity, Internet governance and freedom of expression via broadband networks. ITU management may achieve some of its mission expansion goals, but at the risk of losing its reputation as a fair steward offering its "good offices" for anticipating and resolving conflicts in a timely and equitable manner.

Carriers and equipment vendors should share some of the blame for 5G spectrum planning controversies. Ventures appear to have overstated the near-term benefits from 5G. Accordingly, the U.S. and other nations keen on speedy rollout of 5G service should make every effort to frame 5G spectrum planning as a major, but conventional chapter in frequency reallocations and not industrial policy, or tilting the competitive playing field for 5G components, equipment and handsets made by the national heroes of any specific country. More broadly, nations need to redouble efforts to apply best practices in spectrum planning and coordination, with emphasis on traditional goals benefitting all nations.

A. Old Lessons Forgotten, Ignored or Avoided

The perceived lack of progress in 5G spectrum planning may evidence misapprehension about how the ITU operates and what one can expect ITU forums to deliver. Spectrum planning remains an ongoing undertaking notwithstanding the emphasis on the several weeks of intensive deliberations occurring at World Radio Conferences meeting every four years. The process operates incrementally over many years of study,

testing, consensus building and conflict avoidance. There are few shortcuts and vehicles to expedite this process.

5G has and will continue to present challenges in light of the new services the technology will offer and the variety of new stakeholders with strategic plans to serve 5G markets. Proliferating services, both in terms of types and companies new to the ITU process, can exacerbate preexisting tensions, particularly that between incumbents with spectrum allocation entitlements and advocates for new services that seek accommodation typically by forcing incumbents to share spectrum.

No incumbent wants the logistical and potentially costly burden of having to make do with less spectrum, even ones who have evidenced the ability to abandon exclusivity and even specific frequency band access rights without measurable harm. The FCC has softened the insult by creating opportunities for incumbents to abandon spectrum in exchange for financial compensation. In addition to the incentive auctions already conducted in the UHF television band, and the proposal to compensate incumbent C-Band satellite carriers to relinquish part of their exclusive allocations, the FCC recently proposed to allow operators of closed educational television networks to auction off, instead of simply lease spectrum to mobile wireless carriers (FCC, 2019a). [16] These networks operators have limited time of use needs and specific geographical regions, but without an enhanced financial inducement they would likely take every step to delay the onset of having less bandwidth available and more spectrum use coordination burdens.

The FCC cannot always secure legislative authority to create financial incentives and even the seemingly straightforward process of inducing public and nonprofit educational organizations to give up exclusive spectrum rights has generated controversy about its

[16] The FCC even has proposed to allow licensed commercial wireless carriers to use unlicensed Wi-Fi spectrum (FCC, 2015a).

potential to bolster incumbent wireless carrier market power (Reardon, 2019). Even more controversial and difficult spectrum reallocation challenges abound, particularly for incumbent government users. The laws of physics and radio sometimes foreclose simply inducing or forcing incumbents to change frequencies, often by moving to higher bands. For example, military users of C-band spectrum have balked to the prospect of having to relocate to other, higher satellite frequencies. The C-band spectrum has favorable propagational characteristics particularly for maritime users operating in rainy tropical locations. Moving to higher frequencies adds risks of so-called rain fade, when moisture reduces or eliminates the ability to transmit and receive possibly mission critical communications.

VI. Conclusions

Unilateralism in the ITU spectrum allocation process can and often does impose high costs to equipment manufacturers, carriers and consumers. The incompatibility of GSM and CDMA wireless handsets provides a current example. Accordingly, a nation's decision to "go it alone" in the absence of expedited multi-lateral consensus should occur only when significant, measurable benefits accrue. A faster rollout of 5G equipment and services may satisfy such a requirement, but the anticipated benefits have been overstated, at least in the short term. 5G technology eventually will promote widespread use of Internet-connected devices and sensors, but current and near-term benefits will largely emphasize faster bit transmission speed and reduced latency.

The assessment of benefits has become even more difficult, because advocates for the Sprint-TMobile merger, real or imagined concerns about national security and the perception of lost wireless technology leadership also drive United States government agencies to undertake risky strategies, including ones that come across as politically driven.

The United States risks significant loss in trust and stature at the ITU if its delegates persist in nudging or pushing this inter-governmental forum to abandon its traditional

methods for addressing new spectrum requirements. The ITU must resolve real and pressing need for more spectrum to accommodate growing demand, including that which 5G will stimulate. However, there is nothing particularly different about 5G spectrum demand that differentiates it from the variety of previous mission-critical, time-sensitive spectrum requirements. The ITU has regularly confronted conflicting spectrum requirements and warring constituencies throughout its history.

It appears that the United States preparations from WRC-19 have matched best practices, albeit still plagued by last minute conflict between perennial opponents such as terrestrial versus satellite carriers. World Radio Conferences never satisfy all national or private venture goals, even as they always have unanticipated controversies resulting in tension and uncertainty. [17] Having undertaken an aggressive and unconventional campaign seeking expedited action at the ITU, United States stakeholders should recognize the risks of achieving less than optimal results.

[17] "'The real fight at every conference is the agenda item you don't pick as your priority agenda item. There's hasn't been a single [WRC] conference that I've been at where we haven't been surprised by an agenda item we thought was going to be peacefully solved in week one and in week four, at 11.59 pm on the last day, we're still talking about it'" (Waterman, 2019) (quoting Charles Glass, chief of the International Spectrum Policy Division at the National Telecommunications and Information Administration).

References

AT&T (2019). 5 Facts on AT&T 5G; Retrieved from: https://about.att.com/content/dam/snrdocs/5%20Facts%20On%20ATT%205G%20-%202%2018%2019.pdf.

Amadeo, R. (2019). The latest barrier to 5G speeds? The summer. *Arstecnica*. Retrieved from: https://arstechnica.com/gadgets/2019/07/the-latest-barrier-to-5g-speeds-the-summer/.

Atarashi, H. et al (2016). 2015 ITU World Radiocommunication Conference (WRC-15) Report—Standardization of Mobile Phone Spectrum. *NTT Docomo Technical Journal*. Retrieved from: https://www.nttdocomo.co.jp/english/binary/pdf/corporate/technology/rd/technical_journal/bn/vol18_1/vol18_1_010en.pdf.

Belen, M. (2016). Implications of WRC-15 on spectrum and 5G, European Commission, *JRC Technical Reports*. Retrieved from: https://ec.europa.eu/jrc/en/publication/implications-wrc-15-spectrum-and-5g.

CableFree (n.d.). Introduction to Millimeter Wave E-Band Technology. Retrieved from: https://www.cablefree.net/wirelesstechnology/millimeter-wave-technology/.

Cook, C. (2017). WRC-19 agenda item 1.13 IMT-2020 between 24.25 and 86 GHz. 1st ITU Inter-Regional Workshop on WRC-19 Preparation (Geneva, 21-22 November 2017). Retrieved from: https://www.itu.int/dms_pub/itu-r/md/15/wrc19prepwork/c/R15-WRC19PREPWORK-C-0012!!PDF-E.pdf.

Dine, A.F. (2017). WRC-19 Preparation, presented at the ITSO/ITU Conference on Satellite Communications, Nairobi July 17-21, 2017). Retrieved from: https://itso.int/wp-content/uploads/2018/04/akim_Day-3-1-WRC-Peparation.pdf.

Eggerton, J. (2019). C-Band Alliance Provides FCC More Info on Band-Clearing Plan, *Multichannel News*. Retrieved from: https://www.multichannel.com/news/c-band-alliance-provides-fcc-more-info-on-band-clearing-plan.

El-Moghazi, Whalley, J. & Irvine, J. (2017). World radiocommunications conference—2105: Reflections on Africa international spectrum policy. *Telecommunications Policy 41*, 631-641.

Ermert, M. (2012, Dec. 13). WCIT Split After Split "Vote" On Internet Governance Resolution. *Intellectual Property Watch*. Retrieved from: http://www.ip-watch.org/2012/12/13/wcit-split-after-split-vote-on-internet-governance-resolution/.

European Parliament (2019). Policy Department for Economic, Scientific and Quality of Life Policies, Directorate-General for Internal Policies. 5G Deployment, State of Play in Europe, USA and Asia. Retrieved from: https://www.europarl.europa.eu/RegData/etudes/IDAN/2019/631060/IPOL_IDA(2019)631060_EN.pdf.

FCC (2019). The FCC's 5G FAST Plan. Washington, D.C.: Federal Communications Commission. Retrieved from: https://www.fcc.gov/5G.

FCC (2019a). Transforming the 2.5 GHz Band, WT Docket No. 18-120, Report and Order, FCC 19-62. Retrieved from: https://docs.fcc.gov/public/attachments/FCC-19-62A1.doc.

FCC (2019b). China Mobile International (USA) Inc. Application for Global Facilities-Based and Global Resale International Telecommunications Authority Pursuant to Section 214 of the Communications Act of 1934, as Amended, ITC-214-20110901-00289, Memorandum Opinion and ORDER, FCC 19-38 (rel. May 10, 2019). Retrieved from: https://docs.fcc.gov/public/attachments/FCC-19-38A1.pdf.

FCC (2018). The FCC's 5G FAST Plan. Washington, D.C.: Federal Communications Commission. Retrieved from: https://docs.fcc.gov/public/attachments/DOC-354326A1.docx.

FCC (2018a). Expanding Flexible Use of the 3.7 to 4.2 GHz Band, GN Docket No. 18-122, Order and Notice of Proposed Rulemaking, 33 FCC Rcd 6915. Retrieved from: https://docs.fcc.gov/public/attachments/FCC-18-91A1_Rcd.pdf.

FCC (2018b). Protecting Against National Security Threats to the Communications Supply Chain Through FCC Programs, WC Docket No. 18-89, Notice of Proposed Rulemaking, 33 FCC Rcd 4058 (2018). Available at: https://docs.fcc.gov/public/attachments/FCC-18-42A1.docx.

FCC (2017). How It Works: The Incentive Auction Explained. Retrieved from: https://www.fcc.gov/about-fcc/fcc-initiatives/incentive-auctions/how-it-works.

FCC (2017a). Broadcast Incentive Auction and Post-Auction Transition. Retrieved from: https://www.fcc.gov/about-fcc/fcc-initiatives/incentive-auctions.

FCC (2016). Auction 1000 Web site. Retrieved from: https://www.fcc.gov/auction/1000.

FCC (2016). Primer for Broadcasters, Repacking. Retrieved from: https://www.fcc.gov/about-fcc/fcc-initiatives/incentive-auctions/primer-broadcasters.

FCC (2015). World Radiocommunication Conference 2015 (WRC-15), Presentation to the FCC Open Meeting December 17, 2015. Retrieved from: https://docs.fcc.gov/public/attachments/DOC-336915A1.pdf

FCC (2015a). Public Notice, Office of Engineering and Technology and Wireless Telecommunications Bureau Seek Information on Current Trends in LTE-U and LAA Technology, ET Docket No. 15-105, DA 15-516. Retrieved from: https://transition.fcc.gov/Daily_Releases/Daily_Business/2015/db0505/DA-15-516A1.pdf.

FCC (2014). Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions, Report and Order, GN Docket No. 12-268, 29 F.C.C. Rcd. 6567. Retrieved from: https://docs.fcc.gov/public/attachments/FCC-14-50A1.pdf.

FCC (n.d.). The Broadcast Television Spectrum Incentive Auction
Innovation in Policy to Ignite Innovation for Consumers and Business, FCC Staff Summary, Retrieved from: https://docs.fcc.gov/public/attachments/DOC-318455A1.pdf.

FCC (n.d.). WRC-19. Retrieved from: https://www.fcc.gov/wrc-19.

Frieden, R. (2019). The evolving 5G case study in spectrum management and industrial policy. *Telecommunications Policy 43(6)*, 549-562.

GSMA (2018). The 5G Era in the US. Retrieved from: https://www.gsmaintelligence.com/research/?file=4cbbdb475f24b3c5f5a93a2796a4aa28&download.

GSMA (2017). An Introduction to the WRC. Retrieved from: https://www.gsma.com/spectrum/wp-content/uploads/2017/02/An-Intoduction-to-the-WRC.pdf.

GSMA (2015). A Guide to WRC-15 Agenda Item 1. Retrieved from: https://www.gsma.com/spectrum/wp-content/uploads/2015/07/Guide-to-WRC-15-AI-1.1.pdf.

GSMA (n.d.). The GSMA WRC series – getting ready for WRC-19. Retrieved from: https://www.gsma.com/spectrum/wrc-series/.

Henry, C. (2019). Satellite industry prepares for WRC-19 on multiple fronts. *Space News*. Retrieved from: https://spacenews.com/satellite-industry-prepares-for-wrc-19-on-multiple-fronts/.

Henry, C. (2017). ITU: mobile networks want some C- and Ka-band spectrum for 5G. *Space News*. Retrieved from: https://spacenews.com/itu-mobile-networks-want-some-c-and-ka-band-spectrum-for-5g2/.

Horwitz, J. (2018). Huawei's first 5G phone reportedly guzzles power, needs big heatsink. Venturebeat. Retrieved from: https://venturebeat.com/2018/07/30/huaweis-first-5g-phone-reportedly-guzzles-power-needs-big-heatsink/.

Inter-American Telecommunication Commission (n.d.). Web site. Retrieved from: https://www.citel.oas.org/en/Pages/About-Citel.aspx.

Internet Law Center (2012). Western Nations Refuse to Accept ITU Net Proposal: Has Cyber Cold War Begun? *Cyber Report*. Retrieved from: https://ilccyberreport.wordpress.com/2012/12/14/western-nations-refuse-to-accept-itu-net-proposal-has-cyber-cold-war-begun/

ITU, 2018). 2nd ITU Inter-regional Workshop on WRC-19 Preparation - Geneva, Switzerland, 20-22 November 2018. Retrieved from: https://www.itu.int/en/ITU-R/conferences/wrc/2019/irwsp/Pages/2018.aspx.

ITU (2018). Setting the Scene for 5G: Opportunities & Challenges. Retrieved from: https://www.itu.int/pub/D-PREF-BB.5G_01-2018.

ITU (2017). World Radiocommunication Conference 2019 (WRC-19), Agenda and Relevant Resolutions. Retrieved from: https://www.itu.int/dms_pub/itu-r/opb/act/R-ACT-ARR.1-2017-PDF-E.pdf.

ITU (2015). Press Release. Mobile broadband enabled globally in the 694-790 MHz frequency band. Retrieved from: https://www.itu.int/net/pressoffice/press_releases/2015/55.aspx.

ITU, WRC-2015 Resolution 238. Retrieved from: https://www.itu.int/dms_pub/itu-r/oth/0c/0a/R0C0A00000C0014PDFE.pdf.

ITU (2012). Tutorial for Rapporteurs and Editors. Retrieved from: https://www.itu.int/ITU-T/studygroups/tutorials/201211/programme.html.

ITU (n.d.). ITU towards "IMT for 2020 and beyond." Retrieved from: https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2020/Pages/default.aspx.

ITU (n.d.). *Overview of ITU's History, Radio*. Retrieved from: https://www.itu.int/en/history/Pages/ITUsHistory-page-2.aspx

ITU (n.d.). What does ITU do? Retrieved from: https://www.itu.int/en/about/pages/whatwedo.aspx.

ITU Radiocommunication Bureau (2019). Report of the CPM on technical, operational and regulatory/procedural matters to be considered by the World Radiocommunication Conference 2019. 2nd Session of the Conference Preparatory Meeting for WRC-19. Retrieved from: https://www.itu.int/dms_pub/itu-r/opb/act/R-ACT-CPM-2019-PDF-E.pdf.

ITU Radiocommunications Bureau (2019a). Preparations for WRC-19. Presentation at a meeting of the Caribbean Spectrum Management Task Force, Trinidad and Tobago 18th and 19th July 2019. Retrieved from: https://www.ctu.int/wp-content/uploads/2019/07/WRC-19_preparations_ITU_for_Caribbean_terrestrial_18_07_2019.pdf

Kadyrov, T. (2017). Non-GSO satellite issues. Retrieved from: https://www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/Documents/Events/2017/Aug-ISS2017/PAPER_Workshop_S3_Timur.pdf.

Kastrenakes, J. (2019). Verizon will launch 5G in 30 cities this year, *The Verge*. Retrieved from: https://www.theverge.com/2019/2/21/18234755/verizon-5g-30-cities-2019-launch.

Lowenstein, U. (2018). The global move towards 5G between WRC-15 and WRC-19. Retrieved from: http://www.haddentelecoms.com/sites/default/files/2018-05/Telefonica_Uwe_Loewenstein_5GBriefing_Istanbul_2018.pdf.

Magoun, A. (2012). The Titanic's Role in Radio Reform, *IEEE Spectrum*. Retrieved from: https://spectrum.ieee.org/static/the-titanics-role-in-radio-reform.

Manner, J. (March 15, 2018). Op-ed Balancing terrestrial & satellite 5G needs for international spectrum harmonization. *Spacenews*. Retrieved from: https://spacenews.com/op-ed-balancing-terrestrial-satellite-5g-needs-for-international-spectrum-harmonization/.

Manner, J. (2003). *Spectrum Wars: The Policy and Technology Debate* (Boston: Artech House).

Maniewicz, M. (2016). Outcome of the World Radiocommunication Conference, 2015. Retrieved from: http://dynamicspectrumalliance.org/wp-content/uploads/2016/04/DSA-Summit-2016-Keynote-Address-Day2_Mario-Maniewicz.pdf.

Matas, A. (2017). *WRC-19 Agenda items and challenges*. Retrieved from: https://www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/Documents/Events/2017/Aug-ISS2017/PAPER_S2_Workshop_Attila_Matas.pdf

McDowell, R. (2013). Statement of Commissioner Robert M. McDowell, Federal Communications Commission, Before the United States House of Representatives Committee on Energy and Commerce Subcommittee on Communications and Technology and Committee on Foreign Affairs Subcommittee on Terrorism, Nonproliferation, and Trade and Committee on Foreign Affairs Subcommittee on Africa, Global Health, Global Human Rights, and International Organizations Fighting for Internet Freedom: Dubai and Beyond. Retrieved from: https://docs.house.gov/meetings/IF/IF16/20130205/100221/HHRG-113-IF16-Wstate-McDowellR-20130205.pdf.

McDowell, R. (2012, Feb. 21). The U.N. Threat to Internet Freedom. *The Wall Street Journal*. https://www.wsj.com/articles/SB10001424052970204792404577229074023195322.

Masnick, M. (2012). Why You Should Be Worried About the ITU's Bizarre Claim To Have A Mandate Over Internet Security, *Techdirt*. Retrieved from:https://www.techdirt.com/articles/20121004/02262820588/why-you-should-be-worried-about-itus-bizarre-claim-to-have-mandate-over-internet-security.shtml.

NTIA (2018). Building Spectrum Policy to Meet Advanced Communications Capabilities, Remarks of David J. Redl Assistant Secretary of Commerce for Communications and Information TIA Policy Forum: Federal Spectrum Policy for the 5G Era. Retrieved from: https://www.ntia.doc.gov/speechtestimony/2018/building-spectrum-policy-meet-advanced-communications-capabilities.

NTIA (2015). Achieve of official U.S. Proposals to WRC-15. Retrieved from: https://www.ntia.doc.gov/page/us-proposals.

NTIA (2015a). Office of Spectrum Management, Commerce Spectrum Management Advisory Committee. Meeting transcript. Retrieved from: https://www.ntia.doc.gov/files/ntia/meetings/120215_csmac_transcript.pdf.

NTIA (n.d.). WRC-2019. Retrieved from: https://www.ntia.doc.gov/category/wrc-19.

Nordrum, A. & Clark, K. (2017). 5G Bytes: Millimeter Waves Explained. Retrieved from: https://spectrum.ieee.org/video/telecom/wireless/5g-bytes-millimeter-waves-explained.

O'Reilly, M. (2016). *2015 World Radiocommunication Conference: A Troubling Direction*. United States Federal Communications Commission Blog, Retrieved from https://www.fcc.gov/news-events/blog/2016/01/15/2015-world-radiocommunication-conference-troubling-direction.

Pfanner, E. (2012, Nov. 27). Integrity of Internet Is Crux of Global Conference, *The New York Times*. Retrieved from: https://www.nytimes.com/2012/11/28/technology/dark-warnings-about-future-of-internet-access.html.

Reardon, M. (2019). 5G gets boost in controversial FCC spectrum vote, *Cnet.* Retrieved from: https://www.cnet.com/news/fcc-paves-the-way-for-more-5g-spectrum/.

Scholl, R. (2011). The Art of Reaching Consensus, ITU-T Rapporteur and Editor Tutorial. Retrieved from: https://www.itu.int/dms_pub/itu-t/oth/06/5B/T065B00000A0005PDFE.pdf.

Selding, P. (Oct. 27, 2015) Satellite Operators' 11th Hour Effort to Stop Wireless Industry's Spectrum Grab; Retireved from: https://spacenews.com/satellites-11th-hour-effort-to-stop-wireless-industrys-spectrum-grab/.

Shackelford, S. Richards, E. Raymond, A. Kerr, J. & Kuehn, A. (2017). IGovernance: The Future of Multi-Stakeholder Internet Governance in the Wake of the Apple Encryption Saga, *North Carolina Journal of International Law*, 42, 883-931.

Thomas, D. Waters, R. & and Fontanella-Khan (2012, Aug. 27). The internet: Command and control, *Financial Times*, Retrieved from: https://www.ft.com/content/fab58818-e63a-11e1-ac5f-00144feab49a.

TMobile & Sprint (2019). Creating a 5G Future for All; retrieved from: https://newtmobile.com/.

United States Government (2012). Middle Class Tax Relief and Job Creation Act of 2012, Pub. L. No. 112-96, §§ 6402 (codified at 47 U.S.C. § 309(j)(8)(G)), 6403 (codified at 47 U.S.C. § 1452), 126 Stat. 156 (2012).

Verizon (n.d.). Verizon 5G Home FAQs. Retrieved from: https://www.verizonwireless.com/support/5g-home-faqs/#benefits.

Waterman, S. (2019). Spectrum Issues Will Dominate WRC-19. *ViaSatellite*. Retrieved from: http://interactive.satellitetoday.com/via/satellite-2019-show-daily-day-4/spectrum-issues-will-dominate-wrc-19/.

Wheeler, T. (June 20, 2016). Prepared Remarks of FCC Chairman Tom Wheeler "The Future of Wireless: A Vision for U.S. Leadership in a 5G World," National Press Club Washington, D.C. Retrieved from: https://transition.fcc.gov/Daily_Releases/Daily_Business/2016/db0620/DOC-339920A1.pdf.

Whitt, R. (2013). A Deference to Protocol: Fashioning a Three-Dimensional Public Policy Framework for the Internet Age, *Cardozo Arts and Entertainment Law Journal*, 31, 689-768.

World Broadcasting Unions (2018). WBU-TC Position on the UHF band for WRC-19 and WRC-23. Retrieved from: https://worldbroadcastingunions.org/wp-content/uploads/2018/07/Public-WBU-TC-UHF-Band-Position-2018-07-31-final.pdf.

World Radiocommunication Conference (2019). Retrieved from: https://www.itu.int/en/ITU-R/conferences/wrc/2019/Pages/default.aspx.