THE ITU IMT-2020 STANDARDIZATION: LESSONS FROM 5G AND FUTURE PERSPECTIVES FOR 6G

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ABSTRACT

The evaluation of candidate International Mobile Telecommunications-2020 (IMT-2020) radio interfaces ended in February 2021, with three technologies being approved while another two were granted additional time to demonstrate their suitability. This marks a useful milestone at which the International Mobile Telecommunications (IMT) standardization process can be evaluated, and its implications for 6G explored. We argue that the relationship between IMT standardization and identification is increasingly problematic, with identification requiring the refarming of spectrum already allocated to other services. Furthermore, as standardization is largely done outside of the International Telecommunication Union (ITU), being part of IMT is largely a way to obtain more spectrum. While these developments question the value of the existing approach, we argue that changes are necessary to the IMT standardization processes given the value to be gained from a single global mobile standard.

Keywords: IMT-2020, 5G, 6G, ITU, spectrum

If we want to build the global village which is the ambition of the ITU, we need to try to converge on a single standard harmonized worldwide

—Francois Rancy, ITU-R Director, 2018

The Radio Sector of the International Telecommunication Union (ITU) has been involved in two aspects of personal mobile cellular communication under the label International Mobile Telecommunications (IMT): defining the radio interfaces for IMT and the identification of spectrum

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for IMT systems within mobile services. This was mainly in response to the lack of interoperability between 2G standards and the need to achieve global roaming. The evaluation of candidate International Mobile Telecommunications-2020 (IMT-2020) radio interfaces recently ended in February 2021 with the approval of two 3rd Generation Partnership Project (3GPP) 5G technologies (radio interface technology [RIT] and set of radio interface technology [SRIT]) and Telecommunications Standards Development Society (TSDSI) (5Gi). The TSDSI technology was supported by the Indian government but was objected to by operators, who argued that deviating from 3GPP will increase the cost of equipment and services. Two non-3GPP technologies—Digital Enhanced Cordless Telecommunications (DECT) SRIT and Nufront—were rejected by the ITU while being granted an exceptional extension to provide additional material. The first is supported by ETSI, and the latter has been commercially deployed in China. Eventually, it was possible to reach an agreement over the DECT submission while Nufront's supporters decided to make a new submission in the future.

The 5G (IMT-2020) evaluation process has raised a lot of questions regarding the validity of the ITU's involvement in cellular mobile standardization, and whether such a process should continue for 6G. More specifically, it seems that since the emergence of 4G, 3GPP has been the sole cellular mobile standard, with alternatives such as Nufront and DECT struggling. Their struggles are somewhat surprising given how Nufront has been adopted in China, and DECT was developed by leading standardization organizations such as ETSI.

With this in mind, this article examines the relevance of the IMT standardization process for 6G in the light of having a dominant standard for 5G New Radio (NR) worldwide, and the influence of additional IMT identification on the development of other services. To achieve this, the article adopts a qualitative approach focusing on the IMT-2020 standardization process and related spectrum identification that is occurring in preparation for World Radiocommunications Conference of 2023 (WRC-23). Primary data was collected through the participant observation of the lead author who engaged in relevant IMT-2020 activities.

The rest of the article is organized as follows. The section "IMT Standardization" addresses the IMT Standardization process in detail, through its beginning with IMT-2000 during the 3G era and then with IMT-Advanced during the 4G era. The section examines then the evaluation process of IMT-2020 and the submission of different 5G technologies. Following this, the section then points out the different activities related to the development of 6G within the ITU and at the national level. The section "IMT Spectrum Identification" highlights the IMT spectrum identification through the last WRCs in the low, mid, and high bands. The "Discussion" section is a discussion with a focus on 5G frequencies issues, the development of 5G in India, and whether the standardization process and generations of mobile technologies are still relative. Conclusions are drawn in the final section of the article.

IMT Standardization

Broadly speaking, IMT is the generic term used by the ITU community to designate broadband mobile systems, which encompasses IMT-2000, IMT-Advanced, and IMT-2020.[1] The IMT standardization process accommodates four phases: setting out the ITU-R vision on the technology, defining minimum requirements and evaluation criteria, initiating the different proposals and evaluation groups, and finally approving the specifications.[2]

It was the emergence of several technological standards for 1G and 2G that motivated the ITU to intervene in the standardization process of cellular mobile telecommunication, with the lack of interoperability between 2G mobile standards being especially problematic (Savage 1989; ITU-R 2007c). The first step in the ITU standardization activities on mobile technologies occurred in the 1980s when Future Public Land Mobile Telecommunication System (FPLMTS) was discussed in the ITU-R.[3] FPLMTS was renamed IMT-2000 by the Radiocommunication Assembly (RA) prior to WARC-97.[4] The minimum requirements for IMT-2000 radio interfaces were defined as providing a data rate of up to 2 Mbit/s.[5]

In the next four subsections, we examine in detail the activities of the ITU-R regarding the standardizations of IMT-2000, IMT-Advanced,

1. ITU, "ITU-R FAQ on IMT."
2. ITU News.
3. ITU, "The ITU Takes Mobile into the Third Millennium."
4. U.S. Congress Office of Technology Assessment.
5. Engelman

IMT-2020, and IMT-2030. These were and have been developed during 3G, 4G, 5G, and 6G respectively.

IMT-2000

The ITU-R established a procedure for submitting and evaluating the IMT-2000 radio interfaces proposed by national and regional standardization bodies.[6] The ITU-R invited in 1997 applicants for IMT-2000 radio transmission technologies to apply, with 10 terrestrial proposals being submitted in the following year.[7] Among these proposals, five radio interfaces were approved to be part of the IMT-2000 standards: Wideband Code Division Multiple Access (WCDMA) (also known as UMTS), CDMA 2000, Time Division-Synchronous Code Division Multiple Access (TD-SCDMA), Enhanced Data rates for GSM Evolution (EDGE), and DECT.[8]

In 2006, the IEEE submitted a proposal to include the Worldwide Interoperability for Microwave Access (WiMAX) standard Internet Protocol-Orthogonal Frequency-Division Multiple-Access (IP-OFDMA) into the IMT-2000 family of standards.[9] This was opposed by China, Germany, and several industry bodies.[10] The Chinese Evaluation Group indicated, in May 2007, that they were missing information and, therefore, it would be difficult to conclude whether or not the WiMAX technology would meet the requirements for IMT-2000.[11] In addition, several industry bodies, mostly representing competing technologies, felt that the compliance of WiMAX with the minimum performance capabilities of IMT-2000 needed further work.

Therefore, a special meeting was held in August 2007 to address the concerns related to the inclusion of WiMAX.[12] This meeting was able to achieve notable progress and resulted in forwarding the agreed documents to the Chairman of Study Group 8 for his consideration.[13] During the meeting, China raised several difficulties with the WiMAX proposal and

6. ITU, "WRC-97 News."
7. Leite, Engelman, Kodama, Mennenga, and Towaij.
8. ITU-R, "ITU-R Report SM.2093-1."
9. ITU-R, "ITU-R Recommendation M.1457-8."
10. WP 5D Chairman, "Chapter 01—Working Party 5D Chairman's Report, Kyoto Meeting."
11. Chinese Evaluation Group (CHEG).
12. WP 5D Chairman, "Chapter 01—Working Party 5D Chairman's Report, Soul Meeting."
13. WP 8F Chairman.

indicated it need further improvement to meet the requirements and currently it is not appropriate for inclusion in IMT-2000. Germany also was concerned over the values of the adjacent channel leakage ratio (ACLR) values related to the WiMAX.

It is interesting that several ITU-R Sector Members, including mobile operators (e.g., France Telecom, China Mobile) and manufacturers (e.g., Ericsson, Qualcomm), highlighted several outstanding technical concerns including the ability to provide seamless handover. The meeting concluded with Germany and China still having some reservations but with the majority of those attending supporting the inclusion. ITU-R RA-07 agreed in October 2007 to officially include WiMAX in the IMT-2000 family.[14]

IMT-Advanced

As with 4G, the ITU-R invited proposals for candidate RITs for the terrestrial components of the successive systems to IMT-2000, which were named "IMT-Advanced."[15] The key feature of IMT-Advanced was set to be the provision of enhanced peak data rates of up to 100 Mbit/s for high mobility and 1 Gbit/s for low mobility.[16] Figure 1 illustrates the capabilities of IMT-Advanced compared to IMT-2000.[17]

Six different proposals were submitted containing two main technologies: IEEE (IEEE 802.16m) and 3GPP (LTE Release 10).[18] There were also identical proposals—Japan submitted two proposals identical to the IEEE and 3GPP IMT-Advanced submissions; China submitted an identical submission to the 3GPP IMT-Advanced submission; and the Telecommunications Technology Association (TTA) of Korea submitted a submission identical to that of the IEEE.[19] Hence, the six IMT-Advanced submissions were ultimately identical to the two submissions from IEEE and 3GPP, and a single evaluation was needed for each one of them. Later, these six proposals were consolidated into two IMT-Advanced technologies: LTE-Advanced and WirelessMAN-Advanced.[20] These two technology

14. ITU-R, "ITU-R Recommendation M.687-2."
15. WiMAXForum.
16. Sims.
17. ITU-R, "ITU-R Recommendation M.1645."
18. ITU, "Development of IMT-Advanced: The SMaRT Approach."
19. ITU-R, "ITU-R Report M.2198."
20. ITU-R, "ITU-R Recommendation M.1822."

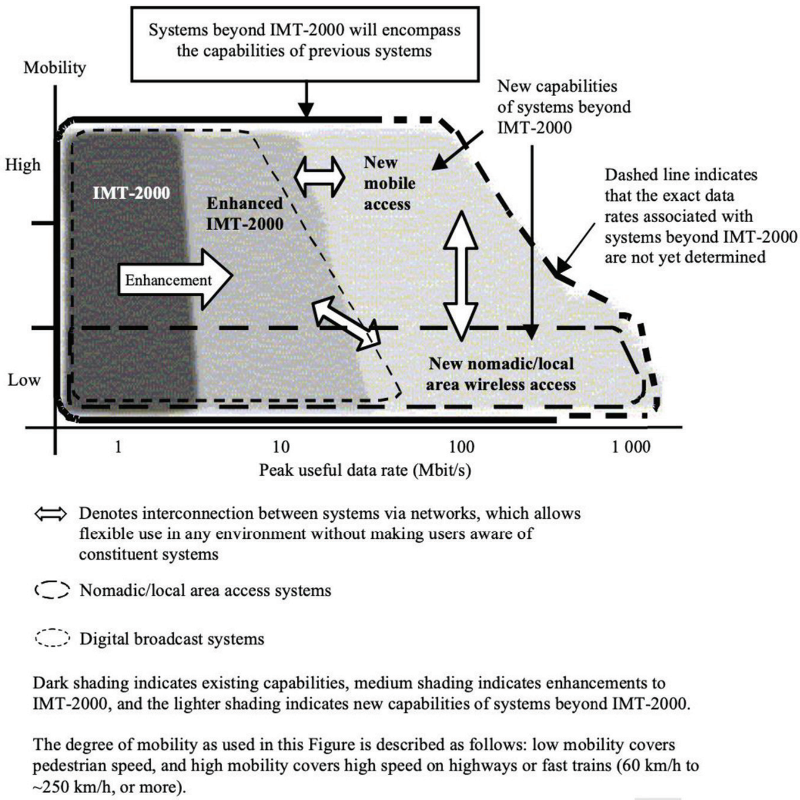


FIGURE 1 Illustration of capabilities of IMT-2000 and systems beyond IMT-2000.[21]

standards were submitted to RA-12 and were agreed by ITU-R Member States.[22]

Submitting identical proposals can be interpreted as an indirect support from countries (e.g., China, South Korea, Japan) for specific submissions. More specifically, Japan and South Korea were neutral toward both technologies (LTE-Advanced, WirelessMan-Advanced) and perceive them to meet the IMT-Advanced requirements. On the other hand, China's identical submission to 3GPP technology could be perceived as supporting the technology to be deployed in the country at the expense of IEEE technology.

21. Ibid.

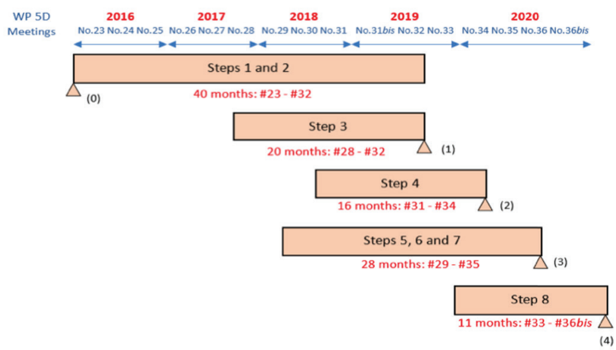
22. WP 5D Chairman 2009, "Chapter 01—Working Party 5D Chairman's Report, Geneva Meeting."

IMT-2020

Regarding 5G standards, the ITU-R has defined three usage scenarios for IMT-2020: enhanced mobile broadband, massive machine type communications, and ultra-reliable and low latency communications.[23] The key defining characteristics of IMT-2020 are to have a peak data rate of 20 Gbit/s compared to 1 Gbit/s and user experienced data rate of 100 Mbit/s compared to 10 Mbit/s in IMT-Advanced.[24]

The detailed schedule for the IMT-2020 evaluation and submission processes is shown in Figure 2. The process started in March 2016 when the ITU-R issued an invitation for the submission of proposals for candidate RITs or a set of RITs (SRITs) for the terrestrial components of IMT-2020.[25]

By the end of 2019, seven candidate IMT-2020 proposals had been submitted and evaluation reports from the independent evaluation groups had



Steps in radio interface development process:

- Step 1: Issuance of the Circular Letter
- Step 2: Development of candidate RITs and SRITs
- Step 3: Submission/Reception of the RIT and SRIT proposals and acknowledgement of receipt
- Step 4: Evaluation of candidate RITs and SRITs by Independent Evaluation Groups
- Step 5: Review and coordination of outside evaluation activities
- Step 6: Review to assess compliance with minimum requirements
- Step 7: Consideration of evaluation results, consensus building and decision
- Step 8: Development of radio interface Recommendation(s)

Critical milestones in radio interface development process:

- (0): Issue an invitation to propose RITs — March 2016
- (1): ITU proposed cut off for submission of candidate RIT and SRIT proposals — July 2019
- (2): Cut off for evaluation report to ITU — February 2020
- (3): WP 5D decides framework and key characteristics of IMT-2020 RIT and SRIT — June 2020
- (4): WP 5D completes development of radio interface specification Recommendations — November 2020

FIGURE 2 Evaluation procedures of IMT-2020.[26]

23. ITU-R, "ITU-R Recommendation M.2083."
24. ITU, "ITU Agrees on key 5G Performance Requirements for IMT-2020."
25. ITU-R, "Report ITU-R M.2483-0."
26. Ibid.

been received.[27] Two of these were the 3GPP submissions for IMT-2020, which were independent of one another. NR was submitted as a RIT proposal for IMT-2020, while NR and E-UTRA/LTE were jointly submitted as two component RITs of a set of radio interfaces. 5G NR is the 3GPP name for the 5G radio interface.[28] China and Korea submitted another two proposals, which were identical to 3GPP RIT submissions, with the remaining three proposals being DECT SRIT, Nufront RIT, and TSDSI RIT.

Report ITU-R M 2412 provides details of the evaluation of candidate technologies for IMT-2020. Those proposing a technology should provide a complete self-evaluation and external evaluation groups may perform complete or partial evaluation of one or more of the proposals to assess the compliance of the technologies with the minimum requirements of IMT-2020.[29] Thirteen independent groups evaluated these proposals.[30]

The evaluation reports confirmed that 3GPP SRIT and RIT fulfill the minimum requirements for the five test environments comprising the three usage scenarios. It was also confirmed that China's submission is technically identical to the 3GPP RIT proposal and that NB-IoT is part of the 3GPP SRIT candidate technology proposal.[31] Korea's submission is also technically identical to the 3GPP RIT proposal. Similarly, the reports from the evaluation groups have also confirmed that the candidate technology submission from the TSDSI fulfilled the minimum requirements for the five test environments comprising the three usage scenarios.[32]

Regarding the SRIT submission from ETSI (TC DECT) and DECT Forum, one component of the submission was confirmed to be identical to the 3GPP RIT candidate. Meanwhile, the evaluation results for the other component of the submission (i.e., DECT 2020 NR RIT), which applies only to Urban Macro-Ultra-Reliable Low Latency Communications (URLLC) and Urban Macro-massive Machine Type Communication (mMTC) test environments, were inconclusive. More specifically, several reports indicated that they did not meet the minimum requirements of the Urban Macro-URLLC test environments. Accordingly, it was agreed that the SRIT submission from ETSI (TC DECT) and DECT Forum

27. ITU-R, "Addendum 5 to Circular Letter 5/LCCE/59."
28. 5GAmericas.
29. ITU-R, "ITU-R Report M.2412-0".
30. ITU-R, "Addendum 6 to Circular Letter 5/LCCE/59."
31. Ibid."
32. Ibid."

will require additional evaluation to determine their final assessments. Similarly, the candidate RIT submission from Nufront received several inconclusive evaluations reports and was deemed to require additional evaluation.[33] It should be noted that for DECT and Nufront, there were reports that perceived the technologies to meet the minimum requirements of the required test environments.

The evaluation of candidate IMT-2020 radio interfaces formally ended in February 2021 with the approval of two 3GPP technologies (5G-SRIT and 5G-RIT) and TSDSI technology (5Gi), with the latter being largely based on 3GPP-NR and an additional component (LMLC) to provide low-cost 5G in rural areas.[34] These results are included in the ITU-R recommendation M.2150 that states the detailed specification of the IMT-2020 radio interfaces which are 3GPP 5G-SRIT, 3GPP 5G-RIT, and 5Gi.[35]

Two submissions were formally evaluated as being inconclusive: DECT SRIT and Nufront RIT. However, it was decided that these two submissions required additional evaluations to conclude their respective final assessment and will be exceptionally granted an extension to provide additional material.[36] As of June 2021, there were still outstanding issues for both of DECT and Nufront including their connection density, reliability, peak data rate, and user experienced data rate.[37]

In August 2021, the Sub-Working Group Technology Aspects conducted a virtual meeting to address the final evaluation reports results. As there were outstanding issues for DECT and Nufront submissions, it was decided to continue the discussion to be finalized at the next WP 5D meeting in October 2021.[38] However, while there has been one outstanding issue for DECT submission (connection density), this was not the case for Nufront submission (e.g., user experience data rate, peak data rate for DL, reliability).[39] The evaluation process was concluded in October 2021 where there has been consensus that the DECT proposal met the five test environments comprising the three usage scenarios. However, for the Nufront submission, no conclusion was reached, and the technology proponent

33. Ibid.
34. ITU-R, "ITU-R Recommendation M.2150."
35. Ibid.
36. ITU-R, "Addendum 7 to Circular Letter 5/LCCE/59."
37. WP 5D Chairman, "Chairman's Report 38th e-Meeting of Working Party 5D."
38. WP 5D Technology Aspects Chairman
39. Ibid.

agreed to withdraw the submission and consider the opportunity of making a new candidate technology submission with no prejudice.[40]

IMT-2030

The race for 6G has already started with Finland's 6G Flagship and Japan's Beyond 5G Promotion cooperating, and with the United States and United Kingdom agreeing to a technology partnership agreement at a G7 summit to examine emerging technologies including 6G.[41] In the United States, the Alliance for Telecommunications Industry Solutions (ATIS) launched the Next G Alliance, an industry initiative for 6G, while India has established a 6G initiative with a focus on 6G use cases and requirements.[42]

6G systems are expected to provide speeds of up to a 1 Tbit/s. This would enable applications such as real-time automation, which is one of the enabling technologies for 6G that projects within Europe are currently investigating.[43] 6G systems are expected to operate mostly in the THz band to provide much higher speeds up to 1 Tbit/s utilizing bandwidth up to 20 GHz.[44]

The ITU has started work on its "beyond IMT-2020 strategy" with a focus group on "technologies for network 2030" in the ITU-T dealing with non-radio standardization aspects, and documents on vision and technology trends are under development within ITU-R.[45] More specifically, the work within the ITU-R has started for future technology trends for "IMT toward 2030 and beyond" to anticipate new use cases for IMT[46]—for simplicity we will use the term "IMT-2030" though this is not a formal term used within the ITU.

There are currently two main documents: ITU-R Report M (IMT Future Technology Trends for the evolution of IMT toward 2030 and beyond) and ITU-R Recommendation M (IMT Vision 2030 and beyond) that address IMT-2030. The draft recommendation accommodates the key objectives of the vision and includes the need for lower latency and

40. WP Chairman, "Chairman's Report 38th e-Meeting of Working Party 5D."
41. Handford.
42. COEDIS.
43. EC, "Europe Moves Towards 6G."
44. Marti, "Stakeholders Seek to Influence 6G Standardisation Process."
45. Marti, "ITU to Publish Post-5G Vision by 2023."
46. ITU-R, "Addendum 8 to Circular Letter 5/LCCE/59."

extremely high user data rates. It is expected that the ITU shall be involved in standards development and their enhancement and spectrum matters of IMT-2030.[47] It is also expected that future technology trends toward 2030 and beyond will deliver peak data rate >1 Tbps or at least 50 times faster than that of IMT-2020 systems, and that spectrum from 100 GHz to 1 THz is a candidate for IMT 2030 systems due to the existence of many tens of GHz of bandwidth that are currently unutilized.[48]

In this section, we have outlined the developments of IMT systems within ITU-R, starting from the FPLMTS concept in the 1980s, before moving onto IMT-2000 in the 1990s, IMT-Advanced in the 2000s, IMT-2020 in the 2010s, and finally the vision of IMT-2030 today. These developments were accompanied with activities related to the spectrum bands where these systems are expected to operate; this will be clarified in the next section.

IMT Spectrum Identification

The previous section focused on the IMT standardization process. Such processes have been associated with identifying the radio spectrum bands to be used by the various standards. To understand the meaning of spectrum identification, it is important to first know that the ITU Radio Regulations (RR) establish the allocation of several frequency bands for mobile services. Within some of these allocated bands, several World Radiocommunication Conferences (WRCs) have identified specific frequency bands for the deployment of IMT systems. This identification does not preclude the use of this band by any application of the services to which it is allocated and does not establish priority in the RR.[49]

The first IMT identification was when WARC-92 identified the 1,885–2,025 MHz and 2,110–2,200 MHz bands for countries wishing to implement FPLMTS in RR footnote No. 5.388.[50] Furthermore, WARC-92 upgraded the service status in the 1,700–2,690 MHz band to primary for

47. WP 5D Chairman, "Chairman's Report 38th e-Meeting of Working Party 5D."

48. Ibid.

49. ITU, "ITU-R FAQ on IMT."

50. ITU-R, "Invitation for Submission of Proposals for Candidate Radio Interface Technologies for The Terrestrial Component of The Radio Interface(s) for IMT-2020 and Invitation to Participate in Their Subsequent Evaluation."

the mobile service within which FPLMTS can operate.[51] The first forecast of additional spectrum for IMT emerged in ITU-R report M.2023 which perceived a need for 160 MHz of additional spectrum for terrestrial IMT-2000, beyond the terrestrial IMT-2000 spectrum already identified in the RR footnote No. 5.388.[52]

Subsequent WRCs have identified more frequencies for IMT in several bands.[53] For instance, WRC-07 and WRC-12 identified the 800 and 700 MHz bands respectively for IMT which had historically been utilized for broadcasting service. WRC-15 identified the 470–694 MHz band for IMT in a few countries in Region 2 including the United States and Canada and a handful of island countries in Region 3.[54] WRC-15 also identified the L-band (1,427–1,518 MHz) for IMT.[55]

With respect to 5G frequencies, WRC-19 addressed the potential IMT identification in the millimeter bands under Agenda Item 1.13, which considered the identification of frequency bands for the future development of IMT in accordance with Resolution 238 of WRC-15.[56] Such a resolution is related to the frequency for IMT identification including the possible additional allocations to mobile services on a primary basis in parts of the frequency range between 24.25 and 86 GHz. The focus of the studies has been on the frequency bands (e.g., 24.25–27.5, 47.2–50.2, and 81–86 GHz), which have allocations to mobile services on a primary basis, as well as those bands (e.g., 40.5–42.5 and 47–47.2 GHz) which may require additional allocations of mobile services on a primary basis. Eventually, WRC-19 identified three bands—24.25–27.5, 37–43.5, 66–71 GHz—on a global basis for IMT, and other bands—45.5–47 and 47.2–48.2 GHz—in some countries via footnotes.

Table 1 highlights the different frequency bands identified for IMT, associated footnotes within the RR for the ITU-R three regions, and the available bandwidth in each spectrum band.[57]

51. ITU, "WARC-92 Concludes After Strenuous Negotiations."

52. ITU-R, "ITU-R Report M.2023-0 (2000)."

53. ITU-R, "RR 2001 Article 5: Frequency Allocations"; ITU-R, "RR 2008 Article 5: Frequency Allocations"; ITU-R, "RR 2012 Article 5: Frequency Allocations"; ITU-R, "RR 2016 Article 5: Frequency Allocations"; U.S. Congress Office of Technology Assessment.

54. ITU-R, "WRC-15 Final Acts Article 5: Frequency Allocations."

55. Ibid; ITU-R, "Resolution COM4/6 (WRC-15)."

56. ITU-R, "WRC-15 Resolution 238."

57. ITU, "ITU-R FAQ on IMT."

TABLE 1 Identified Spectrum Bands for IMT[58]

Frequency bands identified for IMT (MHz)	Footnotes identifying the band for IMT in the radio regulations			**Available bandwidth (MHz)**
	Region 1	Region 2	Region 3	
450-470	5.286AA			20
470–698	–	5.295, 5.308A	5.296A	228
694/698–960	5.317A	5.317A	5.313A, 5.317A	262
1,427–1,518	5.341A, 5.346	5.341B	5.341C, 5.346A	91
1,710–2,025	5.384A, 5.388			315
2,110–2,200	5.388			90
2,300–2,400	5.384A			100
2,500–2,690	5.384A			190
3,300–3,400	5.429B	5.429D	5.429F	100
3,400–3,600	5.430A	5.431B	5.432A, 5.432B, 5.433A	200
3,600–3,700	–	5.434	–	100
4,800–4,990	–	5.441A	5.441B	190
24,250–27,500*	5.532AB			3,250
37,000–43,500*	5.550B			6,500
45,500–47,000*	5.553A			1,500
47,200–48,200*	5.553B			1,000
66,000–71,000*	5.559AA			5,000

In addition, WRC-23 will study the identification of IMT for the following bands[59]:

- 3,600–3,800 MHz and 3300-3400 MHz (Region 2)
- 3,300–3,400 MHz (Region 1)
- 7,025–7,125 MHz (globally)
- 6,425–7,025 MHz (Region 1)
- 10.0–10.5 GHz (Region 2)

58. Ibid.
59. ITU-R, “WRC-2019 Resolution 811.”

In summary, successive WRCs (WARC-1992, WRC-2000, WRC-2007, WRC-2012, WRC-2015, WRC-2019) have identified tens of GHz of bandwidth for IMT with more to be identified in WRC-23 subsequent to the completion of various studies and the agreement of the conference. While the last two sections have provided an overview on the IMT standardization and spectrum identifications processes, the next section will focus on the different problematic issues related to these two processes including the relationship between them.

Discussion

One of the main issues we want to shed light on is indirect link between IMT standardization and identification. At a first glance, one of the compliance requirements for the technical performance of the IMT evaluation is related to spectrum capability requirements and whether the candidate technology can utilize at least one frequency band identified for IMT in the ITU RR.[60] In addition, for IMT-2020, there have been expectations that the technology will be deployed in higher frequency bands. One of the compliance requirements for technical performance is whether the candidate technology is able to utilize the higher frequency range/band(s) above 24.25 GHz.[61]

A closer look at the footnotes identifying spectrum for IMT (e.g., RR footnote No. 5.388, 5.384A) reveals a paradox within those footnotes where they explicitly state that such use for IMT does not preclude the use of these bands by other services to which they are allocated and that the IMT identification does not establish priority in the RR.[62] Meanwhile, there are strong signals in different ITU-R documents that those bands identified for IMT should be used for IMT. For instance, Resolution 212 clearly states that those countries that implement IMT-2000 should use those frequencies identified for IMT-2000 at that time. In addition, Report M.2023 highlights that the 1,885–2,025 and 2,110–2,200 MHz bands, which are identified for IMT, should be made available for IMT-2000.[63] It is also argued that in cases where those footnotes identifying IMT

60. ITU-R, "Report ITU-R M.2483-0."

61. Ibid.

62. ITU-R, "RR 2020 Article 5: Frequency Allocations."

63. ITU-R, "WARC-1992 Resolution 212."

explicitly mention just a few countries, this indicates clearly that the bands will be used for IMT and that this sends strong signals to the market that those countries are interested in deploying IMT in the band. For instance, Footnote 5.441A states that "*In Brazil, Paraguay and Uruguay, the frequency band 4800-4900 MHz, or portions thereof, is identified for the implementation of International Mobile Telecommunications (IMT).*"

In other cases, the IMT identification is shaped by the protection offered to the incumbent in the band. For instance, Footnote 5.429B states that "*The use of the frequency band 3300-3400 MHz by IMT stations in the mobile service shall not cause harmful interference to, or claim protection from, systems in the radiolocation service, and administrations wishing to implement IMT shall obtain the agreement of neighbouring countries to protect operations within the radiolocation service.*" However, a closer look at the footnote suggests that the band could be used either of mobile or radiolocation services, and, if one country decides to use the band for IMT, then this must not cause interference to neighboring countries where a radiolocation service operates.

The situation is more complex in bands such as UHF that have excellent propagation characteristics and can achieve long distances and for incumbent services such as broadcasting that operates with a high transmitted power. In particular, as shown in the table of service allocations in the band 470–890 MHz in Table 2, broadcasting has historically been the incumbent service in the band.

TABLE 2 Table of International Service Allocation in the UHF Band[64]

460–890 MHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
460–470	FIXED MOBILE 5.286AA Meteorological-satellite (space-to-Earth) 5.287 5.288 5.289 5.290	
470–694 BROADCASTING	**470–512** BROADCASTING Fixed Mobile	**470–585** FIXED MOBILE 5.296A BROADCASTING

(*Continued*)

64. ITU-R, "RR 2020 Article 5: Frequency Allocations."

TABLE 2 Table of International Service Allocation in the UHF Band (*Continued*)

460–890 MHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
	5.292 5.293 5.295	5.291 5.298
	512–608 BROADCASTING 5.295 5.297	**585–610** FIXED MOBILE 5.296A BROADCASTING RADIONAVIGATION 5.149 5.305 5.306 5.307
	608–614 RADIO ASTRONOMY Mobile-satellite except aeronautical mobile-satellite (Earth-to-space)	**610–890** FIXED MOBILE 5.296A 5.313A 5.317A BROADCASTING
5.149 5.291A 5.294 5.296 5.300 5.304 5.306 5.312	**614–698** BROADCASTING Fixed Mobile 5.293 5.308 5.308A 5.309	
694–790 MOBILE except aeronautical mobile 5.312A 5.317A BROADCASTING 5.300 5.312	**698–806** MOBILE 5.317A BROADCASTING Fixed 5.293 5.309	
790–862 FIXED MOBILE except aeronautical mobile 5.316B 5.317A BROADCASTING 5.312 5.319	**806–890** FIXED MOBILE 5.317A BROADCASTING	
862–890 FIXED MOBILE except aeronautical mobile 5.317A BROADCASTING 5.322		
5.319 5.323	5.317 5.318	5.149 5.305 5.306 5.307 5.320

This explains why there are several footnotes identifying parts of the UHF band for IMT that provide protection to broadcasting services. For instance, Footnote 5.308A states that "*in the Bahamas, Barbados, Belize,* *Canada, Colombia, the United States, Guatemala and Mexico, the frequency band 614-698 MHz, or portions thereof, is identified for International Mobile Telecommunications (IMT) . . . Mobile service stations of the IMT system within the frequency band are subject to agreement obtained under No. 9.21 and shall not cause harmful interference to, or claim protection from, the broadcasting service of neighbouring countries.*"[65]

However, the issue is that coexistence of broadcasting and mobile services in the same band is quite problematic and ideally, within the same country, a guard band of 8 MHz is recommended.[66] In fact, there are real cases of interference between neighboring countries operating mobile and broadcasting in the same band where the former suffers from interference from the latter.[67]

That is why, in most cases, having spectrum in the UHF identified for IMT indicates that the broadcasting service should be refarmed from the band and move to another one. In fact, tracing the history of IMT identification in the UHF band, as shown in Figure 3, reveals how the mobile service and IMT identification have expanded into the UHF band.

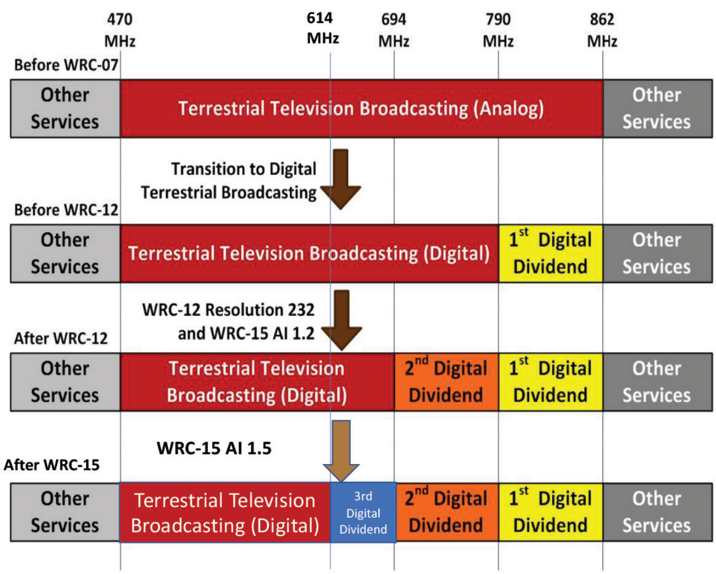


FIGURE 3 IMT identifications in the UHF band.[68]

65. Ibid.
66. Abdelghany and Digham.
67. RSPG, "24th Progress Report of the RSPG Sub-group on Cross-Border Coordination."
68. Compiled by the authors.

Historically, most of the UHF band (470–862 MHz) was planned for analog terrestrial broadcasting services in Region 1. In 2006, the Regional Radiocommunication Conference 2006 (RRC-06) planned the digital terrestrial broadcasting service in Region 1 and in the Islamic Republic of Iran to be in the 174–230 and 470–862 MHz frequency bands.[69] Shortly afterward, the WRC-07 approved an additional allocation in the 790–862 MHz frequency band to mobile service effectively from June 17, 2015 (ITU-R 2007a). WRC-12 added an additional mobile allocation and IMT identification in the 698–790 MHz band in Region 1.[70] WRC-15 identified the 470–698 MHz band for IMT while protecting the broadcasting service in several countries (including the United States) in addition to these other countries that managed to obtain IMT identification only in the 614–698 MHz band.[71] Meanwhile, many countries including India failed to have IMT identification in the 470–694 MHz band due to objections from their neighbors.[72] It was agreed to have a new A.I. for WRC-23 to review the spectrum use and spectrum needs of existing services in the 470–960 MHz frequency band in Region 1.[73]

It appears, therefore, that IMT identification usually indicates the refarming of the other services in the band unlike the language used in the RR (e.g., intended for use, does not establish priority). The expansion of IMT into the frequencies of other services in recent years (e.g., Satellite in the C-band, Broadcasting in the UHF) should be reconsidered as it may have a negative influence on these services and their associated technologies development. If not, IMT will be used as a tool to acquire spectrum while the actual standardization is conducted outside the ITU.

Another area that is worth examining is the candidate spectrum bands for 6G or IMT operation, which are assumed to be in the THz bands, and their IMT identification. The THz spectrum bands are useful for delivering data-intensive, high bandwidth applications at super-fast speeds for a short distance and are perceived to be the main bands for 6G technologies. However, there is still a debate whether THz bands will enable mobile connectivity due to interference and attenuation issues.[74] In particular, it is

69. ITU, "RRC-06 Article 1: Definitions."
70. Compiled by the authors.
71. ITU-R, "WRC-15 Final Acts Article 5: Frequency Allocations."
72. ITU-R, "Summary Record of the WRC-15 Twelfth Plenary Meeting."
73. ITU-R, "WRC-15 Resolution COM 6/2."
74. Marek, "Marek's Take."

argued that the THz band could be used to deliver mobility solutions with the support of directional antennas and small cell densification.[75]

Several regulators have taken steps with respect to THz bands with the FCC opening four new unlicensed bands with a total bandwidth of 21.2 GHz above 95 GHz on a noninterference basis to other users. Japan and CEPT countries made a similar decision with different details (e.g., transmitted power, bandwidth).[76] THz spectrum could be used in nano-machine communication and intra-body communication of nano-machines to support ultra-high speed and low latency applications. Standardization activities in the THz have recently started with IEEE 802.15.3d-2017, the first standard for THz fixed point-to-point links operating at carrier frequencies between 252 and 321 GHz.[77]

An important question to ask is whether spectrum identification would be needed for 6G given that the THz spectrum is different in that it allows short-range connectivity with high frequency reuse factor and better sharing with other systems.[78] Moreover, 6G raises the issue of whether licensing would be needed at all, and there may be no need for traditional network operators.[79] In essence, spectrum management in the 6G era would focus on protecting existing services, spectrum sharing, and interference between the different wireless systems.[80] Therefore, it is important to examine the current service allocation in the THz band. ITU-R service allocation ends at the 275 GHz but the table of allocation per se extends to 3,000 GHz with two footnotes in the RR as shown in Table 3.

The first is Footnote 5.564A, which establishes that *"The frequency bands 275–296 GHz, 306–313 GHz, 318–333 GHz and 356–450 GHz are identified for use by administrations for the implementation of land mobile and fixed service applications, where no specific conditions are necessary to protect Earth exploration-satellite service (passive) applications."* It also mentions that *"The frequency bands 296–306 GHz, 313–318 GHz and 333–356 GHz may only be used by fixed and land mobile service applications when specific conditions to ensure the protection of Earth exploration-satellite service (passive) applications are determined in accordance with Resolution 731 (Rev. WRC-19)."*[81]

75. Marti, "The THz debate"
76. Marcus, "Progress in Opening Access to Spectrum above 100 GHz."
77. Tripathi et al., "Millimeter-Wave and Terahertz Spectrum for 6G Wireless."
78. Pärssinen, "White Paper on RF Enabling 6G."
79. Standeford, "6G Raises Novel Spectrum."
80. Matinmikko-Blue et al. "Spectrum Management in the 6G Era."
81. Ibid.

TABLE 3 Table of Service Allocation in the 248–3,000 GHz Band[82]

248–3,000 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
248–250	AMATEUR AMATEUR-SATELLITE Radio astronomy 5.149	
250–252	EARTH XPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive) 5.340 5.563A	
252–265	FIXED MOBILE MOBILE-SATELLITE (Earth-to-space) RADIO ASTRONOMY RADIONAVIGATION RADIONAVIGATION-SATELLITE 5.149 5.554	
265–275	FIXED FIXED-SATELLITE (Earth-to-space) MOBILE RADIO ASTRONOMY 5.149 5.563A	
275–3,000	(Not allocated) 5.564A 5.565	

The second is Footnote 5.565, which also determines that *"The use of the range 275–1000 GHz by the passive services does not preclude use of this range by active services. Administrations wishing to make frequencies in the 275–1000 GHz range available for active service applications are urged to take all practicable steps to protect these passive services from harmful interference until the date when the Table of Frequency Allocations is established in the above-mentioned 275–1000 GHz frequency range."*[83] The footnote also identifies several frequency bands in the 275–1,000 GHz range for use by passive service applications. Another important footnote is 5.340 that prohibits all emissions in 21 spectrum bands including 10 bands above 100 GHz.

82. ITU-R, "RR 2020 Article 5: Frequency Allocations."
83. Ibid.

Marcus (2021) clarifies that many of these THz bands are utilized for passive services, with this being decided at WRC-2000. The prohibition of emission could be perceived as being valid at lower bands but not at bands above 100 GHz where sharing could be possible. However, it is unlikely that the passive community would allow another allocation for active services (e.g., mobile) in these bands even if the prohibition of emission was established decades ago in lower bands with different propagation characteristics.[84]

Agenda Item 1.15 of WRC-19 addressed the identification of frequency bands for use by countries for the land-mobile and fixed services applications operating in the frequency range 275–450 GHz. WRC-19 identified the 275–296 GHz, 306–313 GHz, 318–333 GHz, and 356–450 GHz bands for the implementation of LMS and FS applications with no specific condition and use the 296–306 GHz, 313–318 GHz, and 333–356 GHz bands by LMS and FS applications subject to specific conditions ensuring the protection of EESS (passive) applications.[85] It is argued that such a decision may support the implementation of future THz communication systems in the 252–450 GHz frequency band due to the existence of four contiguous bands with large bandwidths with one of them (252–296 GHz) being favorable for fixed outdoor links while the other three could be used for short range indoor applications.[86]

In all cases, as long as there are sharing issues with existing services, IMT identification will be likely needed for the THz bands even if 6G systems operating in these bands are fixed in nature. IMT identification has several advantages over having only service allocation including the certainty provided by the sharing studies conducted by the ITU-R and ensuring the protection of the existing service allocations.[87] In addition, 6G will still need to utilize medium bands and mmWave bands in addition to the THz bands.[88] Therefore, it is inevitable that IMT identification would be needed. More specifically, different 6G different applications could make use of the various spectrum bands as shown in Figure 4.

Even for 5G systems, where there were individual approaches from CEPT to utilize IMT systems without IMT identification in the 3.6–3.8

84. Marcus, "Technical and Spectrum Policy Challenges for Use of Spectrum above 100 GHz."
85. OFCA, "World Radiocommunication Conference 2019."
86. Kürner and Hirata, "On the Impact of the Results of WRC 2019 on THz Communications."
87. El-Moghazi and Whalley, "IMT Spectrum Identification."
88. IMT-2030 (6G) Promotion Group, *6G Vision and Candidate Technologies*.

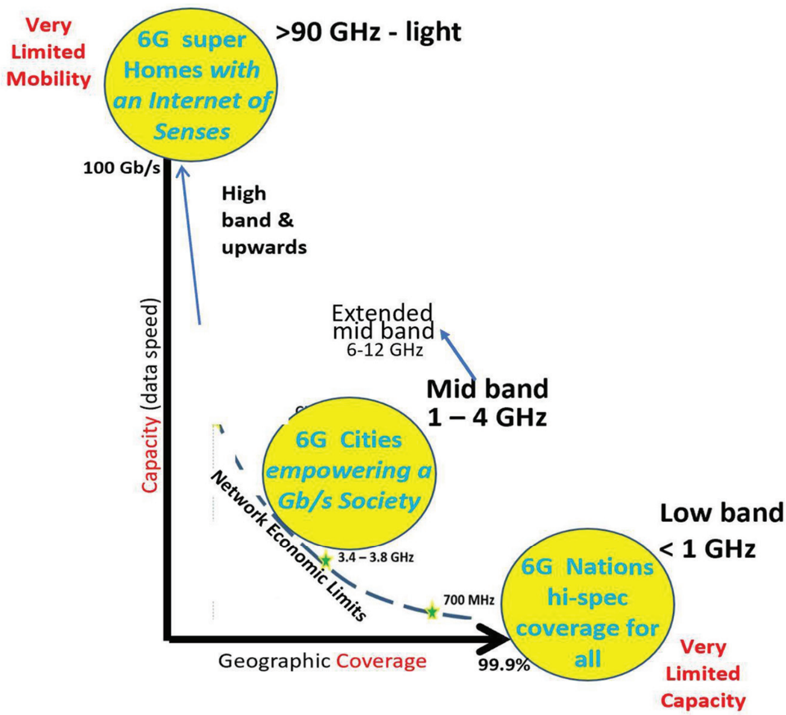


FIGURE 4 6G different applications and spectrum bands.[89]

GHz[90] and in the 24.25–27.50 GHz band before being agreed by WRC-19,[91] such approaches need to align with the RR and service allocations in these bands. As was stated in the relevant EU decision "*The 24,25–25,25 GHz frequency band is not allocated to the mobile service in Region 1 of the ITU, which includes the European Union. That does not prevent the Union from using this frequency band for wireless broadband electronic communications services as long as it complies with inter national and cross-border obligations under the ITU Radio Regulations at its external borders.*"[92] Furthermore, RSPG recommended that any regulatory provisions intended to be included in the RR following the conference to protect other services need to be consistent with the EU technical harmonization decision.[93]

89. SPF, Report of the Outcome of the SPF-DCMS Supported UK Universities 6G Research Initiative.

90. EC, "Commission Implementing Decision (EU) 2019/235."

91. EC, "Commission Implementing Decision (EU) 2019/784."

92. EC, "Commission Implementing Decision (EU) 2019/235."

93. RSPG, "Final RSPG Opinion on the ITU-R World Radiocommunication Conference 2019."

In addition, the harmonization of spectrum bands and having a multilateral approach to IMT identification is still valid even for 5G terminals where there is a difficulty to use a single handset in multiple countries via different carriers. Having said this, there is still a need to resolve sharing issues between terrestrial and space services.[94] It is possible that countries seeking individual IMT identification or applying 5G without identification at all is part of the race for 5G. In other words, working without ITU IMT identification has its downsides but also provides an advantage in terms of quickly obtaining access to spectrum.[95]

One must admit that even an individual decision to utilize a band for IMT without formal identification from the WRC is not always straightforward. For instance, although there is currently recognition in several European countries that the upper 6 GHz (6,425–7,125 MHz) range may meet the additional spectrum demand in the mid-band in addition to the C-band, it is difficult to overlook Fixed Satellite Service (FSS) that have international protection via the RR. Therefore, there is a need to conduct compatibility studies and to agree on operating conditions for potential IMT identification in the band.[96]

The third topic is related to whether the IMT standardization process encourages innovation and competition between the different standards given that the ITU vision at the early stages of IMT standardization was to choose a single global standard for mobile communications mainly to achieve economies of scales. This was mainly motivated by the lack of interoperability between 2G standards.[97] At that time there was an intense debate between CDMA and GSMA proponents regarding which technology is better.

During the 3G era, there were also different technology submissions, and as a result, it was not possible to obtain consensus on this—as a result, the process of choosing technologies for IMT-2000 ending up with five technologies for reasons largely related to intellectual property issues.[98] At that time there was competition among the three dominant standards (TD-SCDMA, CDMA 2000, and WCDMA) when it came to market deployment.[99] WiMAX then joined the IMT-2000 family and

94. Frieden, "The Evolving 5G Case Study in United States."
95. Frieden, "The Evolving 5G Case Study in Spectrum Management and Industrial Policy."
96. RSPG, "Interim Opinion on WRC-23."
97. ITU, "The ITU Takes Mobile into the Third Millennium."
98. Funk, "Competition between Regional Standards and the Success and Failure of Firms in the World-Wide Mobile Communication Market."
99. Blust, "Global Deployments of Technologies Utilizing IMT Specifications and Standards."

its evolution competed with LTE during the 4G era with both becoming IMT-Advanced standards, but, in practice, LTE-Advanced rather than WiMAX Advanced dominates the market.[100]

The situation is different in the 5G era where innovation is not among competing technologies but rather among competing manufacturers (e.g., Huawei, Ericsson, Nokia) that are different in terms of their pricing strategies instead of spectrum utilization efficiency or data rates as was the case among 2G (GSM vs. CDMA) and 3G technologies (e.g., CDMA-2000 vs. WCDMA). In particular, all 5G technologies are 3GPP-based with the same radio access interface, and their commercialization deployments have started before the approval of these technologies as part of IMT-2020 family. In other words, operators were not waiting for the ITU decision on 3GPP technologies.[101]

Even at the ITU level, nearly all submissions are based on 3GPP technologies and submissions with the exception of TSDSI, Nufront and DECT-2020—see Figure 5.[102] Nufront was disqualified by seven of the

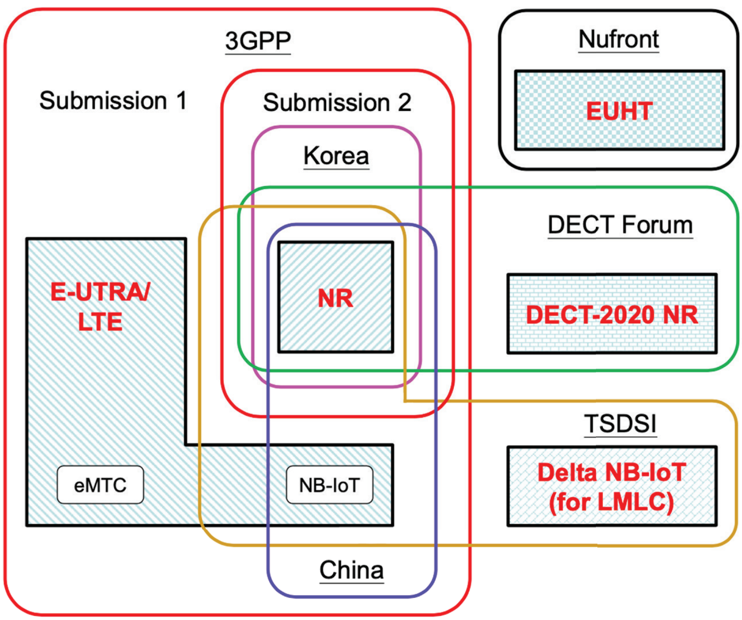


FIGURE 5 Components of IMT-2020 submissions.[103]

100. Ibid.
101. Pongratz.
102. Trans-Pacific Evaluation Group.
103. Ibid.

eight evaluation groups and DECT-2020 was also disqualified even though DECT technology was part of the IMT-2000 family. Meanwhile, TSDSI submission, which is mostly based on 3GPP with minor amendments, was approved with no support from local operators.

This could be related to the collective desire of the main standardization agencies and operators to have a single global 5G technology. In fact, the proponent of the 3GPP 5G submissions to ITU-R is collectively the 3GPP Organizational Partners, namely, ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, and TTC.[104] In other words, 3GPP is an alliance of the largest standardization agencies around the world including TSDSI and ETSI that have attempted to develop 5G standards in parallel to 3GPP. This could be due to the weak competition between LTE and WiMAX during the 4G era. However, it is not clear whether this is related to the IMT standardization process as it was open to all technologies proponent and evaluation was conducted by interdependent groups using pre-set and agreed methodology by all ITU Member States and Sector Members.

While the existence of one global mobile technology such as 3GPP NR could boost the technology deployment around the world which was the case, it may have negative influence on the long term of 6G development. More specifically, 3GPP is the new incumbent when it comes to mobile technology, and there is a little motivation for significant change in the 3GPP NR while operators must adopt later versions of 3GPP. In other words, there was a motivation at the time of 2G and 3G to develop a revolutionary technology. However, it seems that this is not the case for 3GPP NR, which is mainly based on OFDM and thus similar to 3GPP LTE.

With respect to innovation, it is most likely that 6G will be an evolution of 3GPP with no revolutionary concept given that it would be the same stakeholders developing 3GPP 6G. Therefore, there needs to be a way to encourage innovative companies to participate in the discussions related to IMT-2030. If not, 3GPP technologies will monopolize the mobile world with far-reaching implications for other mobile technologies as well as unlicensed devices. As argued by Benkler, companies that can bid for spectrum and internalize the benefits of exclusive control of the spectrum are more involved in the spectrum policy debate and can lobby in more

104. Pongratz, "Harmonized ITU IMT-2020 Standards."

efficient ways compared to unlicensed advocates.[105] The dominance of 3GPP technologies and the idea of new generations within and outside the ITU (e.g., IMT-2030) encourages the re-farming of new spectrum for cellular mobile services as a new generation of mobile technologies usually indicates that the new frequencies are needed. Such dominance also raises concerns regarding the influence of central planning when it comes to IMT within the ITU—there is a steep (and costly) learning curve for newcomers to the ITU process even if they bring innovation(s) with them.

The fourth issue that is worth examination is the influence of the IMT standardization process on the development of new technologies especially given that DECT has been developed by a standardization organization such as ETSI and that Nufront is claimed to have been developed, in practice, in China. More specifically, DECT-2020 NR is a standard developed by ETSI that offers local deployment options without the need of a separate network infrastructure or network planning supporting URLLC and mMTC use cases.[106] The DECT submission was initiated in 2018 by ETSI to fulfill both mMTC and URLLC requirements of the 5G to support local deployments without separate network infrastructure.[107]

Similarly, while 3GPP 5G technologies exceeded all the requirements of IMT-2020, Nufront was disqualified by seven of the eight evaluation groups.[108] This is odd given that, according to the technology proponents, their technology submission is the only industrial-level wireless communication technology that meets the performance requirements of 5G technology (R15/R16) and has been applied in large-scale industrial applications in many fields. Furthermore, it is the only wireless communication technology that supports both high-speed moving, high-capacity transmission and industrial-level high reliability and low latency requirements. Moreover, the technology is claimed to achieve both up to 32 Gbit/s. for download speeds and to be evaluated in accordance with ITU requirements.[109]

In fact, it is worth highlighting the Nufront proponent statement following its disqualification by the WP 5D products and systems of EUHT-5G have been deployed in many scenarios since 2016. In February 2019, International Solid-State Circuits Conference (ISSCC) awarded

105. Benkler, "Open Wireless vs. Licensed Spectrum."
106. Penner et al. "Link Level Performance Evaluation of IMT 2020 Candidate Technology DECT 2020 New Radio."
107. Kovalchukov et al., "DECT-2020 New Radio."
108. Pongratz, "Harmonized ITU IMT-2020 Standards"
109. NUFRONT, "EUHT Technical Advantages."

Nufront "Technology Innovation Award: The World's First Deployed URLLC Wireless Communication System and SoC." In June 2019, China Institute of Communications appraised the scientific and technological achievements of the project "EUHT high reliability, low latency wireless communication system, chip and industrialization" (WP Chairman, 2021b).[110]

To this end, is the extensions granted to the Nufront and DECT submissions related to the technology applicants being unfamiliar with the evaluation process, or is it due to the desire to have only one global 5G standard (3GPP)? This is worth examining WiMAX as it faced objections related to its technology as it sought to be part of the IMT-2000 family. Several industry bodies (mostly from competing technologies) expressed the view that the compliance of WiMAX with the minimum performance capabilities of IMT-2000 needed to be further examined. In particular, the technology evaluation group established by China under ITU regulations found that WiMAX did not meet the requirements to become an IMT-2000 standard.

However, it is necessary to note that WiMAX was perceived as a competitor to 3G technologies at that time (e.g., UMTS),[111] and countries such as China supported the IMT-2000 standard TD-SCDMA, which is TDD-based similar to WiMAX. China was also concerned with the assessment of the compatibility and coexistence of WiMAX and the existing IMT-2000 technologies including the Chinese 3G standard, TD-SCDMA.[112] Therefore, one may argue that the objection of China may be related to competition issues rather than technology specifications. In particular, it is hard to comprehend that a standardization organization such as ETSI is not able to meet the requirements of the ITU-R regarding IMT-2020.

Fifthly, the role of India in the IMT-2020 standardization needs further examination. India proposed the concept of Low Mobility Large Cell (LMLC) as a mandatory component of the Rural enhanced mobile broadband (eMBB) test environment.[113] India also sought to incorporate such changes within the 3GPP standard but this was not agreed.[114] As a result, TSDSI transposed the 3GPP 5G technology specifications with

110. WP Chairman, "Chairman's Report 38th e-Meeting of Working Party 5D."
111. Alden, "WRC-07 Results and Impact on Terrestrial Broadband."
112. China, "Proposed Way Forward."
113. Nishith.
114. Kar.

some amendments to reflect its views regarding the concept of LMLC and submitted as a candidate IMT 2020 technology.[115] TSDSI highlighted, in conjunction with 3GPP, that the amendments made to the 3GPP 5G technology specifications need to be harmonized and added to these specifications to enable interoperability between entities implementing pure 3GPP specification and TSDSI specification.[116]

The reply from 3GPP was not in favor of the TSDSI proposal and clarified that 3GPP is not responsible of modifications made outside the organization in order to ensure a single global 5G ecosystem. They stated "*It is not possible for 3GPP to retroactively ensure compatibility with modifications which were done outside of 3GPP. 3GPP has already made extensions to its RRC specifications that conflict with modifications done by TSDSI . . . 3GPP RAN can only ensure forward- and backward-compatibility for specifications maintained inside 3GPP. 3GPP invites TSDSI to propose their modifications in 3GPP using its normal processes so that these can be discussed and integrated in the specifications based on 3GPP's consensus-based decision-making process. This process ensures a single global 5G ecosystem, inherently avoids fragmentation and avoids incompatibilities.*"[117]

The GSA also expressed concerns that TSDSI's 5G standards would lead to interoperability issues between devices and networks. The reply from TSDSI was that while the ITU process does not address interoperability, there is a commitment to ensure that TSDSI 5Gi interworks seamlessly with the 3GPP 5G technology (Khan 2020). Indian operators also rejected the India standard and called for taking advantage of global 3GPP ecosystem and not disturbing it by reporting submissions directly to the ITU. Meanwhile, TSDSI responded that its standards only make 3 to 5 percent changes or enhancements to the 3GPP specification that can be adjusted by software on base stations and mobile phones.[118] TSDSI also clarified that the Indian and 3GPP standards have a similar cost and can interoperate in networks across the world with better coverage for rural areas for the Indian standard.[119]

It has been perceived that TSDSI would not be able to convince 3GPP to include its specifications into its core standards, which will make it difficult for 5Gi to be interoperable with 3GPP 5G NR.[120] More specifically,

115. TSDSI.
116. Ibid.
117. Chairman of 3GPP RAN 2019.
118. Electronic Paper.
119. Nishith, "5G Technology in India."
120. Ibid.

the issue with the TSDSI 5G standard is that it requires that the signal transmission radius of 5G base station to be extended to 6 km, and the power transmission level of 5G mobile phones to be increased from 23 to 26 dbm, which is inconsistent with 3GPP 5G technology.[121] In order for India to promote the TSDSI 5G standard, at least within developing countries, there is a need for massive deployment within India. However, the 4G penetration rate is only 56 percent,[122] and, therefore, large-scale 5G adoption in India does not seem likely in the near future.

Surprisingly, by the end of 2021, the 3GPP announced a plan of action to allow the merger of 5Gi into 5G, with specific milestones set for both 3GPP and TSDSI in order to have a single radio access proposal for the IMT-2020 family of standards. Moreover, TSDSI has committed to the merger of 5Gi into 3GPP with no further 5Gi updates in ITU-R.[123] Meanwhile, it is expected that 5Gi's coverage-enhancing transmission mode will become part of 5G NR specifications.[124]

The sixth issue to highlight is related to the need of defining generations of cellular technologies. In particular, Webb argues that the release of new cellular mobile generations every 10 years is unusual when compared to other (similar) industries.[125] Moreover, while the previous generations include significant improvements in terms of radio technology (1G was analog, 2G was TDMA, 3G was CDMA and 4G was OFDM), 5G is mostly based on OFDM and, therefore, it should not be considered as a new generation.[126] Instead, Webb suggests a marginal enhancement to 4G where needed and not to be forced to move a new generation each decade.[127]

Focusing on the case of 5G, the practical deployments have not met the expectations due to the need to deploy large numbers of small cells and large bandwidth of spectrum to exceed 4G. Therefore, it is argued that 4G was more revolutionary than 5G as the latter has not delivered the expectations of a new generation.[128] Moreover, the availability of 5G networks does not necessarily mean that users will switch from 4G to 5G. For instance, in developed countries such as Germany, there are users that

121. Electronic Paper, "India lmlc Technology into the Global 5G Standard."
122. Ibid.
123. 3GPP, "Merging 5Gi and 3GPP Specifications."
124. *The Economic Times*.
125. Webb, "Why Do We Still Play the Mobile Generation Game?"
126. Ibid.
127. Ibid.
128. Webb, "How Well Is 5G Shaping Up?"

have not yet subscribed to a 4G plan or have a 4G device although there is widespread 4G coverage.[129] Similarly, when it comes to 6G there is an argument that advanced technologies could be integrated into 5G and that 6G plans should be drafted when there is a clear vision of the technical and business requirements while considering actual operational problems in the 5G era.[130]

To this end, one may wonder why several operators have enthusiastically and extensively embraced 5G and whether this is motivated by companies eager to introduce new services, or by equipment vendors eager to capitalize on the investment that is occurring? Or maybe it is related to the competition among operators as to who will deploy 5G first even if it is by software upgrade to display 5G icon when operating on LTE- Advanced (LTE-A) network.[131]

Similarly, was the uptake of 5G faster compared to 3G or 4G due to the existence of a single 5G standard (3GPP)? There are benefits of having one standard, but one may also wonder whether the 3GPP 5G standard has been adopted because it is the best or because it is the evolution of LTE? If so, this then raises another question regarding the need for IMT-2020 standardization – quite simply, what value does it bring beyond identifying the appropriate spectrum?

We still need the IMT standardization process as it is a unique platform for competing manufacturers, operators, and countries to exchange views on what the next generation of cellular mobile technology should be. However, the process needs to be revisited to enable new stakeholders (with new innovations) to participate in the process.

In addition, the extensions granted to DECT and Nufront submissions highlight the flexibility within the process to provide a second chance for disqualified applicants. In particular, while the IMT-2020 standardization should have finalized in November 2020, it was agreed to establish a second path for DECT and Nufront proponents as shown in Figure 6.

However, the failure of these submissions shows that there is a steep learning curve for new entrants and that there is implicit support for a single 5G standard (3GPP). Having said this, at least if the ITU is unable to achieve a single global harmonized standard, efforts should be exerted to make sure that the standards that emerge are interoperable. That several

129. Rizzato, "Understanding Why So Many German Smartphone Users Are Still 3G-Only."
130. Marti, "How Will 6G Differ from 5G, and Will It Revolutionise Society?"
131. Bell, "When Is 5G Not 5G?"

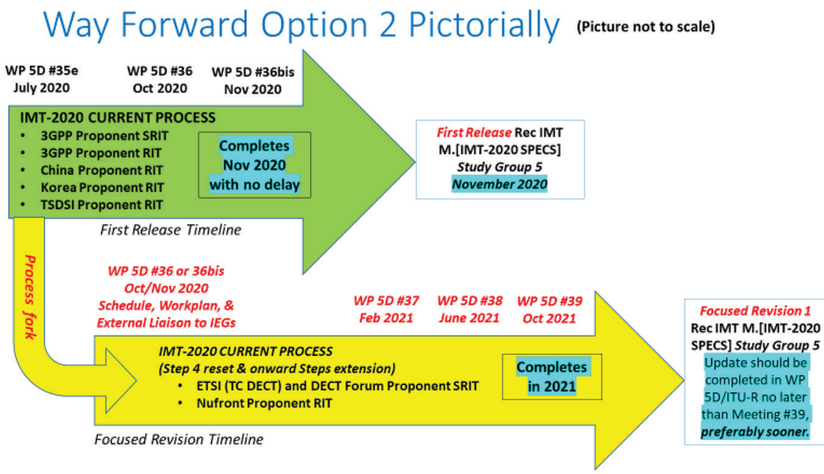


FIGURE 6 Way forward for disqualified proponents.[132]

standards bodies and technology developers go to a lot of effort to participate in the IMT standardization process highlights the benefit of being part of the IMT family—they benefit from obtaining access to IMT identified spectrum and acquiring international recognition, which appear to be related to each other. In other words, even a large standardization organization such as 3GPP cannot develop their mobile technologies in a manner isolated from the vision and service requirements of the ITU groups. In addition, they need to adhere to these requirements in order to obtain access to spectrum identified for IMT, and, therefore, to their technologies. In both cases, lobbying and strong participation are critical to influencing the output of both the standardization and spectrum identification processes.

The last issue to highlight in this section is related to the argument that discussions within ITU-R are sometimes influenced by the larger geo-political debate where countries such as China, United States, and Russia have different interests.[133] Although there is a significant tension between the United States and China when it comes to 5G equipment, especially when the United States barred the supply of US-origin technology to Huawei,[134] this has not been the case when it comes to IMT identification and standardization. In other words, there has not been a great

132. WP 5D, “”Detailed Schedule and Actions.”
133. O’Rielly, “Statement of FCC Commissioner Michael O’Rielly.”
134. Hoffmann et al., “Networks and Geopolitic.”

divergence regarding the positions on IMT identifications in WRC-19 between China and the United States with the exception of 6 GHz (which will be discussed at WRC-23). Both the United States and China support the 3GPP submission to be part of the IMT-2020 family of standards. Furthermore, the ITU-T focus group on 5G activities was led by a Chinese company representative while the ITU-R group leading the IMT-2020 standardization activities was chaired by a US company representative.[135]

In addition, China has changed its focus regarding mobile technologies standardization from developing national standards (e.g., TD-SCDMA) to supporting a global 5G standard set at 3GPP through submitting 40 percent of the standards and 32 percent of the documents.[136] Moreover, China used 4G to promote the globalization of Chinese technologies that were compatible with international specifications and actively participated in the global standard-making process through 3GPP.[137] Chinese companies such as Huawei have benefited from financial support provided by their government, which has enabled them to offer equipment competitive in terms of its low cost to operators.[138]

The IMT standardization process has helped to resolve competition issues among technology developers. For instance, during 3G, there was a dispute regarding the IPR of CDMA technology between Ericsson and Qualcomm that the two companies were able to resolve to their mutual benefit through being part of the IMT family under the threat that the ITU would only accept TDMA technologies.[139] In other words, it was the ITU standardization framework that enabled cooperation among these competing companies. There have been suggestions for countries such as the United States, which on several occasions act separately from the ITU (e.g., IMT systems in the 28 GHz), to establish a G7-like organization as an alternative to the ITU.[140] However attractive this may be, it would appear to be quite a difficult idea to operationalize due to the high cost of deviating from global harmonization even for large countries such as the United States.

In summary, in this section we have addressed the indirect relationship between IMT standardization and spectrum identification, and how that

135. Bruer and Brake, "Mapping the 5G Leadership Landscape".
136. Brake, "A U.S. National Strategy for 5G and Future Wireless Innovation."
137. Nanni, "The 'China' Question in Mobile Internet Standard-Making."
138. NTIA, *National Strategy to Secure 5G Implementation Plan*
139. Hjelm, "Rough Road to IMT-2000 RTT Standard."
140. O'Rielly, "Statement of FCC Commissioner Michael O'Rielly."

IMT identification usually indicates the re-farming of the other services in the band. Secondly, we have shown that as long as there are sharing issues with existing services, IMT identification will be likely needed for the THz bands even if 6G systems operating in these bands are fixed in nature. The IMT-2020 standardization process has revealed that nearly all submissions are based on 3GPP submissions, and their commercial deployments started before the approval of these technologies as part of IMT-2020 family.

We have also highlighted the influence of the IMT standardization process on the development of new technologies, especially given that DECT has been developed by standardization organization such as ETSI and that Nufront is claimed to have been developed, in essence, in China. India has played an important role in the IMT-2020 standardization process with their own submission of 5Gi, though this is expected to merge with 3GPP systems. The sixth issue that we highlighted is related to the need to define generations of cellular technologies and the importance of the IMT standardization process as it is a unique platform for competing manufacturers, operators and countries to exchange views on what the next generation of cellular mobile technology should be. Finally, we have shown that the IMT standardization process has helped to resolve competition issues among technology developers regardless of the larger geo-political debates.

Conclusion

This article has focused on the IMT standardization process. With the completion of the evaluation of candidate IMT-2020 RITs in February 2021, it is clearly timely to examine this process given that the ITU has begun 6G standardization. We have demonstrated the complexity of the IMT standardization process, not least due to the increasing array of services that require spectrum but also the diverse array of stakeholders that now populate the mobile telecommunications industry. The increasing fraught relationship between IMT standardization and identification is evident for all to see, demonstrated through the increasing challenges associated with re-farming spectrum with competing service allocations. More broadly, the willingness of some countries not to wait for ITU processes to run their course questions their suitability as well as illustrates the dynamic interplay between technical and commercial issues.

Notwithstanding the challenges inherent to IMT standardization, it is worth remembering that there are benefits to be gained. Technical and operational uncertainties can be reduced, and the possible market for equipment expanded. This is, however, not to suggest that the current system is faultless. Our analysis has shown that changes are needed, not least to ensure the continued relevance of an institution that productively brings together a diverse set of stakeholders. IMT standardization was largely immune to the geo-political tensions between China and the United States, though national interests are evident in how countries like China and India engaged with the process.

The extent to which new actors can contribute is unclear. The failure of candidate IMT-2020 radio interfaces to gain recognition suggests that those coming new to the process face an uphill battle, which may encourage some stakeholders not to participate and thus engage in standardization processes outside the ITU. Although this could begin to undermine the widespread acceptance of the ITU, the ITU will arguably continue to play a key role as long as it continues to allocate spectrum in a way that minimizes interference while maximizing harmonization. The challenge for the ITU therefore comes one of finding ways to incorporate new stakeholders into its processes so that their contributions can be heard without diluting the robust manner in which new technologies are evaluated and spectrum allocated.

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