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25 August 2022

ITU-APT Foundation of India (IAFI)

PROPOSED UPDATES TO WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW APT REPORT ON 5G IMPLEMENTATION IN FREQUENCY BANDS ABOVE 24.25GHZ

1) Background:

At the 29th Meeting of AWG the working document on "5G Implementation in frequency bands above 24.25 GHz" report was further progressed. AWG-29 considered the input contributions and incorporated the changes into the working document from the AWG-28 meeting. The meeting also agreed to request all APT members to submit further contributions to the next AWG meeting on this work item.

2) Discussion:

The 26 GHz band (24.25-27.5 GHz) is a key mm-wave band identified globally for 5G following WRC-19. India recently concluded the 5G spectrum auction on August 1, 2022. The auction was held for spectrum in various low-frequency bands which included 600MHz, 700MHz, 800MHz, 900MHz, 1800MHz, 2100MHz, 2300Mhz, one mid-frequency band of 3300MHz and one high-frequency band of 26GHz.

3) Proposal:

Given the ongoing progress of this work, further modifications are proposed to the working document in AWG-30/INP-xx in the attachment to include the results of spectrum auctions in 26 GHz in India in section 6.8 of the working document as highlighted.

Contact: **Email:**

[Editor's Note: AWG-29 reviewed the texts from section1 to introductory part of section4. AWG-30 would start reviewing from section 4.1.]

[Editor's Note: Numbering on figures and tables will be adjusted after contents become stable.]

WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW APT REPORT ON 5G IMPLEMENTATION IN FREQUENCY BANDS ABOVE 24.25GHZ

1 Introduction

The use of mm Wave bands is essential for the success of IMT-2020/5G mobile communications especially for broadband applications. With the outcome of WRC-19 agenda Item 1.13, frequency bands in 24.25-27.5 GHz, 37-43.5 GHz and 66-71 GHz have been identified to IMT globally with several technical conditions defined in several Resolutions in the Radio Regulations to protect other services.

3GPP has specified multiple frequency bands support between 24.25-52.60 GHz, mm Wave spectrum is important to provide high data rate and capacity, complementing the sub-6 GHz band.

[It is noted that the frequency range 24.25-29.5 GHz or portions of thereof has been implemented, planned, or being considered for 5G services in some countries.]

[With such trends, it's important to capture various 5G case studies, field trials, 5G developments, 3GPP developments and case studies in some countries. Such information on global 5G implementation would be helpful to provide guidance to APT countries those who wish to deploy 5G in mm Wave band.]

2 Scope

[Editor's Note: The description of the scope may need to be reviewed based on the content of the following sections.]

This report addresses the studies of current or intended implementation of 5G in the frequency bands above 24.25 GHz focusing on the following aspects:

- Global trends of 5G implementation
- On-going specification developments by 3GPP
- ITU-R studies and developments
- On-going industry developments
- Case studies in those countries that have implemented or plan to implement 5G

3 Vocabulary of terms

[TBD]

4 Global trends of 5G implementation

[Editor's Note: This chapter provides 5G implementation progress in the frequency bands above 24.25 GHz in global area and could provide the relevant information to Asia Pacific countries.]

The World Radiocommunication Conference 2019 (WRC-19) have identified additional radio-frequency bands for International Mobile Telecommunications (IMT), in Article 5 of the Radio Regulations for the frequency bands 24.25-27.5 GHz (RR No 5.532AB), 37-43.5 GHz (RR No 5.550B), 45.5-47 GHz (RR No 5.553A), 47.2-48.2 (RR No 5.553B) and 66-71 GHz (RR No 5.559AA) for the deployment of IMT (e.g. for 5G networks). Resolutions 241 (WRC-19), 242 (WRC-19), 243 (WRC-19), 244 (WRC-19) and 750 (Rev. WRC-19) apply. The Radio Regulations contain measures to ensure existing services remain protected, including limits to protect the Earth Exploration Satellite Services, used for meteorological and other passive services in adjacent bands.

In total, 17.25 GHz of spectrum has been identified for IMT by the Conference, in comparison with 1.9 GHz of bandwidth available before WRC-19, which will facilitate the development of fifth-generation (5G) mobile networks

Administrations are considering multiple candidate frequency bands suitable for 5G, including millimeter-wave bands. Although there are some differences in frequency bands between administrations it is generally considered that the frequency bands below 6GHz will be mainly used to provide continuous coverage, basic capacity and high mobility of 5G systems, and millimeter-wave frequency bands will be mainly used to optimize 5G transmission rate and increase system capacity

4.1 Trend on 26/28GHz band

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[Many countries are implementing or considering implementing IMT / 5G in the 24.25-27.5 GHz band. Several countries such as Canada, Japan, Korea, Singapore, USA, India have either licensed or are considering 27.5 -29.5 GHz (as part of 26.5-29.5GHz) for 5G]. This is in addition to what was identified for IMT at WRC-19 and is a national choice, based on their spectrum availability and equipment readiness from mobile industry. Other countries are consulting on mmWave frequency ranges for 5G.

mmWave spectrum is extremely important to provide high data rate and capacity, complementing the sub-6 GHz band that deliver the coverage. Consideration, identification, and assignment of the bands by the administrations have been mentioned below [1].

or

In addition, several countries such as Canada, Japan, Korea, New Zealand, Singapore, USA have either licensed or are considering parts of 26.5-29.5GHz to 3GPP based 5G technology, based on their spectrum availability and equipment readiness from mobile industry.

mm Wave spectrum is extremely important to provide high data rate and capacity, complementing the sub-6 GHz band that deliver the coverage. ~~Consideration, Identification, and assignment of the band between 24.25 to 29.5 GHz by the administrations have been mentioned below .~~ [Current situation of various administrations from various regions is provided below on their plans on spectrum between 24.25 to 29.5 GHz./Considerations and assignments of the band between 24.25 to 29.5 GHz by some administrations across the world as prepared by GSA is shown below [2]

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[1] Mm WAVE BANDS: GLOBAL LICENSING AND USAGE FOR 5G MEMBER REPORT MAY 2021
[2] Mm WAVE BANDS: GLOBAL LICENSING AND USAGE FOR 5G MEMBER REPORT MAY 2021

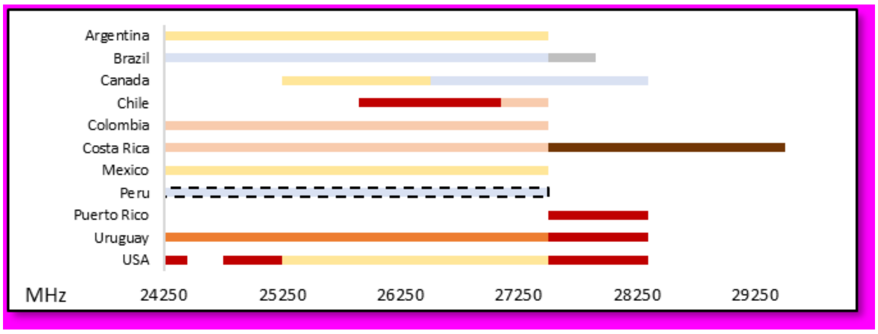

Table 1 : 5G spectrum positions in the 26 & 28 GHz bands - The Americas (ITU- Region 2)

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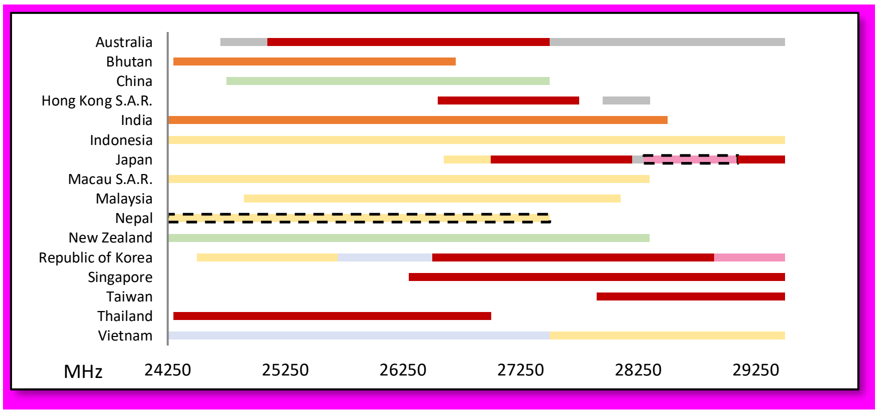

Or

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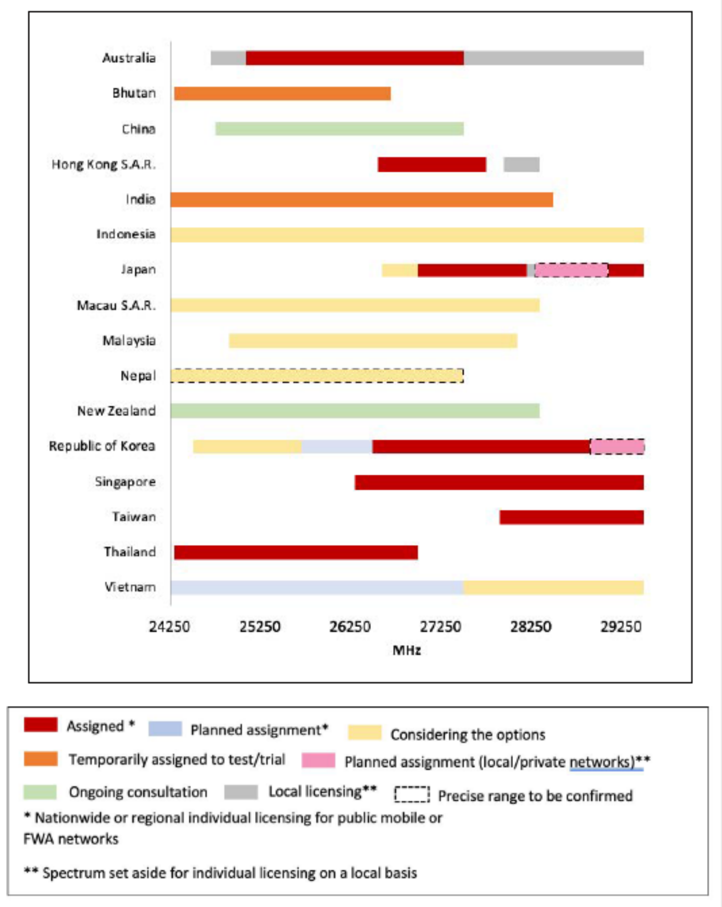

Table 2 : 5G spectrum positions in the 26 & 28 GHz bands- Asia-Pacific (ITU- Region 3)

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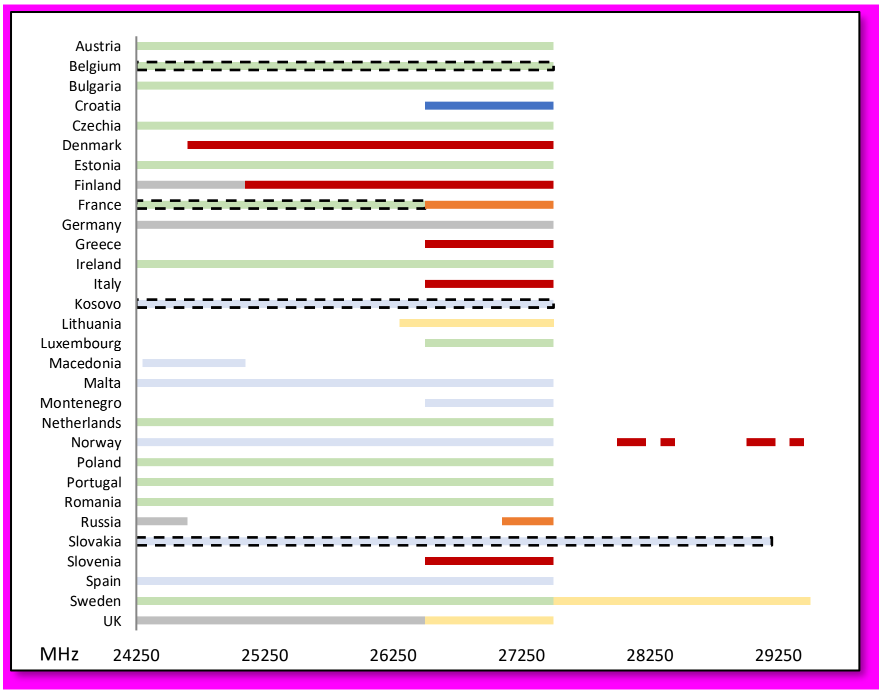

Table 3 : 5G spectrum positions in the 26 & 28 GHz bands- CEPT (ITU- Region 1)

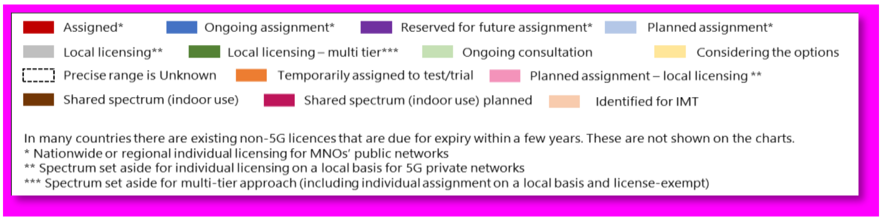

Figure 1: Assignment status of 5G spectrum

4.2 Trend on other bands than 26/28GHz

In addition to 26 and 28 GHz, administrations are working to identify additional mmWave spectrum in 37 and 40 GHz. Early information received from GSA has mentioned below[3].

3GPP-compliant 5G networks using this spectrum. Band n260, covering 37–40 GHz, is also used, with 28 companies in five countries/territories investing in licences for, or have networks using this spectrum. Of those, 27 hold licences. (The majority of those are based in the USA and its territories.) Three operators in the USA have launched 5G using Band n260.

The United States has additionally awarded fifteen operators with licences to use spectrum at 47.2-48.2 MHz.

[3] Mm WAVE BANDS: GLOBAL LICENSING AND USAGE FOR 5G MEMBER REPORT MAY 2021

Country	Band info	Description	Time frame
USA	37-40 GHz	Many companies and operators are investing in Band n260 which is covering 37–40 GHz. Three operators in the USA have launched 5G using Band n260.	May-20
USA	47.2-48.2 GHz	The United States has additionally awarded fifteen operators with licences to use spectrum at 47.2-48.2 MHz.	May-20
Canada	37.66-40 GHz 64-71 GHz	A Flexible licensng model is also to be adpted for spectrum in the 37.66-40 GHz with TDD use only.(Decision on 37.0 -37.6 GHz was deferred). 64-71 GHz frequncy band as license exempt.	May-22
Belgium	31.9-33.4 GHz 40.5-43.5 GHz	In 2018, BIPT announced plans to auction spectrum for 5G, 31.8–33.4 GHz and 40.5–43.5 GHz from 2022 to 2027.	May-18
Estonia	40.5 -43.5 and 66-71 GHz	Estonia's Ministry published a 5G spectrum roadmap in March 2019, which set out plans for a public consultation, which noted the potential to use40.5–43.5 GHz and 66–71 GHz for 5G.	Mar-19
Noway	38 GHz (37.058-37.17/38.318-38.43 GHz; 37.394-37.506/38.654-38.766 GHz;37.730-37.842/38.99-39.102 GHz)	Service and technology neutral	01-05-2020
UK	57-71 GHz	Ofcom made licence-exempt spectrum available under a technology neutral regime in the 57–71 GHz band, which could be used for future 5G services.	
Colombia	37–43.5 GHz, 47.2–48.2 GHz, 45.5–47 GHz and 70 GHz.	ANE launched a 5G spectrum consultation, mentioned spectrum at 37–43.5 GHz, 47.2–48.2 GHz, 45.5–47 GHz and 70 GHz.	01-09-2020
Mexico	40 GHz (37–43.5 GHz)	In May 2021, IFT announced that the frequency bands 40 GHz (37–43.5 GHz) could be auctioned from 2023 onwards	May-21
Nigeria	37-43.5 GHz 45.4-47 GHz 47.2-48.2 GHz 66-71 GHz	Nigeria's NCC published its draft 5G deployment plan in August 2020, on 37–43.5 GHz. . The plan also envisages releasingm spectrum at 45.4–47 GHz, 47.2–48.2 GHz and 66–71 GHz in a secondwave.	Aug-20

Table 4: Information on mmWave bands other that 26/28 GHz in band above 24 GHz

4.3 Trend on 5G ecosystem

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With the completion of the standalone (SA) Release 15 of 5G specifications by 3GPP in June 2018, the 5G System specification has now reached its official stage of completion, and the whole industry is taking the final sprint towards 5G commercialization. Many countries play an important role in guiding the global 5G industrialization actively, and have accelerate the promotion of 5G frequency planning and licensing scheme.

or

In addition to 5G non-standalone (NSA), standalone (SA) was completed in Release 15 of 5G New Radio (NR) specifications by 3GPP in June 2018 and the 5G NR specification is complete with 5G now being commercialized.

]

Device ecosystem in the mm Wave band (especially 3GPP bands n257, n260, and n261) is growing as mentioned below and it is comparative with ecosystem of other 5G bands

[Editor's Note: This should be updated to include n258 and n259, this should also be update for the latest information noting the information below is from 2019]

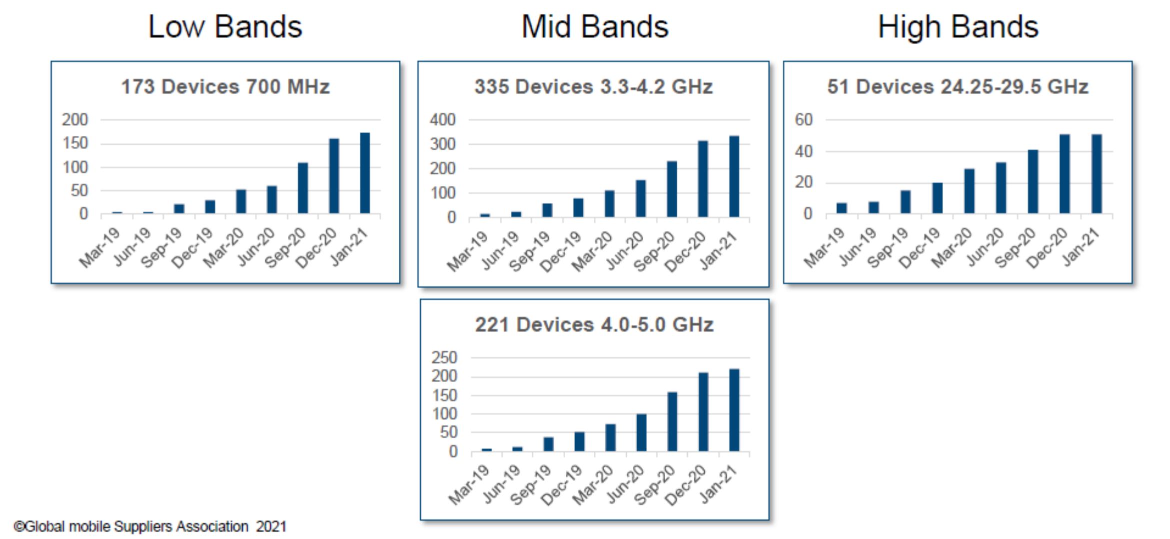

Figure: Device ecosystem in 3GPP bands

~~In the latest edition of the Ericsson Mobility Report, Ericsson estimate that 5G subscriptions are expected to reach 1.9 billion in 2024 thus being 400 million more than in our earlier forecasts. In 2024, 5G coverage is expected to reach 45 percent of the world's population and will carry about 35 percent of all global mobile traffic. Mobile technology is the fastest scaling technology known, and 5G may well be the fastest scaling of them all.~~

~~According to statistics from Global mobile Suppliers Association (GSA) there has until May this year been tests/trials/launches by 235 operators in 83 countries (see below in Figure 1). By far the most used bands for these events are the 3GPP band 78 (3300-3800 MHz) and band 257 (26.5-29.5 GHz).~~

In the latest edition of the Ericsson Mobility Report, Ericsson estimate that 5G subscriptions are expected to reach 1.9 billion in 2024 thus being 400 million more than in our earlier forecasts.

In 2024, 5G coverage is expected to reach 45 percent of the world's population and will carry about 35 percent of all global mobile traffic. Mobile technology is the fastest scaling technology known, and 5G may well be the fastest scaling of them all.

To be successful in 5G, timely buildup of the ecosystem is needed. As per Ericsson mobility report June 2021, 5G subscriptions are growing rapidly; on average 1 million subscriptions added every day. 5G service providers at the forefront of FWA adoption Globally, the average monthly usage per smartphone now exceeds 10GB and is forecast to reach 35GB by the end of 2026

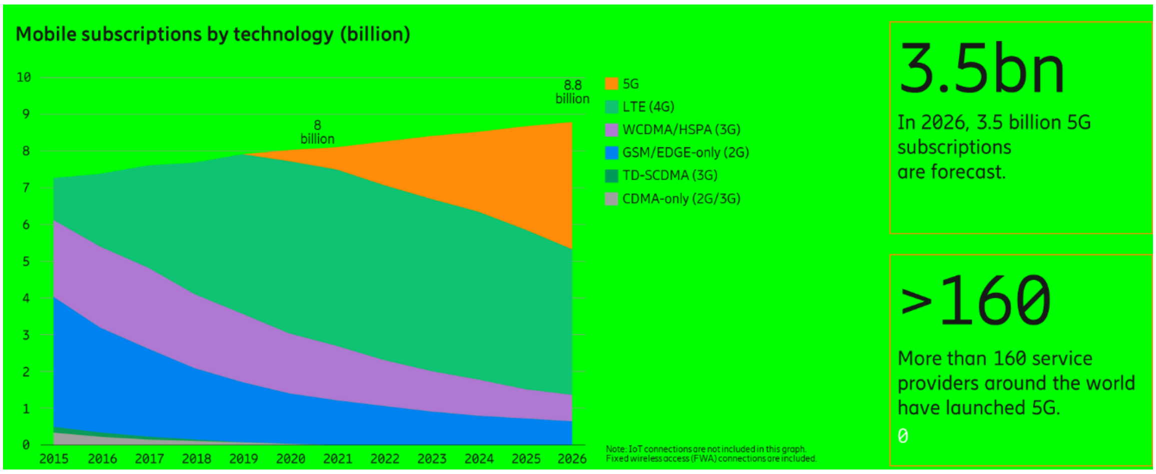

Figure 2 : Mobile subscription by technology

We are witness of changing to use mobile subscription, as per Ericsson mobility report June 2021. 91 percent of all subscriptions will include mobile broadband in 2026.

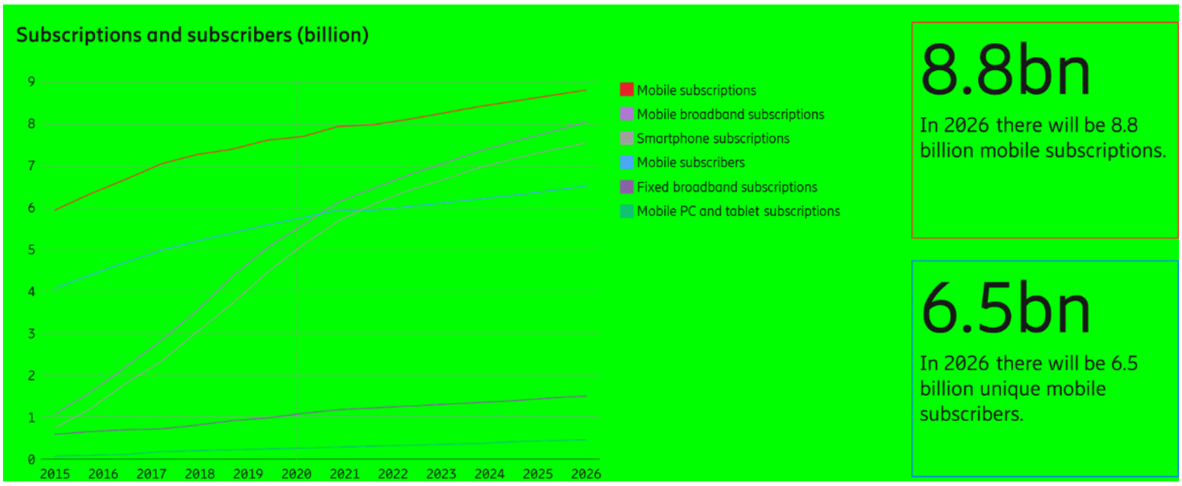

Figure 3 : Trend of mobile subscriptions

According to statistics from Global mobile Suppliers Association (GSA) there has until July this year been tests/trials/launches by 132 operators in 22 countries (see Figure below) in mmWave frequency bands.

Mm Wave rollout

- 192 operators in 48 countries/territories have been investing in 5G mmWave (testing, trialling, planning, acquiring licences, deploying, or operating networks)
  - 26/28 GHz
  - 37-40 GHz
  - 47-48 GHz

- Plus historically some trials at 66-76 GHz and 81-86 GHz

- 140 operators in 24 countries/territories hold licences enabling mmWave deployment in one of 26/28 GHz, 37-40 GHz and 47-48 GHz
- 28 operators in 16 countries identified as actively deploying mmWave spectrum for 5G

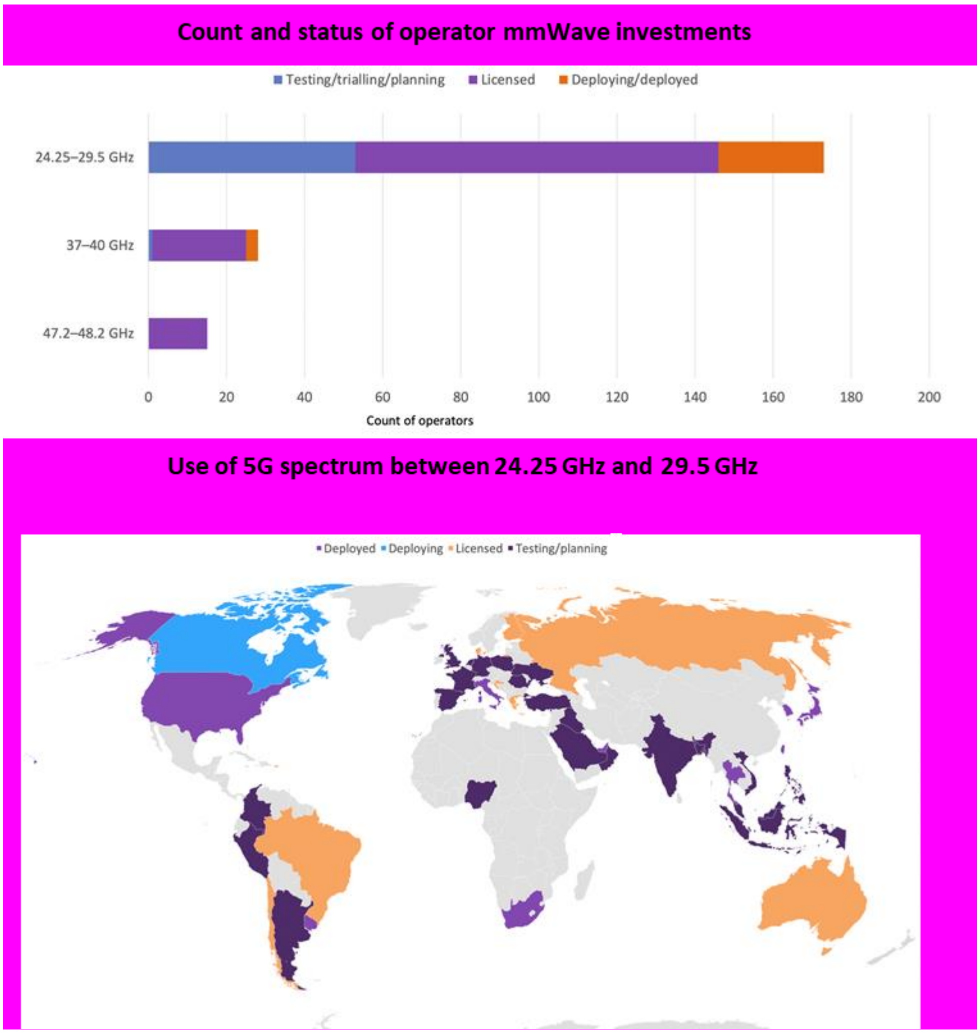

Figure 4 : Status of mm Wave 5G roll out

To be successful in 5G, timely development and ramping up of the ecosystem is essential. The figure below shows a clear commitment from the chipset and device vendors in the mobile industry towards increasing the vibrant 5G ecosystem in mmWave spectrum.

Strong eco-system is emerging around mmWave bands.

- 57 vendors have announced mmWave devices
- Announced / available
  - Any mmWave: 152
  - n257(26.5-29.5GHz):41
    n258(24.25-27.5GHz):31
    n261(27.5-28.35GHz):73
    n260 (37-40 GHz) : 71
- Supported by mmWave chips from five vendors

- Indoor and outdoor CPE nearly 20% of all announced devices
- Phones 45% of all announced models
- Commercially available: 97 devices
    - 44 of which are phones
    - mmWave devices 17% of all commercial devices.

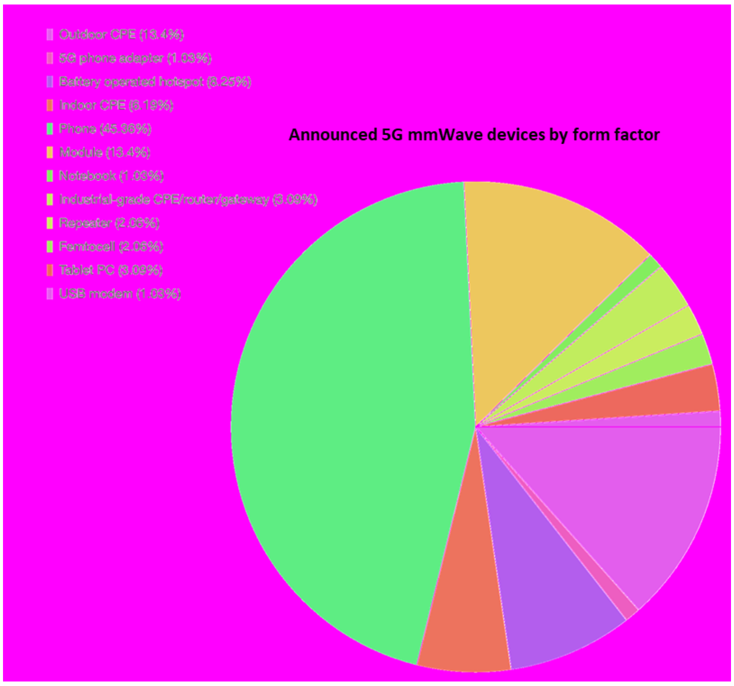

Figure 5 : Status of mmWave 5G device eco system

5 5G Standardization activities

5.1 ITU-R

The World Radiocommunication Conference 2019 (WRC-19) have identified additional radio-frequency bands for International Mobile Telecommunications (IMT) in the frequency bands 24.25-27.5 GHz, 37-43.5 GHz, 45.5-47 GHz, 47.2-48.2 and 66-71 GHz, which will facilitate the development of 5G mobile networks. In addressing the technical compatibility with services also allocated in these frequency bands, WRC-19 concluded on a number of measures as outlined in the *resolves* parts of Resolutions **241 (WRC-19)**, **242 (WRC-19)**, **243 (WRC-19)** and **244 (WRC-19)**, which are mandatory text, since these Resolutions are incorporated by reference in Article **5** of the ITU Radio Regulations (RR). Administrations wishing to implement 5G in these frequency bands are required to comply with these measures, as appropriate.

WRC-19 also took measures to discuss the elements of Article **21** of the ITU Radio Regulations, including the applicability of the conducted power limit in No. **21.5** for terrestrial stations to be deployed with Active Antenna Systems (AAS) in frequency bands above 24.25 GHz. This provision is critical for the protection of the receiving space station.

From WRC-19 Document 550 – “ITU-R is invited to study, as a matter of urgency, the applicability of the limit specified in RR No. **21.5** of the Radio Regulations to IMT stations, that use an antenna that consists of an array of active elements, with a view to recommend ways for its possible replacement or revision for such stations, as well as any necessary updates to RR Table 21-2 related to terrestrial and space services sharing frequency bands. Furthermore, the ITU-R is invited to study, as a matter of urgency, verification of RR No. **21.5** regarding the notification of IMT stations that use an antenna that consists of an array of active elements, as appropriate."

RR No. **21.5** states:

> *The power delivered by a transmitter to the antenna of a station in the fixed or mobile services shall not exceed +13 dBW in frequency bands between 1 GHz and 10 GHz, or +10 dBW in frequency bands above 10 GHz, except as cited in No.* ***21.5A***.

In the case of 5G/IMT-2020 stations using an antenna that consist of an array of active elements in AAS, it is unclear how the above provision could be interpreted when using AAS where the total power delivered to the antenna in this case is typically calculated as Total Radiated Power (TRP).

The ITU is facing the difficulty that the Radiocommunication Bureau (BR) is not in a position to examine notices submitted for a 5G/IMT-2020 station operating in the terrestrial mobile service within a frequency band above 24.25 GHz shared with the space service (Earth-to-space) due to the lack of appropriate interpretation of the data elements 8AA (power delivered to the antenna) and 8B (maximum radiated power) as per Appendix **4** of the RR that are mandatory to be notified with respect to the criteria as outlined in RR No. **21.5**.

It is noted that this work [as of Q1 2021] is still under study by the relevant ITU-R working parties, particularly WP 5D. Once the guidelines that can be used by administrations in obtaining the data element 8AA for a station employing AAS are developed, BR would propose the Radio Regulation Board to consider the guidelines and adopt a Rule of Procedure, as necessary, to make them mandatory for application.

Descriptions of TRP and EIRP for AAS

AAS is a beamforming antenna based on an antenna array and consists of a number of identical radiating elements located in the yz-plane with a fixed separation distance (ideally at λ/2), see Figure 1. However, any separation between radiating elements with a spacing larger than λ/2 could generate undesired grating lobes and thus require additional measures to be taken in mitigating the effect of these grating lobes.

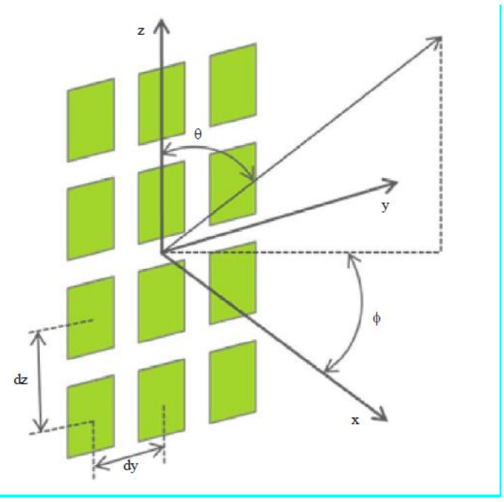

Figure 6: AAS layout

TRP is the total sum power level radiated to all angles. Thus, it is a maximum transmitted level. Typically, the power levels will vary over time in one specific direction depending on active beams depending on e.g. mobility of served users and transmission needs like in time etc. A user may use some resource blocks while another user will use other transmission blocks in time.

Out-of-band emissions are always using TRP since the lobes are defined in-band and not controlled outside of the band and thus energy can be seen as randomized over frequency, time, phase.

$Total\ Radiated\ Power = \frac{1}{4\pi}\int_0^{2\pi}\int_0^{\pi} P_E(\theta,\varphi)\sin(\theta)\, d\theta d\varphi$ and

Where

θ:	Elevation angle from 0 to 180 degree
φ:	Azimuth angel from -180 to 180 degree
$P_E(\theta,\varphi)$:	power level with given elevation angle(θ) and azimuth angle (φ)

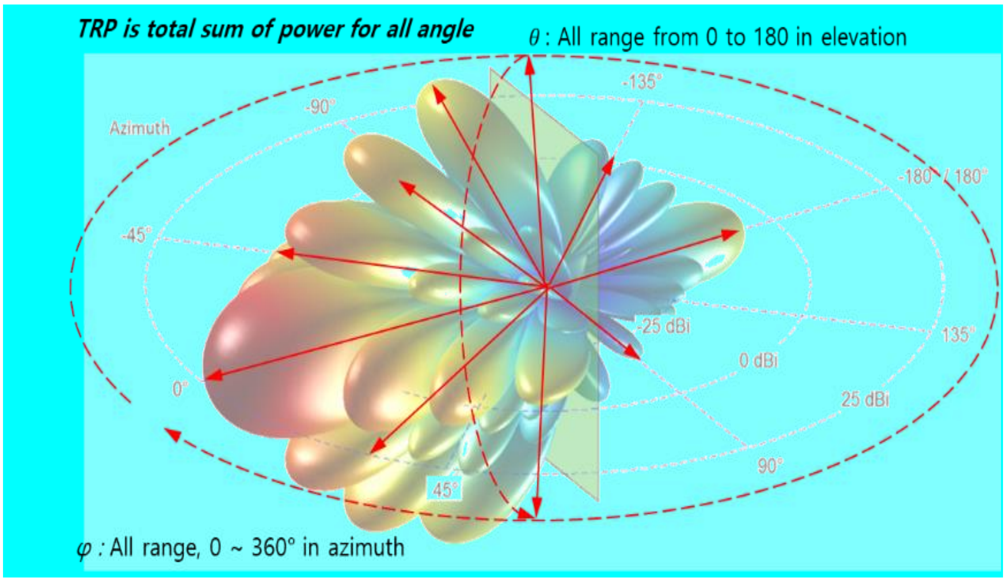

Figure 7: Antenna beams and TRP.

EIRP (Equivalent Isotropic Radiated Power) is a power level in main beam direction, $EIRP = P_E(90, 0)$, see Figure 3.

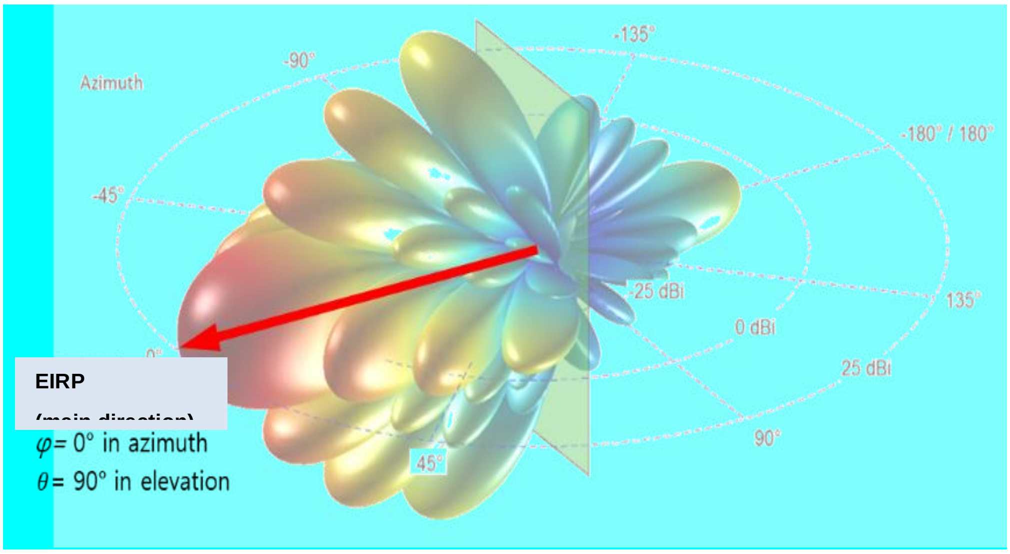

Figure 8: EIRP vs TRP

5.2 3GPP

3GPP was early to specify some frequency bands prior to WRC-19 and have continued its work on various mm Wave bands. Table mentioned below shows the most recent status.

3GPP has include new 5G/NR bands in Release 15, which are being defined in the following two frequency ranges (FR) in Table 6.

Table 5: Definition of 3GPP frequency range

Frequency range designation	Corresponding frequency range
FR1	410 MHz – 7125 MHz
FR2	24250 MHz – 52600 MHz

For the frequency band above 24.25GHz, the operating bands for 5G/NR are defined as n257 to n261 in 3GPP TS 38.104.

Table 6: NR operating bands in FR2

NR *operating band*	Uplink (UL) and Downlink (DL) *operating band* BS transmit/receive UE transmit/receive $F_{UL,low}$ – $F_{UL,high}$ $F_{DL,low}$ – $F_{DL,high}$	Duplex mode
n257	26500 MHz – 29500 MHz	TDD
n258	24250 MHz – 27500 MHz	TDD
n259	39500 MHz – 43500 MHz	TDD
n260	37000 MHz – 40000 MHz	TDD
n261	27500 MHz – 28350 MHz	TDD
n262	47200 MHz – 48200 MHz	TDD

6 5G industry studies on development scenario

[Editor's Note: This chapter provides the industry development of 5G implementation, including 5G products, equipment, RF, terminals and other aspects.]

For a full 5G capabilities, spectrum in three frequency ranges is required in the initial phase; low-bands like 600/700 MHz for wide area coverage and deep indoor penetration, mid-bands like 3300-4200/4400-5000 MHz for capacity and coverage, and then high-bands like 24.25-29.5/37-43.5 GHz for extreme low latency and high bitrates.

6.1 Study on deployment scenario

In Figure 3 below some different characteristics of various deployment scenarios are studied together with frequencies used. The usability depends on deployment and building characteristics, but the interworking between lower bands and high bands are crucial to achieve good coverage and extreme capacity at the same time.

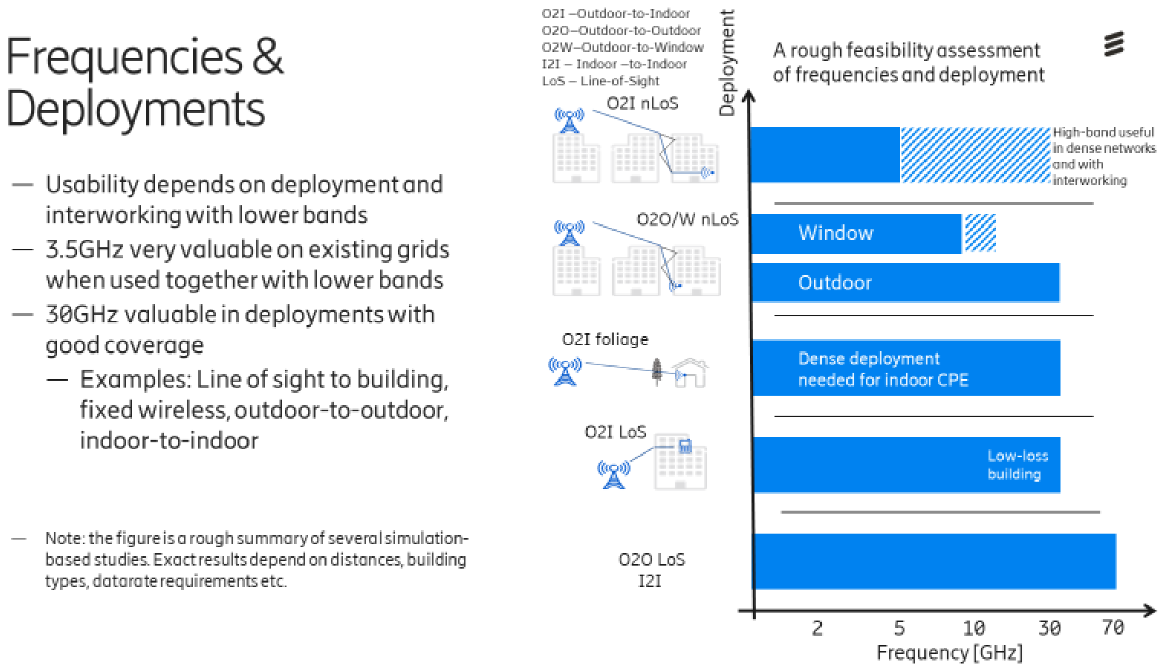

Figure 9 : Summary of several simulation studies on frequencies and deployments

5G at mid and high bands is well suited for deployment at existing site grid, especially when combined with low-band LTE. Adding new frequency bands to existing deployments is a future-proof and cost-efficient way to improve performance and meet the growing needs of mobile broadband subscribers and deliver new 5G-based services.

Beamforming and antenna technology means that the need for site densification is much smaller than anticipated. In Figure 4 below the result of a simulation study of NR in 26 GHz with 200 MHz bandwidth showing the coverage in London while using an existing site density. It shows that there is very good outdoor downlink coverage, but also to some extent indoor coverage in low-loss buildings near sites.

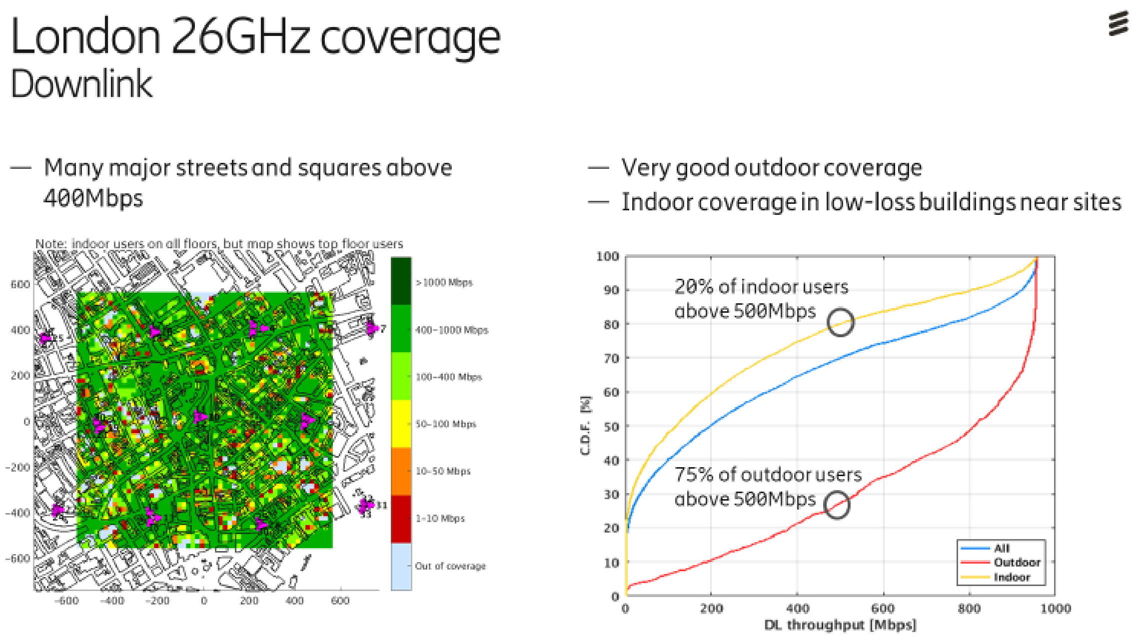

Figure 10: Urban area coverage in 26 GHz downlink with existing site density

Also the uplink coverage is good in outdoor environments in the 26 GHz band using the existing site density in an urban environment especially along major streets and squares as seen in Figure 5 below.

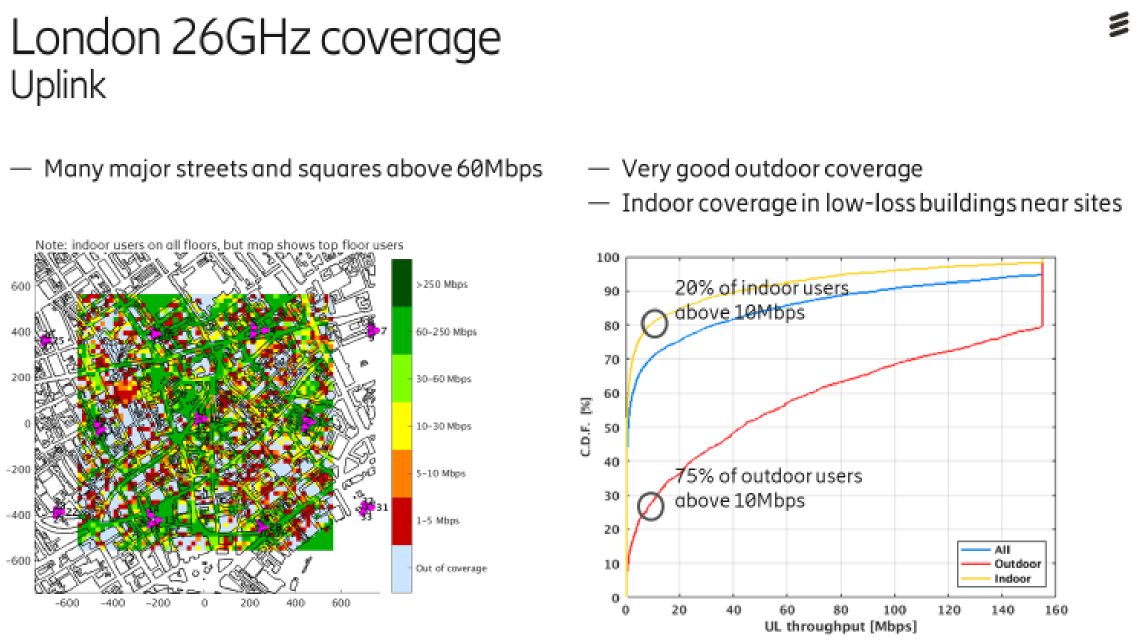

Figure 11 : Urban area coverage in 26 GHz uplink with existing site density

When considering also interworking between LTE and NR and then in various frequency bands the performance is increased. In this study 100 MHz of NR in the 3.5 GHz band was added to the 200 MHz in 26 GHz band, as well as 2x10 MHz of LTE in 800 MHz band and 2x20 MHz LTE in both 1800 and 2600 MHz bands. The result is shown in Figure 6 below for downlink achieving data rates above 1 Gbps in many major streets and squares with indoor coverage.

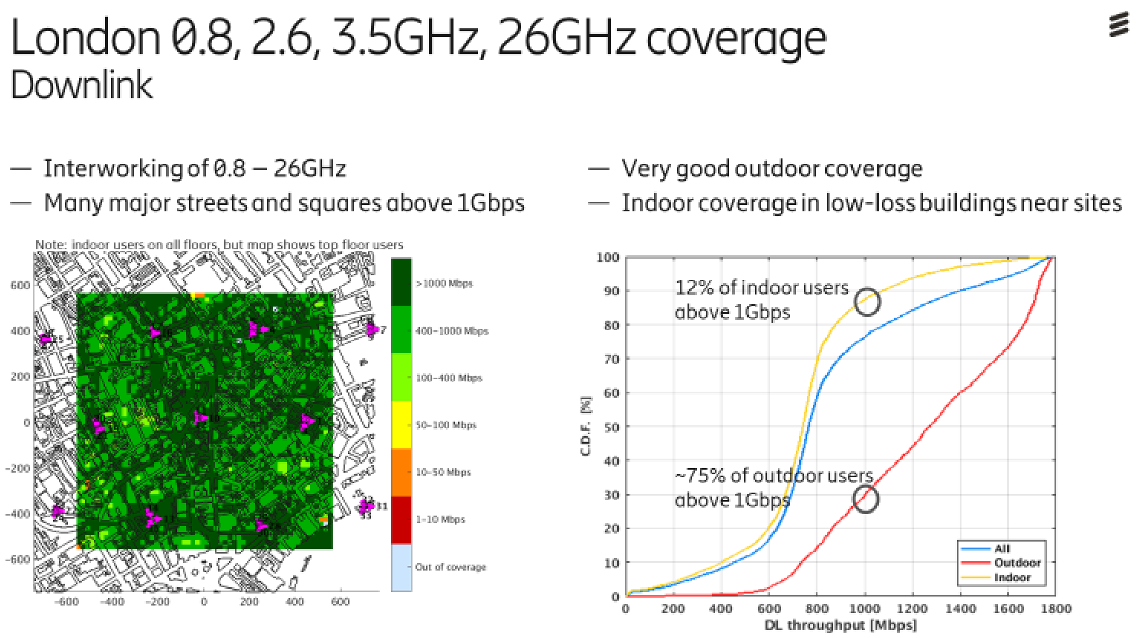

Figure 12: Interworking of LTE+NR downlink in 0.8-26 GHz using existing site density

The corresponding result for uplink is shown in Figure 7 with very good outdoor coverage complemented with low-band indoor coverage.

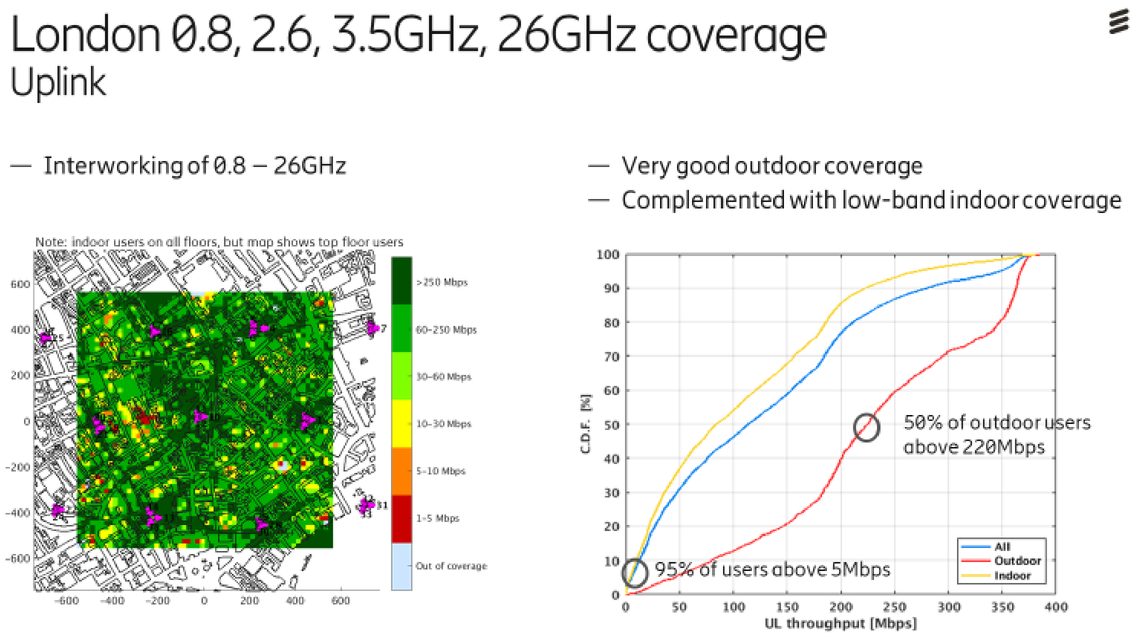

Figure 13: Interworking of LTE+NR in 0.8-26 GHz using existing site density

It is shown above that combining 5G NR with LTE and using a various frequency bands gives a very good wide area performance in urban areas by using the existing site density. Densification is thus not needed from the start when launching 5G but can happen at later stage and may also be difficult in some countries/cities. Additional information can be found in the Ericsson Technology Review entitled "5G NR with LTE at existing sites"[4].

6.2 GSA on mm Wave in 26/28 GHz

GSA has published report in 2020 on mmWave considering co-existence and 5G implementation aspects in India. GSA has conducted simulation including some of the 5G features with practical deployment in addition to ITU-R recommendation.

In the study, two scenarios were considered, a) Interference from 5G base station to EESS active earth station was evaluated with less than 2.5 km of protection distance in 26 GHz b) Interference from 5G base station to high throughput satellite space station was evaluated in 28 GHz.

Results were compared with available co-existence studies for Indian satellite and found that sufficient margin can be obtained for mobile and satellite service to operate in interference free manner. Moreover, GSA has also noted that practical deployment measures and 5G features can be explored for further enhancement of interference margin.

Report has further suggested that, current spectrum identification process would take more than 8 month which includes, NFAP (National frequency allocation plan), reference to national regulator (TRAI), spectrum auction. Report has suggested that early availability of 5G spectrum for below 6 GHz and above 6GHz is the key to leverage the 5G potential in India.

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[4] https://www.ericsson.com/en/reports-and-papers/ericsson-technology-review/articles/the-advantages-of-combining-5g-nr-with-lte

6.3 5G implementation and field trials

mm Wave bands have garnered attention for field trails and 5G deployment due to availability of wide bandwidth. Trails conducted by various administrations found mmWave band an attractive solution for eMBB applications like surveillance and remote health diagnostic, which demands very high data rate. Trials were also conducted for FWA application to enhance coverage in rural area. Details of field trails from various countries could be found in Annex1.

7 Case studies for 5G implementation in some countries

[Editor's Note: This chapter provides the case studies in those countries that have implemented or plan to implement 5G. It could provide the experience or solutions of solving interference problems (for example, the interference between IMT and other services) when implementing or planning to implement 5G in those countries.]

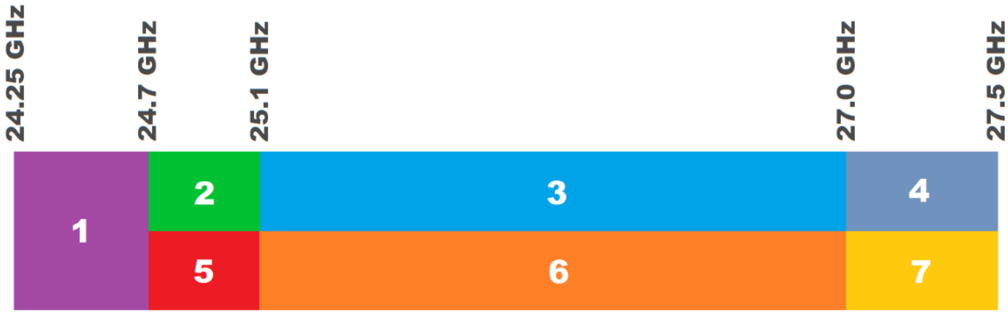
7.1 Australia

In April 2019, the ACMA released the Future use of the 26 GHz band—Planning decisions and preliminary views paper which:

- Identified the frequency range 25.1–27.5 GHz (the 26 GHz band) for spectrum[5] licensing in 34 specified cities and regional centres.
- Identified a range of apparatus[6] and class[7] licensing measures to facilitate a broad range of wireless broadband use cases in the 26 GHz band.

These arrangements in the 26 GHz band are illustrated below:

[5] Spectrum licensing refers to wide-area licensing for ubiquitous, high-density deployments, typically by mobile network operators (MNOs), within specified technical and operating conditions.
6 Area wide apparatus licences (AWLs) share some of the features of spectrum licences, including being geographically limited and providing for flexible and scalable deployments.
7 Class licensing is a standing authorisation for unlimited, uncoordinated deployments within specified technical and operating conditions.



- 1 Class-licensing for indoor use (Australia-wide).
- 2 Class-licensing for indoor and outdoor use (Australia-wide).
- 3 Spectrum licensing defined areas. Includes additional conditions to protect SRS earth stations.
- 4 Spectrum licensing with additional FSS coexistence conditions within certain areas.
- 5 Area wide apparatus licensing (AWL) - Australia-wide.
- 6 Area wide apparatus licensing (AWL) - Australia-wide, except defined areas. Includes additional conditions to protect SRS earth stations.
- 7 Area wide apparatus licensing (AWL) with additional conditions to protect FSS uplinks (Australia-wide except defined areas). New FSS earth stations will also be permitted, on a first-in-time coordinated basis with apparatus licensed wireless broadband services.

The "defined areas" described above refer to the areas which will be available for spectrum licensing[1], which comprises cities and major regional centres. Area wide Apparatus licensing will be available in the frequencies subject to spectrum licensing outside these defined areas, and in all areas in the frequency range 24.7-25.1 GHz, while class licensing will be applied from 24.25-25.1 GHz in various forms. The intent of this licensing mix is twofold:

- To ensure protection of passive earth exploration satellite services operating in the frequency range 23.6-24 GHz from out of band emissions; and
- To accommodate a mixture of potential IMT-2020 use cases, which have been categorised under three discrete types of use:
  - type 1 – wide-area wireless broadband deployments traditionally undertaken by mobile network operators (MNOs) or some fixed telecommunication carriers;
  - type 2 – smaller, local area market subscriber services such as those provided by wireless internet service providers (WISPs) or dedicated (e.g. government only) wireless broadband networks;
  - type 3 – private, localised deployments or networks within private property to enable deployments by non-traditional users such as retail/commercial facilities, academic institutions, hospitals, mine sites, government facilities, factories and other industrial plants.

In October 2019, the Minister for Communications, Cyber Safety and the Arts declared the 25.1-27.5 GHz frequency range for reallocation by issue of spectrum license in 29 defined areas within major population centers.

Following consultation in July/August 2020, the technical and allocation instruments were made in late 2020 and the auction for 15-year spectrum licences in the 25.1-27.5 GHz frequency range in 29 defined areas within major population centres was subsequently completed in April 2021.

In addition to the spectrum auctioned in the 25.1-27.5 GHz frequency range, the ACMA also finalized its arrangements for area-wide apparatus licensing in the 26 and 28 GHz bands in December 2020, such that apparatus licences can be issued on a case-by-case basis for:

- fixed and mobile wireless broadband (IMT-2020/5G) in the following frequency ranges:
    - 24.7-25.1 GHz Australia-wide,
    - 25.1-27.5 GHz outside of the 29 defined areas within major population centres,
- fixed wireless access (FWA) in the following frequency ranges:
    - 27.5-28.1 GHz co-primary with coordinated FSS earth stations in the 29 defined areas within major population centres, but secondary to all FSS outside these areas,
    - 28.1-29.5 GHz on secondary basis to FSS.

Arrangements in the 28 GHz band are illustrated below:

7.2 China

5G trial progress in China

China has been actively promoting the domestic coordination and R&D of some candidate frequency bands listed in ITU-R Resolution 238 (WRC-15). On June 2017, China issued the spectrum consultation to the public on use of the fifth-generation international mobile communication system (5G) in the millimeter-wave band, seeking the opinions on 5G system frequency planning on 26GHz, 40GHz or other millimeter-wave band. On July 2017, China approved 26 GHz and 40GHz frequency bands to be utilized as the spectrum of IMT-2020 R&D trial. Recently, China plans to continue the trial on research and testing the key technologies on 26GHz frequency band and plans to focus on the 5G base station function, RF and performance test in the later stage.

Spectrum consideration on 26/28GHz bands

China introduces its spectrum applications related to 24.25-27.5 GHz and 27.5-29.5 GHz frequency bands. WRC-19 identified the frequency band 24.25-27.5 GHz for IMT. Noting harmonized worldwide frequency bands for IMT are desirable in order to achieve global roaming and the benefits of economies of scale, China is considering the use of the frequency band 24.25-27.5 GHz, or parts thereof, for terrestrial IMT, while leaving the frequency band 27.5-29.5 GHz for satellite usage since this 2 GHz Ka band is not identified for the implementation of IMT in accordance with the ITU Radio Regulations. We understand the ITU will not receive with a favorable finding of a notification of a MS station for the implementation of IMT under the nature of service “IM” in the frequency band 27.5-29.5 GHz. In China, we had stipulated regulatory procedures to meet the required sharing the compatibilities between existing and future space and terrestrial services including their applications. The use of the Ka band relates to a number of ITU Resolutions, such as Resolutions **242**(WRC-19) and **750** (Rev.WRC-19) which established sharing and compatibility conditions in the frequency band 24.25-27.5GHz and limits on unwanted emissions in the frequency band 23.6-24 GHz from IMT base stations and IMT mobile stations within the frequency band 24.25-27.5 GHz.

Since more and more administrations are deploying or planning to deploy satellite systems using Ka band (as well as Q and V bands) with a large service area in the APT region, this administration notes that there is potential aggregate interference from the deployment of IMT systems in the same frequency bands. The RR No. **21.5** stipulates that the power delivered by a transmitter to the antenna of a station in the fixed or mobile services shall not exceed 10 dBW in frequency bands above 10 GHz, except as cited in No. **21.5A**. Besides following relevant ITU Resolutions, China views that the applications of IMT in the APT region in the frequency band 27.5-29.5 GHz shall also meet the provisions of RR Nos. **21.2**, **21.3**, **21.5** and **21.5A** as indicated in RR Table **21-2**. When necessary, coordination is also needed and shall be initiated when all these relevant RR limits are exceeded and/or a special sharing and compatible condition is required.

China noted the ITU-R is invited to study, as a matter of urgency, the verification of RR No. **21.5** for the notification of IMT stations operating in the frequency band 24.45-27.5 GHz which use an antenna that consists of an array of active elements, and will actively participate in the ITU-R studies.

7.3 Japan

In order to investigate a possibility to deploy 5G systems in the frequency band 27.0-29.5 GHz in Japan, sharing and compatibility studies between 5G and incumbent applications mentioned below were conducted.

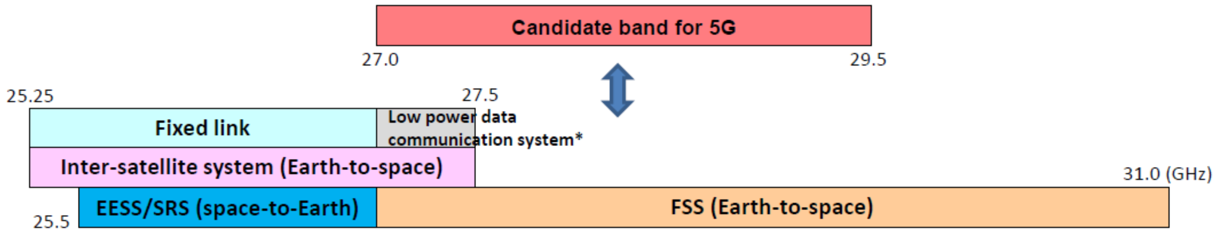


Figure 14: Incumbent applications considered in sharing and compatibility studies in Japan

It could be seen that Japan has the fixed satellite service allocation in Earth-to-space direction in the frequency band between 27 to 31 GHz. Interference originated from 5G stations will be received at the space station and may have some bearing with the operation of the fixed satellite services.

Japan has conducted a study to evaluate the signal received at the space station with the help of simulation, which considers free-space propagation loss, with and without clutter loss based on Recommendation ITU-R P.2108. Japan has considered a specific location of 5G base stations, where those stations are expected to be deployed. In specific, Japan has considered signal originated from 5G base stations within beam view footprint of the space stations for different fixed satellite systems concerned in Japan.

The study from Japan has considered antenna pattern of 5G base station and dynamic beamforming of beam paring between 5G base stations and UEs. “Envelop antenna pattern model” and “Average antenna pattern model” based on the Monte-Carlo simulation was considered in the study with variation due to dynamic beamforming.

From the study in the Earth-to-space scenario and interference from 5G stations to space station has concluded that more than 50,000 base stations for 5G, under the assumptions used in the study, can be deployed within a beam view of the satellite operating in the band between 27-29.5 GHz while meeting the protection criteria of the satellite space station receivers[8] [9]. Based on the results of this study, an interference coordination mechanism between terrestrial and satellite operators in Japan has been established in order to protect the satellite space stations.

[Editor's Note: Suggest that more information is provided on the technical assumptions regarding 5G stations, the assumed characteristics of FSS earth stations, and the interference coordination mechanism that is referred to above.]

7.4 Republic of Korea

5G spectrum

The Republic of Korea has auctioned 5G spectrum including 3.5GHz (3420 – 3700 MHz) and 28GHz (26.5 – 28.9 GHz) on June 2018 and launched world's first 5G services on April 2019. The number of 5G subscribers at the end of June 2021 is 16.4 million which accounts for 22.9 % of the total 71.62million mobile subscription in the country.

In order to be at the forefront of the global 5G competition, the Republic of Korea completed the auction process on June 2018 for the 3.5 GHz and 28 GHz bands, which made available a total of 280 megahertz in the 3.5 GHz with 28 blocks and 2,400 megahertz in the 28 GHz with 24 blocks. The spectrum cap with limit on 10 blocks per each band was applied to prevent an operator from overtaking the market. Participant operators were SK Telecom, KT, and LG U+. The telcos paid a total of 3.6183 trillion won (US $3.3 B) for the spectrum, 340 billion won higher than the starting price of 3.3 trillion won. The 3.5 GHz band licenses have a ten-year term, and the 28 GHz band licenses have a five-year period.

In addition to the 5G spectrum auction in 2018, the Ministry of Science and ICT (MSIT) announced the plan for a local 5G spectrum on June 30, 2021. The MSIT will offer 100 megahertz in the 4.7 GHz band and 600 megahertz in the 28 GHz band later 2021 for what it terms 5G specialized network (a.k.a. Local 5G) services. It is expected that many enterprises across the country acquire frequencies in the two bands and then build specialized 5G networks in locations such as a campus or inside buildings. The frequencies are to be allocated administratively and there will be an annual radio wave usage fee.

Local 5G spectrum is 10 blocks of 10 megahertz in 4.72-4.82 GHz and 12 blocks of 50 megahertz in 28.9-29.5 GHz. The basic charge for each band is KRW 100,000 ($88) per 10 megahertz in 4.7 GHz and KRW 50,000 ($44) per 50 megahertz in 28 GHz. Applicants can apply for a license duration from two to five-year term, with a deployment obligation within six months after being licensed. The assignment fee of which calculation formula uses factors such as the basic charge for each band, area, license duration and bandwidth is set higher for cities with a denser population and is also significantly lower for 28 GHz than 4.7 GHz.

The figure 2 shows the 5G spectrum above 24.25 GHz in the Republic of Korea.

[8] https://www.soumu.go.jp/main_content/000567503.pdf (in Japanese)

[9] https://www.soumu.go.jp/main_content/000567504.pdf (in Japanese)

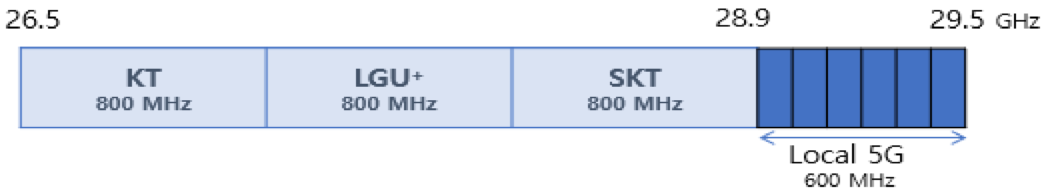
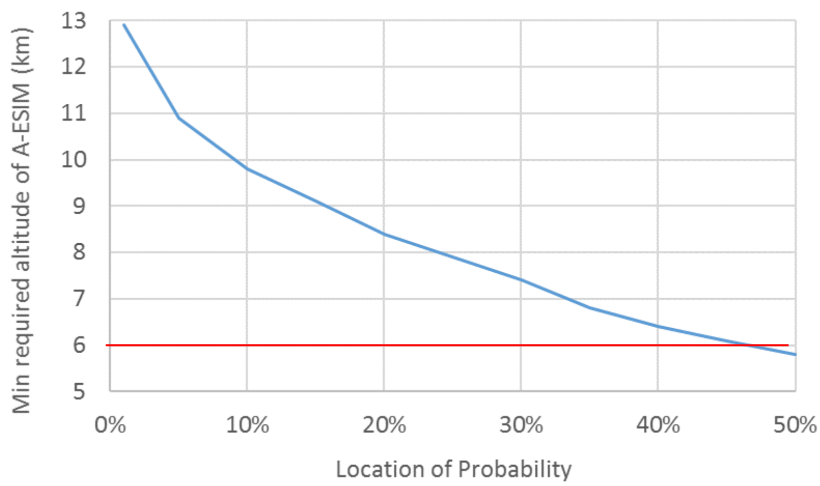


Figure 15: **5G spectrum above 24.25 GHz in the Republic of Korea**

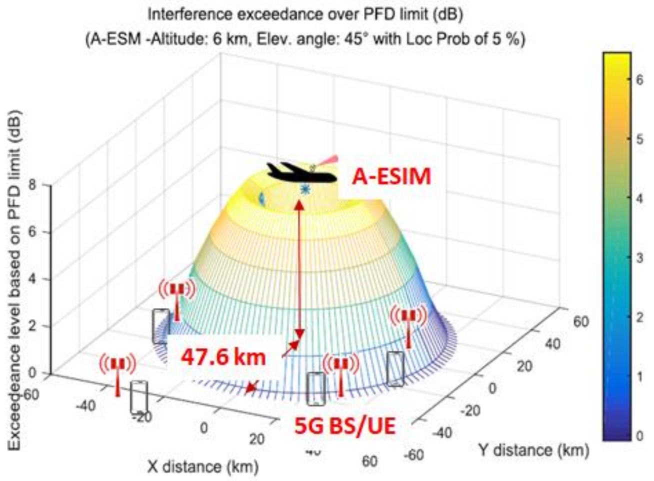
Implementation of A-ESIM and 5G system

To assist successful 28GHz commercialization, the Republic of Korea conducted the study how to coordinate with other services in 28GHz. 28GHz (27.5 – 29.5 GHz) is identified as global bands for ESIM usages at WRC-19. In the other hands, administrations are getting interested in using 28GHz for 5G services since the 28GHz 5G ecosystem is already available. Therefore, to coordinate between especially Aeronautical-ESIM services and 5G, the Republic of Korea conducted the study to investigate the applicable direction to implement A-ESIM and 5G simultaneously by assessing interference exceedance from A-ESIM to 5G as Mobile services.

The study intends to protect all types of 5G systems which are defined in Recommendation ITU-R M.2134. The study evaluates, in a given altitude of A-ESIM, how much interference exceedance at which location from BS A-ESIM causes to protect all 5G system in 50% and 5% location probability of clutter environment. The study results in the 6 km altitude at which A-ESIM does not cause unacceptable interference from -6dB I/N of all 5G systems based on medium (50%) location probability of clutter environment. It is shown in Figure below



Furthermore, the study results in within 47.6 km ground distance from A-ESIM where BS receives exceedance interference under 5% location probability of clutter environment. It is shown in Figure below



With those results, as the main purpose of study, 6 km of ESIM altitude is an appropriate altitude above which A-ESIM service could be allowed without any restriction to 5G services. It means normally to ensure the protection of terrestrial 5G services from A-ESIM below the altitude of 6 km. In addition, It could be also learned that neighboring countries located less than 147.6 km far from an international airport could receive unacceptable interference of A-ESIM with 5% probability of location. It is due to the fact that an international takeoff flight could move at least 100 km[10] at ground level to reach 6 km altitude.

7.5 Singapore

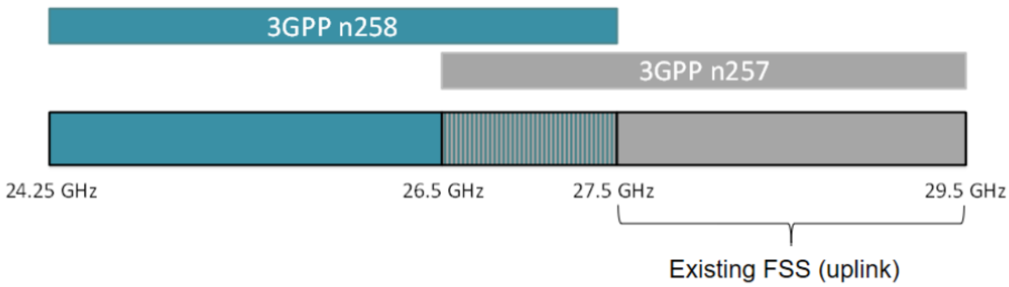


Figure 16 : mmWave bands and incumbent services in Singapore

Singapore has noted that number of mmWave bands such as the 26 GHz and 28 GHz (i.e., 24.25 – 27.5 GHz and 27.5 – 29.5 GHz) have been identified for 5G deployment. Many stakeholders have agreed that mmWave bands are important in providing extremely high data rate and capacity, complementing the sub-6 GHz bands that deliver coverage and service continuity. However, as per propagation characteristics of mmWave bands, 5G mobile systems operating in mmWave spectrum will mainly be deployed in hotspots and indoor scenarios.

Singapore has observed that developments in the 28 GHz band had been driven by major mobile markets such as the U.S., South Korea and Japan, and early 5G deployments are taking place in this band. The ecosystem, use-cases and business models developed in the 28 GHz are also estimated to accelerate the development of the other mmWave bands, particularly the 26 GHz band. Wide tuning range spanning across 26 GHz and 28 GHz bands in commercial equipment will benefit mmWave deployment.

Satellite community has drawn the attention towards 28 GHz in specific, where in, 28 GHz band is heavily used worldwide for various satellite services and extensive satellite investments have

[10] This distance was estimated from www.flightstats.com

been incurred in the 28 GHz band. The 28 GHz band is also seen as a critical band for the continued innovation and deployment of the high throughput satellites ("HTS") and very high throughput satellites ("VHTS"). Satellite community feels that co-channel coexistence between satellite services and 5G networks is generally difficult, and that FS and FSS in neighbouring countries would cause interference to the IMT services deployed in the 28 GHz band in Singapore.

In Singapore, the 28 GHz band is currently used for FSS (uplink), and specifically transmission from maritime vessels to the satellites, to provide on-board broadband connectivity. Singapore recognises that coexistence between IMT and FSS services could be made possible through coordination of the technical parameters and usage in this band.

In future, it is also expected that there will be additional satellite deployments in the 28 GHz band for aircraft platforms. However, since satellite operations are confined to air and space platforms or Earth station in motion(ESIM), Singapore is of the view that coexistence between these satellite service and 5G is possible. If necessary, IMDA will put in place operational guidelines within the licensing condition for satellite services to mitigate interference issues. For example, the minimum distance away from shore and stage of flight for these platforms to transit from terrestrial to satellite services. With the exception of satellite services, there are no indications from the industry of any future planned local deployments in this band.

After taking a comprehensive view on global developments related to the use of the 26 GHz and 28 GHz bands for 5G services, IMDA has decided to allocate these bands on a primary basis to mobile service, in addition to existing allocations, if any. Under this arrangement, mobile service and fixed satellite service operating in the frequency band 28.5 – 29.5 GHz will be on a co-primary basis. Stations in the FSS are expected to take measures to ensure protection of, and not impose undue constraints on, 5G services operating in the band[11].

7.6 United States of America

FCC-16-89A1 report has noted that mmWave high frequencies previously have been best suited for satellite or fixed microwave applications; however, recent technological breakthroughs have newly enabled advanced mobile services in these bands, notably including very high speed and low latency.

In 27.5-28.35 GHz and 38.6-40 GHz bands, commission create new upper microwave flexible use licenses authorizing mobile operations in these bands using geographic area licensing. In the 27.5-28.35 GHz band (28 GHz band), Commission adopt county-sized geographic area licenses. In the 38.6-40 GHz band (39 GHz band), FCC adopt Partial Economic Area(PEA) licenses. FCC maintain the co-primary Federal FSS and MSS allocations in the 39.5-40 GHz band, limited to military systems.

The Commission proposed to grant mobile operating rights to existing fixed Local Multipoint Distribution Service (LMDS) and 39 GHz band licensees. LMDS operates in the 28 GHz and 31-31.3 GHz bands. The 28 GHz band is part of the larger 27.5-29.5 GHz band, which is allocated to the fixed, fixed-satellite (Earth-to-space), and mobile services on a primary basis for non-Federal use. As per Second LMDS Report and order had put them on notice that mobile service might eventually be authorized in the 28 GHz band.

In the Second LMDS Report and Order, the Commission stated. Although LMDS is allocated as a fixed service, we know of no reason why we would not allow mobile operations if they are proposed and we obtain a record in support of such an allocation. Commission believes this would be consistent with their goal of providing LMDS licensees with maximum flexibility in

[11] IMDA: Second-Public-Consultation-on-5G-Mobile-Services-and-Networks/Second-5G-Public-Consultation-7-May-2019

designing their systems.78. Commission grants mobile operating rights to existing active LMDS licensees. This grant is in fulfillment of the Commission's original mobile allocation for 28 GHz and its stated expectation of allowing mobile use in the band in "providing LMDS licensees with maximum flexibility in designing their systems

Opponents of authorizing new flexible and mobile use in the 28 GHz band raise three basic objections:

(1) that there is no international consensus to authorize mobile services in the band;

(2) that LMDS operators do not have an equitable expectation of mobile rights in the band; and (3) that mobile services in the 28 GHz band would impair vital satellite services.

Most industry evaluations of potential mmW mobile base station deployments appear to assume that such stations' antennas will be tilted downward at a slight angle, typically from a street lamp pole or a location on a building at a similar height[12]. Intel explains that this configuration is necessary not only to direct transmissions toward user equipment but also to limit interference between adjacent cellular base stations. In fact, says Intel, failure to adopt this downtilt configuration would impair throughput to users at cell edges by about 60 percent.

Mobile base stations in this band will probably use antenna systems that employ dynamic beamforming techniques to produce beams as narrow as 1.0 degree[13] [14] [15] [16], which will substantially reduce the likelihood that such beams will point directly at satellite receivers. User equipment will also employ antenna arrays to generate dynamic beamforming, varying both azimuth and elevation in order to maintain signal connections with their base stations. Again, terrestrial operators are likely to deploy this technology of their own accord: by Intel's analysis, choosing not to use dynamic beamforming technology would reduce throughput at cell edges by about 70 percent.

Base stations and user equipment will also likely employ dynamic power control, both to avoid draining batteries and to limit intersystem interference. In fact, both base stations and user equipment could be entirely silent much of the time; terrestrial operators report that, in current deployments, network loading rarely exceeds 30 percent. All of these features will limit the extent of skyward transmissions from terrestrial mobile systems.

FCC has reviewed the studies submitted by the various parties, including the satellite operators. FCC conclude that the various studies submitted by the parties do not support establishment of an aggregate interference limit. From the satellite operators' perspective, part of the challenge is that mmW mobile is a new, rapidly evolving technology, and the terrestrial mobile industry is still developing system designs and propagation models. Even so, there has been substantial progress in that regard[17], and the interference models submitted by satellite operators in this proceeding do not take into account prospective features of mmW mobile systems that are readily accessible on the public record, as recounted above., for example, assumes that mmW

[12] 148 Young-Han Nam, et al., of Samsung Telecommunications America, Full-Dimension MIMO (FD-MIMO) for Next Generation Cellular Technology, IEEE Communications Magazine, Vol. 51, No. 6, June 2013, 172 at 174

[13] 5G Channel Model for Bands up to 100 GHz, (May 2016, revised version 2.1)

[14] Robert W. Heath, Jr. "Coverage and Capacity Analysis of mmWave Cellular Systems", (June 15, 2013)

[15] Tianyang Bai,Ahmed Alkhateeb, and R. W. Heath, Jr.,Coverage and Capacity of Millimeter Wave Cellular Networks, IEEE Communications Magazine (2014 vol. 52, no. 9) at 70-77

[16] Tianyang Bai and R. W. Heath, Jr., Coverage and Rate Analysis for Millimeter Wave Cellular Networks, IEEE Transactions on Wireless Communications, (2015 vol. 14,no. 2)

[17] AT&T, Nokia, T-Mobile, Samsung and Verizon May 6 and 12, Ex Parte Letters; 5G Channel Model; ITU-R Report M.2376-0; National Institute of Science and Technology, Communications Technology Laboratory,5G mmWave Channel Model Alliance

mobile user equipment will employ no beamforming at all, and will generate omnidirectional signals. Interference models submitted by other parties do not adequately account for, and in some cases do not take into account at all, antenna beamwidths, downtilts, beamforming, power control, traffic patterns, number of simultaneously transmitting stations, the obstruction losses that terrestrial signals are likely to encounter before reaching satellites at low elevations, and the fact that the majority of transmissions will occur indoors.

Terrestrial operators have every incentive to design networks that direct the signals they are transmitting to the locations of the receivers – either another fixed point on a vertical structure, or a mobile unit within a couple of meters of the ground – especially given the propagation characteristics of these frequencies. Furthermore, mobile units, which are likely to be transmitting at angles more skyward, are operating at powers significantly lower than base stations.

For the reasons stated above, FCC has concluded that the satellite industry has not shown that it has a legal right to protection from aggregate interference or that harmful aggregate interference is likely to occur from the mobile operations now being authorized for LMDS. Commission also recognize that SES, EchoStar, and ViaSat believe that satellite and mobile operations can coexist. Nonetheless, FCC are sensitive to the concerns raised. FCC note that the satellite and wireless industries have begun the process of modeling the terrestrial systems under consideration for this band to provide further information concerning their potential impact on satellites. FCC encourage both industries to continue working cooperatively on this issue, including by submitting any relevant data demonstrating changes in the amount of aggregate interference.

7.7 Europe

The CEPT has harmonised the 26 GHz band (24.25 – 27.5 GHz) for 5G system, through ECC Decision (18)06 for implementation across Europe.

Within the European Union (EU), the European Electronic Communications Code (ECCC) directive specifies the availability of at least 1 GHz of the 26 GHz band by the end of December 2020. The band was identified by the Radio Spectrum Policy Group and harmonized worldwide for IMT at WRC-19. In reality, only a few countries achieved this objective, with the main reasons stated as lower than expected demand, uncertainty regarding the business case and a lack of clarity for the award mechanisms. Nevertheless, seven EU countries have made mmWave spectrum in the 26 GHz range available, with more expected to award part of the band by the end of 2021[18].

Among those, Finland has released the most bandwidth in the 26 GHz band: 800 MHz for each of their mobile operators. Given the large contiguous 3.25 GHz bandwidth offered by the 26 GHz band, even with such extra-large assignment per Mobile Network Operator (MNO), there was enough spectrum in the band to cater for operators' needs, while still having 850 MHz leftover to be licensed to vertical players such as local and/or private networks.

Another example is Italy, which licensed a total of 1 GHz in the 26 GHz band, i.e. 200 MHz to each of their 5 MNO, and also introduced an innovative 'club licensing' model. Under this approach, licensees will be able to share any unused spectrum from the other licensees, improving their offering and overall spectral efficiency at no extra cost. As it stands, Italy is the

[18] Those include Denmark, Finland, Germany, Greece, Italy, Slovenia and the U.K. Russia has also already awarded spectrum in the 26 GHz band for 5G. Spectrum awards for 26 GHz in Spain, Sweden, Croatia, Estonia and Malta are expected later this year.

only European country with a 5G mmWave network, which FastWeb has operated since December 2020[19].

Regarding the 28 GHz band (27.5-29.5 GHz), in the CEPT this band is identified for FS systems and FSS systems. The FSS applications include coordinated earth stations, uncoordinated earth stations and ESOMPs/ESIMs – see ECC Decisions (05)01, (13)01 and (15)04. According to the CEPT Roadmap for 5G[20], the 28 GHz band is not available for 5G systems.

CEPT is also developing new deliverables to establish harmonised measures for the use of 5G systems in the bands 40.5-43.5 GHz and 66-71 GHz. This work is partly driven by a mandate from the European Commission to CEPT[21].

7.8 India

On 30th November 2022, Telecom Regulatory Authority of India (TRAI) has released a Consultation Paper [22] on "Auction of spectrum in the frequencies identified for International Mobile Telecommunications (IMT) / 5G". Consultation has sought recommendation from the stakeholders on Reserve price, band plan, block size, quantum of spectrum to be auctioned and associated conditions for auction of spectrum in 526-698 MHz, 700 MHz, 800 MHz, 900 MHz, 1800 MHz, 2100 MHz, 2300 MHz, 2500 MHz, 3300-3670 MHz and 24.25-28.5 GHz bands for IMT/5G.

Auction of following spectrum bands for 5G was conducted by the DoT which took seven days and 40 rounds for a license duration of 20 years –

(i) 612-703 MHz
(ii) 703-803 MHz
(iii) 3 300-3 670 MHz
(iv) 24.25-27.5 GHz

Spectrum procured by the MNOs is as shown below -

		Rjio										Bharti									
Sno	LSA	600	700	800	900	1800	2100	2300	2500	3600	26000	600	700	800	900	1800	2100	2300	2500	3600	26000
1	AP		10							100	1000									100	800
2	AS		10	5						100	1000				3.8					100	800
3	BH		10							100	1000						5			100	800
4	DL		10							100	1000						5			100	800
5	GU		10			10				100	1000						5			100	800
6	HA		10							100	1000						5			100	800
7	HP		10							130	1000					5				100	800
8	JK		10	5						130	1000				5					100	800
9	KA		10							130	1000									100	800
10	KE		10							130	1000						5			100	800
11	KO		10							100	1000					5				100	800
12	MP		10			10				130	1000									100	800
13	MA		10			10				100	1000					5				100	800
14	MU		10							100	1000					4				100	800
15	NE		10	5						130	1000				4					100	800
16	OR		10			10				100	1000					5.2				100	800
17	PU		10							100	1000									100	800
18	RA		10			10				130	1000									100	800
19	TN		10							100	1000									100	800
20	UPE		10			10				100	1000					0.8				100	800
21	UPW		10	5						130	1000									100	800
22	WB		10							100	1000						5			100	800

		VI										Adani									
Sno	LSA	600	700	800	900	1800	2100	2300	2500	3600	26000	600	700	800	900	1800	2100	2300	2500	3600	26000
1	AP					3.4			10	50	200										50
2	AS																				
3	BH									50											
4	DL									50	200										
5	GU									50	450										100
6	HA									50	400										
7	HP																				
8	JK																				
9	KA						5			50	200										50
10	KE									50	800										
11	KO									50	200										
12	MP									50	400										
13	MA									50	400										
14	MU									50	200										100
15	NE																				
16	OR																				
17	PU								10	50	300										
18	RA									50	300										50
19	TN									50	300										50
20	UPE									50	250										
21	UPW									50	350										
22	WB									50	400										

Summary:

S.			**Spectrum Allotted on 05-08-2022**

[19] https://www.analysysmason.com/contentassets/3716b071d2f647c9a9e57e56900b4f66/analysys-mason---status-costs-and-benefits-of-5g-26ghz-deployments-in-europe.pdf

[20] https://www.cept.org/Documents/ecc/57839/ecc-20-055-annex-15_cept_5g_roadmap

[21] https://cept.org/files/6813/ECC(20)057-A01_Mandate%20to%20CEPT%20on%20mm-wave%20bands.pdf

[23] The Planned bands used by GSO systems in accordance with Appendices 30, 30A and 30B of RR may not be auctioned. Use of Planned bands by foreign GSO satellites is not permitted in India.

No.	Freq Band MHz	Spectrum for Auction MHz	Adani	Bharti	Jio	Vodafone
1	26000	62700.00	400	17600.0	22000.00	5350.0

The results of these auctions are summarized below:

Reliance Jio:

Reliance Jio has also acquired the 1,000MHz spectrum in the millimeter wave band (26GHz) in each of the 22 circles, total 22,000 MHz, which will be crucial for the company to provide high-quality streaming services.

Airtel:

India's second-largest service provider, Bharti Airtel, acquired 17,600 MHz spectrum in the millimeter wave band (26GHz) by securing a pan-India footprint and selected to purchase of radio waves in low and mid-band spectrum.

Vodafone Idea:

Vodafone Idea has acquired mmWave spectrum (26 GHz band) in 16 LSA, total 6228 MHz

Adani Data:

The Adani Group, a multi-national business conglomerate that made a surprise entry in the auction through its subsidiary Adani Data Networks, purchased only 400MHz spectrum in 26 GHz band The quantity indicates that the spectrum will be mainly used for setting up 5G private networks for its ports, airports and other businesses across the country.

DoT planned for additional 5500 MHz Spectrum for 5G Services:

DoT has formed an internal committee to chalk out a strategy to incorporate 37.0 - 42.5 GHz as International Mobile Telecommunication (IMT) bands, which will allow telecom companies to use the spectrum for 5G Services. This band, is also known as the millimetre wave band, can be useful in offering 5G fixed wireless access services.

After DoT gives its proposal on the 37.0-42.5 GHz band, the matter will be taken to a committee of secretaries, which will officially notify the band as IMT. Once that happens, the spectrum can be put on sale.

DoT plans for auction of spectrum bands for space based services:

DoT has sent a reference to TRAI for evaluating and recommending the government on auction of space spectrum on exclusive basis with additional feasibility of sharing of auctioned spectrum bands between satellite networks and terrestrial networks. The frequency bands[23] under consideration for auction are as follows –

(i) 10.7-12.7 GHz (s-to-E)
(ii) 12.75-13.25 GHz (E-to-s)
(iii) 13.75-14.5 GHz (E-to-s)
(iv) 17.7-18.6 GHz (s-to-E)[24]
(v) 18.8-21.2 GHz (s-to-E)
(vi) 27.5-31 GHz (E-to-s)[25]

7.9 Indonesia

5G trial progress in Indonesia

Indonesia has noted that mm Wave bands such as 26 GHz and 28 GHz have been identified for 5G deployments. Mm Wave band is important as a data layer in providing very high data speed and capacity and is very supportive for 5G use cases that require very low latency.

Considering the importance of the 26 and 28 GHz bands for 5G services, since 2017 the Ministry of Communications and Informatics of the Republic of Indonesia in collaboration with cellular operators have been conducting 5G mm Wave field trials using mm Wave bands to test various use cases, namely:

1) 5G Peak Throughput
2) Interworking 4G – 5G EN-DC (E-UTRA – NR Dual Connectivity) & Mobility
3) Mm Wave propagation characteristics (range, losses, data transfer rate in indoor conditions)
4) Latency in 5G mm Wave (Cloud Gaming and 3D hologram)
5) AR – VR experiences
6) Smart City concept
7) Fixed Wireless Access

Details of field trials in Indonesia are contained in Annex1.

8 Summary

[Editor's Note: Concerns were raised about the inclusion of this section 8.4 that may be too conclusive and would make readers confused. If retained, this section should be reviewed when the preceding sections are stable.]

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[23] The Planned bands used by GSO systems in accordance with Appendices 30, 30A and 30B of RR may not be auctioned. Use of Planned bands by foreign GSO satellites is not permitted in India.

[24] 17.7-18.4 GHz is also used for E-to-s

[25] 27.5-28.5 GHz has been identified for implementation of 5G in India

This report has found similarities among case studies from USA Japan and GSA with respect to interference scenario, deployment, arguments, and conclusions in the band between 27-29.5 GHz. We have also noted that administrations in region 1, 2 and 3 have developed early interest in band 37 GHz to 43 GHz band for the deployment of 5G services, which are in line with 3GPP-specified bands. Administrations have recognized that the realistic modeling of mmWave 5G with key design component such as dynamic beamforming, power control are indispensable to evaluate the interference among operating services. Studies conducted by the USA and Japan shows that co-existence between 5G services and satellite services in band between 27-29.5 GHz is possible.

Korea has highlighted the co-existence challenges of 5G system with A-ESIM. The study result shows that A-ESIM operation should be restricted below 6 km altitude for 5G to operate in non-interfering manner.

Industry has shared valuable analysis on how LTE and mm Wave 5G could be deployed to leverage potential of mm Wave band for capacity layer, while coverage layer is provided by the LTE. Report has also indicated that wider bandwidth could enhance achievable capacity of mm Wave.

Globally administration is conducting field trials to evaluate the practical achievable throughput for mobile services and for FWA

Report has captured most of the aspect of 5G implementation, which includes filed trials, 5G co-existence, and 5G deployment scenario’s using mm Wave band.

In the end, we also suggest that, a new study on how to deploy 5G systems in mm Wave bands taking into account the allocations and operations of systems in other services will be helpful. Such study could include technical and/or regulatory conditions for the coexistence of 5G systems with other services. AWG is the right place to conduct such study which would assist APT member countries to make decisions on 5G deployment in mm Wave bands.

ANNEX 1: Field Trials

Field Trials in Romania

The objective of the Friendly User Trial in Romania was to put 5G FWA to the test in a European environment so e could collect valuable information in terms of performance, installation, customer voice and so on.

We used Samsung's commercial 5G FWA Radio Access equipment, including a virtualised RAN, Access Units and CPEs together with Cisco's virtual Packet Core and Orange Romania's infrastructure, as illustrated in Figure below[26].

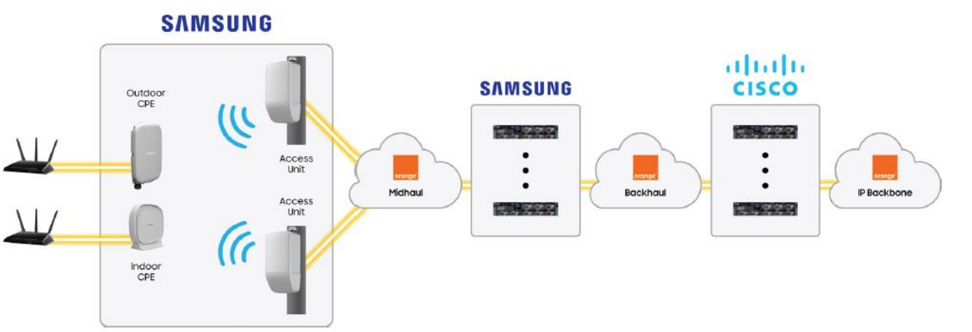


Figure 17 5G trial deployment setpup for CPE

As illustrated in figure- 12 500MHz within the 26.5 and 27.5 band was used for the Trial, which translated into an aggregated capacity o 6.25Gbps.

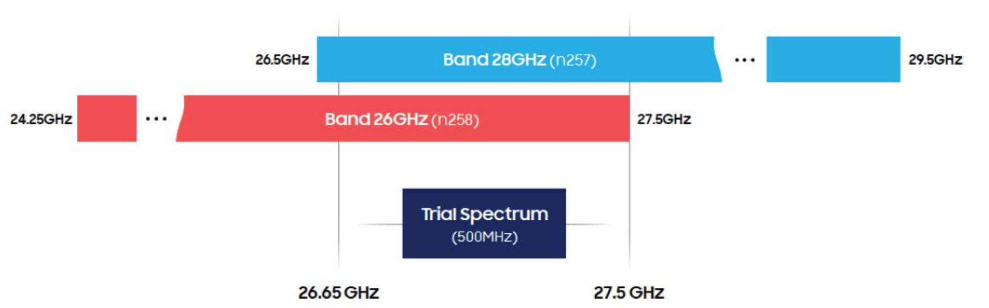


Figure 18 Trail spectrum in 26 & 28 GHz

3D Radio Planning tools are required to make mmWave networks viable as we need to understand coverage before deploying the network and look for the best cell site locations.

[26] https://www.samsung.com/global/business/networks/insights/case-studies/5g-for-fixed-wireless-access-orange-romania-case-study/

CPEs in good radio conditions

Samsung CPE ID	Service Cell	Distance from AU (m)	CPE Type LoS/NLoS	BRSRP (dBm)	DL / UL Speed (Mbps)	SINR (dB)	Latency (ms)
S613C50450	Cell15	160	Outdoor/LoS	-74	856 / 330	22	11
S614200325	Cell15	530	Outdoor/LoS	-76	917 / 354	24	12

Samsung CPE ID	Service Cell	Distance from AU (m)	CPE Type LoS/NLoS	BRSRP (dBm)	DL / UL Speed (Mbps)	SINR (dB)	Latency (ms)
S614200305	Cell17	321	Outdoor/LoS	-75	860 / 114	24	12
S614200322	Cell17	763	Outdoor/LoS	-77	901 / 140	22	11
S613C50457	Cell17	390	Outdoor/LoS	-79	918 / 153	22	12

CPEs in medium radio conditions

Samsung CPE ID	Service Cell	Distance from AU (m)	CPE Type LoS/NLoS	BRSRP (dBm)	DL / UL Speed (Mbps)	SINR (dB)	Latency (ms)
S613C50439	Cell15	781	Outdoor/LoS	-84	621 / 170	N/A	12
S614200310	Cell15	722	Outdoor/LoS	-85	952 / 169	22	12

Samsung CPE ID	Service Cell	Distance from AU (m)	CPE Type LoS/NLoS	BRSRP (dBm)	DL / UL Speed (Mbps)	SINR (dB)	Latency (ms)
S614200315	Cell17	1119	Outdoor/LoS	-84	954 / 70	21	11

CPEs in poor radio conditions

Samsung CPE ID	Service Cell	Distance from AU (m)	CPE Type	BRSRP (dBm)	DL / U Speed (Mbps)	SINR (dB)	Latency (ms)
S614367088	Cell17	321	Indoor/LoS	-93	667 / 67	20	12
S614367109	Cell17	452	Indoor/LoS	-94	491 / 137	17	9
S76D0111	Cell17	358	Indoor/LoS	-96	711 / 18	13	9
S613C52804	Cell17	560	Indoor/LoS	-98	939 / 141	12	15
S613C52805	Cell17	475	Indoor/LoS	-98	807 / 132	15	14
S613C50459	Cell17	847	Outdoor/NLoS	-100	342 / 4	11	12
S614367101	Cell17	400	Indoor/NLoS	-102	521 / 64	0	11

Table 7: Results obtained during 5 trails in Romania with CPE

Summary

Customer feedback was overwhelmingly positive, with some users reporting a better experience than on their current fixed broadband services. Cell15 (rooftop) has better throughput, higher data volumes, better RSRP, CQI,Rank Indicator & Measurements. Cell17 (hilltop) performance was hindered by the NLoS conditions and a number of distant CPE locations. LoS CPEs, both outdoor and indoor, delivered a solid DL performance almost regardless of radio conditions, whereas UL performance was more dependent on radio conditions (additional beamforming gain in downlink, which was not applicable for uplink). NLoS Outdoor CPE showed a decent performance providing current fibre-like service levels on DL Outdoor-to-Indoor Loss did have an impact in the RSRP, with values between -90 and -100dBm.

Field Trials in USA

5G mmWave delivers unparalleled user experience. 3.6 Gbps in peak download speed and significant gain in average throughput observed by 5G mmWave users. 28 GHz (n257) with NSA option 3xusing 2.1 LTE anchor has deployed at railway station for field-testing[27].

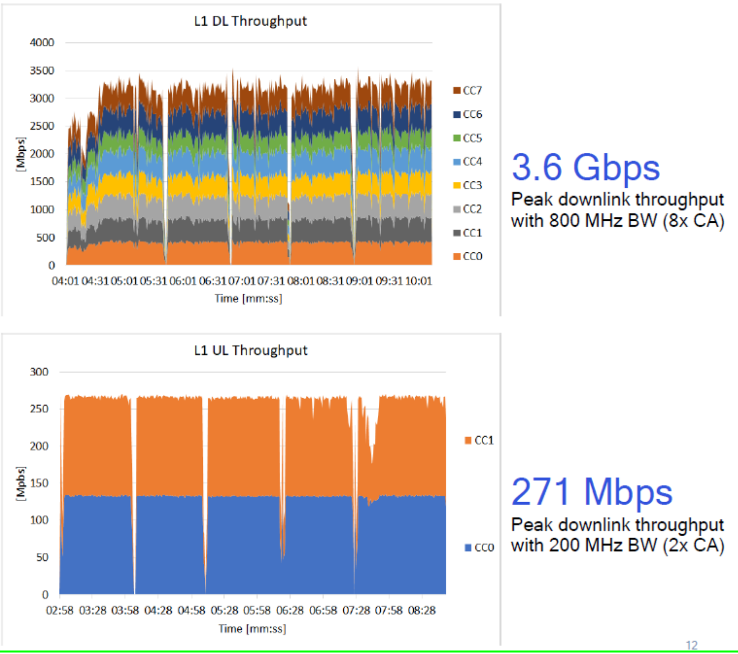


Figure 19 : Results obtained during 5G trials in USA for mobile service

Rural America: Extended-Range mmWave delivers significant coverage improvement

Field trial collaboration with U.S. Cellular operator and Ericsson.

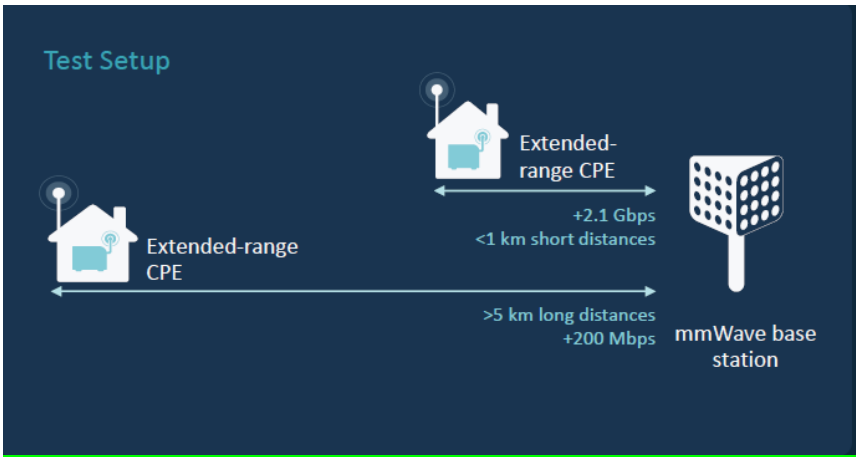


Figure 20 Results obtained during 5G trials in USA for CPE

Field Trails in Hong Kong S.A.R. China

In response to the Hong Kong Government proposal of establishing 5G network in 26GHz to 28GHz frequency band, PCCW has conducted a field trial aimed to explore the radio characteristics of 5G mmWave. The field trial was conducted in Lai Chi Kok area in the period of 21-May to 22-Jun 2018 and the scope of the test was concentrated on the propagation characteristics, radio signal strength coverage and indoor signal penetration capability of

27 https://www.qualcomm.com/news/onq/2020/11/10/deploying-mmwave-unleash-5gs-full-potential

mmWave in some typical environment in Hong Kong. Specific field test were conducted to measure the LoS, penetration, diffraction, reflection loses with objects. The following 7 materials were selected during test to block the UE receive antenna and the penetration loss due to material blocking is as below[28].

Material	Received RSRP	Signal loss
Clear view	-71dBm	---
Clear glass	-75dBm	4dB
Glass with sun shade sticker	-75dBm	4dB
Plasterboard	-73dBm	2dB
Wet towel	-78dBm	7dB
Semi-Wet towel	-75dBm	4dB
Thick wet newspaper	-78dBm	7dB
Thin wet newspaper	-74dBm	3dB

Table 8: Field Trail Results obtained to evaluate propagation loss in Hong Kong

Download throughput was tested with MIMO Vs Distance in LOS coverage area.

Measurements for three scenarios are summarized below.

Distance	Average RSRP	Transmission (MIMO)	Physical layer peak throughput	MAC and RLC layer peak throughput
30m	-70dBm	4T4R	14Gbps	12.9Gbps
30m	-70dBm	2T2R	9.3Gbps	8.7Gbps
120m	-80dBm	2T2R	7.9Gbps	7.1Gbps

Table 9: 28 GHz Field Trail Results obtained with MIMO in Hong Kong

Observation

The propagation loss on 28GHz mmWave is so much higher than the existing LTE band. It limits effective cell radius down to approximately 110m. Together with a high diffraction loss, 28GHz mmWave is not favorable to serve as a Macro coverage layer.

Besides, the higher penetration loss makes 28GHz mmWave not favorable to provide in building signal coverage served by surrounding outdoor base station.

On the other hand, smaller effective cell radius 28GHz mmWave NR reduced potential interference between adjacent NR. This helps 5G mmWave to serve as a capacity layer at hotspot locations. However, for extensive 5G outdoor coverage and considerable indoor user experience where indoor coverage system are not in place, a mid-band such as 3.5GHz/4.9GHz coverage layer is essential.

Field Trials in India

The Department of Telecom (DoT) has allocated spectrum to telecom operators to start 5G trials in the country, sources said. "Telecom operators have been allocated spectrum in 700 MHz band, 3.2-3.667 gigahertz (GHz) band and 24.25-28.5 GHz band across various locations," a telecom company official said. During the trials, application of 5G in Indian settings will get tested. This includes tele-medicine, tele-education and drone-based agriculture monitoring etc. Telecom operators will be able to test various 5G devices on their network. The duration of the trials, at present, is for a period of 6 months. This includes a time period of 2 months for procurement and setting up of the equipment.

[28] https://www.ofca.gov.hk/filemanager/ofca/en/content_669/tr201812_01.pdf

Field Trials in Japan

Minister of Internal Affairs and communications has conducted '5G Field Trails" with many stakeholders to create a new market through actualization of 5G. Key industry players NTT communications, KDDI, ATR, Softbank, NICT and many other players has participated in 5G Trails to show case various use case related to eMBB, URLLC, mMTC[29].

NTT Docomo has tested eMBB to ensure the necessary requirements in a dense urban area. In precise, outdoor environment with mobility speed of less than 30 km/h, bases station would be able to achieve transmission speed of 2.4 Gbps using 4.5 GHz band (BW-100 MHz), while base stations using 28 GHz band(BW-800 MHz) would be able to achieve transmission speed of 10 Gbps. In order to evaluate the long distance transmission; base station were mounted in the dense urban Tokyo skytree area and two UEs were kept in a van and on a trolley. Peak DL system total throughput of 10.2 Gbps was achieved during the trial.

In another long distance transmission experiment, BS was placed at the Tokyo Skytree's observatory, at the height of 340 meters from ground level, while UE was located on the roof of Tobu Railways Asakusa station 1.2 km aways. Results shows that in long distance transmission using 700 MHz bandwidth. DL and UL maximum throughput were 4.5 Gbps and 1.5 Gbps respectively

[29] https://5gmf.jp/en/wp-content/uploads/2019/04/The_First_Report_on_5G_System_Trials_in_Japan_2018_Rev1_0423r14_A4_5GMF-HP2.pdf

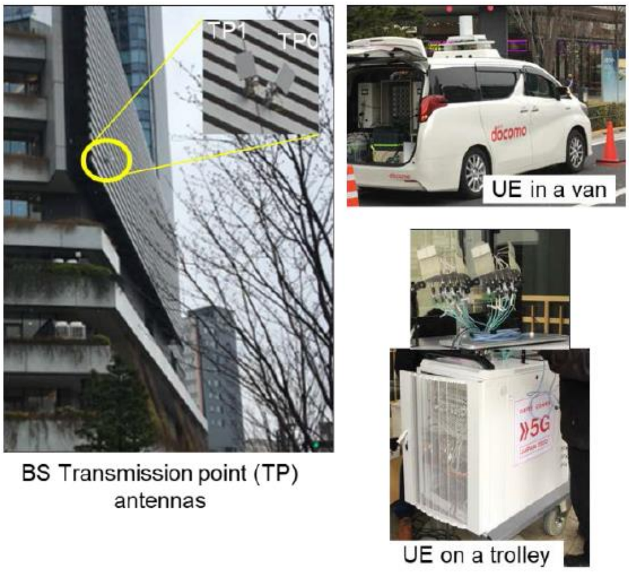


Fig. 3.2.1 Over 10 Gbps transmission experiment using two UEs

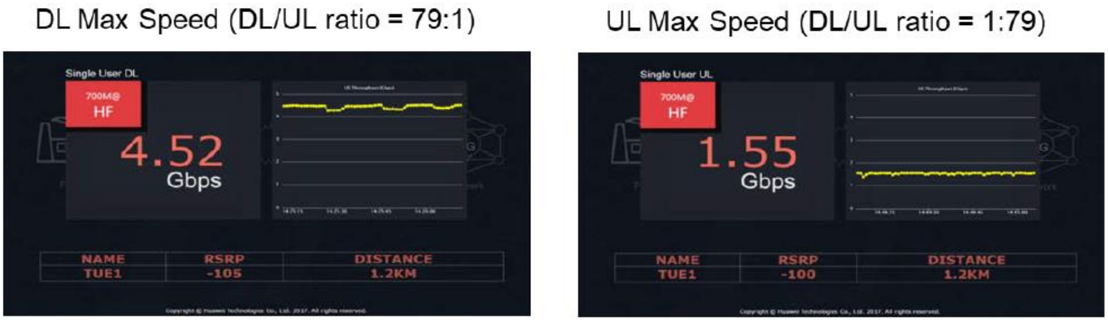


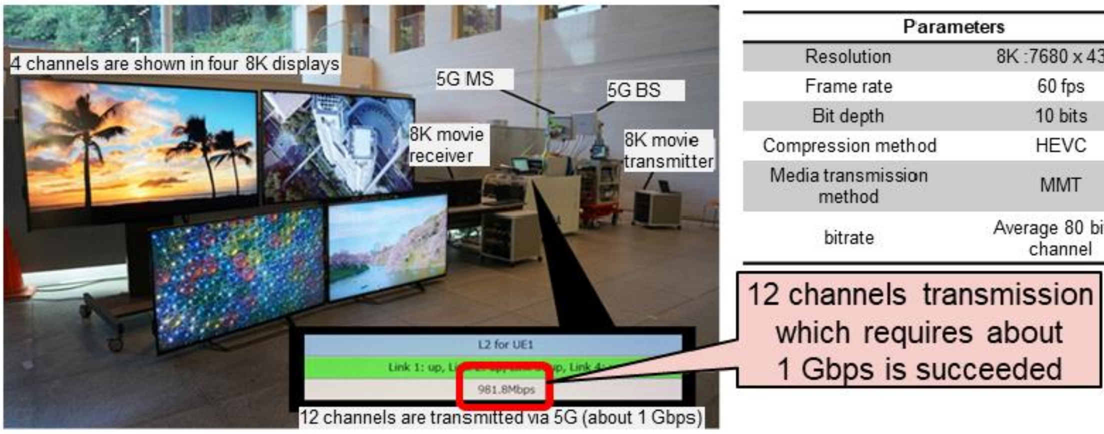
Fig. 3.2.2 Evaluation results in long-distance transmission

Figure 21: 28 GHz Field Trail Results obtained for Mobile service and CPE in Japan

System performance evaluation with services.

5G trails equipment systems could deliver 12 channel transmissions of 8K video, since 12 channels transmission of the 8K video requires about 1 Gbps, the large number of channel can be realized by 5G capability over 10 Gbps.

Security services in the field of smart city were evaluated. This includes placing security camera and security personal with wearable camera in the dense urban areas such as stadium at the Tokyo Olympics. These cameras deliver high definition video via 5G networks provided by 5G trail equipment to a security centre to be analyzed to cover wide area’s to be observed



Parameters	
Resolution	8K :7680 x 4320
Frame rate	60 fps
Bit depth	10 bits
Compression method	HEVC
Media transmission method	MMT
bitrate	Average 80 bits / channel

Fig. 3.2.4 8K video multi-channel transmission

Figure 22: 28 GHz Field Trail Results obtained for Mobile service with multi channel

In other trials, Doctors carried out remote diagnostics close-up camera and full HD video taken by tablet-type ultrasonic image diagnosis.

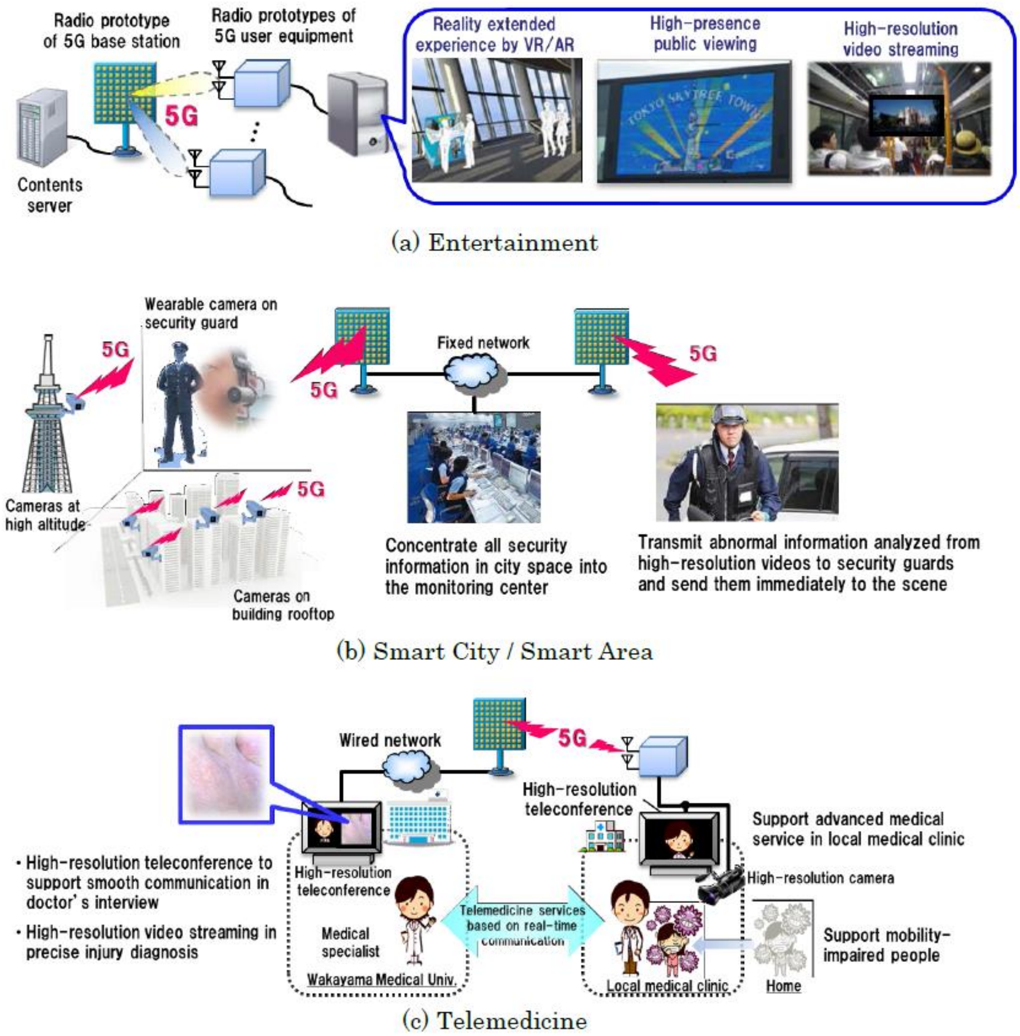


Fig. 3.2.3 5G system performance evaluations

Figure 23: Field trial setup in Japan

Field Trials in Indonesia

The Ministry of Communications and Informatics of the Republic of Indonesia in collaboration with cellular operators (Telkomsel, Indosat Ooredoo Hutchison/IOH, XL Axiata) have been conducting 5G mmWave field trials to test the 5G performance on various use cases as follows:

A. Field Test Trial with Telkomsel

Three trials were conducted:

1. <u>5G FWA Trial at Asian Games in 2018 in Jakarta</u>

The trial configuration is illustrated below:

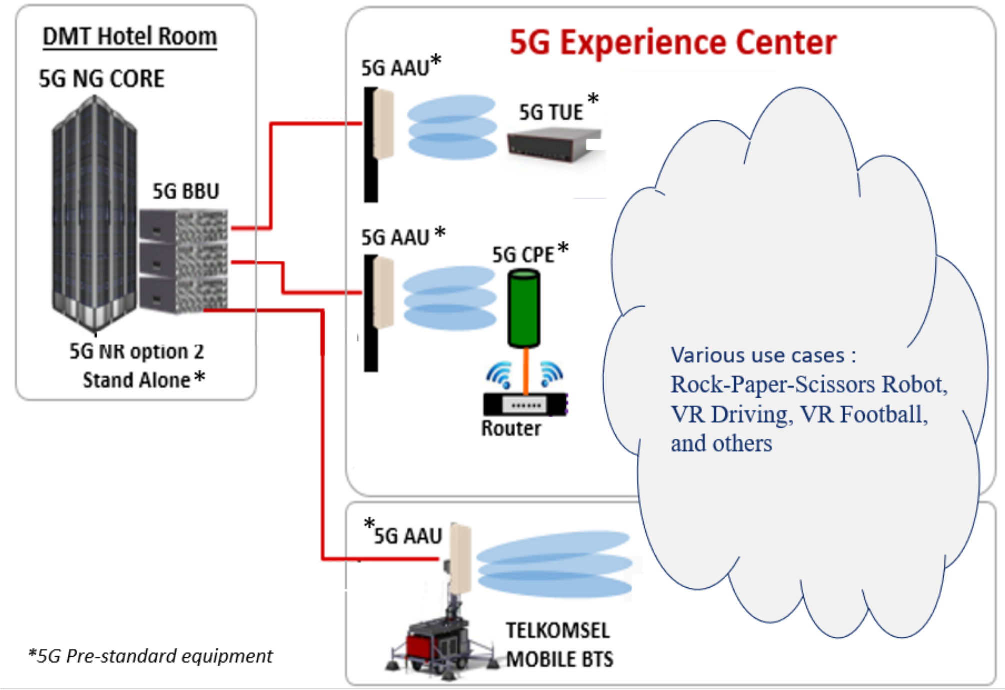


Figure xx4: 5G Trial topology in Asian Games 2018 in Jakarta

During the indoor trial, 5G performance of DL peak single-user throughput was tested with the result below:

Table xx: Single User Throughput Test Result at Asian Games 2018

Time	Event	Location	Architecture	Freq. Range	Bandwidth	Throughput
August 2018	Asian Games 2018	Gelora Bung Karno, Jakarta	SA Option 2	26.725 – 27.525 GHz	800 MHz	5.15 Gbps
				27.525 – 28.325 GHz	800 MHz	8.7 Gbps
				28.325 – 29.125 GHz	800 MHz	8.4 Gbps

On the outdoor trial, the throughput distribution performance of mmWave AAU* was tested. Various transmit power -0.9 dBm, -0.3 dBm, and -0.05 dBm were configured as illustrated below:

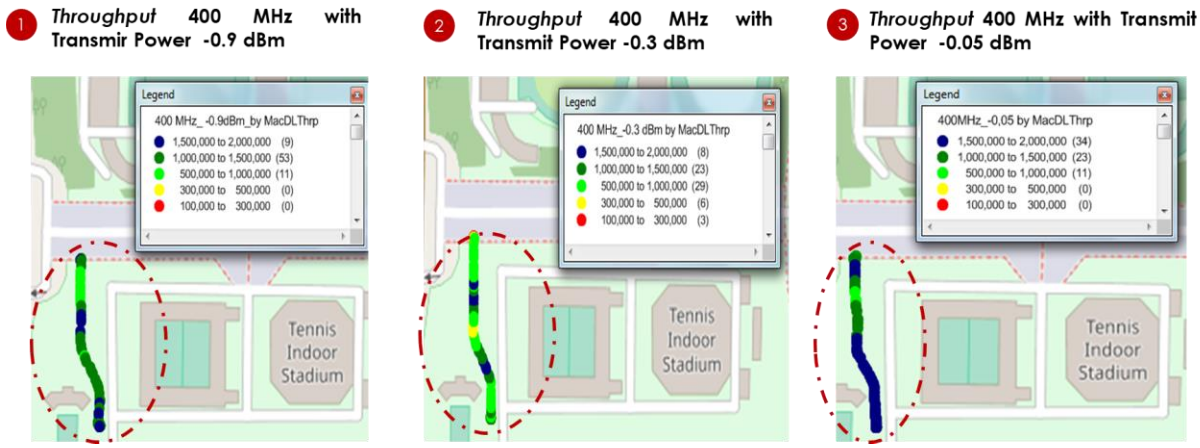


Figure xx5: Throughput distribution in various transmit power

Based on the throughput distribution above, with the same bandwidth channel allocation, the higher power transmit configured at AAU 5G, the better bandwidth signal strength which results in the better throughput performance experienced by 5G users.

*AAU (Active Antenna Unit) is the same as AAS (Active Antenna System) terminology

2. <u>5G for Industry 4.0 in 2019 in Batam</u>

The trial configuration is illustrated below:

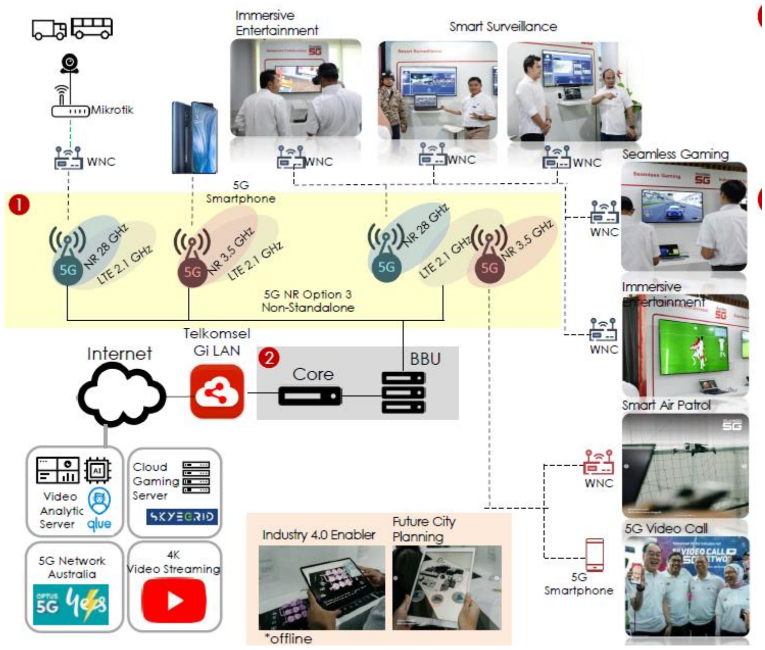


Figure xx6: Trial Topology Telkomsel 5G for Industry 4.0 in 2019 in Batam

During the indoor trial, 5G performance of DL peak single-user throughput was tested with the result below:

Table xx: Single User Throughput Test Result at 5G for Industry 4.0 in 2019 in Batam

Time	Event	Location	Architecture	Freq. Range	Bandwidth	Throughput
November	5G for Industry 4.0	Telkomsel Office, Batam	NSA Option 3x	27.9 – 28.3 GHz	400 MHz	1.9 Gbps

2019						

At 5G for Industry 4.0 event in Telkomsel Office, Batam Indoor Area, the signal strength distribution performance of mmWave AAU was tested which the output power configured for 33 dBm as illustrated below:

Figure xx7: Signal strength distribution

The signal strength performance of mmWave depended on the line-of-sight condition and distance. Based on the signal distribution, it shows that the signal strength was weakened at the farther area and blocked by the wall corner.

3. <u>5G mmWave AAU and CPE at Next Dev Summit 2019 in Jakarta</u>

The trial configuration is illustrated below:

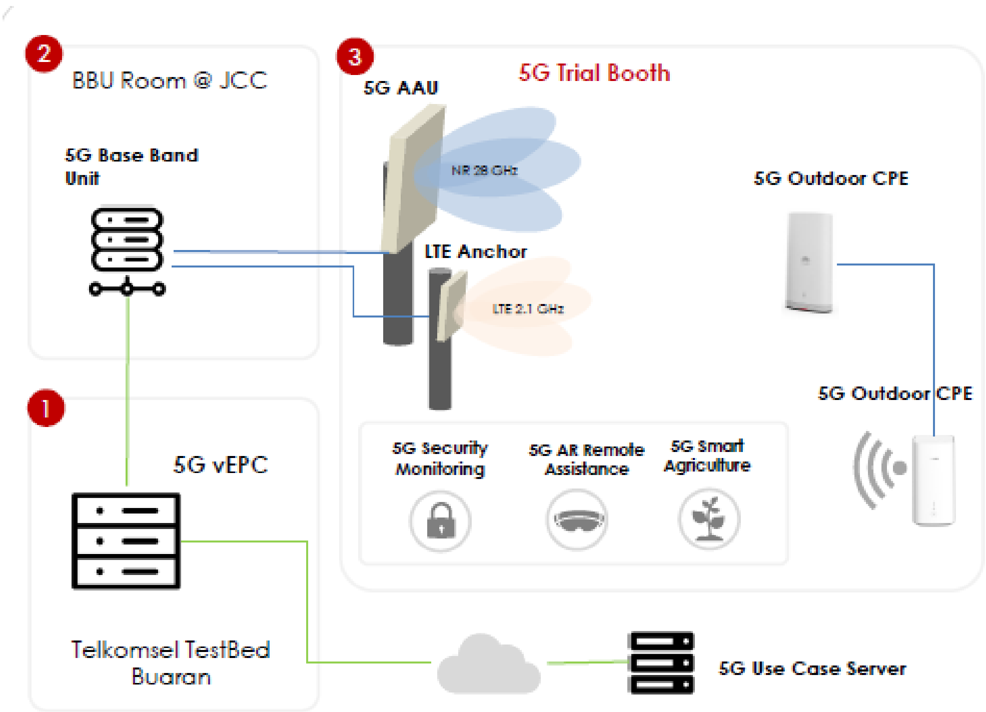


Figure xx8: Trial Topology Next Dev Summit 2019 in Jakarta

During the indoor trial, 5G performance of DL peak single-user throughput was tested with the result below:

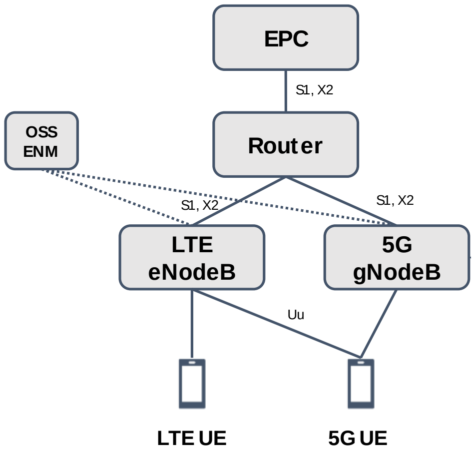
Table xx: Single User Throughput Test Result at Next Dev Summit 2019 in Jakarta

Time	Event	Location	Architecture	Freq. Range	Bandwidth	Throughput
December 2019	Next Dev Summit 2019	JCC Hall Senayan, Jakarta	NSA Option 3x	26.6 – 27.4 GHz	800 MHz	621 Mbps*

*Due to CPE capability limitation can only utilize 100 MHz bandwidth.

B. Field Test Trial with Indosat Ooredoo Hutchison (IOH)

5G mmWave trial was conducted in both indoor and outdoor environments to study the propagation characteristics and their impact on performance. This trial was aimed to understand 5G mmWave deployment options either as indoor hotspot or macro site deployment in an urban area.



3D Augmented Reality

Figure XX. 5G Trial Architecture.

- We observed the peak throughput (single user) with the following configuration:

Table XX. RAN Configuration for mmWave Trial.

Year	Location	Freq. Range	Bandwidth	Power	Throughput
2019	KPPTI Jakarta (Indoor)	27.9 – 28.3 GHz	400 MHz	5 Watts	0.4 – 1.7 Gbps*
2019	KPPTI Jakarta (Outdoor)	27.9 – 28.3 GHz	400 MHz	40 Watts	0.4 – 1.7 Gbps*

*Due to UE capability limitation to maximum utilize 100 MHz bandwidth.

- During the testing in an indoor environment, it is observed that various types of obstacles could impact the performance and the thicker obstacle would result in lower throughput. The summary of observation is shown in the following Table XX and the point of testing is shown in Figure XX.

Table XX. Performance of 5G mmWave (28 GHz) with various types of obstacles in an indoor environment.

No.	Obstacle	Throughput	RSRP	MCS	Location
1.	LOS	1.7 Gbps	– 87 dBm	24	1
2.	NLOS / Reflection	0.6 Gbps	– 105 dBm	12	2
3.	LOS with Body Shield	0.7 Gbps	– 105 dBm	15	3
4.	2-Ways Body Shield	< 0.4 Gbps	– 124 dBm	< 10	3
5.	Full Body Shield	5G Dropped	< – 140 dBm	–	3
6.	Inside a backpack	> 1 Gbps	– 93 dBm	>20	3
7.	Window glass	0.7 Gbps	– 105 dBm	12	4

8.	Open glass door (LOS)	0.7 Gbps	– 102 dBm	12	5
9.	Closed glass door (LOS)	0.4 Gbps	– 112 dBm	10	5

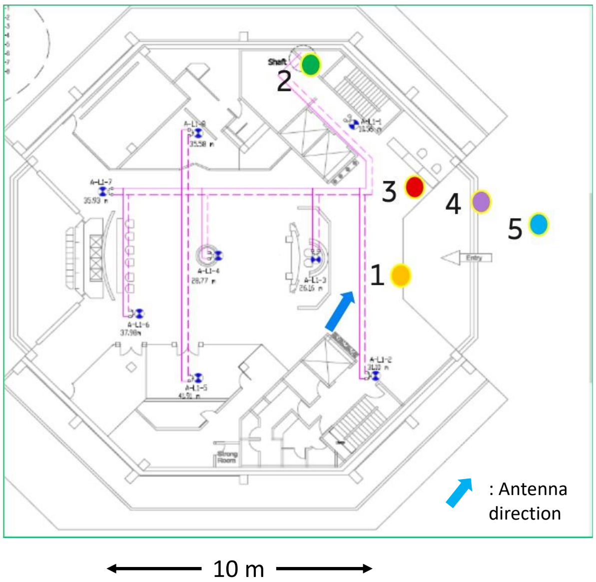


Figure xx. Testing Position for Indoor Test.

- Subsequently, the same methodology was performed for outdoor testing at surrounding IOH HQ Office (KPPTI) with various types of obstacles i.e., LOS (close and long-distance), foliage, building/wall, and inside a car. The summary of observation is shown in Table XX and the testing position is shown in Figure XX.

Table XX. Performance of 5G mmWave (28 GHz) with various types of obstacles in an outdoor environment.

No.	Obstacle	Throughput	RSRP	MCS	Location
1.	LOS (20 m)	1.6 Gbps	– 88 dBm	24	1
2.	LOS (200 m)	1.2 Gbps	– 100 dBm	15	2
3.	Light Foliage	0.7 – 1 Gbps	– 100 dBm	19	3
4.	Heavy Foliage	5G Dropped	< – 140 dBm	–	4
5.	Building / Wall	5G Dropped	< – 140 dBm	–	5
6.	Inside a car	5G Dropped	< – 140 dBm	–	6
7.	Thin-Fiber canopy	0.7 Gbps	– 90 dBm	19	7
8.	Foliage at 250 m	5G Dropped	< – 140 dBm	–	8

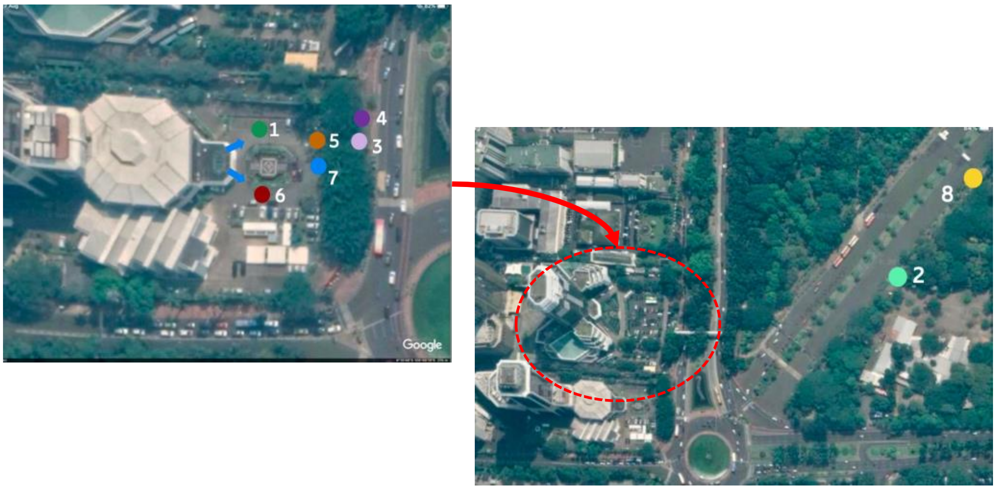
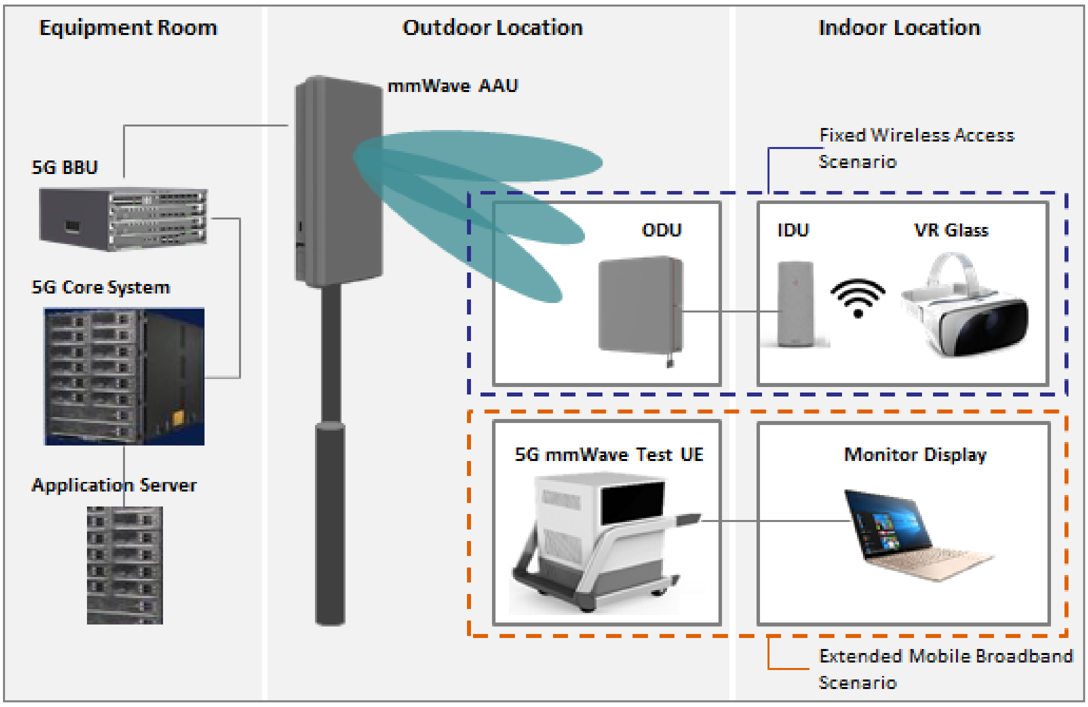


Figure xx. Testing Position for Outdoor Test.

C. Field Test Trial with XL Axiata

XL Axiata has tested eMBB, URLLC, and mMTC use cases using the 28 GHz band in 2018 (indoor) also supported by local government and in 2019 (indoor and outdoor), with the following test results:

1. <u>Test eMBB Peak Throughput, FWA, VR, Massive MIMO, and Beam Forming</u>



- Achieved Peak throughput > 10 Gbps
- VR provided throughput > 100 Mbps and latency < 1 ms
- FWA, Massive MIMO and Beam forming mmWave AAU work as expected for the various use cases tested (including smart city and VR use case)

Figure xx9: Trial Topology XL 5G for eMBB 2018 in Kota Tua

5G mmWave AAU technical specification:

- Operating Frequency: 26.65GHz - 29.19 GHz
- Bandwidth: 8*100 MHz
- Power: EIRP 62 dBm

2. <u>The Characteristics Test of mmWave 28 GHz Propagation</u>

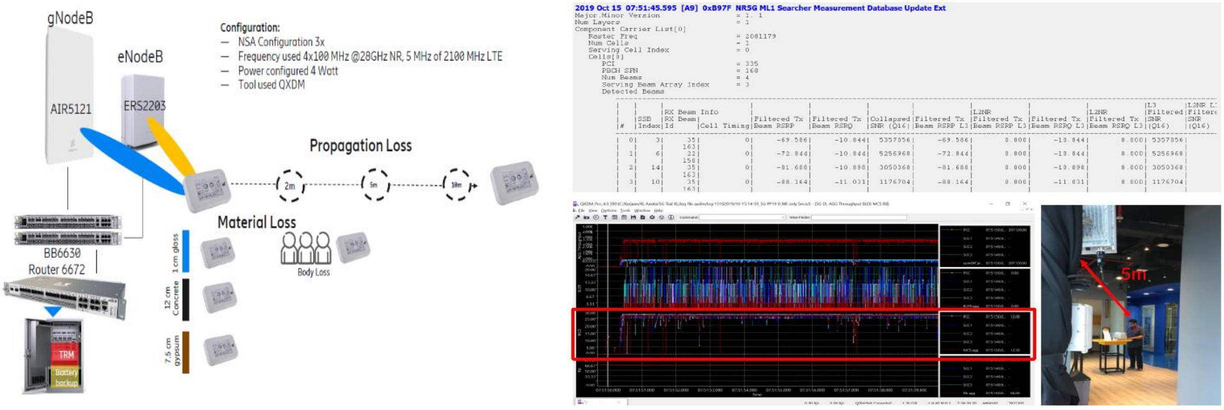


Figure xx10: Trial Topology XL 5G for mmWave propagation 2019 in Graha XL

Table xx. Performance of 5G mmWave propagation (28 GHz) with various type of Propagation Loss Testing.

Test Case	Scenario	RSRP/Loss	MCS	Throughput
Propagation	LOS 2 m	-88 dBm	15-22	1.18 GBps
Propagation	LOS 5 m	-73 dBm	25-27	1.70 GBps
Propagation	LOS 10 m	-99.6 dBm	17-22	1.25 GBps
Loss	Glass	4.46 dB	23-25 → 18-24	1.56 GBps → 1.07 GBps
Loss	Concrete	13 dB	17-22 → 5-7	1.25 GBps → 0.303 GBps
Loss	Gypsum	3.6 dB	15-22 → 15-22	1.18 GBps → 1.02 GBps
Loss	Body Loss	6.06 dB	25-27 → 19-25	1.70 GBps → 1.37 GBps

mmWave bands have high propagation loss, this will cause a low coverage range at 28 GHz, concrete has the largest losses while gypsum has the smallest losses.

5G mmWave AAU technical specification:

- Operating Frequency: 27.5–28.35 GHz
- Bandwidth: 4*100 MHz
- Power: EIRP 55 dBm

a. Test Interworking 4G – 5G (EN-DC)

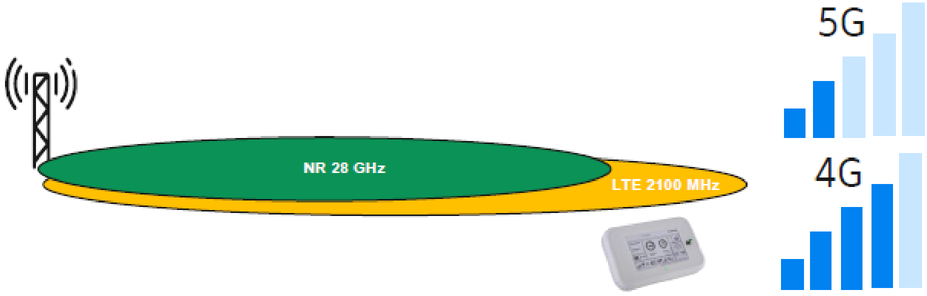


Figure xx: Trial Topology XL Interconnectivity with LTE 2019

- Dual Connectivity between 4G and 5G is working
- The Throughput of 5G in the edge of the coverage is increased after deploying EN-DC
- 4G as the coverage layer, it can increase the throughput of a user in the cell edge of the 5G coverage thus increasing the application coverage of 5G
- Having NSA of mmWave 5G with 4G is the optimum way of deploying the network, by doing 4G as coverage layer while 5G is the capacity layer
- 28 GHz should be bundled with the lower band to improve the performance, especially in cell edge
- The comparison of throughput EN-DC and Non-EN-DC can be shown in the following table:

Table xx. Performance of LTE and 5G Dual Carrier Connectivity Result

Test Case	**MCS**	**Throughput Without EN-DC (Mbps)**	**Throughput With EN-DC (Mbps)**
Test 1	5-7	323	352
Test 2	5-8	349	383
Test 3	4-6	237	274
Test 4	5-7	316	344
Test 5	5-7	329	352

b. Test 3D hologram

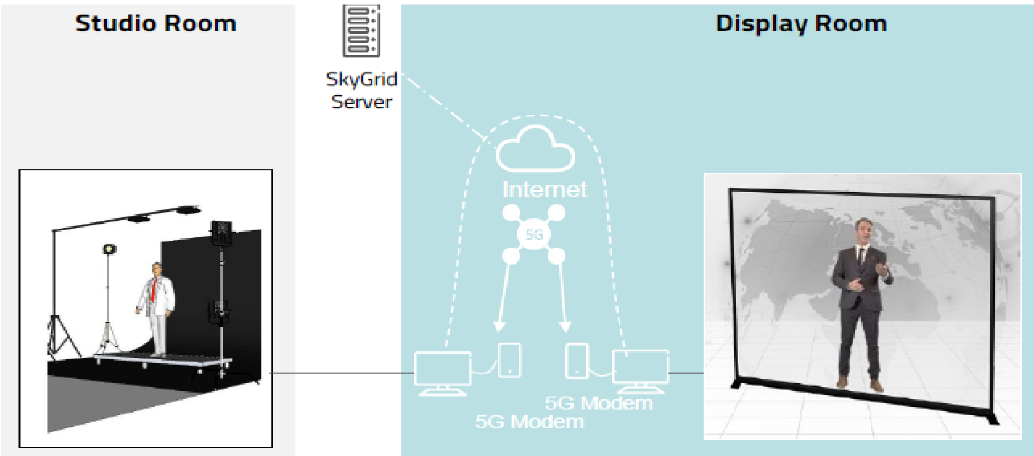


Figure xx: Design of 3D Hologram Trial in 2019

Figure xx: XL Axiata Trial in Holographic Communication via 5G Network in 2019

3D hologram interactive communication service runs as expected.