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The Economics of Releasing the V-band and E-band Spectrum in India

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1 Introduction

Broadband internet users in India have been on the rise over the last decade and currently stand at more than 290 million subscribers.[1] As this number continues to increase, it is imperative for the supply side to be able to match consumer expectations. It is also important to ensure optimal usage of the spectrum to maximise economic benefits of this natural resource. So, as the government decides to release the presently unreleased spectrum, it should consider the overall economic impacts of the alternative strategies for releasing the spectrum. In this note, we consider the potential uses of both V-band (57 GHz - 64 GHz) and E-band (71 GHz - 86 GHz), as well as the economic benefits that may accrue from these uses. This analysis can help the government choose a suitable strategy for releasing spectrum in these bands.

This note begins with a brief overview of the characteristics of the bands. After that, we present a review of the approaches different countries have taken while releasing this spectrum, and a section on the present policy stance in India. This is followed by a section on policy thinking on unlicensed spectrum bands. After that, we delve into the economic aspects of this issue, beginning with an overview of studies on how internet has impacted the Indian economy, and studies from other countries on the economic benefits of unlicensed spectrum bands. This is followed by an analysis of the potential uses of the bands in India. We attempt to quantify the scale of these uses to the extent possible, based on benchmarking with global standards. In the penultimate section, we attempt to map the economic benefits that can accrue from different uses of these bands. The note concludes with a few key insights.

2 Band characteristics

2.1 V-band spectrum

Spectrum in the V-band (57 GHz - 64 GHz) can be used for high capacity transmissions over short distances. Using point-to-point or mesh topologies, the spectrum can be put to a variety of backhaul and access uses. The large

[1] Telecom Regulatory Authority of India. *Press Release on Telecom Subscription Data*. June 31, 2017. URL: http://www.trai.gov.in/sites/default/files/Press_Release_No50_Eng_13072017.pdf.

bandwidth (7 GHz) in the band allows for wide channels in which data can be transmitted at high speeds. Further, since its propagation characteristics, especially high oxygen absorption, mitigate the level of interference, there is lesser need for active interference management. As the typical antenna beamwidths in this spectrum are less than five degrees, many links can be put in the same area just by having them point in slightly different directions. These features of the band were highlighted by TRAI in their recommendations on the allocation of these bands.

Since many countries have released this spectrum, there is now significant progress on development of technical standards, and manufacturing and sale of devices. The last few years have seen strong global momentum behind the IEEE 802.11 ad, or WiGig standard which also uses 60 GHz and is making available very low cost semiconductors and system solutions. More recently, a new standard 802.11ay has been defined, with specifications that can enable 100 Gbps communications through a number of technical advancements. Experience on usage of this spectrum in a variety of contexts is gradually accumulating. This is the right time for India to consider releasing this spectrum.

2.2 E-band spectrum

Like V-band, the E-band has large bandwidth (10 GHz) capabilities allowing transmission of high speed data over short distances (2 to 3 kms). E-band's frequencies enable point-to-point and line of sight radio communication. These unique transmission properties of very high frequency millimeter waves enable simpler frequency coordination, interference mitigation and path planning compared to lower frequency bands.[2]

E-band uses antennas which are highly directional and this coupled with the propagation limitations allows for highly focussed point to point "pencil-beam" links allowing for much higher frequency reuse in a given area. As of August 2014, more than 40 countries have come up with license plans for E-band.[3] There are some licensing exceptions, but most of the world follows a lightly licensed regime for E-band.

[2] Telecom Regulatory Authority of India. *Recommendations on Allocation and Pricing of Microwave Access (MWA) and Microwave Backbone (MWB) RF carriers*. Aug. 29, 2014. URL: https://trai.gov.in/sites/default/files/MW%20Reco%20Final29082014.pdf.

[3] Ibid.

Figure 1 Regulatory options for spectrum licensing

Individual authorisation (Individual rights of use)		**General authorisation** (No individual rights of use)	
Individual licence	**Light-licensing**		**Licence-exempt**
Individual frequency planning / coordination Traditional procedure for issuing licences	Individual frequency planning / coordination Simplified procedure compared to traditional procedure for issuing licences With limitations in the number of users	No individual frequency planning / coordination Registration and/or notification No limitations in the number of users nor need for coordination	No individual frequency planning / coordination No registration nor notification

Source: ECC Report 132

Although the E-band does not have the oxygen absorption characteristics of V-band, the availability of large spectrum allows for wider channels that can have potential uses in last mile connectivity. This spectrum band has a longer distance range as well as better weather characteristics, which make it a good frequency for backhaul usage. Both the ITU and CEPT have provided detailed channel plans for this band and its use has also been considered in India's National Frequency Allocation Table (NFAP) 2011.[4]

3 Licensing approaches: international experience

Before diving into the types of license regimes followed, it is important to understand the difference between individual and general authorisation.

As per the ECC report 132 (Article 5.1 of the Authorisation Directive), usage of radio frequencies where risk of harmful interference is negligible, should not be subject to grant of individual rights of use, and should instead have conditions of usage under general authorisation. This means that general authorisation should be used as the overarching framework, when coordination between users is not necessary. The license structures under the two types of authorisation is presented in Figure 1.

[4]Telecom Regulatory Authority of India, *Recommendations on Allocation and Pricing of Microwave Access (MWA) and Microwave Backbone (MWB) RF carriers*.

1. *Individual licensing* - This is the conventional link-by-link coordination, usually made under an administration's responsibility; sometimes, the administration delegates this task to the operators, but it keeps control of the national and cross-border interference situation.[5] The likelihood of significant interference with the use of both these bands would be low and as such individual licensing or link-by-link coordination may not be the best approach going forward.

2. *Light licensing* - It is a combination of license-exempt use and protection of users of spectrum. This model typically has a 'first come first served feature where the user notifies the regulator with the position and characteristics of the stations. The database of installed stations containing appropriate technical parameters is publicly available and should thus be consulted before installing new stations.[6] Figure 1 shows how light licensing is different under an individual authorisation structure and a general authorisation structure, with no individual coordination required under the latter. In practice, the general features of light licensing can be enumerated as follows:

   (a) For installing a new link, the regulator must be informed. There is generally a database available to view all installed links.

   (b) Licensing fees tend to be low.

   (c) Provides a first come first serve protection, in the sense that if two links are installed in one location, and there is interference between the two, in such a case the link installed first is protected and the second link will be reconfigured or removed to prevent interference.

3. *License exempt* - This method offers the most flexible and low cost usage, and is more popular in specific bands (e.g. 2.4 and 5.8 GHz) where short range devices are allocated, but fixed service applications may also be accommodated. Although this does not guarantee any interference protection by the regulator, it should be noted that alternate interference management techniques are available today to deal with the issue. Some of these include cloud based routing through mesh, single frequency network, listen-before-talk and multi-antenna signal processing.

[5] ETSI. *E-Band and V-Band - Survey on status of worldwide regulation.* 2015. URL: http://www.etsi.org/images/files/ETSIWhitePapers/etsi_wp9_e_band_and_v_band_survey_20150629.pdf.

[6] As defined by the ECC Report 80(25)

4. *Block assignment regimes* - Under this regime, assignment is made through renewable licensing or through permanent public auctions, or through other allocation mechanism. This is most common when fixed wireless access (point to multi-point) is concerned and the user is usually free to use the block in the best possible way to deploy its network. For some frequency bands this method is considered the best compromise between efficient spectrum usage and flexibility for the user.[7] The deployment of E-band and V-band is likely to see more P-MP links.

Different countries evaluate their markets and eco-systems differently and there is no uniform licensing approach towards spectrum. In the following sections, we review the general licensing framework implemented globally under both of these bands. However, a question that needs to be addressed in India's context is: does the legal framework allow any approach other than auctioning the spectrum?

3.1 Legal position on release of spectrum

It is relevant for our paper to discuss the impact of the 2G case[8] which would be considered by the Government, whenever it decides to release spectrum. In this case, the Supreme Court quashed several spectrum licenses granted to telecom service providers due to irregularities in the manner of allocation of spectrum to licensees on first-come-first-served basis. The Court observed that a duly publicised auction, conducted fairly and impartially, is perhaps the best method for discharging the burden of alienating scarce public resources like spectrum, etc as opposed to first-come-first-served basis which is likely to be misused. The Court was of the view that while transferring or alienating the natural resources, the State is duty-bound to adopt the method of auction by giving wide publicity so that all eligible persons can participate in the process.[9]

The Central Government filed a review petition that was later withdrawn. Thereafter, the Government moved the Supreme Court with a Presidential Reference[10] for its opinion on issues arising out of its 2G case. The clarification was sought, inter alia, on: whether auction is the only methodology to

[7] ETSI, *E-Band and V-Band - Survey on status of worldwide regulation*.

[8] See, Centre for Public Interest Litigation and Others. V. Union of India (2012) 3 SCC 1.

[9] Ibid.

[10] Re: Special Reference No. 1 of 2012 [Under Article 143(1) of the Constitution of India]

be adopted by the Government for alienation of all public resources in the country. The Supreme Court exercised its advisory jurisdiction and clarified that the law laid down in 2G case was limited to the facts of that case i.e., distribution of spectrum where the "Court evaluated the validity of the methods adopted in the distribution of spectrum from September 2007 to March 2008". The Court further observed, "Auction as a mode cannot be conferred the status of a constitutional principle. Alienation of natural resources is a policy decision, and the means adopted for the same are thus, executive prerogatives....However, when such a policy decision is not backed by a social or welfare purpose, and precious and scarce natural resources are alienated for commercial pursuits of profit maximising private entrepreneurs, adoption of means other than those that are competitive and [will] maximise revenue may be arbitrary and may face the wrath of Article 14 [equality before law]"

On the methodology, the Supreme Court noted, "...is clearly an economic policy. It entails intricate economic choices and the court lacks the necessary expertise to make them. It cannot, and shall not, be the endeavour of this court to evaluate the efficacy of auction vis-a-vis other methods. The court cannot mandate one method to be followed in all facts and circumstances. Therefore, auction, an economic choice of disposal of natural resources, is not a constitutional mandate."

The court in its opinion also stated that auction method may also suffer from problems and mere likelihood of abuse of any alienation method does not vitiate it unless there are actual problems. It was clarified that it is the prerogative of the Government to decide the methodology of alienation of other public resources, provided the method is transparent, fair and backed by social or welfare purpose. The Court also discussed revenue maximisation theory and stated that this need not be the sole objective while alienation of public resources and in fact this is subservient to the goal of serving common good of the society.

Auction is not the only option to alienate all public resources of the country. The key is to ensure that the method spectrum release should have a social or welfare purpose, and should not arbitrarily benefit certain parties.

As far as the question of releasing the V-band and E-band spectrum is concerned, the Government in the past has unlicensed spectrum (Wi-fi frequency) which yielded several benefits for the Indian economy. Moreover, globally the microwave bands like V-band and E-band have been either delicensed or subjected to light touch licensing. As long as it is clear that a given method of releasing the spectrum would maximise social benefits, and would not arbitrarily benefit anyone, it will probably withstand judicial scrutiny.

3.2 International experience for V-Band

A number of countries all over the world have adopted license free-frameworks for adopting the 60 GHz band. Table 1 indicates some of these along with the year in which they were adopted.[11]

Table 1 Timeline V-band adoption

Country	**Year of adoption**
Belgium	2014
Canada	2010
China	2015
Japan	2014
Korea	2013
Malaysia	2015
Philippines	2016
Poland	2014
Slovakia	2015
Switzerland	2011
UK	2010
US	2010

These countries have seen benefits in going for a license free regime and the fact that the license structure has not changed in recent times seems to be a sign of the existing structure working. While both the European Commission and the Federal Communications Commission (FCC) have made recent policy changes in the power level ranges for short-range devices (applicable to V-band), the overall license free structure has been maintained.

Singapore, is an example of a country with a licensed 60 GHz regulatory environment, for outdoor links. The rationale for such decision is based on the concern that being a highly dense urban environment, it was prudent to regulate the location of high powered links to ensure that there is no interference between band receivers. No licensing restrictions have been placed on low power band devices, which are more suitable for indoor environments.

[11] The database reporting this information is available at http://www.etsi.org/images/files/ETSIWhitePapers/etsi_wp9_e_band_and_v_band_survey_database.zip

3.3 International experience for E-band

Many countries have decided to open up the 71-76 and 81-86 GHz ITU frequencies for ultra high capacity point-to-point communications. Countries have recognised that licensing fees based on the amount of data transmission or bandwidth usage may result in extremely high tariffs that can have a detrimental effect on the adoption of these bands. As such, most regulators have decided to adopt the "light license" approach when regulating this band. Some of the countries that have opened up this spectrum are represented in Table 2.[12]

Table 2 E-band adoption and price

Country	**License structure**	**License fee**
USA	Online light license	$75 - 10 year license
UK	Light license	50 pounds per year
Czech Republic	Unlicensed	Free of charge
Russia	Light license	Minimal registration fee
Australia	Light license	AU$187 per year
UAE	Traditional PTP	4,500 Dirhams per year
Ireland	Traditional PTP	952.30 Euros per year
Jordan	Traditional PTP	JD200 per year
Bahrain	Traditional PTP	1% of generated link revenue

Both the FCC in the United States and the Ofcom in the United Kingdom were among the early adopters of these bands. In the following section, we take a deeper look at the respective approaches taken towards regulating the use of these bands.

3.4 Federal Communications Commission - USA

V-band

FCC has been working to delicense spectrum to promote wireless connectivity and other innovative uses (like RFID) which can have industrial, scientific and medical applications. Users can operate without an FCC license, any spectrum designated as "unlicensed" or "license-exempt". The Commission permits the operation of radio frequency (RF) devices within the band of (57 GHz - 71 GHz) without an individual license from the Commission or the

[12]E-Band Communications Corp. *Light licensing benefits of the 71-76 and 81-86 GHz frequency bands*. 2010.

need for frequency coordination.[13] This exemption, is however, not applicable if the equipment is being used on aircrafts or satellites, field disturbance sensors, including vehicle radar systems, unless the field disturbance sensors are employed for fixed operation, or used as short-range devices for interactive motion sensing. Further, the operators must use certified radio equipment and comply with the technical requirements, including power limits, limits on spurious emissions, etc. as stated in FCC's Part 15 Rules. Users of the license-exempt bands do not have exclusive use of the spectrum and are subject to interference. The technical standards for Part 15 are designed to ensure that there is a low probability that these devices will cause harmful interference to other users of the spectrum.[14]

The primary operating conditions are that the operator of a device must accept whatever interference is received and must correct whatever harmful interference[15] is caused. Should harmful interference occur, the operator is required to immediately correct the interference problem, even if correction of the problem requires ceasing operation of equipment causing interference.[16]

In the US, WirelessHD and WiGig commonly use the 60 GHz unlicensed band to achieve multi-gigabit data transfer over the range of a few meters. Applications of these technologies include home entertainment, data networking and wireless docking.[17] In the US, an interesting study was conducted that dispelled some common myths on 60 GHz outdoor mobile communication, to establish that outdoor 60 GHz picocells[18] can augment existing cellular networks and have the potential to deliver orders of magnitude increase in

[13] 47 C.F.R. part 15 Radio Frequency Devices (15.255). Available at https://www.law.cornell.edu/cfr/text/47/15.255

[14] FCC, Notice of Inquiry, In the Matter of Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Systems, August 20, 1998.

[15] Harmful interference is defined as "Any emission, radiation or induction that endangers the functioning of a radio navigation service or of other safety services or seriously degrades, obstructs or repeatedly interrupts a radiocommunications service operating in accordance with this chapter." See: https://www.ecfr.gov/cgi-bin/text-idx?SID=b633881c90ea1e08594154bfe7b9301a&mc=true&node=se47.1.15_13&rgn=div8

[16] 47 C.F.R. 15.5 General conditions of operation. Available at: https://www.law.cornell.edu/cfr/text/47/15.5

[17] Levin J. Milgrom P. and Eilat A. *The Case for Unlicensed Spectrum*. 2011. URL: https://web.stanford.edu/~jdlevin/Papers/UnlicensedSpectrum.pdf.

[18] A picocell is a small cellular base station typically covering a small area, such as in-building (offices, shopping malls, train stations, stock exchanges, etc.), or more recently in-aircraft. In cellular networks, picocells are typically used to extend coverage to indoor areas where outdoor signals do not reach well, or to add network capacity in areas with very dense phone usage, such as train stations or stadiums.

network capacity.[19]

E-band

On October 16, 2003, the FCC adopted a Report and issued an Order establishing service rules to promote the private sector development and use of the spectrum in the 71-76 GHz, 81-86 GHz,(E-band frequencies) and 92-95 GHz bands.[20] In 2005, this order was subsequently modified by the Memorandum Opinion and Order issued by FCC.[21] FCC adopted a *light licensing* framework for the E-band that does not require separate FCC license applications for most links or traditional frequency coordination among non-Federal Government users. A license to operate a link in the E-band spectrum consists of two parts - *a non-exclusive nationwide license combined with registration of each link.*[22]

First, an interested party has to obtain nation wide non-exclusive license from the FCC. Once approved, the licensee can register for any number of individual E-band links in the US and its territories. The non-exclusive nationwide license does not authorise operation until the link is registered as an approved link in the *Link Registration System* which is administered by three FCC-selected third party database managers. The band manager then undertakes a four-step automated analysis of the link. The licensee may use the E-band for any point-to-point, non-broadcast service. There is no limit to the number of non-exclusive nationwide licenses that may be granted for this band. The license term is ten years, beginning on the date of the initial authorisation (nationwide license) grant. Registering links will not change the overall renewal period of the license. License fee is USD 75 for a 10 year license.[23]

The applicant has to provide interference analysis to the third-party database manager to establish that the potential for harmful interference to or from all previously registered non-government links has been analysed according

[19] Zhu et al. *Demystifying 60GHz Outdoor Picocells*. 2014. URL: https://www.cs.ucsb.edu/~ravenben/publications/pdf/60pico-mobicom14.pdf.

[20] Federal Communications Commission. *Millimeter Wave 70/80/90 GHz Service*. URL: https://www.fcc.gov/wireless/bureau-divisions/broadband-division/millimeter-wave-708090-ghz-service.

[21] Federal Communications Commission. *Memorandum Opinion and Order*. Feb. 24, 2005. URL: https://apps.fcc.gov/edocs_public/attachmatch/FCC-05-45A1.pdf.

[22] Federal Communications Commission, *Millimeter Wave 70/80/90 GHz Service*.

[23] Federal government of the United States. *US Title 47, CFR Part 101. 1501 Chapter 1*. URL: https://apps.fcc.gov/edocs_public/attachmatch/FCC-05-45A1.pdf.

to the prescribed standards in the Code of Federal Regulations and generally accepted good engineering practice.[24] Further, the analysis must show that the proposed non-government link will not cause harmful interference.[25]

Further, since the 70/80/90 GHz bands are allocated on a shared basis with Federal Government users, each link must be coordinated with the National Telecommunications and Information Administration (NTIA) with respect to Federal Government operations as part of the registration process.[26]

3.5 Office of Communications (Ofcom) - UK

V-band

Ofcom has opened the spectrum in the 59-64 GHz band for fixed point to point wireless systems (FWS) and combined this with the 57-59 GHz band under one overall licence exempt authorisation approach for FWS. This decision created one contiguous and flexible block of spectrum providing 6.8 GHz of available bandwidth (57.1-63.9 GHz) taking into account two 100 MHz guard bands.[27]

The 60 GHz band has been available for FWS on a licence exempt basis across the UK, with the exception of three small geographical areas to protect Ministry of Defence radio location systems against likely harmful interference.

The UK has one of the highest densities of Wi-Fi networks in the world. A 2012 survey by Strategy Analytics found that 73.3% of UK households have a home Wi-Fi network, a proportion second only to South Korea. The UK also leads Europe in the deployment of public Wi-Fi hotspots. This goes on to define the market for license exempt radio devices in the U.K. The IEEE 802.11ad standard, sometimes referred to as Wi-Gig, effectively caters for Wi-Fi type deployments in this band and has recently been formally adopted by the Wi-Fi Alliance, with suggested applications including cable replacement for displays, wireless docking between devices like laptops and tablets, instant data synchronisation and backup and simultaneous streaming

[24] United States, *US Title 47, CFR Part 101. 1501 Chapter 1*.

[25] Ibid.

[26] Federal Communications Commission, *Millimeter Wave 70/80/90 GHz Service*.

[27] Statement on "Release of the 59 - 64 GHz band". *Ofcom*. Dec. 11, 2009. URL: https://www.ofcom.org.uk/__data/assets/pdf_file/0016/40516/statement.pdf.

of multiple, ultra-high definition and 4K videos.[28] There have been reported utilisations of 63-64 GHz band in road traffic communication.[29]

Further, UK has explored use of V-band for vehicle to vehicle communication links.[30]

E-band

In March, 2007 after substantial public consultation, Ofcom allowed a new class of license 'Self Coordinate Links' for operation in E-band frequencies. Similar to US, UK has also adopted a *light licensing* approach for E-band spectrum which can be used for point to point wireless communications. The licence fee is 50 Pounds which includes the charge for registration of the first link for the first year of the licence. Any further links registered by the licensee is charged at 50 Pounds per link per year. An applicant has to first obtain non-exclusive national licences. Thereafter, a licensee may register point-to-point fixed wireless links in the UK, through a link registration process administered by Ofcom.[31]

Ofcom follows a *first come first served basis* wherein it provides date and time record to each link on the register. This record is used to establish priority within the band for interference purposes. A link with a date time record will have priority over links registered later. If a new link is likely to cause interference to an existing link, the licensee of the new link should coordinate with the existing licensee in order to avoid interference. In the event where this is not possible, the new link should not be registered. If the link is registered, the later link will be removed from the register if an interference complaint is received by Ofcom. The interference assessment between registered links and new links is the responsibility of the licensees. Ofcom does not conduct interference assessments.[32]

[28] UK Spectrum Policy Forum. *Future use of Licence Exempt Radio Spectrum*. July 14, 2015. URL: http://www.plumconsulting.co.uk/pdfs/Plum_July_2015_Future_use_of_Licence_Exempt_Radio_Spectrum.pdf.

[29] Ofcom. *Radio systems at 60GHz and above*. 2006. URL: https://www.ofcom.org.uk/__data/assets/pdf_file/0018/44811/radio60ghzreport.pdf.

[30] Brown et al. *Vehicle to vehicle communication outage and its impact on convoy driving*. 2000. URL: https://eprints.soton.ac.uk/75222/.

[31] Ofcom. *Guidance Notes for Self Co-ordinated Licence and Interim Link Registration Process in the 64-66 GHz, 73.375-75.875 GHz and 83.375-85.875 GHz bands*. 2013. URL: https://www.ofcom.org.uk/__data/assets/pdf_file/0021/84018/ofw_369_guidance_notes_65_70-80ghz_final.pdf.

[32] Ibid.

In 2013, after extensive stakeholder engagement, Ofcom adopted a new licensing approach with respect to E-band frequencies. The consultation process revealed growing perception among stakeholders that current self-coordinated approach did not offer the certainty required for the high availability (above 99.99%) applications, specifically for supporting 4G networks. Therefore, Ofcom decided to change the former regime on management and authorisation approach with respect to E-band frequencies to provide a balance between the different user communities and sufficient interference management assurance for those stakeholders wishing to deploy high availability.[33]

The current position is a double regime where the band is sub-divided into two parts, the lower segment of 2 GHz regulated as fully Ofcom coordinated (link-by-link) and the upper segment of 2.5 GHz part remains self-coordinated (light licensing) as per the previous policy.[34]

4 The present policy stance on E-band and V-band in India

The TRAI has been exploring the use of millimeter wave bands such as E-Band and V-band since 2014. In its recommendations on *Allocation and Pricing of Microwave Access (MWA) and Microwave Backbone (MWB) RF carriers* dated 29th August 2014, TRAI recommended that:

- *...in order to increase broadband penetration in India, the usage of high capacity backhaul E-band (71-76 / 81-86 GHz) and V-band (57-64MHz) may be explored for allocation to the telecom service providers.*
- *... both E-band and V-band should be opened with 'light touch regulation' and allotment should be on a 'link to link basis'. The responsibility for registration and database management should lie with WPC wing of DoT. For this purpose, WPC should make necessary arrangements for an online registration process by developing a suitable web portal. Responsibility for interference analysis should rest with the licensee, who needs to check the WPC link database prior to link registration*

[33] Ofcom. *Review of the spectrum management approach in the 71-76 GHz and 81-86 GHz bands.* Aug. 21, 2013. URL: https://www.ofcom.org.uk/__data/assets/pdf_file/0029/46775/condoc.pdf.
[34] Ibid.

(links should be protected on a "first come, first served" basis). WPC can also maintain a waiting list for the same spot.

Subsequently, in its recommendations on *Delivering broadband quickly: What do we need to do?* on 7th April 2015, TRAI stated that most countries have already de-licensed the 60 GHz band(V-band or WiGig band using 802.11ad) and this band has a good device ecosystem; India should also de-license the 60 GHz band immediately and make it available for consumers.

In October 2015, the Department of Telecommunications (DoT) asked for some clarity on the licensing as well as prices recommended by TRAI in its recommendations on *Allocation and Pricing of Microwave Access (MWA) and Microwave Backbone (MWB) RF carriers*. TRAI issued a response to DOT's reference in November 2015, wherein TRAI specified that for V-band a light touch regulation may only be required for backhaul applications, also stating that the V-band be unlicensed for both indoor and outdoor access applications. The Authority recognised the importance of both bands in the proliferation of broadband through Government/Public Private Partnerships (PPP) enabled hotspots in public spaces. The Authority also cited the congestion of the existing Wi-Fi bands as one of the reasons for the need to explore alternatives.

While access applications need not be monitored, the Authority said that for V-band, light touch regulation should be in place for backhaul applications, mainly for the purpose of interference management. Such management would lie in the hands of the licensee who would need to verify the existing databases before setting up a backhaul link in this frequency. The Authority also made reference to stakeholder comments during the consultation process, which said that a number of countries world over have liberalised sections of the V-band in an unlicensed manner for both access and backhaul, and that India should follow suit.

In its recent recommendations on *Proliferation of broadband through public wi-fi networks* dated 9th March 2017, the Authority has reiterated its previous recommendations asking for the Government to expedite the process of allocating E-band and V-band in India.

5 Unlicensed spectrum bands in India

It is often assumed that licensing the spectrum, especially through an auction process, helps allocate the spectrum to those who are most likely to use the spectrum efficiently. This argument underpins the auction-based approach to spectrum allocation in India and other countries. However, in most countries, it has been acknowledged that certain spectrum bands are best left unlicensed, or may be subjected to a "light touch" licensing regime, with minimal regulation. The International Telecommunication Union (ITU), European Union telecom regulatory bodies, as well as leading state telecom policy makers and regulators such as the FCC and Ofcom have recognised that the optimal use of radio spectrum is dependent on flexible spectrum management policies and the multi-time sharing of this precious resource.

As of now, a number of spectrum bands are in unlicensed in India. These include: 2.4 GHz and 5.8 GHz spectrum bands used for Wi-Fi access; 865 MHz - 867 MHz band used by RFID devices; 402 MHz - 405 MHz spectrum band used for medical wireless devices; 335 MHz for remote control of cranes; and so on. In the National Telecom Policy, 2012, one of the strategies for spectrum management is:

> *....To identify additional frequency bands periodically, for exempting them from licensing requirements for operation of low power devices for public use.*

The experience of unlicensed spectrum bands suggests that it is difficult to predict in advance what kinds of applications the spectrum will be used for. For example, RFID spectrum has generated huge economic benefits in the retail sector - the scale of which could not have been predicted in advance. Later in this note, we present findings from some studies that show the scale of economic benefits from unlicensed spectrum.

One of the major concerns around use of unlicensed spectrum tends to be interference management, and a possible solution here tends to be the use of interference free spectrum which drives short range connectivity. Technological advancements such as Wireless Local Area Network (WLAN), Ultra Wide Band (UWB), Radio Frequency Identification (RFID), Near-Field Communication (NFC) systems, and others have demonstrated that when an opportunity for cost-efficient and flexible spectrum usage is presented in the form of unlicensed spectrum, the market is likely to respond through innovation and expansion.[35]

Further, because of development of technological solutions for interference management, the regulatory role in this has been reduced. Still, it is impor-

[35] The Centre for Internet and Society. *Unlicensed Spectrum Policy Brief for Government of India*. URL: https://cis-india.org/telecom/unlicensed-spectrum-brief.pdf.

tant for regulators to specify and enforce technical standards to ensure that devices used are not leading to unfair interference.

In a country like India, unlicensed spectrum can play a big role in bridging the digital divide. However, the country is still behind when compared to unlicensed spectrum availability in the U.S. and UK which have already integrated innovative spectrum management techniques in their telecom policies. These policies aim to create a flexible, market-driven approach to spectrum regulation and management through integrating spectrum sharing techniques and meeting the industry demand for unlicensed spectrum.

6 Evidence on economic impact of Internet and unlicensed spectrum

The strategy for releasing a spectrum band should comprehensively consider the consequences of the alternative approaches. In considering the consequences, we can draw lessons from two types of studies. First, since one of the main impacts of these bands is improved access to Internet (discussed later), studies on economic impact of Internet are useful. Second, there are studies on economic impact of unlicensed spectrum that can help us understand how leaving a spectrum unlicensed or lightly licensed can lead to economic benefits that might not have accrued had the spectrum been more strictly licensed.

6.1 Economic impact of Internet in India

Two types of studies on the economic impact of Internet in India have been conducted.

- *Studies on the economic impact of marginal increase in Internet penetration:* Typically, such studies estimate the percentage impact on GDP growth resulting from marginal increase in the number of subscribers. This impact includes not just the increase in the Internet economy, but also the externalities of Internet.

  A 2012 study by ITU presented an overview of the variety of impacts of broadband deployment.[36] For India, the study found that every 10

[36] Katz R. *The Impact of Broadband on the Economy.* 2012. URL: https://www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_Impact-of-Broadband-on-the-

percent increase in broadband penetration was leading to 0.31 percent increase in the GDP of the respective region.[37] A 2012 study published by Kathuria et al from Indian Council for Research on International Economic Relations (ICRIER) estimated that every 10 percent increase in the number of Internet subscribers was leading to 1.08 percent increase in a state's GDP.[38]

In a similar study published in 2016, Kathuria et al use a modified growth multiplier method to estimate the economic impact of Internet.[39] They find that a 10 percent increase in Internet subscribers results in an increase of 2.4 percent in the growth of state's per capita GDP. The most recent study, published in 2017, found that 10 percent increase in India's total Internet traffic delivers on average a 3.3 percent increase in India's GDP.[40]

Usually, the rising penetration of Internet enables its application to an increasing variety of services. This is consistent with the intuition of network economics, which suggests that as the economy gets better networked, the economic benefits from access to Internet should increase. The famous Metcalfe's Law proposes that the value of a network is proportional to the square of the number of users. So, each additional user adds higher value than the previous user. This might be the reason why more recent studies find greater economic impact of marginal increase in internet penetration. These studies suggest that the marginal economic impact of increased Internet access is accelerating. This is also consistent with the finding presented in various studies that the economic impact of marginal increase in Internet access is higher for countries that are already well-networked.

- *Studies on the contribution of the Internet to the economy:* Such studies estimate the contribution of Internet to India's GDP. These studies usually include only the direct contribution of the internet. McKinsey and Company, 2012 estimated that the Internet contributed about 1.6

`Economy.pdf`.

[37] It is worth noting that although the study found the coefficient to be statistically significant, there is a risk of potential endogeneity, which means that it is possible that the causal relationship between broadband penetration and GDP growth runs in both directions. The study's methodology may not have sufficiently overcome this problem.

[38] Kathuria et al. *India: The impact of Internet*. ICRIER, 2012.

[39] Kathuria et al. *Quantifying the Value of an Open Internet for India*. ICRIER, 2016. URL: `http://icrier.org/pdf/open_Internet.pdf`.

[40] Kathuria et al. *Estimating the Value of New Generation Internet Based Applications in India*. 2017.

percent to India's GDP.[41] They contrasted this with the average contribution of the Internet in developed countries, which was estimated to be 3.4 percent. The study used data from 2010. A 2015 report by the Boston Consulting Group estimated that in 2013, the Internet contributed 2.7 percent to India's GDP.[42] The report projected that this contribution would grow to 4 percent of the GDP by 2020.

Kathuria et al, 2016, use national accounts (expenditure) data as well as growth multiplier method to estimate the economic value of Internet for India.[43] They estimate the aggregate expenditure on the Internet in India to be between 2.2 percent and 4.8 percent of GDP. The upper bound is the estimate if both connectivity and the Internet are considered. Using the growth multiplier method, the study estimates the value of the Internet to be 3.38 percent of the nominal GDP.

These studies cannot be directly compared, because they use different methodologies. However, if their conclusions are considered chronologically, they suggest that the direct contribution of Internet to the economy has been growing.

To the extent the use of V-band and E-band leads to cheaper, broader and better quality access to Internet, it could lead to acceleration in GDP growth, and also increase the GDP contribution of the Internet. The pathways and scale of these impacts depend on the specific uses of the spectrum, which are discussed later. The key findings from the studies on the economic impact of Internet in India are summarised below.

6.2 Economic benefits of unlicensed spectrum

Although there are no studies estimating the economic benefits of unlicensed spectrum bands in India, studies have been conducted in other jurisdictions. For ease of comparability across studies, we have reviewed studies in one country - the United States of America. The studies are:

[41] Gnanasambandam et al. *Online and upcoming: The Internet's impact on India.* McKinsey & Company, 2012.

[42] Shah et al. *India@digital.Bharat: Creating a USD 200 billion Internet economy.* The Boston Consulting Group, 2015. URL: https://timedotcom.files.wordpress.com/2015/04/file180687.pdf.

[43] Kathuria et al., *Quantifying the Value of an Open Internet for India*.

- *Thanki, 2009:*[44] This study estimated the benefits from residential Wi-Fi, hospital Wi-Fi and RFID technology.
- *Milgrom et al, 2011:*[45] This study estimated the benefits from mobile offloading, residential Wi-Fi, and Wi-Fi tablets. However, in estimating the benefits from mobile offloading, it only included consumer surplus and benefits from higher speed. It did not consider producer surplus and benefits that may emerge from new business revenue.
- *Cooper, 2012:*[46] This study focused on benefits from mobile offloading, and use of residential Wi-Fi. Contrary to Milgrom et al, 2011, while estimating the benefits of mobile offloading, this study only includes producer surplus, and leaves out consumer surplus, benefits from higher speed, and other benefits.
- *Thanki, 2012:*[47] This study estimates benefits from mobile offloading and use of residential Wi-Fi.
- *Katz, 2014:*[48] This is the most comprehensive study. It focuses on public Wi-Fi, residential Wi-Fi, mobile offloading, Wi-Fi tablets, RFID technology, and innovative business models, such as bluetooth products.

Understanding the different types of impact of unlicensed spectrum bands from these studies can help us identify the pathways of economic benefit from V-band and E-band. Table 3 summarises the findings of these studies (we have adjusted the estimates for inflation for the time since the studies were conducted).

An interesting insight from these studies is that some of the biggest economic benefits of unlicensed spectrum may come from real economy uses that are difficult to predict in advance. The use of RFID in clothing and healthcare sectors contributes more than half of the estimated economic benefits of unlicensed spectrum in USA. These sectors have used this spectrum to improve their processes, and this has yielded rich returns.

[44] Thanki R. *The economic value generated by current and future allocations of unlicensed spectrum*. Perspective Associates, 2009.

[45] Milgrom P. and A., *The Case for Unlicensed Spectrum*.

[46] Cooper M. *Efficiency gains and consumer benefits of unlicensed access to the public airwaves*. 2012.

[47] Thanki R. *The economic significance of licence-exempt spectrum to the future of the Internet*. 2012.

[48] Katz R. *Assessment of current and future economic value of unlicensed spectrum in the United States*. 2014.

Table 3 Economic benefits of unlicensed spectrum in USA (figures in USD Billion)

Benefit	Thanki (2009)	Milgrom et al (2011)	Thanki (2012)	Cooper (2012)	Katz (2014)
Wi-Fi mobile offloading	NA	39.6	8.9	48.4	16.3
Residential Wi-Fi	4.81 - 14.1	13.5	16.3	40	37.31
Wi-Fi only tablets	NA	16	NA	NA	44.4
Hospital Wi-Fi	10.7 - 18	NA	NA	NA	NA
Clothing RFID	2.24 - 9.1	NA	NA	NA	98.25
Wireless Internet service providers	NA	NA	NA	NA	1.5
Wireless personal area networks	NA	NA	NA	NA	2.25
Health care RFID	NA	NA	NA	NA	37.3
Total	17.75 - 41.2	69.1	26.2	88.4	237.31

There are no similar studies on V-band or E-band spectrum. So, the methodological choices must be made with little support from existing studies. Also, since the deployments of these bands in other countries are still small in scale, there is not enough experience to learn from. So, our focus is on identifying the categories of benefits, and quantifying them. For the most part, we desist from monetising the benefits. We leave that to a later date, when more experience has accumulated, and data availability is less constrained.

7 Broadband Internet in India

The context of broadband Internet in India will determine the kinds of benefits that India can get from V-band and E-band. The following are a few key facts about broadband Internet in India.

- *Reliance on mobile broadband:* In India, most users access broadband Internet through mobile broadband. As on May 31, 2017, wired connections comprised only 6.3 percent of the broadband connections. The trend also seems to be towards greater reliance on mobile broadband. The density of wired broadband connections in India is 1.4, while the average for OECD countries is 30.6.[49] World average is about 11.6 fixed broadband subscriptions per 100 inhabitants.

  This shows how much India deviates from the global norms in terms of its reliance on mobile broadband. Many other countries also rely significantly on mobile broadband, but almost all of these countries have much lower population density and fewer densely populated urban areas. This may be the reason why wired connections are considered less feasible in those countries. So, India's disproportionate reliance on wireless connections is unique when compared to countries with similar population density.

  Although India has managed to rapidly expand access to broadband using mobile broadband, this approach has certain limitations:

  - *Mobile broadband congestion:* In densely populated areas, as more people get on to wireless broadband, the mobile spectrum bands may get congested. This was experienced in the 3G spectrum bands - as more people started using the spectrum band, con-

[49] OECD. *Broadband statistics.* June 2017. URL: http://www.oecd.org/sti/broadband/broadband-statistics/.

gestion increased. This necessitates more cell sites and higher backhaul speeds.

- *Constraints on speed and consistency of connection:* Compared to wired connections, especially fiber optic connections, mobile broadband provides lower speeds and less consistent connectivity. High speed, consistent connectivity is crucial for high quality usage at homes and offices. Wireless Internet on mobile devices is necessary only while using Internet in transit and outdoors.

- *Low potential for community hotspots:* If density of wired connections remains low, this will constrain the potential of developing community hotspots, where residential or business hotspots are made available for use by other users of the network. The proliferation of such hotspots is one of the most remarkable stories in the growth of Internet in recent years. Globally, community hotspots have grown from 19.38 million in 2013 to 251 million in 2017. Such hotspots provide high speed, consistent connectivity, while offloading from mobile networks - a benefit that India will not be able to realise without proliferation of fixed broadband connections.

Since India is already making considerable progress on mobile broadband, it is worth considering how it could expand access to high speed fixed broadband Internet, which complements mobile broadband.

- *Relatively lower use of higher speed fixed broadband connections:* A negligible percentage of the fixed broadband connections are fibre optic-based. Most of the wired connections use DSL, Dial-up, or Ethernet, all of which offer potentially lower speeds than fibre optic. This situation is very different from what is seen in developed countries, and also in comparable developing countries. From the fixed Internet connections in India, about 62 percent are DSL-based; 14.7 percent are dial-up connections; 14 percent are Ethernet/LAN connections, and 6.9 percent are cable modem connections. Only 1.8 percent of the connections are fiber optic connections. Leased lines comprise a negligible percentage.

- *Low density of commercial Wi-Fi hotspots:* Commercial Wi-Fi hotspots, whether offered for a fee or made available for free through third-party financing, can help augment the mobile broadband and private residential and commercial hotspots as well as mobile broadband. They are an important part of the broadband infrastructure in a country. In many other countries, there is much greater availability of such hotspots. Use of public Wi-Fi can help offer consistent, reliable and high speed Internet to users, while decongesting mobile broadband. India has only about 36,270 public Wi-Fi hotspots.[50] The total number of public Wi-Fi hotspots in the world is over 12 million.[51]

Given this context, we take the key intermediate goals for broadband Internet India to be: expanding access to fixed broadband; decongesting mobile broadband in dense urban environments; and proliferating commercial Wi-Fi hotspots. Achieving these intermediate goals would help improve quality and quantity of internet access in India. It is also crucial for India to ensure that it does not miss the bus with the new spectrum-based technologies and business models being developed, especially those that will rely on spectrum bands such as V-band and E-band.

8 Identifying the potential uses of V-band and E-band in India

The scale and nature of economic benefits from these bands may depend on: the variety of use cases for the spectrum; the potential scale of each use case; the value of economic activity supported by the spectrum; and so on. Based on stakeholder consultations, literature review, and above analysis of broadband Internet in India, we have identified the following key uses of the V-band and E-band spectrum:

- *Support proliferation of commercial Wi-Fi and Wi-Gig hotspots:* these bands can help backhaul the commercial Wi-Fi infrastructure in a cheaper and quicker manner, especially in dense urban locations.
- *Support expansion of fixed broadband Internet in urban areas:* these bands can help solve the last mile problems of getting high speed wired broadband Internet into dense urban locations.
- *Backhaul for mobile broadband:* these bands can provide higher capacity backhaul for mobile broadband, thereby easing congestion
- *Other uses:* these bands can be put to a variety of other uses. These, inter alia, include: extension of local area networks between buildings

[50] iPass. *Wi-Fi growth map*. Mar. 2018. URL: https://www.ipass.com/wifi-growth-map/.
[51] Ibid.

within a building complex; Internet of Things; Vehicle to vehicle communication; Augmented Reality (AR)/Virtual Reality (VR) Systems; and so on.

Most of the benefits discussed in this section depend not just on release of the spectrum, but also on other enabling conditions. This raises the question: *what do we assume about the policy environment in the next few years?* For the purpose of our analysis, we assume an optimised policy environment, which means that we expect that the other necessary steps will be taken, and no further impediments will be created. The benchmarks we are proposing are not ambitious but in line with the performance that can be expected in India in an optimal scenario.

Our analysis is for the five-year period between 2017 and 2022. This seems to be a reasonable time period, because a longer period would render the conclusions inutile, given the rapid changes in technology, and any short period may lead to under-estimation of benefits, as benefits are expected to accrue over a few years.

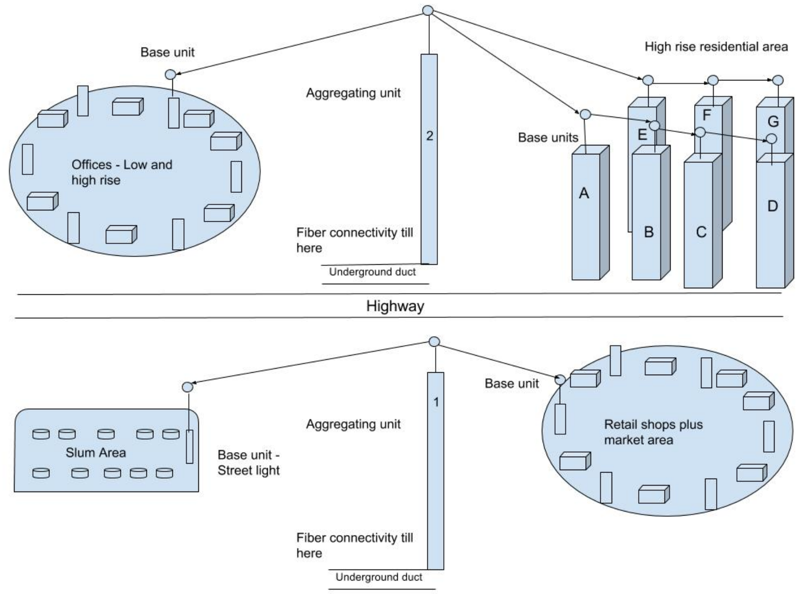
To understand the specific types of benefits from these bands, it is useful to think about a specific densely built urban habitat. It may comprise residential, recreational as well as commercial places. To help identify the benefits, we have developed a hypothetical case of a dense urban area to see the benefits that are likely to accrue to producers and consumers.

8.1 Case study on use of the bands for improving connectivity

In this hypothetical example, we consider the usage of this band for last-mile connectivity. We assume that fiber connectivity is available upto aggregate sites, beyond which fiber becomes impractical to use due to a number of reasons. We also assume that backhaul from this base site is extended using these bands, which will cater to a market area (eg. inner circle of Connaught Place in Delhi), high rise residential area, slum area and office complex.

In figure 2, we have drawn out a hypothetical dense urban environment. It is comprised of a slum, market area, an office complex and a residential area. If a service provider wants to extend Internet services from the aggregating unit to any of these areas, they can use these bands to extend the backbone. We make the following assumptions respectively for the commercial and residential area:

Figure 2 Case Study of a Dense Urban Environment



- *Residential area*
  - This consists of a number of high rise buildings.
  - Each building in the residential area will have a cell at the top and using ethernet and existing utility ducts, Internet can be made available to each home.
- *Market area*
  - This is a busy marketplace of the kind that is seen in every city.
  - It has a high daily average footfall of, say, 100,000 people.
- *Office Area*
  - Several high rise buildings and low rise buildings in the office area.
  - The high rise buildings would have more bandwidth requirement than low rise buildings.
- *Slum area*
  - This is a habitation comprising of low rise temporary and semi-permanent constructions that are densely packed in a small area.

We work with the assumption that the bands have a radius which allows connection to a respective base station in all four areas, with one or more hops. As the aggregation sites are connected using fiber, the bandwidth they can carry is assumed to be very high. These base units would then connect to other cells (within line of sight) to ensure adequate coverage of each area. The use of these bands will ensure high throughput as compared to the existing licensed microwave bands such as 13, 15 18 and 21 GHz.

The office buildings will require high speed Internet to be made available to employees. Such buildings may require multiple cells to be placed on each of them. The residential buildings may have lower requirements, and one cell per building may suffice, and the distribution within the building may be done using DSL, ethernet or any other solution. For the slum area, the service provider may situate towers in strategic locations, from which it could distribute within the area. The market place is a suitable location for commercial Wi-Fi hotspots. A mesh of Wi-Fi hotspots backhauled using these bands can provide high speed connectivity in the market place, while helping decongest the mobile network.

This illustrates how these bands can be deployed to improve connectivity in dense urban environments where laying cables is expensive and time consuming, and may even be infeasible in certain locations.[52] These bands can enable quicker and cheaper backhaul solutions in such contexts.

Considering this, we have identified the key economic benefits expected from use of V-band and E-band in India.

8.2 Proliferation of commercial Wi-Fi and Wi-Gig hotspots

At present, service providers offering commercial Wi-Fi hotspots must mainly rely on wired backhaul. In urban areas, establishing wired backhaul is expensive, time-consuming, and, in some places, even infeasible. As discussed earlier, this problem can be potentially overcome by the use of V-band and E-band. India has about 25 commercial Wi-Fi hotspots for every 1 million inhabitants, while the global average is 1470.[53] In 2013, the global average was about 1000, while in India this was about 22.[54] So, in spite of the low base, the pace of proliferation in India is low. For our analysis, we assume that the government and TRAI will take the necessary measures to help

[52] This point was made repeatedly in consultations with stakeholders.

[53] iPass. *Wi-Fi growth map*. Sept. 2017. URL: https://www.ipass.com/wifi-growth-map/.

[54] Ibid.

proliferate commercial Wi-Fi hotspots in India. To estimate the number of public Wi-Fi hotspots that will use these bands for backhaul, we first need to establish a reasonable benchmark for the density of such hotspots that India could achieve in the next five years.

Since the use of these bands for backhauling Wi-Fi hotspots is primarily in densely populated urban areas, we need to find a relevant benchmark for such areas in India. In 2016, the per capita income in India in purchasing power parity (PPP) terms was about 40 percent of the average per capita income in the world.[55] According to Government's estimates, in 2011-12, per capita income in urban India was about 2.5 times of that in rural areas.[56] From this, we can derive that, in 2016, per capita income in urban India was about 68 percent of the average per capita income of the world. Assuming that the rate of growth in per capita income between 2011 and 2016 will persist between 2016 and 2022, this will be 84 percent in 2022. However, given the low density of hotspots in India, it might take a few years for the proliferation to take place. Hence, we propose benchmarking the density of commercial Wi-Fi hotspots in urban India at 60 percent of the average density in the world by 2022.

Beginning with the present global benchmark, we project the proliferation of commercial Wi-Fi hotspots in the next 5 years. For this, we assume that the present rate of growth in population and number of commercial Wi-Fi hotspots will continue.[57] This yields a global benchmark of 2267 hotspots for every 1 million inhabitants in 2022. Sixty percent of this is 1360 - this is the density we expect to see in urban India by 2022.

About 75 percent of broadband subscribers are in urban areas.[58] Since we do not have information about urban-rural distribution of commercial Wi-Fi hotspots, we assume that 75 percent of commercial Wi-Fi hotspots are in urban areas. So, about 24,600 hotspots are estimated to be in urban areas - about 57 hotspots per million inhabitants.[59] Table 4 presents our

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[55] The World Bank. *World Bank Data*. 2016. URL: https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD/.

[56] The Times of India. *Big gap in per capita income in urban and rural areas*. 2016. URL: http://bit.ly/2wlJI9Z.

[57] For rate of growth in commercial Wi-Fi hotspots, we consider the rate between 2014 and 2017. The rate of proliferation of public Wi-Fi hotspots globally decelerated from 15 percent in 2013-14 to 10 percent 2014-15, but it has been the same since then.

[58] Telecom Regulatory Authority of India. *The Indian Telecom Services Performance Indicators January - March, 2017*. July 5, 2017. URL: http://www.trai.gov.in/sites/default/files/Indicator_Reports_050720174.pdf.

[59] Using the urban population in 2011 (377 million) as the base, and applying the annual

Table 4 Projected public Wi-Fi hotspots in urban areas in India: 2017 to 2022

Year	Population projection for urban India (millions)	Commercial Wi-Fi hotspots in urban India	Density (hotspots per million)
2017	432	24600	57
2018	442	47471	107
2019	452	91604	203
2020	462	176768	382
2021	473	341110	721
2022	484	658240	1360

projections of the number and density of commercial Wi-Fi hotspots. The yearly projections are based on the compounded annual growth rate required to go from the present density to the benchmark density in 2022. Although the annual rate of growth required may appear to be high, this is consistent with the rate at which hotspots have proliferated in other countries.

So, we project about 6,33,640 new commercial Wi-Fi hotspots to be established in urban areas during the next five years, if all the necessary steps, including release of these spectrum bands, are taken. Now, to estimate the number of these hotspots that will need to use V-band and E-band for backhaul, we consider it important to distinguish between the top 15 most populated cities[60] and the other urban areas. The top 15 cities have the highest right of way costs, labour costs, and other difficulties in laying wired backhaul network. We assume that 35 percent of the total public Wi-Fi hotspots in India are in these 15 cities.[61] So, we expect about 2,95,699 new commercial Wi-Fi hotspots to come up in the top 15 cities.

Given the challenges of alternative backhaul options, we expect that, if these bands are released, about 40 percent of the new commercial Wi-Fi hotspots established in the top 15 cities will use them for backhaul, while only 20 per-

growth rate in urban population in India (2.3 percent), we estimate the population in 2017 to be 432 million.

[60] These cities, which have been selected on the basis of population in 2011 census, are: Delhi, Mumbai, Bangalore, Kolkata, Hyderabad, Chennai, Ahmedabad, Surat, Jaipur, Pune, Kanpur, Nagpur, Indore, Thane.

[61] This assumption is based on our estimate that about 35 percent of broadband subscribers are in these 15 cities.

cent will do so in other urban areas. Further, we expect that about 10 percent of the hotspots in the top 15 cities and 5 percent in the other urban areas cannot be established without these bands or any similar backhaul spectrum, because of infeasible backhaul costs. The benefits from these hotspots can be fully attributed to these bands, while those from other hotspots that use this band for backhaul can only be partly attributed. So, according to our estimates, about 46,467 commercial Wi-Fi hotspots in India would not come up unless these spectrum bands are made available. Further, we expect 1,39,401 other commercial Wi-Fi hotspots to use these spectrum bands for backhaul even though they could have been established otherwise, but at a higher cost and with significant delays.

8.2.1 Deployment of commercial Wi-Gig hotspots

Wi-Gig can offer multi-gigabit data transfer rates to users. Since the technology is in early stages of adoption, it is difficult to project the scale of its proliferation. Wi-Gig hotspots are expected to be about 10 percent of the Wi-Fi hotspots by 2020.[62] For our analysis, we expect that Wi-Gig hotspots in India will be about 10 percent of the hotspots in urban locations by 2022. We expect about 65,000 commercial Wi-Gig hotspots to be deployed by 2022 in urban locations in India. Although all these hotspots may not use V-band or E-band for backhaul, since all of them will use V-band for access, the economic benefits arising from them can be fully attributed to these spectrum bands.

8.3 Proliferation of fixed broadband connections

In densely populated urban areas, because of the existing built-up area, it is expensive and often very difficult to take wired Internet to homes and offices. Even if wired network can be taken into certain locations, extending it to adjacent areas can be challenging because of difficulties of obtaining right of way permissions, or the physical obstructions on the way. These observations were made by the stakeholders we held discussions with. TRAI also observed in its "Recommendations on Delivering Broadband Quickly: what do we need to do (2015)", the following:

> ....Fibre to the Home (FTTH) or Fibre to the curb (FTTC) networks require installation of a new fibre link from the local ex-

[62] See, for instance: http://bit.ly/2vhSVCK

> change (central office) directly to or closer to the subscriber. Even though fibre is known to offer the ultimate in BB bandwidth capability and is not very expensive, installation costs of such networks (cost of fibre and Right of Way (RoW)) have, up till recently, been prohibitively high.

Some stakeholders indicated to us that the fibre breakage rates in India are much higher than those seen in other countries.

V-band and E-band can be used along with fibre optic cables to create a high speed wired Internet network, which can help improve consistency of Internet connectivity in India, and get FTTH and FTTC networks in locations where they are not present currently. This spectrum can also be used to reduce the cost of improving bandwidth availability in locations where wired broadband is already available. The use cases of this spectrum is most obvious in densely populated urban areas, but may also extend to suburban areas and residential clusters in rural areas.

There are about 18.23 million fixed/wired broadband subscribers in India.[63] These include residential as well as commercial locations. This translates to a wired broadband density of 1.4 per 100 inhabitants. Assuming that the share of urban subscribers in the fixed broadband subscriber base is the same as their share in total broadband Internet subscriber base (for which this rural-urban disaggregation is available), we estimate about 13.5 million fixed broadband subscribers in urban India.[64] Based on the estimated urban population for 2017 (432 million), the density of fixed broadband connections in urban areas is estimated to be about 3.13. Further, based on their estimated share in the broadband Internet subscriber base, we estimate about 6.3 million of these connections to be in the top 15 cities.

As discussed earlier, the average density of fixed broadband connections in the world was about 11.6 (per 100 inhabitants) in 2015, up from 9.04 in 2011. Assuming that the rate of growth between 2011 and 2014 continues, the density of fixed broadband connections in the world in 2022 would be about 18. Adjusting for differences in incomes, as discussed earlier, the density for urban India should be about 15 in the year 2022. However, for the purpose of our analysis, the benchmark we are proposing for density of fixed broadband connections in urban India in 2022 is 12. This downward adjustment is driven by our judgment that, given the heavy reliance on mobile broadband

[63] Telecom Regulatory Authority of India, *Press Release on Telecom Subscription Data*.

[64] About 74.3 percent of the total number of broadband subscribers, which include fixed as well as wireless connections, are in urban areas.

Table 5 Projected fixed broadband connections in Urban India

Year	Fixed broadband connections (in millions)
2017	13.5
2018	18.1
2019	24.2
2020	32.3
2021	43.3
2022	57.9

in India, it is not likely that we in India will be able to make a rapid shift to meet the global benchmark in the near future.

To meet the benchmark of 12 fixed broadband connections per 100 inhabitants, India will need about 58 million fixed broadband subscribers in urban areas by 2022. So, 44.5 million more connections will be required in urban areas in the next five years. Assuming that their share in subscriber base remains constant, we estimate about 20.77 million of these new connections to come up in the top 15 cities. V-band and E-band can help in the expansion of the fixed broadband subscriber base in urban areas by making it easier and cheaper to backhaul these connections. Table 5 presents our projections of the number of fixed broadband connections in urban India. The yearly projections are based on the compounded annual growth rate required to go from the present density to the benchmark expected in 2022.

Consistent with the assumptions made regarding commercial Wi-Fi hotspots, we assume that V-band and E-band will be used for backhaul in 40 percent of connections in the top 15 cities, and 20 percent of connections in the other urban areas. Further, we assume that 10 percent of the connections in the top 15 cities and 5 percent of the connections in other urban areas would not come up without this spectrum. For the other new connections, using this spectrum for backhaul would lead to savings of time and money. So, about 3.26 million new fixed broadband connections would depend on the release of this spectrum, and their benefits can be fully attributed to it. Further, about 9.8 million of the additional fixed broadband connections may use this spectrum for backhaul, even though they could have come up using other backhaul solutions, albeit at a higher cost and with delays.

In the next few years, some of these fixed broadband connections may use Wi-Gig devices for access, instead of Wi-Fi or cable. As discussed earlier, such hotspots are expected to be 10 percent of total number of Wi-Fi hotspots in the world by 2020. We assume that, by the 2022, of all the fixed broadband connections, about 10 percent will use Wi-Gig standard devices for access. So, there will be about 5.8 million such connections in urban India in 2022. Their economic benefits can be fully attributed to the availability of these spectrum bands.

8.4 Backhaul for mobile broadband

Only about 15 percent of cell sites in India are connected using fibre optics. The mobile backhaul infrastructure in urban environments suffers from similar problems as the infrastructure for wired broadband network. As TRAI had observed in its "Recommendations on Delivering Broadband Quickly: what do we need to do (2015)".

> ....Another major reason for the poor quality of wireless broadband is non-availability of adequate bandwidth in the backhaul. For 3G and 4G networks, in the absence of adequate fibre, availability of sufficient quantum of backhaul spectrum is a prerequisite.

In the same paper, TRAI had also discussed how the high Right of Way costs for establishing wireless access points of presence and backhaul facilities affected backhaul infrastructure.

Presently, 13/15/18/21 GHz Bands have been made available for backhaul usage. V-band and E-band can be used to augment and extend wired backhaul networks, and perhaps even to substantially replace use of wired backhaul infrastructure with a combination of hops. This would reduce the cost of mobile backhaul and also enable high speed backhaul in areas where high congestion is expected. Further, our discussions with stakeholders so far suggest that the use of V-band and E-band reduces the size of cells, including the base stations. This means that a base station would take smaller space and could be installed at a lower cost and lesser right of way problems. The lower cost of cells, along with higher backhaul capacity, could help potentially reduce congestion in mobile broadband access, and even allow more data to be made available at the same price.

V-band and E-band offer a larger backhaul capacity at short distances than the spectrum bands that have been made available for this purpose. The backhaul range for V-band and E-band can be increased by using multiple hops from one point to another. In dense urban environments, in sites that require high backhaul capacity, these spectrum bands can offer an effective backhaul solution. First, in such locations, laying underground cables is expensive, impossible or a cause for delay. Second, in such locations, there is greater likelihood of congestion of wireless backhaul using the presently available spectrum. With the rapid rollout of 4G, and the expected introduction of 5G, it is quite likely that many locations where backhauling is done using the wireless spectrum will face congestion.

It is difficult to project how many sites in India will face backhaul congestion. Our consultations did not yield a precise estimate. A report by Ericsson estimates that by 2021, the mobile broadband backhaul capacity required in 2021 may be much higher than that required at present.[65] Even with basic mobile broadband, about 20 percent of radio sites may require more than 150 Mbps of backhaul capacity, and a few may even require more than 300 Mbps. Further, the report estimates that with advanced mobile broadband (4G and higher), by 2021, the backhaul capacity required may rise to 1 Gbps for 20 percent of sites, and a few sites may even need 3-10 Gbps of backhaul capacity. For the sites that require high backhaul capacity, the presently available spectrum bands are not going to suffice, and since most of those sites are located in dense urban environments, it will be difficult to rely upon fiber optic cables.

We expect that the sites that face backhaul congestion with the presently available backhaul spectrum bands will comprise about 15 percent of total sites in India by 2022. This assumption is based on other assumptions discussed in this note. For instance, we assume that commercial Wi-Fi hotspots will develop rapidly, and fixed broadband connections will proliferate, thus decelerating the pace of mobile broadband congestion. Hence, we are proposing a modest assumption about the number of cell sites that will face congestion by 2022.

According to a report by the consulting firm Deloitte, the number of cell sites in India is expected to grow to about 1.5 million by 2020.[66] Assuming that the rate of growth in cell sites will reduce because of a shift to fixed broadband and proliferation of commercial hotspots, we assume that the number of cell sites required would rise to about 1.6 million by 2022. So, about 2,40,000 cell sites may need to use V-band and E-band, a similar spectrum band or wired

[65] Ericsson. *Ericsson microwave outlook*. Oct. 2016. URL: https://www.ericsson.com/assets/local/microwave-outlook/documents/ericsson-microwave-outlook-report-2016.pdf.

[66] Deloitte Touche Tohmatsu India Private Limited. *Indian tower industry: The future is data*. June 2015. URL: https://www2.deloitte.com/content/dam/Deloitte/in/Documents/technology-media-telecommunications/in-tmt-indian-tower-industry-noexp.pdf.

backhaul solutions to meet the needs. We expect that about 50 percent of these would use V-band and E-band for backhaul. So, about 1,20,000 cell sites would rely on V-band and E-band for backhaul in 2022.

8.5 Improvements in the quality of Internet access

Use of V-band and E-band spectrum can, by enabling changes in the infrastructure for Internet, help improve the quality of Internet access in India. By helping expand the access to fixed broadband, by enabling proliferation of public Wi-Fi, by helping improve mobile backhaul capacity, and by allowing Wi-Gig connections to begin proliferation, these spectrum bands can help change the way users in India access the Internet. This can have a significant impact on the speed, consistency, and volume of Internet usage.

- *Speed of Internet access:* According to Akamai's State of the Internet Report, in the first quarter of 2017, among the 15 Asia-Pacific countries covered in the report, India has the second lowest average Internet speed, and the lowest average peak speed.[67] One of the reasons for this is that India relies disproportionately on technologies that allow lower speeds. As discussed earlier, most people in India access broadband Internet through mobile broadband, and even fixed broadband connections are mostly based on DSL and dial-up. This constrains the speed available to users. For instance, in Thailand, 72 percent connections are above 10 mbps, in India only 19 percent connections have this speed. Use of V-band and E-band for backhaul and, in some cases, for access can help improve the average Internet speed in India. If, by 2022, urban India has 58 million fixed broadband connections, 6,58,240 commercial Wi-Fi hotspots, and 65,000 Wi-Gig hotspots, the average and peak speeds could be much higher.
- *Consistency of Internet access:* At present, most users in India rely on mobile broadband for broadband Internet. With the advent of 4G, the speeds for mobile broadband are now much higher than they were with 3G. Mobile broadband has the advantage of offering mobility, but it faces constraints on consistency of connection, especially in locations with density of connections. Compared to mobile broadband, Wi-Fi offers a much better consistency of Internet access. As India is rapidly

[67] Akamai. *State of the Internet Q1 2017 report*. May 2017. URL: https://www.akamai.com/fr/fr/multimedia/documents/state-of-the-internet/q1-2017-state-of-the-internet-connectivity-report.pdf.

scaling up Internet access, it is equally important to ensure that the way in which people access Internet meets not just the requirements of mobility and speed, but also consistency of access. This can be done, inter alia, by use of V-band and E-band for improving access to fixed broadband and public Wi-Fi hotspots.

- *Volume of Internet usage:* According to forecasts by Cisco, mobile data usage in India is expected to be 2 Exabytes per month by 2021, up from 266 Petabytes in 2016. Based on population forecasts, this would mean that the volume of mobile data usage would increase from about 200 Megabyte per person per month to about 1.43 Gigabytes per person per month. For fixed connections, the usage is forecasted to grow from 1.5 Exabytes per month (1.13 Gigabytes per person) to 4.96 Exabytes per month (3.57 Gigabytes per person). The average total data usage per person per month is forecasted to increase from 1.33 Gigabytes to 5 Gigabytes. Mobile connections are forecasted to account for about 29 percent of total data usage in 2021, up from 15 percent in 2016. The global forecast for mobile data usage is 49 Exabytes per month (6.36 Gigabytes per person) in 2021, up from 7.2 Exabytes per month in 2016 (about 0.98 Gigabytes per person). For fixed connections, the forecast is that data usage in 2021 will be 196 Exabytes per month (26.74 Gigabytes per person), up from 82.8 Exabytes per month (11.3 Gigabytes per person) in 2016. So, the average data usage per person month is forecasted to increase from 12.3 Gigabytes to 33.1 Gigabytes. Globally, the share of mobile connections in data usage is expected to increase from 8 percent in 2016 to 20 percent in 2021. The following table summarises the status in 2016 and forecasts for 2021.

Table 6 Internet usage forecasts

	Aggregate data usage per month (in Exabytes)			Data usage per person per month (in Gigabytes)		
	Mobile	Fixed	Total	Mobile	Fixed	Total
India						
2016	0.266	1.5	1.766	0.2	1.13	1.33
2021	2	4.96	6.96	1.43	3.57	5
Global						
2016	7.2	82.8	90	0.98	11.3	12.28
2021	49	196	245	6.36	26.74	33.1

Aggregate data usage depends on various demand and supply factors. One of the supply-side factors is the proportion of mobile and fixed connections used for accessing Internet. Also, constraints on backhaul capacity may restrict the number of high speed connections, which may also affect the total usage. Further, as price elasticity studies from other countries and recent experience with increase in data usage with falling prices in India suggest, every unit decrease in price leads to a huge increase in volume of usage. So, to the extent that delicensed V-band and E-band will be able to ease the backhaul constraints, help improve access by deployment of Wi-Gig, and enable lowering the prices, there will be an impact on the volume of data usage in the coming years.

8.6 Other potential benefits

There are a variety of potential use cases of these spectrum bands that are under development. Although it is very difficult to quantify, let alone monetise, the benefits from these use cases, it is nonetheless important to consider them while taking a decision about the release of these spectrum bands. Some of these use cases are summarised below.

8.6.1 Extension of local area networks between buildings

India has a large number of office, college, university, hospital and other complexes wherein multiple buildings are located in a contiguous area, with a local area network spanning the complex. V-band and E-band can help connect different buildings within such complexes using point-to-point cells, so that such connections do not require fibre optics or other cable-based solutions. This can help reduce the cost of networking without significant compromise in the quality of the network.

A typical scenario might involve a company in a high-rise office building that has opened a second office in an adjacent building. Both offices house employees who need to share data on the company's LAN or access databases in real time. This required connectivity could have been provided by the owners of the buildings if they had established a fibre-optic cable run between the two buildings. But often there is no such level of interconnectivity between buildings. So, a second option would be to run dark fibre (i.e., privately operated optical fibre) between the two offices. This type of installation requires a special contractor with high costs. That may be worth it in some cases, but there are other options that do not require such a high capital expenditure.

If the facilities are within line of sight of each other and within the range, the company can easily deploy a connection using these bands, and depending on other usage of the band in the location, it could get multi-gigabit of data transfer rates. After a relatively modest capital expenditure, the company will have a secure, reliable connection with low ongoing operating expenses.

8.6.2 Internet of Things

Internet of Things (IoT) devices can range from small sensors to large industrial equipment and may find usage across industries. IoT applications too are diverse. Consequently, the communications requirements for these applications are quite different. Depending on the intended usage, the application may require city-wide coverage or indoor coverage, or may require the capability to transfer large amounts of data. Certain IoT devices, such as sensors installed in remote areas, may also have low power requirements. Different wireless technologies address these different requirements.

The IEEE standard 802.11ad (WiGig) operates in the 60 GHz spectrum and supports very fast data transfers at a very low latency. These characteristics make WiGig a suitable choice for critical industrial applications where certainty of timely access is key, albeit over short ranges.[68] A typical use case for WiGig would be an industrial control and machine vision system used for robotic guidance. Another IoT use case for WiGig would be a 4K video camera security system with high bandwidth requirements. An example of an existing WiGig implementation is the prototype developed for use at the Tokyo-Narita airport. This system, which combines WiGig with Mobile Edge Computing (MEC) to enable ultra-high speed downloads with low latency, is expected to be used for the 2020 Summer Olympics.[69]

Some experts believe that WiGig is not suited for IoT since WiGig requires line of sight and can't penetrate even thin walls.[70] Another Wi-Fi technology, Wi-Fi HaLow is based on IEEE 802.11ah and operates in the sub 1 GHz spectrum. Longer range, lower power operation and lower throughput compared to other Wi-Fi technologies makes it more suitable for IoT devices distributed in larger areas.

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[68] Wireless Broadband Alliance. *Internet of Things: New Vertical Value Chains & Interoperability*. Mar. 2017. URL: http://www.wballiance.com/wp-content/uploads/2017/03/IoT-New-Vertical-Value-Chains-and-Interoperability-v1.00.pdf.

[69] Sakaguchi et al. *Where, When, and How mmWave is Used in 5G and Beyond*. 2017. URL: https://arxiv.org/ftp/arxiv/papers/1704/1704.08131.pdf.

[70] JB Systems. *Will 60 GHz be the next 2.4 GHz Wi-Fi?* Jan. 19, 2015. URL: http://jbsystech.com/will-60ghz-next-2-4ghz-Wi-Fi/.

8.6.3 Vehicle to vehicle communication

Vehicle to Vehicle (V2V) communication is another potential area of application for WiGig. Vehicles will increasingly utilise sensors, using technologies such as Light Detection and Ranging (LIDAR), to transmit large amounts of data in connected vehicle systems.[71] The data rate requirements for such systems are very high, especially for systems involving autonomous vehicles having enhanced sensing capabilities. WiGig is seen as a solution for these scenarios but challenges such as antenna placement and interference continue to persist.

8.6.4 Augmented Reality (AR)/Virtual Reality (VR) Systems

The demand for AR/VR systems and the data usage by such systems is expected to increase significantly in the coming years. A recent study claims that data traffic for mobile VR applications is expected to grow by 950% between 2016 and 2021.[72] VR systems have high throughput and low power requirements. Current VR displays are wired peripherals though and manufacturers are looking to make them self-contained devices with processing capabilities built inside the device. Such VR headsets need to be lightweight and must ensure that they offer a natural immersive experience to users.[73] WiGig, with its gigabit speeds, low latency and low interference levels, is being seen as a solution to the aforementioned issues with VR systems. Manufacturers such as Intel are already working on employing WiGig for VR systems and such wireless headsets are expected to be more common in the coming years.[74]

[71] Heath R.W. *Vehicular mmWave communication: opportunities and challenges.* 2015. URL: http://users.ece.utexas.edu/~rheath/presentations/2015/DSTOPvehicularMmWave2015Heath.pdf.

[72] Cisco. *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016-2021.* 2017-02.

[73] Bluwireless Technologies. *IEEE 802.11ad (WiGig's) future in virtual reality (VR) systems.* Dec. 21, 2016. URL: http://www.bluwirelesstechnology.com/ieee-802-11ad-wigigs-future-virtual-reality-vr-systems/.

[74] New Atlas. *Intel and HTC tease upcoming WiGig accessory to untether the Vive.* June 30, 2017. URL: https://newatlas.com/htc-vive-intel-wigig-wireless/49784/.

9 Mapping the economic benefits arising from the use cases

In choosing a method for releasing this spectrum, the focus should be on generating the highest net benefits for the society as a whole. In this section, we present the key economic benefits that are expected to accrue from the uses of these spectrum bands. Given the paucity of relevant data and earlier studies, we are unable to reasonably monetise the economic value of these benefits.

If the V-band and E-band spectrum is delicensed or lightly licensed, the pass-through cost of this spectrum will be zero or very small, and only the installation costs incurred will be substantial. In a competitive market, ceteris paribus, reduction in costs will lead to lower prices for consumers. Given the price elasticity of demand for internet, and the rapid evolution of technology, this availability will lead to higher usage of broadband internet by consumers, allow new consumers to use broadband internet, and enable innovative business models and technologies.

Since the use of these spectrum bands will lead to a reduction in costs, and create opportunity to reach hitherto unreachable locations in dense urban environments with high speed Internet, it will be a shift in the supply curve, so that more quantity is made available at a given price. If the quality of Internet access improves, as is expected from the use of V-band and E-band, there may also be a shift in the demand curve, as users may be willing to pay more for the connection. Quality improvement also has larger economic benefits. For instance, if the speed of Internet usage increases, users will be able to put their connections to a wider variety of uses, especially in commercial contexts. Bohlin and Rohman, 2012, estimate that each doubling of broadband speed leads to 0.3 percent increase in GDP.[75]

Following is an overview of the key expected economic benefits arising from the uses of V-band and E-band spectrum. It should be noted that all these benefits cannot be fully attributed to these spectrum bands. Some of them, such as benefits from Wi-Gig devices, may be fully attributed to these spectrum bands, because they rely completely on the availability of this spectrum. Other benefits can be partially attributed to these bands.

- *Producer surplus due to offloading from mobile broadband:* Producer

[75] Rohman I.K. and Bohlin E. *Does Broadband Speed Really Matter for Driving Economic Growth? Investigating OECD Countries*. 2012. URL: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2034284.

surplus is the difference between the price that a service provider charges, and the minimum price the provider will be willing to accept. Producer surplus usually increases if the cost somehow falls without change in price charged. It can also increase if the price increases without corresponding increase in costs. The use of these spectrum bands would enable offloading from mobile broadband which will generate producer surplus.

- *Offloading by users:* Use of commercial Wi-Fi hotspots and fixed broadband would lead to offloading from mobile broadband. This would enable service providers to use the same infrastructure to give more services, especially in congested areas. The producer surplus would be equal to the total cost savings compared to developing the infrastructure for such access using only mobile broadband. Estimating the monetary value of this producer surplus requires information from service providers about the cost of developing backhaul infrastructure using different options - fibre, V-band, E-band. In the current scenario, when telecom sector is under tremendous stress on account of growing losses, debt pile, price war, reduced revenue and irrational spectrum costs, offloading of traffic on commercial Wi-Fi hotspots can significantly reduce the burden on the TSPs.[76]
- *Offloading by service providers:* As some users allow their private Wi-Fi hotspots to double up as community hotspots - a common practice in many countries - this will enable mobile broadband providers to enter into agreements with fixed broadband providers to allow offloading to Wi-Fi hotspots as soon as a user comes within the range of a hotspot. This will create producer surplus, as it will reduce the infrastructure cost. This surplus may accrue to providers of fixed broadband (as fees) as well as to mobile broadband service providers (as additional revenues or lower costs). The global average is one community hotspot per 30 persons.[77] There is a huge opportunity to create producer surplus by developing community hotspots in India, but that needs proliferation of fixed broadband connections.

- *Producer surplus from lower backhaul costs for mobile broadband:* Lower backhaul costs could lead to producer surplus for mobile broadband

[76] Ministry of Finance, Government of India. *Economic Survey 2017-18.* 2017. URL: http://mofapp.nic.in:8080/economicsurvey/.

[77] iPass, *Wi-Fi growth map*.

service providers. This can be calculated by comparing the costs of backhaul using V-band and E-band with the cost of establishing infrastructure for a similar quality of service using other backhaul solutions, such as fibre optic cables. Most of this surplus would arise in congested areas. As per analysis presented earlier, about 15 percent of cell sites may face this situation by the year 2022.

- *Consumer surplus from use of commercial Wi-Fi hotspots and fixed broadband:* Consumer surplus is the difference between the price consumers are willing to pay and the amount they actually pay for a given quality and amount of service. This is the benefit that consumer derive from use of a service or good. Consumer surplus can increase if consumers' willingness to pay for a unit of service increases, which usually happens with perceived improvements in quality. It can also increase if prices of a service fall. A variety of sources for consumer surplus can be identified on the basis of the uses of V-band and E-band presented in the previous section.
  - *Consumer surplus from commercial Wi-Fi in dense locations:* In a densely populated location (eg. market place, tourist spot), for a given level of quality (speed and consistency), commercial Wi-Fi hotspots may be able to provide Internet access at a lower unit cost than mobile broadband. This will produce consumer surplus, which can be calculated as the volume of usage multiplied into the difference between unit cost for a certain quality of mobile broadband use and the unit cost of commercial Wi-Fi use for the same quality of access.
  - *Consumer surplus from free Internet:* Many providers of commercial Wi-Fi hotspots may give a limited amount of Internet usage for free. The entire value of such access would be consumer surplus. This can also be facilitated by third-party financing by government or any other agency.
  - *Consumer surplus from greater use of Wi-Fi and Wi-Gig devices:* Whenever we purchase and use a device, some consumer surplus accrues to us, as the price we pay is lower than the benefit we get from the device. Since greater availability of Wi-Fi and Wi-Gig for access may lead to higher usage of Wi-Fi and Wi-Gig devices, the consumer surplus from these devices can also be partially attributed to use of V-band and E-band, to the extent that this spectrum enables usage of these devices.

- *Consumer surplus from indoor use of fixed broadband:* For a given level of quality, the per unit price for fixed broadband is usually lower than that of mobile broadband. The difference between the price paid for mobile broadband and that for fixed broadband per unit is consumer surplus arising from this proliferation.

- *GDP contributions:* In addition to consumer surplus and producer surplus, there are also GDP contributions that may arise from the use of this spectrum. These are mostly in terms of new or improved businesses and technologies that are enabled by this spectrum band.

  - *GDP contribution of commercial Wi-Fi and Wi-Gig hotspots:* Provision of commercial Wi-Fi in public locations is relatively sparse in India. If such hotspots proliferate, the value addition done by the service providers operating the hotspots with V-band and E-band for backhaul would be a contribution to India's GDP that could not have been made in the absence of this spectrum. The firms would use spectrum, their capital investments and operating expenditure as inputs, and charge fees from users. The difference would be the value addition that would contribute to India's GDP.

  - *GDP contribution of higher speed:* Use of commercial Wi-Fi and Wi-Gig hotspots and proliferation of fixed broadband would lead to higher average speed of Internet usage. In aggregate, this would lead to increase in GDP. If, for example, use of V-band and E-band leads to 50 percent increase in average speeds overall, this may lead to a GDP increase of about 0.15 percent.[78]

  - *GDP contribution due to Wi-Fi and Wi-Gig device sales:* The sale of Wi-Fi tablets in India has been falling in recent years.[79]

    Perhaps this is due to the poor Wi-Fi network in India. If the system of Internet access changes, so that there is better availability of Wi-Fi hotspots and Wi-Gig hotspots, this trend could reverse. The value addition from additional purchase of such devices would be a contribution to India's GDP.

  - *GDP contribution of new or modified businesses and technologies:* Most of the other uses of V-band and E-band discussed in this

[78] Based on the nominal GDP for 2016-17.

[79] Ultra News. *India tablet sales fall 16%, but 4G picks up in Jan-Mar 2017.* June 12, 2017. URL: https://ultra.news/t-t/31689/india-tablet-sales-fall-16-4g-picks-jan-mar-2017/.

note would lead to GDP contributions, just like the technological and business model innovations that followed liberalisation of other spectrum bands. For instance, when RFID was delicensed, its extensive use in retail establishments led to substantial contributions to the GDP.

Since most of these benefits will accrue to consumers and producers, this will also create potential for the government to extract part of this benefit as additional tax collection. For instance, sale of devices and provision of services will create opportunities for the government to collect taxes from these activities. Further, to the extent that these activities will lead to additional profits for service providers, part of that profit will be taxed by the government. The concern that government may lose out on some non-tax revenue if it chooses to delicense this spectrum may be overcome by these revenue opportunities. Further, in light licensing regimes, some fees may also be levied on the usage of the band. However, as discussed earlier, keeping the fees high may impede usage of these bands, and may discourage some types of usage that may generate significant economic benefits. The experience of wi-fi and RFID spectrum supports this contention.

10 Conclusion

We have attempted to quantify the scale of usage of both V-band & E-band, and mapped those uses with potential economic benefits that would accrue from them. The paucity of data and studies prevented us from monetising the value of economic benefits from V-band and E-band. A few key points takeaways from this analysis are worth noting.

First, while choosing a method for releasing this spectrum, the focus should be on ensuring maximum aggregate benefits for the society, and not short-term revenue maximisation for the Government. Among other things, this means that the potential of these bands to help improve India's overall system of broadband Internet access should be realised. There are inherent limitations in the present system of reliance on mobile broadband, near absence of commercial Wi-Fi hotspots, and low penetration of high speed fixed broadband. Some of these limitations could be partially overcome by use of these spectrum bands, along with other suitable policy measures.

Second, based on the analysis in this note, it is safe to say that the economic benefits of these spectrum bands are likely to be substantial. Studies on economic benefits of previously unlicensed spectrum bands suggest that the variety and scale of economic benefits may increase over a period of time. However, if delicensing is not feasible, it will be better to release this spectrum using block licensing or node registration. Link-by-link registration/licensing may not be suitable for backhaul usage, as there will be multiple links between nodes in a given area. Such registration is more suitable for point-to-point networks, and not for mesh networks.

Third, as has happened with other unlicensed spectrum bands, innovation and competition may lead to many types of uses that are difficult to anticipate at present. Hence, it would make sense to liberalise the spectrum without any cumbersome procedures or fees. For instance, levying a fee or auctioning the spectrum may limit the potential uses of the spectrum, as it would have for Wi-Fi and RFID spectrum bands. Since many potential users of the spectrum may be individuals and organisations outside of the regulated telecom sector, placing licensing requirements on them may restrict innovative uses of this spectrum.

Fourth, many of the benefits are not realised by the service providers, and accrue in terms of consumer surplus and GDP contributions of businesses and technological innovations spurred by the availability of this spectrum. If government decides to target revenue maximisation while allocating the spectrum, it will only be able to extract part of the producer surplus. However this will have effect on proliferation and therefore on consumer surplus and GDP contributions. This may lead to significantly lower economic benefits of the spectrum for the economy as a whole. At the same time, government may extract revenue afterwards, which may be linked to the scale of usage.

Fifth, in thinking about the strategy to release the spectrum, it is important to align with global device ecosystems and standards, so that India can benefit from economies of scale in production of devices, and potentially become a manufacturing hub for the devices.

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