Study Paper on the Feasibility of 2.3GHz (Band 40) Implementation for 4G LTE Services in Bhutan

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1. Background

With the increase in the demand for mobile broadband services it is critical to enhance its Quality of Services (QoS) delivered to the customers. Recently, there were issues of degraded mobile broadband QoS especially during the lockdown period and it is important that every possible solution is studied and implemented for enhancing the mobile broadband QoS.

Network densification through deploying more mobile networks is one of the solutions to enhancing the mobile broadband QoS. However, owing to the limited land space especially in urban areas has significantly posed challenges to the telecom operators in expanding their mobile broadband networks.

The other solution to solving such issues is through enhancing the network capacity by issuing more frequency spectrum to the telecom operators. The telecom operators in Bhutan have deployed 1800MHz (Band 3) and 700MHz (Band 28) for 4G LTE and these spectrum bands have been fully utilized. The available spectrum in 2.3GHz (band 40) is considered suitable for deploying the 4G LTE in Bhutan. Being able to deploy band 40 along with band 3 and band 28 will enhance the network capacity of mobile broadband services in the country.

Therefore, this study paper studies the feasibility of deploying the spectrum band 40 for 4G LTE services as an additional capacity enhancement in 4G services.

2. What is LTE Band 40?

LTE Band 40, 2.3GHz (2300MHz - 2400MHz)[1] is a portion of the Ultra High Frequency (UHF) radio spectrum inside the S-band frequency range. It is the eight most popular band used by mobile operators for LTE networks. This band is internationally allocated to the mobile service on a Primary basis and allocated to amateur radio and amateur satellite use on the Secondary basis. This band is deployed mostly for the TDD networks with the channel bandwidth ranging from 5, 10, 15 or 20MHz or more. It is typically deployed due to the wide availability of spectrum and its short range permits dense coverage for maximum capacity and has the coverage area (-100 dBm): 88.60Km^2

LTE-A or LTE-Advanced Pro technologies can be deployed using carrier aggregation to combine various bandwidths of band 40 with other carriers. According to Jakarta, ever since the development of 4G, global operators have regarded 2.3 GHz as a golden frequency. And 2.3GHz

[1] https://www.xgpforum.com/new_XGP/en/001/TDD_band.html
https://www.rfmw.com/data/rfmw_lte_band_chart.pdf

provides both capacity and coverage, which 5G also makes full use of to boost the existing 4G performance[2].

For this frequency band the most common bandwidth is 20MHz which is allocated by 81.8% of the operators that have currently deployed LTE in this band.[3]

3. Services Which Uses 2.3GHz

Since the 2.3GHz band is a part of the S band (2 - 4)GHz, globally, it is used for various purposes such as Cellular mobile broadband, Wifi, Wimax, Amateur radio and Satellite communication.[4] Depending on the country, (2.3 - 2.4)GHz may be used for other purposes too.

For Bhutan, the band is currently being used for Amateur radio services and it is not yet deployed for the Cellular mobile broadband.

4. Frequency that operators have deployed for 4G LTE in Bhutan

The Bhutan has two mobile network operators:

I. Bhutan Telecom Limited (B-Mobile)
II. Tashi InfoComm Limited (TashiCell)

The table below shows the frequencies that the operators have deployed for 4G LTE services in Bhutan.

Sl. No	Operators	Frequencies deployed for 4G LTE	Remarks
1.	B-Mobile	1800MHz (B3), 700MHz (B28)	
2.	TashiCell	1800MHz (B3), 700MHz (B28)	

[2] https://jakartaglobe.id/special-updates/23ghz-band-to-speed-up-ict-industry-growth/
[3] https://halberdbastion.com/technology/cellular/4g-lte/lte-frequency-bands/b40-2300-mhz

[4] https://en.wikipedia.org/wiki/2.4_GHz_radio_use

5. Frequency that operators have deployed for LTE in other countries

More LTE networks have been deployed at 1800 MHz (band 3) than in any other frequency band in other countries. Band 3 is now widely used throughout Europe, Asia Pacific (APAC) and MEA is also deployed in selected countries in South America. Band 3 is now used by just over 46% of all LTE or LTE-Advanced network operators worldwide (Data from GSA's NTS database, 4 January 2019).

The second-most deployed spectrum band in the network worldwide is 800 MHz (Band 20). And the third major band in terms of global deployments is Band 7 (2600MHz), launched in 190 commercial networks[5].

Indian telecom operators have received spectrum license to operate 4G LTE networks over (band 5) LTE FDD (850 MHz), band 3 FDD (1800 MHz), band 40 LTE TDD (2300 MHz), band 28 (700MHz) and band 41 LTE TDD (2500 MHz)[6].

LTE frequency bands B1(2100MHz), B3 (1800MHz), B7 (2600MHz) and B8 (1800MHz) are the most common frequency bands that are deployed by the operators in Europe. Whereas LTE frequency band B2, B4, B17 and B30 are deployed by the operators in America and USA[7].

6. List of LTE networks in Asia

Country	Bands
1. India	B5 (850MHz)
	B8 (900MHz)
	B3 (1800MHz)
	B40 (2300MHz)
	B28 (700MHz)
2. Nepal	B3 (1800MHz)
	B20 (800MHz)
3. Sri Lanka	B1 (2100MHz)
	B3 (1800MHz)
	B8 (900MHz)

[5] https://gsacom.com/paper/lte-ecosystem-july-2020-global-status-report/

[6] https://en.wikipedia.org/wiki/List_of_LTE_networks_in_Asia

[7] https://gsacom.com/paper/band-3-1800-mhz-jan2019/#:~:text=Far%20more%20LTE%20networks%20have,selected%20 countries%20in%20South%20africa.

4. Thailand	B1 (2100MHz)
	B3 (1800MHz)
	B40 (2300MHz)
	B28 (700MHz)
5. China	B8 (800MHz)
	B39 (1900MHz)
	B40 (2300MHz)
	B41 (2500MHz)
6. Japan	B1 (2100MHz)
	B3 (1800MHz)
	B28 (700MHz)
	B11 (1500MHz)
	B21 (1500MHz)
	B18 (850MHz)
	B19 (850MHz)
7. Singapore	B3 (1800MHz)
	B7 (2600MHz)
	B8 (900MHz)
	B28 (planned auction)
8. South Korean	B8 (900MHz)
	B3 (1800MHz)
	B1 (2100MHz)
	B7 (2600MHz)
	B28 (planned auction)
9. Bangladesh	B1 (2100MHz)
	B3 (1800MHz)
10. Malaysia	B28 (700MHz)
	B20 (800MHz)
	B5 (850MHz)
	B8 (900MHz)
	B40 (2300MHz)
	B7 (2600MHz)
11. Afghanistan	B3 (1800MHz)
12. Philippines	B3 (1800MHz)
	B5 (850MHz)
	B28 (700MHz)

7. 2.3GHz Spectrum Allocation as per National Radio Rules and Regulations 2021

As per the National Frequency Allocation Table of Bhutan, the Primary Services allocation in 2.3GHz are for Fixed and Mobile services and the Radiolocation. The Amateur Radio is in the Secondary Services.

The table below shows the frequency allocation table for 2.3GHz

2 170-2 520 MHz

Allocation to services			
Region 1	**Region 2**	**Region 3**	**Bhutan**
2 170-2 200 FIXED MOBILE MOBILE-SATELLITE (space-to-Earth) 5.351A 5.388 5.389A 5.389F			**2 170-2 200** FIXED MOBILE MOBILE-SATELLITE (space-to-Earth) 5.351A 5.388 5.389A 5.389F
2 200-2 290 SPACE OPERATION (space-to-Earth) (space-to-space) EARTH EXPLORATION-SATELLITE (space-to-Earth) (space-to-space) FIXED MOBILE 5.391 SPACE RESEARCH (space-to-Earth) (space-to-space) 5.392			**2 200-2 290** SPACE OPERATION (space-to-Earth) (space-to-space) EARTH EXPLORATION SATELLITE (space-to-Earth) (space-to-space) FIXED MOBILE 5.391 SPACE RESEARCH (space-to-Earth) (space-to-space) 5.392
2 290-2 300 FIXED MOBILE except aeronautical mobile SPACE RESEARCH (deep space) (space-to-Earth)			**2 290-2 300** FIXED MOBILE except aeronautical mobile SPACE RESEARCH (deep space) (space-to-Earth)
2 300-2 450 FIXED MOBILE 5.384A Amateur Radiolocation 5.150 5.282 5.395	**2 300-2 450** FIXED MOBILE 5.384A RADIOLOCATION Amateur 5.150 5.282 5.393 5.394 5.396		**2 300-2 450** FIXED MOBILE 5.384A RADIOLOCATION Amateur 5.150 5.282 5.393 5.394 5.396
2 450-2 483.5 FIXED MOBILE Radiolocation 5.150	**2 450-2 483.5** FIXED MOBILE RADIOLOCATION 5.150		**2 450-2 483.5** FIXED MOBILE RADIOLOCATION 5.150

8. The Countries and Operators Which Deployed 2.3GHz for 4G LTE

Countries	Operators
Australia	Optus nbn
Azerbaijan	Baktelecom
Canada	Telus
China	China Mobile China Unicom China Telecom
Côte d'Ivoire	YooMee Côte d'Ivoire
Gambia	Netpage
Georgia	Silknet
Ghana	Busy Ghana
Hongkong	China Mobile HK (CMHK) 3HK (Three Hong Kong)
Indonesia	Smartfren
India	Airtel Reliance Jio Vodafone Idea
Iraq	Goran Net
Mongolia	Unitel
Aotearoa New Zealand	Spark New Zealand

Nigeria	VDT Communications
Oman	Omantel Ooredoo Oman
Philippines	Smart Philippines Globe Telecom
Russia	MTS Russia Tele2Russia Vainakh Telecom
Saudi Arabia	Saudi Telecom Company (STC)
Sri Lanka	Dialog Sri Lanka
Tanzania	TTCL Smart Telecom Tanzania
Thailand	dtac
United Kingdom	O2UK
Uzbekistan	EVO
Zambia	Zamtel Vodafone Zambia Liquid Telecom Zambia

9. Majority Mobile handsets brands available in Bhutan

The Authority carried out the survey and analysis of the various mobile handsets available in the market of Bhutan. Some of the available mobile handsets and their compatibility with band 3 and band 40 are mentioned in the table below:

Sl. No	Brands	Models	Band 3 (1800 MHz)	Band 40 (2300MHz)
1.	Samsung	Galaxy note 20 (Nu.67,990)	Yes	Yes
		Galaxy note 20 Ultra (12GB RAM)	Yes	Yes
		Galaxy Z fold 3(12GB RAM)	Yes	Yes
		M51(8GB RAM, Nu.24,990)	Yes	Yes
		M51(6GB RAM, Nu.22,990)	Yes	Yes
		A52s (8GB RAM)	Yes	Yes
		A52s (6GB RAM)	Yes	Yes
		A52 (6GB RAM)	Yes	Yes
		A72 (8GB RAM)	Yes	Yes
		F62 (8/6GB RAM)	Yes	Yes
		F42(8GB RAM)	Yes	Yes
		A32 (6GB RAM)	Yes	Yes
		A22 (6GB RAM)	Yes	Yes
		F22 (6GB RAM)	Yes	Yes
		M12 (6GB RAM)	Yes	Yes
		A51(Nu.21,590)	Yes	Yes
		M31s (8GB RAM, Nu.19,690)	Yes	Yes
		Tab A7 (2020) (Nu.19,390)	Yes	Yes
		M31 (8GB RAM,Nu.18,690)	Yes	Yes
		M31s (6GB RAM, Nu.17,890)	Yes	Yes
		M31 (6GB,128GB, Nu.16,190)	Yes	Yes
		M21 (128GB, Nu.14,590)	Yes	Yes
		A21s (128GB, 14,190)	Yes	Yes
		M21 (64GB, Nu.12,990)	Yes	Yes
		A20s (64GB, Nu.12,190)	Yes	Yes
		A21s (64GB, Nu.12,190)	Yes	Yes

		Tab A8 (2019, Nu.10,990)	Yes	Yes
		A20s (32GB, Nu.10,490)	Yes	Yes
		M11 (Nu.9790)		
		M02s (64GB, Nu.9,190)	Yes	Yes
		M02s (32GB, Nu.8,390)	Yes	Yes
		A10s (3GB RAM,Nu.8190)	Yes	Yes
		A10s (2GB RAM)	Yes	No
		M01 (Nu.7,490)	Yes	Yes
		M02 (3GB RAM, Nu.7,190)	Yes	Yes
		M02 (2GB RAM, Nu.6,690)	Yes	Yes
		Galaxy M01 Core 32GB (Nu.5,490)	Yes	Yes
		Galaxy M01 Core 16GB (Nu.4,590)	Yes	Yes
2.	VIVO	V20 Pro (8+128G, Nu.27,990)	Yes	Yes
		Y15A (8+128G, Nu.16990)	Yes	Yes
		Y31 (6+128G, Nu.15,990)	Yes	Yes
		Y20G (6+128G, Nu.14,490)	Yes	Yes
		Y30 (6+128G, Nu.14,490)	Yes	Yes
		Y12S (3+32G, Nu.9,490)	Yes	Yes
		X50 Pro (8+256G, Nu.47,990)	Yes	Yes
		Y20 (4+64G, Nu.12,490)	Yes	Yes
		Y20 (6+64G, Nu.13,490)	Yes	Yes
		Y20i (3+64G, Nu.10,990)	Yes	Yes
		V20 (8+128G, Nu.23,990)	Yes	Yes
		V20 (8+256G, Nu.26,990)	Yes	Yes
		Y91i (2+32G, Nu.7,490)	Yes	Yes
		Y91i (3+32G, Nu.7,990)	Yes	Yes
		Y11 (3+32G, Nu.8,990)	Yes	Yes
		Y12 (3+64G, Nu.10,490)	Yes	Yes
		Y50 (8+128G, Nu.15,990)	Yes	Yes

		Y19 (8+128G, Nu.23,920)	Yes	Yes
		Y15 (4+64G, Nu.11,990)	Yes	Yes
		S1 PRO (8+128G, Nu.18,490)	Yes	Yes
		V19 (8+256G, Nu.26,990)	Yes	Yes
		Y30 (4+128G, Nu.13,490)	Yes	Yes
		V20SE (8+128G, Nu.18,990)	Yes	Yes
		Y20A	Yes	Yes
		Y51A	Yes	Yes
		Y51	Yes	Yes
		Y21 (4GB RAM)	Yes	Yes
		Y53s (8GB RAM)	Yes	Yes
		V21e (8GB RAM)	Yes	Yes
		V21 (8GB RAM)	Yes	Yes
3.	OPPO	OPPO A8	Yes	Yes
		OPPO A11	Yes	Yes
		OPPO A5	Yes	Yes
4.	Apple	IPhone 11 (64GB)	Yes	Yes
		IPhone 11 (128GB)	Yes	Yes
		IPhone 12 (64GB)	Yes	Yes
		IPhone 12 (128GB)	Yes	Yes
		IPhone 12 Pro (128GB)	Yes	Yes
		IPhone 12 Pro (256GB)	Yes	Yes
		IPhone 12 Pro Max (128GB)	Yes	Yes
		IPhone 12 Pro Max (256GB)	Yes	Yes
		IPhone 8 plus	Yes	Yes
5.	Redmi	Redmi 9A	Yes	Yes
		Redmi 7A	Yes	Yes
		Redmi note 8	Yes	Yes

10. Possible Interference with Other Radio Services

Band 40 is adjacent to the ISM band (2.4GHz - 2.5GHz), which may cause interference if all the 100 MHz spectrum in Band 40 is utilized and no guard bands are specified. The ISM band in 2.4GHz frequency is used by Wifi, Bluetooth, Microwave oven, Audio-visual devices and smart power meters. There may be interference on devices using 2.4 GHz for their operation if the proper guard band is not specified between 2.3GHz and 2.4GHz.

However, some of the literature shares the possibility of coexistence of LTE in Band 40 with the devices using 2.4GHz band (ISM) as mentioned below:

1) LTE and Wi-fi

   A study conducted by Phil Kesby, Phil Brown, Phil Ray of Arqiva (Telecommunications company) for the Ofcom (UK's regulatory body for communication services) found that the median blocking level for Wi-Fi devices in presence of LTE waveform is -32.8dBmwhich could be reduced if the Wi-Fi devices have integrated LTE rejection filters. The throughput reduction of all the Wi-Fi devices under test were similar when a LTE network was introduced. The study was conducted in laboratory conditions therefore the authors confirm the need to do the test in live scenarios.[8]

   Another report from Ofcom concludes that Wi-Fi devices could be affected by the new LTE base stations but in all the scenarios they considered, the interference would be minimal and consumers could possibly mitigate the interference.[9]

   The studies are based on only if the Wi-fi devices and the LTE network uses the same frequency which will not be the case with band 40.

2) LTE and Bluetooth equipment operating in the ISM band

   Certain devices use bluetooth in the ISM band and since the ISM band is adjacent to band 40, there are possible risks of interference and blocking. LTE in band 40 could cause interference in bluetooth devices by two dominant mechanisms. The first is through out of band emissions from the LTE signal falling into Bluetooth band and appearing as co-channel interference. The second mechanism is through blocking, which is the result of strong out of band signals driving the Bluetooth receiver front-end into compression and thus reducing the gain to the wanted signal.

[8] https://www.ofcom.org.uk/__data/assets/pdf_file/0021/77034/arqiva_annex_report.pdf

[9] https://www.ofcom.org.uk/__data/assets/pdf_file/0019/36037/updated-analysis.pdf

The study conducted by Macltd for Ofcom concluded that the presence of TDD LTE signals causes a measurable but low-level interference effect to the Bluetooth channels at the low end of the ISM band. However, Bluetooth devices operating with Frequency Hopping enabled were[10] found to be very robust to the LTE signal.

However, it can be mitigated by ensuring that there are no out of band emissions from the LTE networks deployed in 2.3GHz.

3) LTE and other devices operating in the ISM band

Along with Wi-Fi devices and Bluetooth devices, the ISM band is used by ZigBee, medical monitoring equipment and assistive listening devices (ALDs). Similar to the conclusions drawn on Wi-Fi devices and Bluetooth devices, the ZigBee devices and ALDs have a very low risk of interference from LTE base stations. However, it is advised that network operators should closely work with Hospitals if there are plans for establishing base stations near a hospital to ensure that there is no interference to the hospital system.

There are some amateur radio services in the 2.3GHz band. Deploying LTE in band 40 could possibly interfere with the amateur radio services and vice versa. However, the amateur radio services are Secondary in nature of allocation as per the National Frequency Allocation Table of Bhutan. The amateur radio services have frequencies in 2300–2310 MHz (lower segment), 2390–2450 MHz (upper segment[11]) which can be ensured by enabling the guard band.

11. Advantages of Deploying 2.3GHz for Mobile Broadband

The advantages of deploying LTE in band 40 are:

1. **Wide availability of spectrum:** Along with requiring no duplex spacing, band 40 has a wide bandwidth of 100MHz which can provide better performance. It can be deployed as the capacity enhancement to the mobile broadband services along with the other spectrum band.

2. **Dense coverage:** Its short range permits deployment in dense areas where with its wide bandwidth, it can be used to its maximum capacity.

[10] https://www.ofcom.org.uk/__data/assets/pdf_file/0035/68795/the_effect_of_tdd_lte_signals.pdf
[11] https://en.wikipedia.org/wiki/Amateur_radio_frequency_allocations

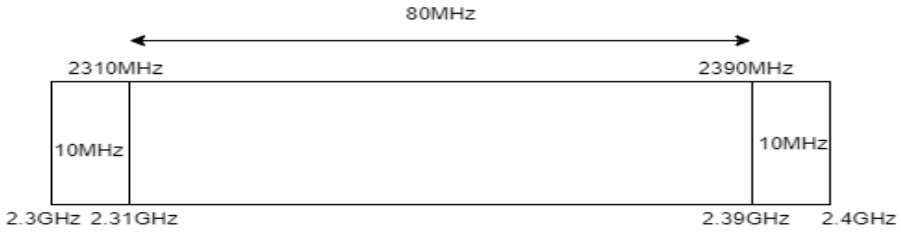
3. **Flexibility in deploying:** Mobile network operators have the flexibility to deploy LTE using band 40 as a single band or as part of a multi-band network. Carrier aggregation can be used to combine various bandwidths of band 40 with other carriers.

4. **Low bandwidth deployment:** LTE TDD networks, in general, can be practically deployed using bands as low as just 10 MHz.

5. **Uses OFDMA modulation:** LTE TDD uses OFDMA modulation on the downlink data stream enabling the relatively simple implementation of multiple-input/multiple-output (MIMO), beamforming, and various other intelligent radio techniques.[12]

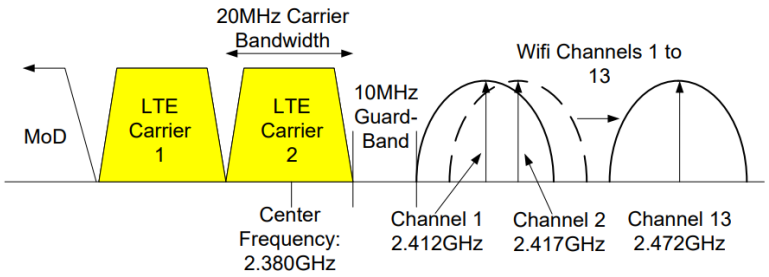
12. Proposed 2.3GHz LTE TDD Band Plan

The figure below is proposed for the frequency band plan to implement LTE TDD in band 40 for Bhutan.



- The 10MHz guard band is proposed at the upper and lower end of the proposed band.

- The 10MHz guard band at the upper end is proposed in order to ensure that there is no interference to the unlicensed band frequency usages for instance to Wifi, Bluetooth and other radio services. The similar guard band is also applied in the LTE band plan of UK as shown in the figure below:



12 https://www.sequans.com/wp-content/uploads/2013/07/TD-LTE_Technology_Roadmap_and_Ecosystem_White_Paper.pdf

- The 10MHz guard band in the lower end is kept in order to ensure that there is minimal interference to the amateur radio services and also the radio services operating at the lower end of the 2.3GHz band.

- The 80MHz is proposed for the LTE TDD implementation in 2.3GHz which can be allocated to both the operators.

13. Recommendation

It is therefore recommended that:

1. The 2.3GHz band 40 may be allocated for implementation of LTE TDD services which can help in maximizing the capacity of existing limited 4G LTE services in the country.

2. As per the mobile handset study, the majority of the handset available in the country also supports both band 3 and band 40 which may not be much issue on the user handset compatibility with the LTE TDD implementation in band 40.

3. The proposed band plan for 2.3GHz band 40 for LTE implementation may be approved. However, it is recommended that the consultation with the telecom operators may be carried out.

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sciencedirect.com/science/article/pii/B9780128205815000122#f0010
https://www.gsma.com/spectrum/wp-content/uploads/2012/03/momemtumbehindltewhitepaperjan10.pdf
https://www.ofcom.org.uk/__data/assets/pdf_file/0021/77034/arqiva_annex_report.pdf
https://www.sequans.com/wp-content/uploads/2013/07/TD-LTE_Technology_Roadmap_and_Ecosystem_White_Paper.pdf
https://www.ofcom.org.uk/__data/assets/pdf_file/0030/81579/info-memorandum.pdf