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Study of spectrum scarcity and community wireless network operators in India

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***Abstract*—The rapid development of the Indian mobile market and the proliferation of operators have increased the demand for licensed spectrum. Moreover, the utilization of allocated bands can hardly be improved given the large number of operators and the geographical division in circles. This paper analyses the scarcity of licensed spectrum in India and discusses the opportunities derived from the utilization of the unlicensed spectrum. More precisely, the paper identifies wireless community network projects that use the unlicensed spectrum. Community wireless networks can play an important role in bridging the Digital Divide[1] in India and in extending the scarce licensed spectrum by improving the exploitation of unlicensed spectrum.**

Keywords - 3GPP operators, Community wireless network operators, spectrum scarce

I. Introduction

India is the second largest telecommunication market in the world with the third highest number of Internet users [1]. Such a large demand combined with a high market competition explains the rapid growth of the telecom economy and the consequent need for an efficient use of the license spectrum. In more detail, the mobile market presents an unusual large number of operators with significantly different market shares.[2] For this reason, the first objective of this paper is to analyze the licensed spectrum scarcity suffered by mobile operators and possible consequences to end users. In this context, Wi-Fi technologies that employ the unlicensed spectrum come into the picture. These can be used in rural areas where 70 percent of Indian population lives and the mobile network is not available in all the places. Furthermore, the lack of mobile service availability explains the emergence of community networks that might support welfare services such as education and health given their knowledge of the local community. Community network operators usually set up the network for the communities welfare and usually build up the infrastructure with the support of the community, other nonprofit/profit organizations to offer wireless access which is much cheaper and relevant to the local needs of that community. Community network operators are easy and faster to flourish since they are aware of the practicalities, the needs of that community and also for the availability of unlicensed spectrum. To lay down the infrastructure for the Wi-Fi network is very inexpensive, since the access points does not require high investments. Also, since the technology operates on unlicensed band, there are no heavy investments to made on the spectrum compared to the investments made by the 3GPP mobile operators on the licensed spectrum. In addition, infrastructure costs might be subsidized by the same community, local government, or nonprofit organizations. Therefore, the second objective of this paper is to discuss the role of community networks in extending Internet coverage in India using the unlicensed spectrum.

The paper is organized as follows. Section II provides the background of the Indian regulatory. Section III introduces the research methods used for the analysis. Section IV provides the analysis of scarcity of licensed spectrum and Community Wi-Fi projects in India. Section V provides the results of the analysis. Section VI provides the conclusion and Section VII imposes the future work of the paper.

II. Indian Regulatory Background

In this section, we will introduce the Indian telecom regulatory framework, the allocation of the licensed spectrum to the mobile network operators, and the government initiatives towards expansion of Internet throughout the country.

The Indian telecom regulatory framework consists of the Department of Telecom (DoT) which is responsible as the licensor, Telecom Regulatory Authority of India (TRAI) which is the regulator and Telecom Disputes Settlement and Appellate Tribunal (TDSAT) who is the judiciary.

India is classified into 22 telecom circles in which the network operator needs to buy a license for a particular area of operation to provide service or the network they choose to deploy. The 22 telecom circles include metro, A, B and C service areas. These are divided based on varied geographical outliers,the population density, the subscriber base and the revenue potential. Metro cities are Delhi, Kolkata, and Mumbai which has the dense population compared to any other cities. Telecom circle 'A' has the highest population density and service area C has the lowest. Appendix A summarizes the Internet, wireless and broadband subscriber base of selected

[1]Digital divide is an economic and social inequality with regard to access to, use of, or impact of information and communication technologies (ICT)

[2]The following list shows operators' subscriber number and their market share: Bharati Airtel Limited(95.3, 25.94%); BSNL(2.03, 9.44%); Vodafone(69.6, 18.94%); Idea Cellular(54.1, 14.72%); Reliance (35.1, 9.57%)

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states from different telecom circles. If a company wants to serve Internet in any one of the telecom circles in India,they must then purchase licenses through auctions by bidding for them. The first auction took place in 1994. Please refer to Appendix B for more details on the frequency bands which were auctioned and bought by different Indian mobile operators. It summarizes the year of Auction, the band which was auctioned, the operators which won the auction to the different telecom circles.The licenses are valid for 20 years and can be extended by 10 years once per license per circle.

There are many initiatives by the Government of India with the vision of creating a digital country. Some of them are 'Digital India' whose vision to transform India into a digitally empowered society and knowledge economy[2]. Another initiative is 'Make in India' with the vision for the companies to manufacture their products in India. This is one of the driving initiatives towards community networks. National Telecom Policy 2012 (NTP – 2012) is one among the other policies which aims to provide secure, reliable, affordable and high quality converged telecommunication services anytime, anywhere for an accelerated inclusive socio-economic development[3]. The National Optical Fiber Network(NOFN) is a project initiated in 2011 with the vision to provide broadband connectivity to over two lakh Gram Panchayat[3] of India.

III. RESEARCH METHODS

The research methodology used for this study is mainly through literature reviews. The preliminary work in this field is focused on study licensed spectrum in India[4]. There are very limited studies performed to analyze community network projects to provide wireless data access in India. There are a lot of initiatives taken by the Government of India in order to provide wireless access to the areas where there is no much connectivity by the network operators.

IV. ANALYSIS

In this section, we try to analyze the spectrum scarcity in the licensed spectrum in India and also analyze the community operators through various community network projects.

Table I gives us a summary of total available licensed spectrum for mobile broadband in various selected countries.[4] The current availability is the spectrum which is currently used to provide the services. The frequency bands for provisioning mobile broadband services uses frequency bands below 2.7GHz and hence we have calculated the spectrum availability with frequencies below 2.7GHz. The spectrum scarcity can be explained by the availability of total spectrum a single subscriber gets. This is calculated approximately by dividing current available spectrum(MHz) by the number of cellular subscribers(in millions). As we see the number of subscribers are relatively huge in India, and that the current availability of the spectrum for the country is low. And as a reason of that, each subscriber gets around 0.2Hz. This explains the spectrum scarcity that the mobile subscribers are facing. All the other countries in the table except for India and China have an average quantity of spectrum per subscriber.

Table I
SUMMARY OF LICENSED SPECTRUM FOR MOBILE BROADBAND IN SELECTED COUNTRIES

Country	Available spectrum (MHz)	Cellular subscribers (in millions)	Spectrum per subscriber(Hz)	MNO	HHI	4G speed (Mbps)
India	221	1127.0	0.2	11	0.14	6.39
USA	608	416.7	1.5	5	0.25	13.95
China	227	1364.9	0.16	3	0.47	21.74
Finland	398	7.3	54.52	3	0.33	24.34
Australia	478	26.5	18.0	3	0.35	32.50
Germany	615	94.4	6.51	3	0.28	20.30
Japan	500	164.2	3.04	3	0.36	22.38

MNO - Mobile network operators ; HHI - Herfindahl-Hirschman Index

Furthermore, we calculated HHI index[5] for the mobile markets for different countries in Table 1. The results provides us insights on market competition[9]. Among the countries presented in the table, India has a huge number of regional mobile network operators. And the competition between them is very high. The HHI index for India is less which means that the market has high competition between the operators. This explains that the telecom market in India is very much fragmented and the spectrum allocated to each operator is fragmented too or available in smaller chunks which cannot be used constructively compared to the other operators in other countries. This justifies the incapability for the operators to provide maximum quality of service in their networks to the subscribers. When compared the 4G speed[6] among the countries from Table 1, it is evident that India has the lowest speed of 6.39 Mbps. Although the table gives us enough evidence for the spectrum scarcity, there are many other reasons accountable too.

Table II gives us the summary of a few of the community wireless network projects that have been successful in providing Internet to the local community. The table describes the project names, the duration and their deployment regions. The telecom circle to which the region belongs is included to study further on the reachability of mobile networks in that area. The investor or the sponsor is the main driver for the projects to sustain. The table also provides the use case domains and the domains they have in focus for their networks.

[3]A local self-government organization in India of the village which is the lowest division under rural India

[4]The countries selected for this initial analysis were based in part on data availability.

[5]Herfindahl Index, also known as Herfindahl-Hirschman Index (HHI), like Concentration Ratio is used to measure the size of the firm in relation to the industry.(Kelly, 1981)

[6]We have considered network measurements from the Opensignal reports

Table II
SUMMARY OF COMMUNITY WIRELESS NETWORK PROJECTS IN INDIA

Projects names	**Project Duration**	**Deployment regions in India**	**Telecom Circle**	**Implementing / Funding entity**	**Transit Provider**	**Technologies employed**	**Coverage Size**	**Usecase Scenarios**
W4C Phase 1	2010-2011	Chanderi in Madhya Pradesh	B	NGO(DEF) / ISOC		Wireless mesh setup(one relay station, 5 point to point nodes)	20-30kms wide	School, Government
W4C Phase 2	2011-2012	Baran in Rajasthan	C			25 hotspots (3 point to point nodes with base station)	10km wide	NGO's, Schools
		Tilonia in Rajasthan	B					School
W4C Phase 3	2012-2013	Giriridh in Jharkhand	C	NGO(DEF), Local community partner (Nav,Jagtri,Yuva Mandal) / ISOC		Tower for wireless network has been set up and wireless mesh network has been deployed. 5 point-to-point nodes with a base station		Government, Banking, Local markets
		Mandla in Madhya Pradesh	B	NGO(DEF)/ ISOC		5 point – to -point nodes have been established with wireless mesh network		Government
		Nangaon in North Tripura	C			5 nodes have been established		Government
W4C Phase 5	2015-2016	Shivpuri, Baran, Guna	B			Mesh network was set up		intranet connectivity to 3 communities
W4C 6	2016-2017	Narayanpet in Mahbubnagar district of Telangana	C		BSNL(state owned)/ 4Mbps			Schools, Health centers
		Tham in Koderma district of Jharkhand	A		Airtel (Private owed) / 4 Mbps			Government, Schools
W4C Phase7 (Zero Connect)	2017-2018	Little Rann of Kutch, Manish Rann, Kharagodah Rann, Patadi and Surendrangar in Gujurat	A			Connected vans via unlicensed spectrum, to lend Internet-enabled devices	100 meters	Schools
AirJaldi	2016	Harisal in Amravati in Maharashtra	A	Microsoft's Affordable Access Initiatives Grant		NOFN Project&using TV White Spaces Technology (link)		Schools,health center and Wi-Fi services to the villagers.
	2010	Ranchi Network in Jharkhand	C	close co-operation with NGO/support from the Ford Foundation			1000 sq.km	Services offered to educational institutions, businesses and individuals.
Gram Marg		Palhgar in Maharashtra	A	IIT Bombay/Tata Teleservices		Using TV White spaces(500-520MHz)		Broadband connectivity to villagers

W4C - Wireless for Communities [5]

V. Results

The analysis revealed that mobile network operators are facing challenges with regard to spectrum since there are a lot of subscribers per operator and the available spectrum allocated to the country is so little that each subscriber gets approximately 0.2Hz. As a result, subscribers suffer from low quality of service. The analysis also revealed that the main project sponsors are DEF (Digital Empowerment Foundation) and ISOC (Internet Society Organization) in close cooperation with few local non-governmental organizations. Regarding backbone connectivity, while some projects used mobile operators such as Airtel and BSNL, few networks related to AirJaldi[6] made use of the The National Optical Fibre Network (NOFN)[7]. The analysis showed that community network operators are building networks mainly to support government processes and also in the field of education and health which is bringing in more added value to the community.

VI. CONCLUSION

To sum up, the paper confirmed that 3GPP mobile operators face huge licensed spectrum scarcity. Regarding the studied community network projects, although the lay down of infrastructure for the Wi-Fi network is very inexpensive and operates on unlicensed spectrum their sustainability is problematic since funding depends on international organizations.

The table only summarizes only few important community network projects. Community networks might become an alternative or a complimentary network provider to 3GG operators depending on geographical market conditions such as service quality and household income. For example, the likelihood of community network success might increase if implemented in urban areas where there are more resources and technical knowledge than in rural areas. However, if community networks are successful these might face problems scaling up their technical solution such as unlicensed spectrum interference or might attract 3GPP operator investments thus increasing competition. We brought out the importance and the necessity of the community network operators to fulfill the vision of 'Digital India'. The evidence from this analysis is that there are a lot of opportunities for the community wireless network operators to become the center of the upcoming wireless generations.

VII. FUTURE WORK

To further our research we plan to study more in depth of alternative solutions who provides wireless access using the unlicensed spectrum. The emerge of the community network operators and the support provided by the Government of India to provide wireless access will be explored.

[7]NOFN is a project initiated in 2011 and funded by Universal Service Obligation Fund to provide broadband connectivity to over two lakh (200,000) Gram panchayats of India[7]

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APPENDIX A
COMPARISON OF VARIABLES IN SELECTED STATES FROM DIFFERENT TELECOM CIRCLES

Variables	**Delhi (Metro)**	**Karnataka (Service Area A)**		**Haryana (Service Area B)**		**Himachal Pradesh (Service Area C)**	
		Urban	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
Population (in millions)	16.75	23.6	37.4	8.9	16.5	0.7	6.2
Internet Subscribers (in millions)	22.27	18.29	5.68	4.90	3.40	1.42	1.86
Internet Subscribers per 100 people	102.89	74.73	14.86	48.52	19.32	169.19	29.66
Population Density (sq.km)	11320	319		573		123	
Wireless Subscriber base (in millions)	2.15	1.9		0.72		0.176	
Broadband subscribers(in millions)	0.59	0.56		0.08		0.02	

APPENDIX B
TIME LINE OF SPECTRUM AUCTIONS HELD IN INDIA

Year of Auction	**Band which were auctioned**	**Details**
1994	900MHz	Chennai, Delhi, Kolkata, Mumbai were given the licenses for the operators
1995	Two blocks of 4.4MHz from the 900MHz band	19 non-metro circles were given the licenses for the operators
1997	4.4MHz of 900 MHz band	state-owned MTNL were given licenses for.
2001	1800MHz	first time in which spectrum than 900 MHz was auctioned in India
2010	3G and 4G	Tata Docomo won and was the first operator to deploy 3G services
2012	2G spectrum in 1800MHz(GSM) and 800MHz(CDMA)	2G Scam happened.
2013	50 MHz of airwaves in the 1800 MHz band and 76.25 MHz of spectrum in the 800 MHz band fixed the price of 900 MHz, two times higher than 1800 MHz.	8 circles were given licenses for the operators. No bidders for 1800MHz and 900MHz,MTS India was the only bidder in the 800 MHz band
2014	sale 307.2 MHz of 1800 and 46 MHz of 900 MHz-wide spectrum	Vodafone and Bharti were already using 900 MHz frequency and had to renew
2012	1800 MHz frequency	Reliance Jio, the only company to have all-India 4G license entered into voice service and won in 14 circles in
2015	Spectrum in the 800 MHz, 900 MHz, 1800 MHz and 2100 MHz bands was auctioned	11% of the spectrum available for auction re-mained unsold
2016	700 MHz, 850 MHz, 900 MHz, 1800 MHz, 2100 MHz, 2300 MHz and 2500 MHz	only 40% of the spectrum put up for auction was sold