Telecom Business Review
15 (1) 2022, 01-10
http://publishingindia.com/tbr/

BASIC Analysis of Green Communications for 5G Implementations: A Case Study of Airtel in Belagavi City

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Abstract

Purpose: This paper discussed the planned rollout of the 5G network in India and its debate on energy pollution by telecom companies after the enhanced bandwidth, antenna systems, and spectral efficiency.

Motivation: The ever-growing subscriber base and data consumption have exerted pressure on telecom companies to expand base stations. However, these base stations are major sources of energy consumption. Indian companies are experimenting with M2M communication, mMIMO, and heterogeneous strategies to make them green. A few companies are also adopting Cognitive radio communications.

Methodology: Researchers analyzed green communication opportunities and challenges from the perspective called BASIC analysis. The analysis focused on Bandwidth, Antenna, Spectral efficiency, Information, and Cost.

Findings: Researchers found that green communication brings down the energy cost. However, challenges of hardware, algorithm, and operational cost remain. More than these challenges, regulatory hurdles for spectrum allocation and spectrum sharing in India have created more obstacles for green communications. Added to these woes, the government of India's 'digital India' initiative put pressure on telecom companies to reduce call drops and sharing towers and increase the speed.

Conclusions: The Telecom sector in India will see a paradigm shift after 5G implementation. The data consumption will skyrocket. However, cost and information trade-offs with telecom equipment and services require sustainable efforts.

Keywords: BASIC Analysis, mMIMO, Heterogeneous Networks, M2M Communication, Green IoT

Introduction

The telecommunication sector has seen unprecedented growth in the past decade. The subscriber base has touched a whopping 1.2 billion. Further, the data consumption reached eye-catching levels reaching 12 GB per month. Thus, the data uptake level has touched 8.7 Exabyte. The sector clocked a record 612 billion rupees' gross revenue during the third quarter of 2020, with average revenue per user of Rs 129 per month. These phenomenal growth indicators exerted pressure on the government, network companies, telecom service providers, and allied industries to expand infrastructure, utilize new technologies and bring product innovations. One such initiative is to migrate telecom technology from 4G to 5G. However, implementing this technology requires massive base stations, antennas, power equipment, wireless devices, and other operating costs. All these infrastructure elements affect the environment through CO2 emissions, energy consumption, electronic waste, and human health issues. Therefore, there is a greater interest among researchers to provide green communication. Green communication is the business process of procuring sustainable communications coupled with network technologies and products through optimum resource utilization. The domain focuses on virtualization, green products, green supply chain management, and consolidation. Further, the green communication ecosystem expanded to include smart homes, smart healthcare, smart cities, and smart governance.

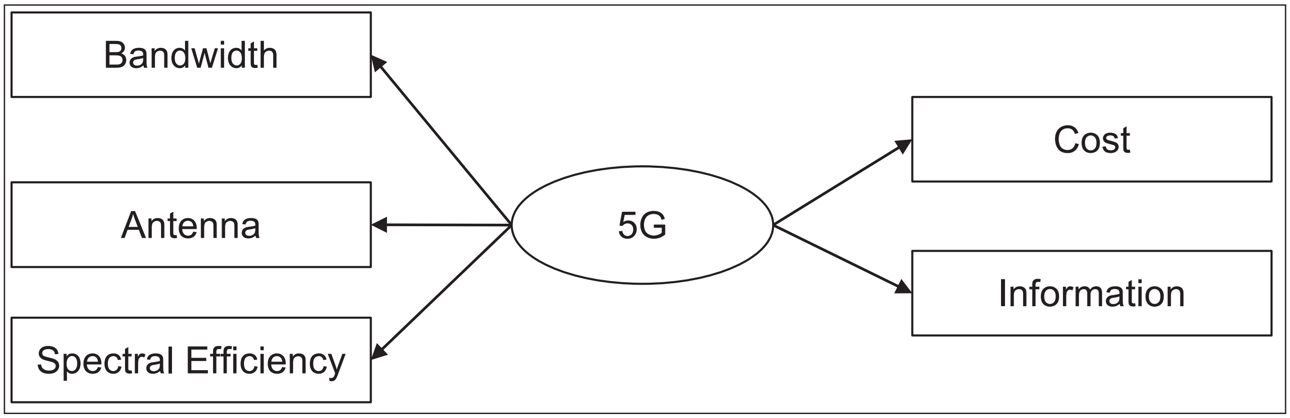
Review of Literature

According to Wikipedia, currently, the world has four billion mobile devices and requires 1.4 Peta watt of electricity per year. The usage of mobile devices puts communication networks under stress to use more servers. Google had one million servers up its capacity to 15 million servers by 2019. Furthermore, video consumption on mobile devices is the main culprit of energy inefficiency the world needs to address as early as possible. Due to these developments, a debate on adopting green communication surfaced. Telecom companies across the globe are putting their efforts into addressing environmentalists' concerns. One such initiative is Machine to Machine communication (M2M). This technology provides unparalleled cost efficiency in the smart home, online health care, and industrial automation sectors (Lu, R., 2011). However, the M2M sector faces a daunting task in bringing green, reliability, and security features (Lu, R., 2011). It was felt in the industry that without Green, reliability, and Security (GRS), M2M will not achieve economies of scale. On the requirement front, M2M communication requires nodes and gateways built on sensors. These gateways used in the M2M cost between Rs 7000 for a smaller application, and for larger gateways, the price shoots up to Rs 1,34,000. The second initiative to make the telecom business greener is the application of Massive MIMO. The Multiple Inputs and Multiple Outputs (MIMO) are integral elements of wireless communication that augment radio links' capacity by adopting numerous transmittable antennas to exploit multiple propagations and receivers (Lipfert, Hermann, 2007). Added to this, MIMO is useful in precoding, spatial multiplexing, and diversity coding. In addition to this, MIMO takes forms based on antennas or users. One such form of MIMO based on multi-user type MIMO widely used in green communication is mMIMO. This technology works on the principles of having fewer terminals compared to base stations (Marzetta, Thomas L., 2010). This system's economies of scale were achieved using different beamforming strategies such as Maximum Rate Transmission (MRT) (Lo, T. K.Y., 1999), Zero Forcing (ZF), and Maximum Ratio Combining (MRC) (Jakes, W. C., 1974). Added to this, these mMIMO works on Time Division Duplex (TDD) and can support Frequency Division Duplex (FDD). In this type of structure, the number of inputs and outputs is massive. Therefore, the power consumption in the circuit is less. In the case of mMIMO, the number of antennas used at the base station is in the hundreds compared to the general 8 MIMO antennas.

Green communication technologies are adopting heterogeneous networks to reduce energy consumption. These networks depend on Macro cells, Microcells, and Pico cells. Further, these network cells depend on spectrum licenses and are controlled by the telecom operator (Mahapatra, R., 2016). Many heterogeneous networks work in an unlicensed spectrum in the short region. It includes WLAN, Bluetooth, RFID, and UWD. Another emerging field that is enticed by telecom companies is green IoT. The Internet of Things (IoT) field is bringing smart homes, smart cities, green habitats, green industrial automation, e-healthcare system, and green energy into its orbit. The massive implementation of IoT in this domain requires efficient wireless networks. The 5G and 6G telecommunications will satisfy these requirements. However, the energy consumed and carbon emissions from these initiatives are massive and anti-nature. Hence, there is a growing demand for the utilization of green IoT. Another notable trend is Simultaneous Wireless Information and Power Transfer (SWIFT). In this technology, nodes are charging their batteries using electromagnetic radiation (Abrol, A., 2016). This technology found to be useful in the IoT sector where access control points are used.

Further, this technology will be used in near-field scenarios, far-field scenarios, and low-power field scenarios. In the case of far-field scenarios, four different types of techniques are used. They are time switching, power splitting, antenna switching, and spatial switching. Due to the inherent property of 5G networks concerning near-field communications, this technology is expected to benefit many companies in the telecom field. Finally, the game changer in the telecom field is Field Programmatic Gate Arrays (FPGA). The hardware parts are crucial for the success of green communications. Earlier, Application Specific Integrated Circuits (ASIC) were used in communication devices. However, these devices are one-time programmable and customized. They had limitations of reuse. This has been overcome by the Field Programmable Gate Array (FPGA). These are matrices of configurable logic block semiconductors. These are standard products and work on the rule of no non-recurring costs. It develops on configurable logic blocks, dedicated blocks, input and output blocks, and routing. FPGAs, in comparison with ASIC, reduce the cost, increase speed, consume fewer materials, reconfiguration, and fewer space requirements.

Theoretical Model



Source: Google.

Fig. 1: BASIC Analysis Model

Bandwidth

Bandwidth analysis for this research was collected from two perspectives, namely IoT & base station sleep mode and Network deployment. The industry expects IoT devices to reach 31 billion by the end of 2022. This means every IoT device requires connectivity that consumes power and results in becoming e-waste someday (Shome, S., & Bera, R., 2020). Ultra-narrow band and narrowband IoT consumes less power due to lesser spectrum requirement. However, the signal-to-noise ratio increases and forces companies to have huge band allocation resulting in extra costs to the company. A few companies used pulse transmitters to reduce power consumption. Further, IoT networks are energy efficient if they have higher longer network lifetime (Sarwesh, P., Shet, N. S. V., & Chandrasekaran, K., 2017). Traffic offloading of the base station using a non-direct link enhances energy efficiency (Gandotra, P., 2017). Further, access networks in the wireless networks consume power up to 70%. From the earlier research, it was evident that energy consumption reaches a peak when the user is near the edge of the cell.

Antenna

The current practice of having a single high-power antenna leads to shadowing losses, increased fade depths, and increased delay speed. These challenges may be overcome using the Distributed Antenna System (DAS). The System improves energy efficiency in green communications. Further, in the research conducted by Seetaith Killer and others, it was found that the DAS system could reduce energy consumption by 27%. It was also noted that DAS systems have better spectral efficiency (Kilaru, S., Padmaja, S., & Reddy, K. V., 2017)

Spectral Efficiency

This sudden interest in the industry and academia on green communications due to concerns expressed by the public towards greenhouse gas effects in the wireless communication deployment is very high. However, the green communication industry encountered challenges in spectral efficiency and energy efficiency. To support better efficiency, the government has to support better spectrum availability. On the technology side, companies are dealing with Cognitive Radio (CR) technology to overcome spectrum efficiency using wireless communications (Gür, G., 2011). These CRs have the capabilities of spectrum sensing. Thus, cognitive nodes will improve energy efficiency. However, the technology has limitations in terms of algorithms, hardware, and design.

Information

Green Communications emphasizes the reduction of the number of links in IP Networks. To achieve these objectives, telecom companies migrated to graph theoretic solutions. Hence, there is a necessity to have better architectural designs for sustainable wireless internet nodes.

Cost

The cost breakup for the green communication implementation includes the cost of installing base stations, cost of the antenna, cost of electricity, and cost of the generator. It was also found that preventive and maintenance of generators also add up to the cost. More than that, operational and capital expenditure affect the green communication implementation.

Objectives

The researchers formulated the objectives to explore:

- The impact of bandwidth expansion required for 5G on the environment.
- The effect of antenna requirements and implications on energy.
- The emerging models to evaluate the spectrum efficiency.
- The requirement of information in setting 5G systems.
- The cost-benefit analysis concerning green communication after the 5G rollout.

Methodology

This research paper conducted descriptive research based on qualitative and quantitative modes. The data was collected from the Airtel company website, Nerf website, and government publications. Further, researchers identified the price of the inputs and prevention and maintenance used in the 5G network from business-to-business marketplaces and estimated the cost. The sample was limited to Airtel, a major player in Belgaum city.

Discussions

The research paper was developed on the BASIC (Bandwidth, Antenna, Spectrum efficiency, Information, and Cost) model. The model evaluation identified that b in India, mobile network operators, and telecom service providers have separate logical networks. Like their western world telecom partners, Indian telecom companies migrated to the Multiple Operator Radio Access Network (MORAN), resulting in lesser usage of infrastructure and a decline in carbon footprint. Further, the regulatory hurdle for green communication in India is the Multiple Operator Core Network (MOCN). Here, sharing the core with the access network is not allowed. Further, signal radio networks had a positive impact on bringing down energy consumption. However, a few Indian companies still adopt legacy technologies instead of using multi-carrier power amplifiers and power supply optimization. In the case of fiberizing telecom towers also, India is way behind compared to other major nations. The below table describes telecom towers fiberized in various countries.

Table 1: Telecom Tower Fiberization

Sr. No.	*Country*	*% Telecom Towers Fiberized*
1	USA	80
2	China	78
3	Japan	75
4	Korea	65
5	India	22

India lags in the fiberizing of the network with 22%, whereas the USA tops the chart with 80%, followed by China with 78%. Contrary to the existing microwave utilization, fiber-based technology emits less greenhouse gas. Earlier research had shown that Fiber Based technology (FBT) consumes less energy. For instance, the coaxial cable uses 10.5 W to cover 300 meters, whereas FBT uses 1W to cover the same distance. Switches and routers consume enormous energy in the telecommunication field. For example, the Core router consumes 10 NJ, and the Ethernet switch consumes 9 NJ energy per bit (Tucker, R., 2011). The earlier research found that the throughput rate increases significantly in mMIMO (12). Further, energy efficiency improved by 100 times, and spectral efficiency improved 10 times in mMIMO. Due to its design, the structure works as a robust jamming network. However, the mMIMO faces the problem of pilot contamination. Conversely, it supports larger spatial freedom (Gandotra, P., 2017).

Researchers collected information about the difference between 4G and 5G networks antenna and energy requirements.

Table 2: The difference between 4G and 5G Networks Antenna and Energy Requirements

Sr. No.	Network Difference		
	Description	4G	5G
1	Number of base stations required	76 lakhs	1crore 12 lakhs
2	Base station density	10 base stations/ km2	50 base stations/ km2
3	Antenna required at base stations	8	100
4	Antenna makes	Patch slot	Phased array
5	Power consumption by Fermo Cells	6W	5W

The researchers found that the number of base stations required will jump from 76 lakhs to 1 crore 12 lakhs (Table 2). This will increase the number of antennas required. It is expected that the number of antennas required at the base station will grow by 25-fold and is expected to move from patch slot to phased array. Further, power consumption is expected to drop from the current 6W in the 4G network to 5W in the 5G network.

The government of India is yet to allocate the E band and V band required for the 5G network. Opposite to the requirement, on the technology front, data uptake in India has reached 9.2 Exabyte, and average data usage has touched 15 GB/ Month. Further, spectrum sharing is not allowed in India. This has become a major hurdle for network cooperation. If spectrum sharing is allowed in the future, optimized utilization of spectrum and service providers' collaboration in this division will reduce the infrastructure requirement. Table 3 depicts that spectrum charges in India are increasing substantially.

Table 3: Spectrum Usage Charges in India

Period	Spectrum Usage Charge (SUC)
Sep 2018	1039
Dec 2018	1059
Mar 2019	1046
Jun 2019	1116
Sep 2019	1109
Dec 2019	1247

Source: COAI Report, 2021.

In September 2018, SUC was at 1039 crores and jumped to Rs 1247 crores in December 2019. Due to this factor, telecom companies are working on cost-benefit analysis. The government of India's digital India mission posed new challenges for telecom players to augment their capacity. This made telecom companies and telecom infrastructure companies revisit their capital investment decisions. Particularly in telecom equipment companies wherein service providers are beneficiaries' competition is intense.

Table 4: Major Players in Telecom Tower Business in India

Sr. No.	Name of the Company
1	Indus tower (Joint venture between Airtel and VI)
2	Reliance infrared
3	Tower Vision
4	ATC
5	GTL

In the Indian tower business, Airtel and VI-owned Indus tower is the market leader, followed by Reliance Infratel by RJIO. The industry is also represented by Towers vision, ATL, and GTL. The Indian government's thrust on smart governance, e-healthcare, smart infrastructure, e-citizen, smart energy, and IoT-based vehicle systems have made operators come out with new equations. Apart from these, the government of India is also making it compulsory to have green buildings. On another side, the subscriber base in India has touched 120 crores which is massive from the infrastructure point of view. Therefore, the government of India wanted to roll out a 5G network as early as possible. However, location cost, Wi-Fi enabled, fiberized backhaul network, and field force utilization are becoming bottlenecks. A few companies in India are working on Radio Access Network (RAN) sharing and network cooperation to overcome future obstacles. They are now working as Mobile Operators Shared Towers (MOST). It is found that higher spectral efficiency requires higher energy power (Mahapatra, R., 2016) which is another bottleneck for implementation.

Network densification and bringing sustainability to it is a daunting task. A few in the business included rate adaptations in long-distance wireless mesh networks. Notably, time average variable length frames are gaining prominence. This phenomenally necessitates remote administration. The remote Administration needs a robust hardware and software infrastructure. A caution to Industry practitioners in upgrading infrastructure is to have energy efficiency. Therefore, telecom players are implementing central processing units (CPU) to reduce consumption and remove waste. Further, green IoTs connected to networks require wireless sensors. However, the challenge is to control these sensors' performances (Malik, N. A., & Ur-Rehman, M., 2017). Here. Ambient Backscatter Communication (ABC) emerged as the better solution. Apart from the above, server consolidation and improving product performance are goals of communications. Hence, there emerged a need for cloud-assisted remote management. The telecommunication industry expects data generated in the 5G network will be huge (Jamil, S, et al., 2020). Hence, they began adopting artificial intelligence and machine learning in managing the data. Above all, these companies are working on coding techniques and adaptive modulation. The industry adopted smart solutions in various subdomains of telecom operations. In the case of passive infrastructure that is low on energy efficiency due to the low voltage and single phase, Integrated Power Management System (IMPS) is implemented. Added to this, the industry worked on energy efficiency by adopting sleep mode in base stations. There are two variants of sleep modes that are light sleep mode and deep sleep mode. In the case of light sleep mode, only power amplifiers are off, whereas, in dark sleep mode, only the black hole is functional (Gandotra, P., 2017). This sleep mode control is achieved by advanced software. To achieve this, Nortel developed Smart Power Management (SMP) software. Alcatel evolved its Dynamic Power Save (DPS) and Nokia Net act into the market. Cellular service providers are spending more money on the energy consumed. The telecom major Vodafone's 57% of the energy consumed by base stations. Similarly, Vodafone's Co2 emission stands at 961982 tonnes which is massive compared to office and retail space's 157258 tonnes. The cost of establishing a Macro base station varies from Rs 28 lakhs to Rs 45 lakhs. Similarly, a Micro base station costs an average of Rs 2.4 lakhs. Further, the Femto base station costs around Rs 80,000. Researchers observed that the rental of telecom towers in India varies from Rs 3.6 lakhs to Rs 20 lakhs per annum.

Table 5: Cost Break-Up of Installing a Tower in India

Sr. No.	***Cost Analysis of Tower Installation***		
	Particulars	***4G***	***5G***
1	Ground-based steel tower height	40 meters	8 meters
2	Cost of steel for the tower (2020 price)	Rs 1600/ meter	Rs 1600/ meter
3	Cost of tower	Rs 24000	Rs 12800
4	No base stations are required for square kilometers	10	50
5	Total cost	2,40,000	6,40,000
6	No base stations actual in India per square kilometer	0.3	Expected 1.5

Researchers tried to understand the change in the cost concerning 5G compared to 4G technology. The cost comparison of telecom towers is given in Table V. The data shows that the cost of a tower will go up by 36.5% in 5G. However, the economies of scale and technology are expected to bring down costs. The antenna is an important part of telecommunications. The number of antennas required per base station is expected to jump from 8 per base station to 100 per base station in 5G technology. Hence, a cost-benefit analysis needs to be calculated. Researchers calculated the cost of the antenna and found that it increases by 23% in the 5G network.

Table 6: Cost of Antenna

Sr. No.		***Cost Analysis of Antenna***		
	Particulars	***4G Ideal***	***4G Actual***	***5G***
1	Antenna per base station	8	2	100
2	Cost per antenna	Rs 28000	Rs 28000	Rs 8000
	Total cost	Rs 184000	Rs 56000	Rs 800000

Energy efficiency is the need of the hour in green communication. Thus, researchers identified the actual cost of electricity if telecom companies do not adopt the new technologies.

Table 7: Cost of Electricity

Sr. No	*Cost Analysis of Electricity*		
	Particulars	***4G***	***5G***
1	Electricity price per unit	Rs 7.25	Rs 6 (using renewable energy)
2	Site average power requirement	2.52 KW	1.89 KW
3	No base stations are required for square kilometers	10	50
5	Total electricity cost per square kilometer	Rs 69,618	Rs 2,06,955

From Table 7 it is evident that the cost of electricity is going to shoot up by 33% after implementing 5G without much usage of new technologies. Hence, there is a need for energy conservation and the use of renewable energy modes at base stations. Diesel generators are necessary for India to give uninterrupted service to customers. Today, companies are using an average of 4 hours of DG. The average diesel consumption per hour is 1,8liter. On the flip side, diesel prices are shooting to new heights. Researchers calculated the impact of diesel prices on telecom companies (Table 7).

Table 8: Cost of Diesel Generator

Sr. No	*Cost Analysis of Electricity*		
	Particulars	***4G***	***5G***
1	Diesel runs an hour per day	4	3 (using renewable energy)
2	Diesel consumption for 2.52 KW per hour	1.8 litre	1.8 litre
3	Diesel cost per liter	80	100
5	Diesel cost per annum per square kilometer base stations	Rs 21,12,576 (10 base stations)	Rs 99,64,000 (50 base stations)

Hence, it is expected that the cost of diesel generator usage will go up by 21%. Researchers considered grid availability in the Karnataka state of India, which is 19 hours. Preventive maintenance of diesel generators is another notable cost incurred by telecom companies in India.

Table 9: Preventive and Maintenance Cost of Diesel Generator

Sr. No	*Operational Expenditure Per Month at a Site*		
	Particulars	***4G***	***5G***
1	Preventive maintenance cost per visit	2000	1500
2	No of hours of visit for PMC	300	300
3	The effective cost of PMC/hour	7	5
4	Minor overhaul frequency	5000 hours	4000 hours
5	Generator cost during the overhaul	700	800
6	Major overhaul cost	50000	40000
7	Number of hours for a major overhaul	10000	8000
8	Cost of diesel generator during overhaul	Rs 6000	Rs 2000
9	The total cost of an overhaul of a generator during the lifetime	Rs 100000	Rs 60000
10	The effective cost of a generator for overhauling	Rs 7 per hour	Rs 5 per hour
	Average diesel generator maintenance cost per day	Rs 200	Rs 180

It is observed that the average diesel generator maintenance cost per day will go down by 10%. Similarly, another PMC in batteries is also expected to go down by 28% (Table 10). The operational expenditure of telecom towers is given below:

Table 10: Operational Expenditure Calculation of Telecom Towers

Sr. No	*Operational Expenditure Per Month at a Site*		
	Particulars	***4G***	***5G***
1	Preventive maintenance costs per visit	Rs 2000	Rs 800
2	Frequency of visits(days)	90	120
3	Other contingency maintenance	Rs 20000	Rs 15000
4	Average maintenance cost of battery	Rs 77	48
	The total cost of equipment in power per day	Rs 210	Rs 150

Similarly, it was observed that Capital expenditure on telecom towers in India is significantly increasing. Telecom tower companies are investing in diesel generators, SMPS, PIUs, and battery banks. Diesel generators cost around Rs 2,00,000, battery bank with 600 Ahr costs Rs 1.5 lakhs, SMPS Rs 60,000 and PIU costs Rs 90,000. Thus, capital expenditure for the tower is approximately 5 lakhs in India. Further, Gateways used in the M2M cost between Rs 7000 for a smaller application, and for larger gateways, the price begins from Rs 1,34000.

Reducing the Cost in the 5G Environment

Outdoor conversion methods adopted by companies are practicing free cooling units, natural cooling units, micro cooling units, transmission cooling units, ingress protection, and Peltier effect cooling cabinets to achieve green communication objectives. Further, base station efficiency is used for cost minimization. Base stations consume a large part of the energy in the telecommunication networks. This consumption can be lowered using biofuels, solar energy, and wind energy. Further, a few researchers opine that reducing the number of base stations or bringing architectural changes in the base station could reduce energy consumption. Apart from this, cell zooming and self-organized network systems will bring down the energy demand. Companies are using Coordinated Multi-Point (CoMP) in the base stations where cells shut down to acceptable service quality (Bu, S., 2012). Green communication enabling tower tubes could reduce the Co2 emission by one-third. This resulted in fewer losses in feeder lines. Hence it brought down the operational expenditure and also capital expenditure. Further, Ericsson has introduced capsule suits that decongest the network in dense urban traffic areas. Nokia, another company in the telecommunication industry, came out with a fixed base station concept wherein networks are monitored remotely and can be adapted to new wireless communication technologies. Similarly, Nokia introduced air scale base stations that adopt the speed with growing traffic using a single RAN. In another instance, cost minimization is achieved through energy efficiency in design Energy efficiency in telecom towers faces the following challenges. First, In India, due to electricity shortage, diesel engines are running for longer hours, usually 4-5 hours in a day. Here, companies are putting green communication concepts by adopting VRLA or Li-ion batteries to reduce diesel usage. Further, they are adhering to BEE-3-star AC and heating, ventilating, and air conditioning (0HVAC) equipment. Second, theft and pilferage add to the increase in energy costs. Third, Capital expenditure on alternative energy sources is falling but still costlier than traditional methods. These challenges led to serious concerns about the business. The rise in operational expenditure brings down the average revenue per user.

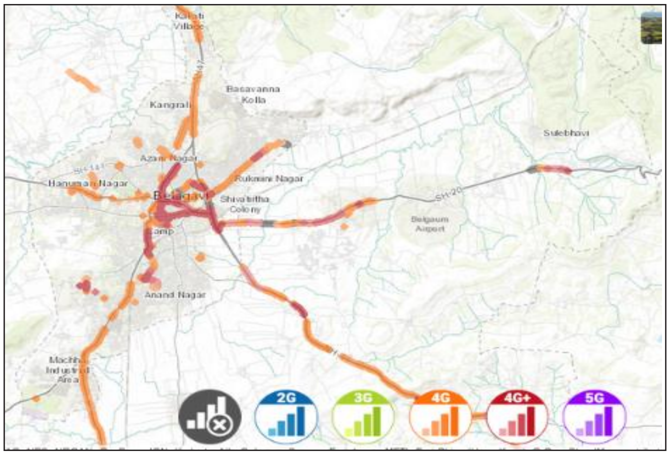
Table 11: Average Revenue Per User in Indian Telecom Companies

Sr. No	*Service Provider*	*ARPU*
1	Airtel	Rs 144
2	JIO	Rs 139
3	VI	Rs 121
	Industry average	129

The wireless communication industry will achieve energy efficiency in the future by adopting cross-layer design and green routing. Researchers expect low energy spectrum sensing will redefine green communications shortly. The energy overload at different points is leading to energy loss which is a major issue in India (Tucker, R., 2011). Time reversal signal transmission will collect the energy from the surroundings and make the network more efficient (Wang, B., 2011). Further, the time reversal signal reduces the radio pollution in the nearby areas.

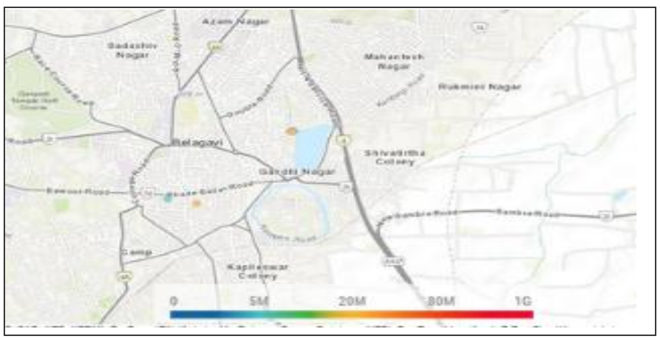
A Case Study of Airtel in Belgavi City

Belagavi is a tier-2 city in Karnataka. It is on the edge of Western Ghats. According to the 2011 census, the city has a population of 4,88,000 with a population density of 5200 per square kilometer. The city corporation area is spread over 94 square kilometers. Airtel is the leading telecom player in India, managed by the Bharati group in India. Apart from providing cellular services, the group is also into the telecom tower business. The group has its own infrastructure company called Bharti Infratel and also has a tie-up with Vodafone and Idea to constitute Indus tower private limited. Researchers examined the network coverage and bit rates of Airtel in Belagavi city and found that data points are 6817 (Fig. 2), and the Bit rate varied from 5M to 1G (Fig. 3).



Source: nperf.com

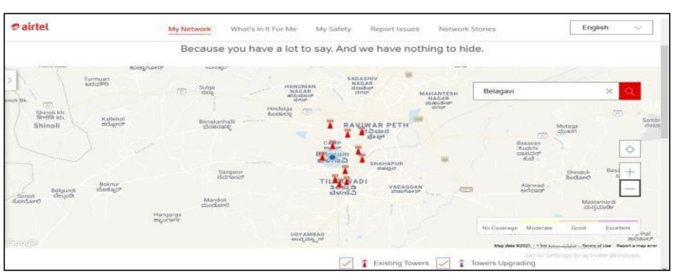
Fig. 2: Network Coveage in Belgaum City Limit by Airtel 6817



Source: nperf.com

Fig. 3: Bit Rates of Airtel in Belagavi City

Researchers used the Airtel open network data to identify the number of towers in Belgaum. The 94 square kilometer Belgaum city is covered with 11 priority towers, and they are upgrading other towers.



Source; Airtel.in

Fig. 4: Airtel Open Network in Belagavi

The researcher analyzed cost analysis for Airtel carrier in Belgaum city and found the following information:

Table 12: Cost Analysis of Airtel in Belgaum City

Sr. No	*Cost Analysis*			
	Description	*4G Ideal*	*4G Actual*	*5G Ideal*
1	Base station density	10 base stations/ km2	0.3 base stations/ square kilo-meters	50 base stations/ km2
3	Antenna required at base stations	8	2	100
4	Antenna makes	Patch slot	Patch slot	Phased ar-ray
5	Power consump-tion by Fermo Cells	6W	6W	5W
6	Direct cost (in Rs) per day	800	240	4000
7	DG maintenance cost per day (in Rs)	200	200	180
8	The total cost of equipment in power per day (in Rs)	210	210	150

The capital expenditure of 11 towers of Airtel was found to be 55 lakhs. The ARPU of 5 lakh Belagavi subscribers is Rs 149. Thus, revenue earned is 745 lakhs per month.

Conclusions

Technologies are reshaping the bandwidth, antenna penetration, and spectral efficiency. However, the energy requirements and cost of building telecom infrastructure are causing worry. More than this, the competition has brought down the average revenue per user. Apart from this, the emergence of IoT requires more reliable telecom services, and 5G will be the answer. There is future scope for research on post-5G implementation and cost analysis. The number of antennas required has increased and moved to the phase method. There is an effort to reduce the power consumption of Fermo cells. The bigger challenge is rising input and direct overhead costs for the telecom companies.

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