Techno-Economic Analysis of Green and Sustainable Infrastructure Sharing in Mobile Communication Systems

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Abstract- Due to the proliferation of smart devices and traffic explosion in the wireless ecosystem, cellular network operators faced challenges of providing enormous network capacity, achieving superior coverage, and improving the user's quality of experience. However, to meet this demand, Mobile Network Operators (MNOs) need to upgrade and extend their network infrastructures to increase capacity. Network infrastructure deployment and maintenance are very expensive and require MNOs to invest heavily investment into it. MNOs deploying infrastructures to the rural area become a challenge; consequently, most of the rural areas are not connected, uncertainties in energy and power supply to the remote cellular is the main challenge to the MNOs in terms of green and sustainable in developing countries. Furthermore, the coverage and quality of services specifically in the rural areas which are regarded as non-profit areas for the MNOs. Network Infrastructure Sharing (NIS) is considered as a promising practical solution for MNOs to reduce both the Capital Expenses (CAPEX), operational expenses (OPEX) and get along with the technological changes to meet the fast-growing demands of data traffic. Aims of this research is to investigate the infrastructure sharing for MNO, the extent of mobile network coverage, optimize the utilization of scarce resources, determine the challenges facing the MNOs in providing services especially in rural areas, and customer satisfaction. Also, this study intends to identify the motivations, impacts, and challenges of infrastructure sharing in mobile communication. This research involves a mixed-methods research approach. The approach adopted for this research falls under the category of a descriptive strategy combining both quantitative and qualitative evidence from network operators. The results show that the telecommunication industry facing main challenges which include poor network coverage, high inter operators' charges, and unreliable power supply. Furthermore, MNOs use diesel generators to power their infrastructure leading to high running costs and environmental pollution. NIS and the usage of renewable energy (RE) by MNOs are very low.

Keywords- 5G, Network infrastructure sharing, Mobile network coverage, CAPEX and OPEX, Techno-economic, Green Communication.

I. INTRODUCTION

For the last few decades, around the globe, mobile communication systems have experienced a rapid growth. They have contributed to expanding communication services to the unconnected population in both developing and developed counties. Recently, there are rapid technology changes, social networks, and mobile applications that tend to enhance the needs for high-quality content access. This trend of high data demand and technology changes is not expected to drop in the recent era. To increase the capacity and meet the demand, MNOs need to upgrade and extend their network infrastructures. Internet development amplified the significance of the communication sector as an important tool for global socio-economic development. Hence, most countries decided to make it a major public policy priority to ensure that the population has access to the network. In the world, the penetration of internet services still lags especially in rural areas where around 4 billion peoples globally have no access to the internet. Most of these population groups are

from developing countries found in Africa and Asia [1].

In the past two decades, the world has witnessed the rapid development of mobile communication technology from 2G Global System Mobile (GSM) to 5G. Today and in the more recent future to meet the challenges and assumptions of the near future, wireless communication needs to be developed in different ways. Wireless networks are making rapid progress, the search for new services and the advent of many new applications encourages the immediate introduction of new technologies on the market. According to reference [2], worldwide mobile data traffic is expected to increase sevenfold in 2017-2022. During these years, mobile data traffic will grow at an annual growth rate of 46 percent, which will exceed 77.5 exabytes per month by 2022. This requires the communication system to move in real-time to user-based network and information. This new trend urges the MNOs to redesign their existing network and seek the advance and most sophisticated techniques to boost and expand their existing network capacity, cost-effective content, and coverage closer to the users.

Due to an increase in cost and high energy consumption network extension is challenging [3]. Similarly, by deploying the mobile network infrastructure in areas that are not attractive from a business perspective is hard and costly for the cellular operator. Hence, the remote area remains unconnected.

Network infrastructure sharing is a promising solution towards cost reduction and energy in cellular networks. Though the deployment of 5G technologies in the early stages, changing the landscape in the cellular network. More specifically, mobile data traffic increasing rapidly.

To cope the pressure, the mobile network operators are expanding their own network infrastructure to meet these significant traffic demands and boost network capacity [4].

Mobile cellular network rapid expansion has become a major challenge both for the network operators and society due to the increased financial cost and high energy consumption respectively. In a recent development to reduce the OPEX and CAPEX expenditures, cellular NIS has been introduced as a promising feasible solution for MNO associated with the operation and the deployment of the mobile networks respectively. This new paradigm, encouraged by legal regulations that obligate the cellular operators to install their antennas on the same buildings [5]. In order to reach their common goal, the MNO adopts a set of approaches that enable the cellular operators to use their resources cooperatively, which lead to guarantee customer service in terms of cost reductions and less energy. From a technical context, with different levels of control and cooperation mobile wireless infrastructure sharing can be divided into three groups[6]: i) Active sharing implies two or more cellular operators sharing the same base station, ii) Passive sharing is limited to sharing sites for antenna tower, backhaul equipment, and iii) Roaming Bae sharing in which one cellular operator relies on another operator coverage on a permanent basis. Regardless of these technical challenges that might arise, in such scenarios, the potential profit of network sharing of networks have been recently estimated up to 2 billion [5], which further motivates collaboration between different cellular network operators.

In connection with the green mobile network, the contribution of Macro Base stations (MBSs) and their role to total energy utilization should be emphasized. In view of many Base stations (BS) (5 million users around the globe) in connection with their relatively high operating power (1.7 kW), it can be determined that around 80-90% of the total cellular network energy is used for the power supply radio locations [7]. Mobile networks are dimensioned according to traffic requirements during peak hours. As a result, when network traffic is minimal some of their resources go unused for certain hours a day.

These facts have recently inspired the research community to switch to disruptive shutdown systems to accomplish dramatic energy efficiency gains [4], [8] The initial work of shutting down the viewed cell clusters with a single operator, whereby part of the BS infrastructure can be temporarily shut down while the remaining active BSs can expand their coverage area to serve the entire network area. Though, by using the coexistence of several mobile network operators in the same area, it is possible to conceive a new auspicious sharing technology that is based on cooperation with mobile network operators: intra-cell roaming-based infrastructure sharing. Infrastructure sharing is a complex process. Many options may be considered when evaluating the viability of infrastructure sharing. These decisions range from sharing towers and other infrastructure facilities to sharing an entire cellular network. From the literature review, there is no standard for classifying ICT infrastructure sharing. There are those who classify it as types, models, forms, and strategies [3][9].

In future 5G, mobile system network energy efficiency is another key point indicator as one of the milestones to reduce the OPEX, many of which rely on energy costs. About 57 % of the BSs operate on diesel generators as a power source which is very expensive., furthermore unreliable and insufficient power supply increases the cost to the operators [12]. If the expensive elements can be shared by the many operators such as civil works trending and laying fibers, tower there will be substantial cost saving which can be used for

network extension even the marginalized population.

II. LITERATURE REVIEW

Since 2015, the number of cellular infrastructures sharing deals nearly tripled and has continued to rise afterward. Indeed, several trends will shape the market for the year to come. As the demand for mobile services increases, mobile infrastructure sharing provides consumers better prices and better options. It can also provide low costs and boost computation.

Due to lower revenue potential and small population, rural areas are still often underserved by mobile network providers, despite government policies to encourages rural areas connectivity. But when network providers sell off their tower, the cost-benefit ratio becomes more attractive [10]. The GSM Association examining the ways in which mobile cellular network infrastructure can be shared and presented an influential report [11]. This study discussed some previous infrastructure sharing agreements that are already in place and describe the regulatory implications and the economic. In reference [5], the authors discuss the benefits of statistical multiplexing that can be achieved by combining capacities in a deployment for sharing a cellular network infrastructure.

In [12] Deng et al. discuss and analyze the economics of the tower sharing agreement. In [10] Malanchini et al. investigated small cell sharing and presented how MNOs could still distinguish themselves (e.g. via power management) even if all network resources are shared.

However, Sharing is seen as a way to facilitate the adoption of expensive technologies such as 5G because service providers can share the cost of providing ubiquitous coverage.

While authors in [13] analyze and compare the system dynamics when they compete with competition for network providers under non-concave cost functions with fixed costs, and there has not been a comparison of how the dynamics under sharing compare to the competitive dynamics. Similarly, in [10], the authors provide a better understanding of the economics of broadband and access networks technologies, the development of competition in the access networks, and their role in the deployment of several services in different regions.

Over the years In Pakistan, mobile teledensity has grown rapidly in contrast to declining fixed-line telephony. In Pakistan, broadband propagation is very slow due to the delayed launch of cellular broadband services and low recognition of fixed-line broadband. In 2014 the cellular broadband within two years of its launch adoption rate has been remarkable however it is noted that the growth of broadband services is the slowdown in the recent era. However, in this survive the era of computation the service providers are reverting to various measures like merges and job cuts. The major barrier to the use of broadband internet services are security concerns, cost factors, the relevance of content and low literacy [14].

In developing countries mobile communication services play a fundamental and vital role in poverty alleviation, increasing productivity, improve governance and enhance economic growth. However, there are plenty remain to be done to raise the mobile network services penetration, mainly in rural areas. The main problem is due to the high-cost development of network infrastructure. This leads to the high prices of the services because MNO need to recover their investment.

In Pakistan lack of infrastructure is one of the greatest obstructions to sustainable development. In Pakistan, MNOs are still investing in their own network infrastructure despite the viability of underlined resources from other MNOs. This trend leads to the difficulties for the MNOs to extends their services to unserved society, consequently reducing the penetration of the service. Hence to tackle these challenges we focus on following goals.

a) Cellular network coverage and penetration.
b) Level of mobile network infrastructure sharing.
c) Power of network infrastructures.
d) Techno economics

We use Azad Kashmir as a case study to achieve the purpose of this investigation.

III. TELECOM INDUSTRY IN PAKISTAN

In 1989 the government of Pakistan granted the first license to mobile network operators. In 1991 Instaphone start as the first cellular service provider. The Pakistani telecommunications company PAKOM Ltd launched Instaphone which was originally belonged to Millicom International (Luxembourg) and later Arfeen Group (Pakistan). Until the mobile operator Mobilink (Pakistan) the company was the only cellular operator in the country, nowadays own of VimpelCom (Netherlands), started to use GSM services in 1994. Ufone entered the market in 2001 as the third mobile operator. The state-owned Pakistan Telecommunication Company Limited (PTCL), which originally belonged to Ufone, and in 2006 26% of its shares were sold to the telecommunications company Etisalat, based in the United Arab Emirates. The Pakistani government auctioned two more cellular licenses in 2004. One of these licenses a subsidiary of the Norwegian company Telenor Group Telenor Pakistan has successfully received.

A telecommunications company Warid Telecom based in Abu Dhabi secured the other. In 2007 China Mobile entered the market and lunch the Zong Pakistan. In Pakistan five cellular network operators are currently competing against each other: Mobilink, Ufone, Warid Telecom, Telenor Pakistan, and Zong. Due to outstanding license fees in 2008, the Instaphone license was suspended. The Pakistan Telecommunication Authority (PTA) in April 2014 auctioned three 3G licenses and two 4G licenses. Zong acquired both 3G and 4G licenses while Telenor Pakistan, Mobilink, and Ufone acquired these 3G licenses. In Asia, Pakistan is one of the fastest-growing mobile phone markets. In the Pakistani telecommunications industry foreign direct investment was $ 12 billion [15][7] and the service covers more than 90% of its geographic area[16]. In 2004, in Pakistan, the total number of mobile subscriptions was almost 13 million inhabitants of 158 million people [17].

In 2015, the total number of mobile subscribers was over 116 million with currently over 180 million inhabitants. In other words, Pakistan's total cellular penetration in 2002-2003 was 3.29%. As of July 2015, it was 61.45%, provided each phone is used by a single person. There are approximately 50 ISPs in Pakistan.

In the development of a country Telecommunication plays an important role. For rapid growth, it provides the prime services that an economy needs, modernization and development. In the expanding economy, as the economy grows, demand for telecom services increases to conduct the increased number of economic transactions. Improved efficiency of the telecom sector generates economy-wide benefits as telecommunications are important intermediate input and diffusion of knowledge and also crucial to the dissemination of the spread of the internet and the dynamism that it has lent to economies around the world is a testimony to the importance of telecommunications services.

The telecommunication industry in Pakistan has done outstandingly well in the past few years due to investment and trade liberalization and openness to modern technology. It shifts a drastic change as the government took initiative to make it a larger player in the industry. According to PTA [18] in the National Economy, the telecommunication sector is one of the developed sectors that deposited RS.488.7 Billion showing a 3.96% growth during Fiscal Year 2017-18. Overall, the financial health of the sector remained stable and networks continue to grow and add more and more subscribers.

Despite these facts recently as of July 2019, the mobile subscription figure stands at 162 million giving a boost to the total teledensity which stands at 56.56% broad and broadband subscribers stand at almost 72 million with penetration crossing 34.05%. It also working on those areas of the county where broadband is still not available at high speed. Pakistan telecom strategies are evolving to address the newly emerging digital

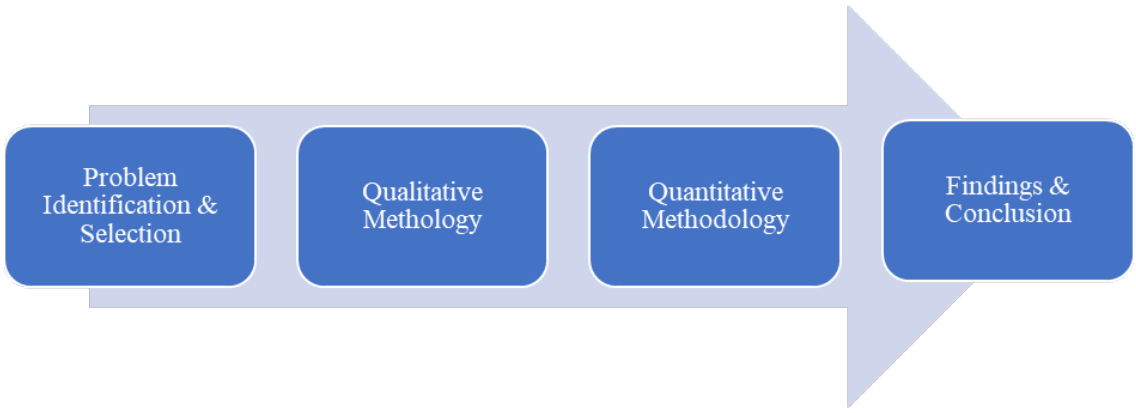


Fig 1: Research Methodology

priorities of Pakistan. With 5G on the global trials of 5G wireless network in Pakistan.

IV. Measurement Method and Approaches

The main aim of this study is to benchmark mobile network coverage and broadband internet services providers from an end-user perspective. Several measures can be used to analyze the end-user experience. The nature of this study with the formulated research question ultimately determines the relevant method for approaching the research problem. Research strategy focuses to provide an appropriate approach that can gather the relevant proof at a minimal time spent. This depends mainly on the study's purpose including; diagnosis, exploration, description, and conclusion. The strategy for this study falls under the category of a descriptive strategy combining

both qualitative and quantitative evidence from MNOs, IaaS experts and mobile network users.
The design of this research involves various stages, which are defining the problem, reviewing the related works, choosing the research methods, collecting and analyzing data. The results from data analysis are used for designing and proposing various solutions to the fundamental research problems. The research methodology is depicted in Figure1. The measurement of end-to-end statistics can provide more useful information.

a) Description of the study area
Telecommunication services in AJ&K were launched in1976 by Special Communication Organization (SCO). SCO was the single largest service provider until the earthquake 2005 having footprints of GSM, CDMA PSTN, and internet provision. However, later, the cabinet's decision deregulation of the sector, PTA in 2006 issued licensed to certain MNO i.e. Jazz, Telenor, Ufone, and Zong) to extend and access to affordable communication services to the unserved areas. When the comparison of the telecommunication services are done in the region, the telecom services and coverage had been lagging far behind form the rest of the country. Unfortunately according to the reference [19], the present MNO does not provide the effective connective and proper coverage. Besides, an internet facility is very poor which needs to be improved substantially to meet the need of the day.
Before the devastating earthquake in 2005, SCO has a responsibility to provide the facility to the peoples of AJ&K NAs across the region and cover almost 80% population of the region [20]. Recently, AJK has experienced tremendous growth in telecommunication having covered almost all the population of magnificent valleys and majestic mountains. The major contribution of rapid growth is the involvement of the private sector and government. However, the internet and Quality of servers are still low.

V. Results and Discussions

This section summarizes the results of our ongoing study. To better understand trends fist, the researcher collects data via questionnaires and interviews from experts involved in the telecommunications industry. In addition, to examine user satisfaction the researcher also collects information from the cellular services end-user. The users are cluster in a different part of Azad Kashmir. The intention of this research to

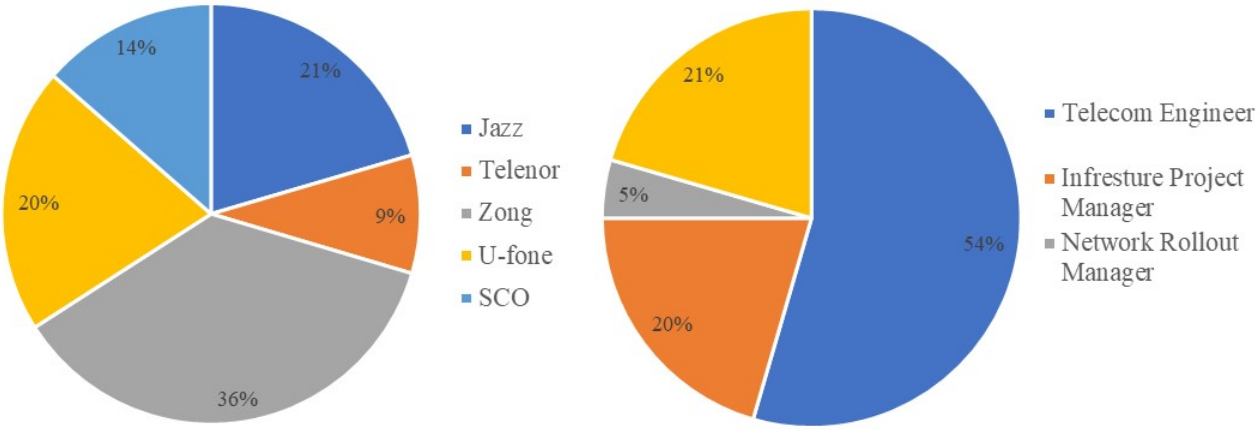


Fig 2: Respondents demographics distribution

find user satisfaction, mobile penetration, the trends in telecom sectors.
To achieve this goal, we collected information about the network infrastructure from the experts in the telecommunication sector as shown in Figure2. The Working Organization of the respondent's 20 percent were working in Jazz, 9.1 percent were in Telenor, 36.4 percent in Zong, 20.5 percent in Ufone and 13.6 percent in SCO. We also collect information about responsibilities like employment and their position in the telecom industry. The current jobs description was shown in the above

Figure.2 where 54.5 percent were telecom engineers, 20.5 were the infrastructure project manager, 4.5 percent were working as network rollout manager and 20.5 percent were as a site supervisor.

a) Mobile network penetration and Coverage

The mobile penetration rate is a term user used to describe the total number of all active cellphone numbers in a given population. It is normally given in percentages. Network coverage describes the geographical area in which the network services are available. Coverage depends on numerous factors, such as area topography and buildings, radiofrequency, technology, distance from the base station and transmitted power. Some frequencies give better area coverage, while other frequencies penetrate better through the different obstacles. buildings in cities.

The researcher had an interest in studying mobile phone penetration and its coverage in developing countries such as Pakistan (Azad Kashmir). Users answer several questions regarding their usage of mobile services, challenges, and associated costs. To identify the nature of the respondents who provide the information collected during the survey. We collect the demographics of the respondents which include gender, age, and education. The age of the respondents out of 860 respondents is 36.6% of them having age less than 20 years,49.1% were 21-40 years, 12.1% belonged to 41-60 years and 2.2% of them have an age greater than 60 years. The gender of the respondents are as 44.3 %of the respondents were females and 55.7 % were male. The profession of the respondents out of which 61.2 percent of them were students, 9.5 were teachers, 21.5 percent were businessmen, 4.8 percent were doctors, 2 percent were engineers and only 1 percent of the respondents were admin officers. 18.7 percent of the respondents were having only primary or even secondary education, 33 percent of them were undergrads, 12.8 percent were post-graduation. The respondents are from different areas like 13.4 percent of the respondent belonged to Muzaffarabad. 12.8 from Hattian Bala, 13.4 from Neelam valley, 3.3 from Mirpur, 7.2 were from Bhimber, 7.4 from Kotli, 18.5 Poonch, 13.8 Bagh, .8 percent from Sudhnati and 9.4 belonged to Haveli. The income level of the respondents was less than 15000 were 40.8, 13.1 were between 15001-30000, 19.3 percent were between 30001-45000 and 26.2 percent were having their income level greater 45000.

The number of Subscriber Identity Module (SIMS) used by the respondents in terms of percentage was 31.6 % used only one SIM, 51.3 percent used two SIMS, 13.8 percent of the respondents were used three SIMS and 3 percent of them were using more than three SIMS. There are many reasons behind using more than one sim at the same point of time. The data shows that 34.3 percent have coverage problems, 9.9 were due to business reasons, 11.9 due to SMS usages, 21.3 percent used because of calls bundles, 20.9 percent were due to internet bundles and only 1.9 did not know about what the reason was they used more than one SIM at a same point of time. Recently, 12.2 % use Jazz, 38.00 % used Telenor, 27.2 % used Zong, 16.0 % Used Ufone and only 6.5 %of the respondents were used SCO SIMS.

Various factors that encourage the respondents to choose these cellular technologies are 31.4 % of them were due to coverage problems, 31.2 % were used due to fair pricing, 32.4 % were due to quality of services and on the other hand, only five percent of the respondents select due to attractive schemes.

Furthermore, in terms of access to technology 9.4 were used 2G services, 15.6 % were 3G, 73.6 % were having access to 4G and 1.2 % of them used other technologies for the Internet.

To check the satisfaction level of the respondents about internet speed provided by the operators only 8.4 were highly satisfied, 37.4 percent satisfied, 17 gave no answer and remains neutral, 29 percent dissatisfied, and 8.3 percent of the respondents were highly dissatisfied.

The provision of services given by the providers in order to check this 6.4 of the respondents said that the overall service was very good, 37.2 good, 37.9 average, 15.1 percent were said that the was poor and 3.4 of the respondents said that the overall services were very poor.

In terms of reliability of services provided on the behalf of network operators, 9.1 percent said it was excellent, 9.5 percent said that it was very good, 54.5 said good, 19.2 percent said poor and 7.7 percent said it was very poor.

To check the awareness level of the respondents regarding various schemes provided by service providers, 37.7 percent of the respondents said yes, they knew about all those schemes and 22.9 percent said no. The amount of money spent from the respondents was 10.5 percent spent RS 100, 12.3 percent between 100-250 RS, 31.7 percent between 251-375 RS, 35.9 percent were between 500-100 RS on the other hand 9.5 percent of the respondents were spending more than 1000 rupees.

The call charges satisfaction of the respondents were as 5.9 % highly satisfied, 50.2% satisfied, 20.7% neutral, 16.7 percent were dissatisfied and on the other hand, 6.4 percent of the respondents were highly dissatisfied.

When we ask about the irrelevant messages from MNO. 77.0% respondent said that the cellular service providers sent irrelevant messages and 22.3 percent said No. The types of messages receive were as follows, 18% of the respondents received advertising agencies messages, 13.5% were received service providers, 40.1% received public awareness messages, 20.7 percent service messages and 7.3 percent were received messages with regards to promotions.

In terms of problems 19.9% found coverage problems, 11.9% have billing, 17.3 faced activation problems, 29% were faced poor service problems, 8.6% customer care, 1.9 roaming, and 11.2% faced poor information problems.

The call drop problems faced by the respondents as 46.5% partially dropped their call problems, 24.9% faced completely call drop problems and 18.8 percent faced both problems.

In terms of rating 9 percent said very well, 18 percent good, 43.7 average, 17.9 said the poor and 10.6 percent said that the rating was very poor.

Satisfaction with the connectivity provided by the service provider the 12.3 percent were highly satisfied, 38 percent satisfied, 32.2 percent neutral and on the other hand 10.3 percent were dissatisfied and 6.4 percent of the respondents were highly dissatisfied.

With regards to connectivity problems faced, 33.8% said that they were faced network busy problems, 19.6% did not range, 26.7% disconnected frequently and 18.4 percent have faced voice problems.

In terms of facing network connection problems, 50.5 percent of them faced inside some specific region, 35.1 percent while traveling and 13.6 outside the region.

In terms of network coverage within the region 10.1 percent faced 100 percent problem, 40.8 percent faced 75%, 32.3 faced 50%,13.5 faced 25% and 2.8 faced zero percent problem. Satisfaction level with Internet service in this regard 9.1 were highly satisfied, 46.4 were satisfied, 18.7 percent were neutral, 18.3 percent were dissatisfied and 7.3 percent of them were highly dissatisfied.

As shown in figure 3 the problem facing while using multimedia on mobile in this regard 64 percent were facing network coverage problems, 34.3 percent were facing bandwidth problem and on the other hand, 1 percent were faced with other sorts of problems.

b) Mobile network infrastructure sharing

To identify potential sharing choices, operators must consider various dimensions, which are technology, geographical, architectural, potential partners and sourcing scopes. Nature of infrastructure sharing arrangements and agreements differs in each country. The choice of the sharing structure depends mainly on a certain number of aspects.

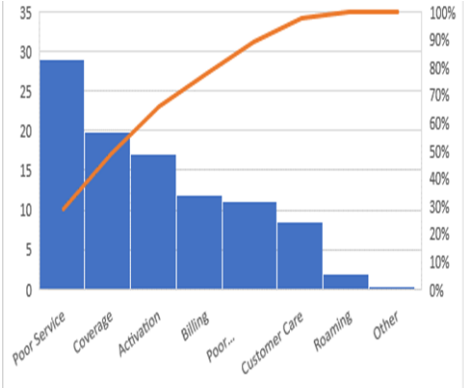


Fig 3: Challenges facing mobile users

These factors among others include lawful and regulatory responsibilities, the level of market maturity, planning and network architecture methods, as well as the installed technology, are critical to influencing which structure fits the given countries. It should be noted that there is no one sharing structure that fits all the requirements. Sharing of network infrastructure with other mobile network operators said that 79.5 % said that they share their network, 20.5 percent said no.

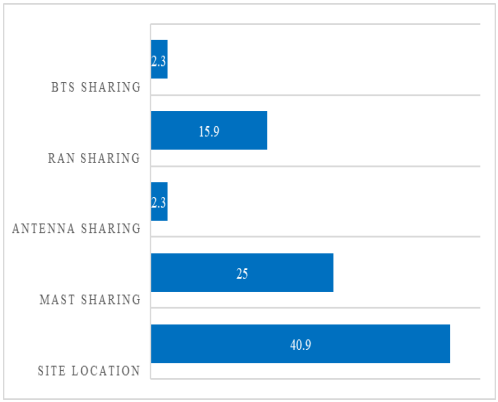


Fig4: Infrastructure sharing among MNOs

The implementation of the sharing network having different paradigms of sharing is shown in Figure 4. From the above graph, we can see that 40.9 percent site location, 25 percent MAST sharing, 2.3 percent antenna sharing, 15.9 RAN sharing, 2.3 BTS sharing.

The main driving factors are 18.2 percent were the environmental factors, 53.3 percent cost reduction, 2.3 percent regular requirement, 9.1 percent increase service coverage, 4.5 improved quality of service, 2.3 reductions of investment, 4.5 percent quick network rollout. In terms of sharing arrangements open for further participation among

operators, 70.5 percent said yes while 18.2 percent said No.

Moreover, challenges, faced by MNOs with infrastructure sharing are 47.7 have market competition, 6.8 not cost-effective, 15.9 percent have regulator problems, 6.8 percent lack of trust among MNOs, 4.5 parent lack of incentives, 2.3 have technological incompatibility, 2.3 percent have no deployment facilities, 2.3 have sharing complexities, 2.3 percent unwilling to share.

c) Power system for remote communication system

The power supply is among the major challenges for MNOs. Electricity is a key component of mobile communication systems' growth. The base station (BS) or base transceiver station (BTS) utilizes about 80% of the energy consumed in telecommunication systems. MNOs and researchers are looking for better ways of reducing cost and greenhouse gas emissions without compromising the quality of mobile services. This can be done in several ways such as minimizing the energy consumptions of BTS, implementing intelligent monitoring for energy consumptions, and generating energy from green sources for off-grid BTSs sites.

The main source of power is 74 percent is electricity and 25 percent is the diesel generator. As compared to the power supply in remotes areas were 4.5 the Grid, 86.4 the diesel, 2.3 the solar system, 6.8 the wind as shown in Figure.

Power shortage per day was 13.6 percent said its less than 2 hours, 27.3 percent 2.4 hours, 27.3 4-6 hours, 29.5 6.8 hours and 2.3 percent 8-10 hours. In terms of renewable energy, 70 percent said yes and 25 percent said no. Similarly facing challenges by using renewable energy in remote areas are as follows 75 percent have high installation cost, 4.5 percent high running cost, 4.5 theft, 2.3 unskilled people. 4.5 percent have no availability of equipment of RE, 4.5 have bad weather conditions, 4.5 percent have lack of motivation, and 2.3 was about the govt policies.

d) Techno-economic and green communication

we further investigate the economic and environmental impacts of integrating the power system for remote off-grid BTS. We investigate the amount of Green House Gasses (GHG) emissions, investment cost (IC), Net Present Cost (NPC), Cost of Energy (COE), the electrical energy produced, RE rate and the fuel consumption per year. The required DG is 5kW approximately, for the AC and DC loads of 1.34 kW divided by DG efficiency of 30% [21] converter efficiency of 95%. In terms of GHG emissions and economic feasibility, the comparison is performed.

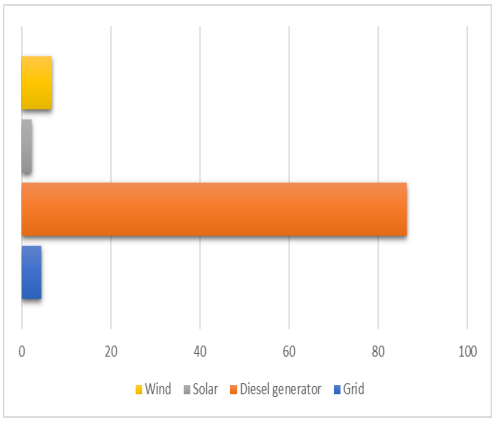
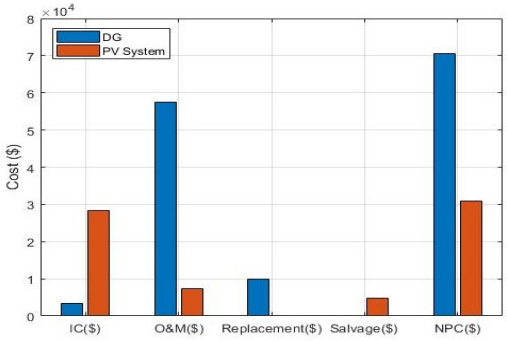


Fig5: The remote/rural area power sources for network Infrastructures

e) IC Cost

In some remotes areas, the mobile base station is only fed by Diesel Generator (DG) which is the traditional power system. The IC cost of DG can be calculated as follows: size 5 kW × cost $660/1 kW = $33000. The IC cost of the PV system proposed is $28,320. The IC cost of the PV system is high than that of the DG as the PV system components are higher and costlier than that of the DG system.

Fig 6: Comparison of the costs of the DG vs. the PV



f) Annual Operating & Maintaining Cost

The annual total cost of DG is calculated as $5740, which contains the following costs: $438 for the annual maintenance of DG. $5302 is the cost of fuel at $1.04/L diesel price. The annual operation and maintenance costs of the PV system can be reduced to $733 which accounts for 87.23% savings. With the continuous rise in fuel prices, the savings are expected to grow.

g) Replacement Cost

The DG in the mobile telecommunication sector needed to be changed every 3 years. So, the total replacement cost of DG is 3 × (size 5 kW × cost $660/1 kW), which accounts for at least $9900. There is no replacement cost of the PV system because the lifetime of the project is years, while the PV array lifetime is 25 years.

h) Salvage Cost
The salvage value of DG is zero. The salvage value of the PV system is $5440.

i) NPC Cost
The NPC cost of DG includes the IC of $3300 + O&M costs of $57400 + replacement costs of $9900 = 70600 through the project lifetime. The NPC of the PV system accounts to $30366. Hence the use of a PV system instead of DG can save up to 56.99 %.

j) GHG Emissions
The emission of CO2 from diesel fuel is 2.68 kg/L [21]. The total CO2 emission is 5098 L × 2.68 kg CO2 /L = 13663 kg per year. Hence the trend of using RESs in telecommunication is increasing all over the world to eliminate the dangerous GHG emissions and also to reduce costs and make the environment green as RESs are green. Figure 9 shows the OPEX of the DG vs. the proposed PV system throughout the project lifetime.
A stand-alone PV system is studied. The PV system covered the BS load without any shortage and excess electricity produced can be stored in batteries to be used in future or power failure. In addition to this, the NPC for the DG was higher than that of the stand-alone PV system. The DG IC cost is very low compared to PV system IC cost. But the replacement cost of DG is high as compared to the PV system which is almost zero. However, 56.13% of operating expenses can be saved if a DG is replaced with a PV energy system. 56.99% operating expense savings can be increased with the use of PV energy system. Considering these results, a PV system is a best and economical method for mobile network operators because of sustainability, cost-effectiveness and clean energy. So, the diesel-powered mobile base station can be replaced with a PV energy system which will provide the following advantages:

- A PV based base station is emission-less and cost-effective in the long-term project.
- It is environment-friendly because there is no emission of GHG and keeps the natural green.
- It is easier for mobile operators to supply uninterrupted power supply to base stations in rural locations.
- By using PV System in remote locations, mobile operators can provide quality service to the largest number of users.

VI. CONCLUSION

The telecommunications industry contributes to economic growth in developing and developed countries. On top of contributing in terms of revenue, it further influences the growth and improvement of many other sectors. Most of the governments in developing countries like Pakistan has recognized the influence and the significance of this industry, which is changing very fast. This project investigates the mobile network systems and infrastructure sharing among the MNOs in AJ&K. It involves the investigation of the level of mobile network penetration, the extent of infrastructure sharing, the challenges facing the users and MNOs. It further proposes Infrastructure sharing strategies and power systems to overcome the challenges being identified.
The results show that mobile phones are used in many users for various purposes. It has been revealed that poor network coverage, inter-operators service charges, and unavailability/unreliable power supply are among the challenges facing the telecommunication industry. Results also indicate in the case of the power shedding while the MNOs power their infrastructures through diesel generators which have high running costs and environmentally unfriendly. Moreover, the results demonstrate that regardless of poor network coverage and power supply problems, the level of infrastructure sharing among the MNOs is very low, mainly shares the locations of the sites. Based on these results, there is a need for developing a system to address the identified challenges in the mobile communication sector. Specially Improve the network coverage in urban and rural areas, maximum utilization of available MN resources which ultimately low cost of the mobile services to the end-users.

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