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Final Dissertation

GREEN RADIO COMMUNICATION IN 5G NETWORKS TO IMPROVE ENERGY EFFICIENCY AND REDUCE GLOBAL WARMING

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A WISE SAYING IN INDIA

"Gurur Brahma Gurur Vishnu Gurur Devo Maheshwaraha".

"Guru Saakshaat Para Brahma Tasmai Sri Gurave Namaha".

Meaning!

Guru(teacher) is the Creator, Guru is the Preserver, GuruDeva is Destroyer. A guru is the absolute Lord himself, Salutations to that Sri Guru.

"The Guru Brahma Guru Vishnu mantra recognizes the value of the gurus (teacher's) teachings in finding a connection with divinity".

Glossary

Computation - The action of mathematical calculation

Frequency Modulation - The encoding of data in a transporter wave by shifting the prompt recurrence of the wave

Green Reform – Supporting reforms to transition to a green economy and fight climate change

Dynamic voltage – A technique that aims at reducing the dynamic power consumption by dynamically adjusting voltage and frequency

Abstract

The technology of Green Radio communication helps in reducing the emission of carbon and helps in the process of reducing the consumption of energy by the base stations of wireless networks. In addition to that, with the help of tools such as Information Communication Technology (ICT) and Multi-Hop Relay Network (MHR), the functionalities and the operational attributes of the technology of Green Radio communication can be improved and the process of energy consumption gets better as well. It is found from the discussion that green networking technology has mainly two core components and the two core components are energy awareness and energy efficiency. The ability of the network to measure the cost per packet is called energy awareness. On the other hand, the ability of a network to decrease the contribution of carbon and extend the lifetime of the network can be called energy efficiency. In addition, the implementation of the technology of Green Radio communication helps in mitigating the issue of future energy crises. Additionally, it has also been understood that Green communication in terms of energy efficiency can help IT industry which has been extensively criticised for the contribution of the carbon emissions as well as the failure to respond to the negative impact on the whole climate. In fact, the next generation networks have imposed the challenges in terms of the provision of the energy efficient solutions which are provided and the transportation of the data along with the vast range of the quality of the services requirement as well as the tolerance of lower optimum services.

Table of Contents

List of Figures

List of Tables

1. Introduction

1.1 Green Radio Communication

Green Radio techniques aid in the enabling of energy efficient networks that are wireless. It has been found out by recently conducted prior research that the current wireless networks lack regarding energy efficiency, especially in the base stations by which the network is accessed by the terminals [1]. Green communication can be termed as the practice to select energy efficient techniques of communication, products and networking techniques regarding minimise resources. The circumstantial aspect is to initiate it wherever possible in providing high output with lesser utilisation of resources. It is becoming necessary to reduce the carbon footprint that is produced by the sector of networking [2]. Green Radio communication has become extremely essential due to the transition of the networking organisations beyond 2G to 4G [3]. The present situation demands a better form of energy efficiency and Green Radio communication is a significant tool in this regard. Green Radio communication also fulfils the aspect of seamless network connectivity, increased stability, and low degree of latency.

1.2 Overview Of Energy Efficiency

Energy is one of the vital quotients for the economic development and growth of a nation. The provision of affordable and sustainable forms of energy is required for enhancing the attributes of living standards and human welfare. Energy is considered as a crucial factor to be utilised in most of the procedures of production and networking operations. In the last 50 years, there have been crucial forms of reforms and development in the paradigm of energy efficiency [4]. Energy efficiency policies are required to be implicated to enable in boosting the credibility of energy security for the upcoming times. Various governments have been incorporating energy performance regulations and the energy saving programs target the suppliers of energy. The "Green Deal" program that was initiated by the UK in 2013 is an efficient energy presumption initiative, especially regarding households and businesses [10]. Energy is a limited resource and hence the concept of green energy has evolved.

1.3 Background of the Study

Energy is being depleted with the passage of time and over utilisation of it. The increase in the users of mobile subscribers is a big reason for the increment of data traffic. Hence, the number of base stations is also being increased due to the aspect of catering to the needs of the customers. The prior conducted research in this domain have concentrated on the improvisation of data rates and system capacity, while neglecting the essence of Green Radio technology

towards a better form of energy efficient networking channel [5]. In a cellular network, the quotient of Green Radio communication is not much incorporated. This is one of the several issues that lead to the increasing number of environmental resource depletion instances. The over rising demand for electronically enabled gadgets for calling and networking, the internet is now available to almost all the mobile users. This aspect has enhanced the level of demand for the broadband networks. Regarding fix this issue, nearly 1, 20,000 base stations are deployed every year [6]. Green Radio communication can be fostered with the aid of green coding and by the removal of pointers of bandwidth power consumption. The intermediate nodes can be made to take part in the statistical formulation of the radio technological components.

The steady increase in the consumption of non-renewable energy has been coupled with the issue of environmental pollution [7]. These aspects have promoted research activities in renewable and alternative energy fuels. Many nations across the globe are consistently on trials of development of methodologies and materials for efficient utilisation of alternate resources of fossil fuel. The globe is marching towards a very dooming energy crisis in the future due to the non-compensation for the biological energy resources [8].

1.4 Problem statement

The energy consumption by the base station of the cellular network is increasing with the course of time and hence is a major challenge for the environmentalists to tackle the problem. It has been noted that the volume of energy consumption regarding RF transmission is the highest [12]. Many telecom services claim that the incorporation of green technological tools and principles may reduce the quality of service that is being provided to the targeted customers of the cellular organisations. The metrics of energy efficiency may be useful in conducting a comparison of the consumption of energy in the various elements of the cellular network. The metrics of the facility level can assess the power usage but are incapable of reflecting the efficiency of energy quotients of the individual parts of the equipment. The amplifiers used by the cellular networks are also not able to synchronise with the energy efficiency of the time domain, Therefore, hindering the motto of utilisation of Green Radio communication technological tools. Till date, the world has encountered three energy crises and they happened in 1973, 1979 and 1990 [11]. Hence, it is crucial to uplift the operational essence of Green Radio technology and implicate it with its greater value.

1.5 Nature of the study

The secondary qualitative research approach suits this topic, as it permits the researcher in formulating proper forms of investigatory approaches regarding the previously conducted

research studies and complex subjects. It is also beneficial in accumulating innovative and fresh ideas along with grasping the various viewpoints of high-profile researchers. The researcher can also utilise this approach in searching for any patterns or themes in a non-numeric data format to answer the research questions regarding the phenomenon. There are two forms of approaches for data synthesisation, and they are termed as quantitative and qualitative approaches. Quantitative research deals with various forms of numeric figures whereas qualitative approaches use literature illustrations of prior research. Qualitative research is more flexible and can be used to provide concrete aspects of new research studies. Qualitative research can be used both in the practical and theoretical paradigms, thus providing an in-depth analysis about the research topic, which can be understood by following this ongoing research.

1.6 Motivation of the Study

The unprecedented growth within the domain of the cellular sector has pushed the operational limits of energy consumption in respect to wireless networks. The number of base stations within the surface of this planet are four million. The number of BS is also being increased since the number of cellular gadgets users is increasing, which is demanding more digital energy. It has been estimated that the BS connected to the electric grid may cost around $3000 per year to channelize the aspect of high energy consumption. On the other hand, if Green Radio communication technology is utilised by the cellular businesses, it can be highly profitable to them. It will also result in minimal carbon footprint on the atmospheric cushion of this planet, thus enriching global life.

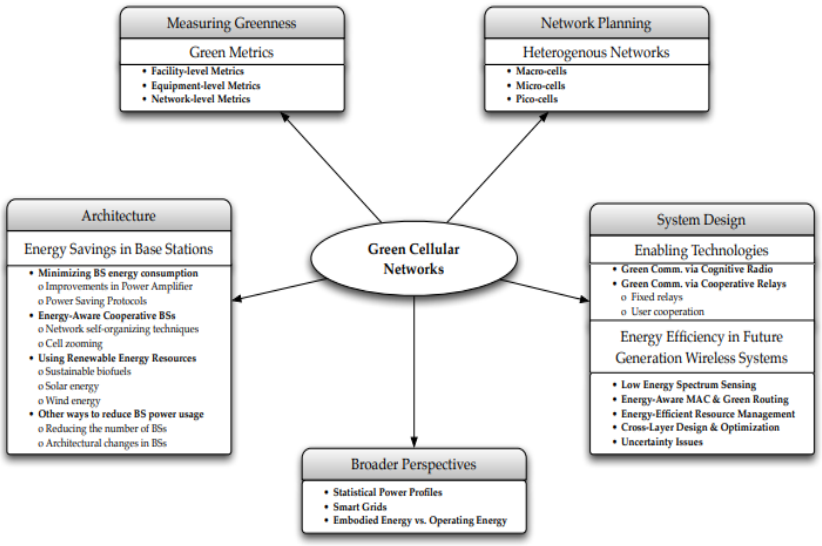

Figure1: Technological roadmap of green cellular network [9]

1.7 Research Aim and Objectives

1.7.1 Research Aim

The aim of this research is to investigate a transparent relationship between the attributes of Green Radio communication technology and energy efficiency. The study will further investigate the aspect of how the Green Radio communication technology can be improvised for catering to the upcoming energy crisis across the globe.

1.7.2 Research Objectives

- Provide a detailed explanation regarding the various aspects of Green Radio communication technology.
- Analyse the functional components of this technology and how it leads to energy efficient outcomes
- Present an in-depth analysis of the tools that foster the operational and functional attributes of this form of technology
- Explore how the tools and this technology will be capable of mitigating the issue of future energy crisis

1.8 Research Questions

- What are the various aspects of Green Radio communication technology?
- How does Green Radio technology lead to energy efficient outcomes?
- What are the tools that that foster the functional and operational components of Green Radio communication technology
- How will the tools and the technology mitigate the issues of the energy crisis of the future?

1.9 Structure of the Thesis

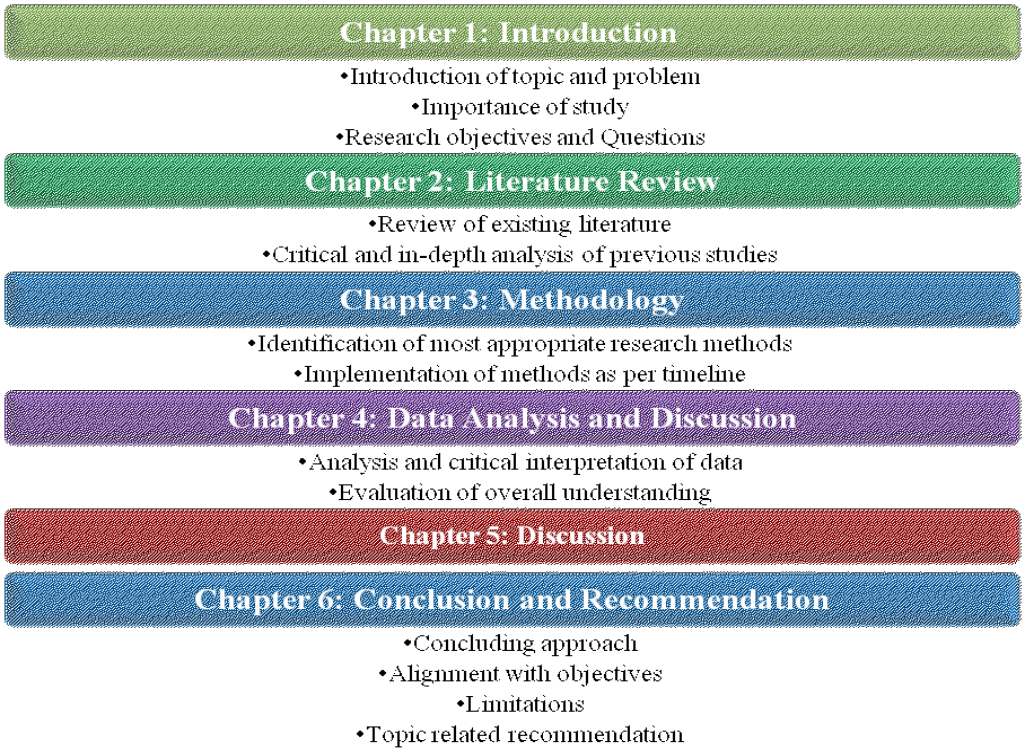

Figure 2: Consecutive stages of the research

There are a total of five chapters within this research study. The above image plays a prime role in illustrating the distinct stages of this research. The initial chapter is introduction, in which the research topic is briefly introduced. The second chapter is literature review, in which a critical analysis and evaluation of the key points of the topic will be discussed. In this chapter, secondary data will be accumulated from existing pieces of literature.

The methodology section of this project will provide the most suitable methodology to conduct the research study. The methodology will be used by the researcher to conduct the proceedings of this research study. The data collection procedure is the next stage of the study and in this chapter, the accumulated data will be interpreted in a critical manner. Finally, the conclusion and recommendations chapter will depict the existing strategies for the resolution of the existing problems.

2. Literature Review

2.1 Introduction

This section plays a key role in the research study because it helps in providing the in-depth analysis regarding the Green Radio communication in terms of energy efficiency.

The Green Radio can be considered as the wireless cellular network and the Green Radio programme basically sets the objective to achieve a 100-fold reduction in the consumption of power over the present communication networks which are wireless. The information communication technology (ICT) market basically leads to the contribution of 2% of the greenhouse gas all over the world. To save costs, major issues have been considered in the green communications such as reduction in the energy consumption for cutting down the expenditure costs of the operations. It is important to develop innovative algorithms regarding reduce carbon emissions.

2.2 Importance of Green Radio Communication In General

The failure of the system of communication may be a catastrophe to the economic attributes and human lives of a nation. The reason behind it is that people will not be able to communicate with each other with convenient quality and timely. Hence, information exchange is more necessary for people than various other aspects in their everyday life or during the occurrence of harsh environments to prevent injury or even death of numerous individuals. Green Radio communication technology can be incorporated in a rapid manner if the necessary allocation resources are available. Mobility control and energy harvesting are some of the crucial significances of utilising Green Radio communication. It also extends the lifetime of the networks, thus enabling the facilitation of next generation communication [14].

It has been opined by [13] that the pocket numbering and reordering attributes of Green Radio communication can be designed by algorithmic quotients. This is useful in the reduction of waiting time to connect to any cellular network from any other operational network and between two or more than two cellular networks. The instances of line corruption and other forms of network glitches is also uncommon in Green Radio communication phenomenon [15]. However, the overlapping of any packet in the stop and wait scheme can be harmful for the overall development of the wide area network in the green communication procedures.

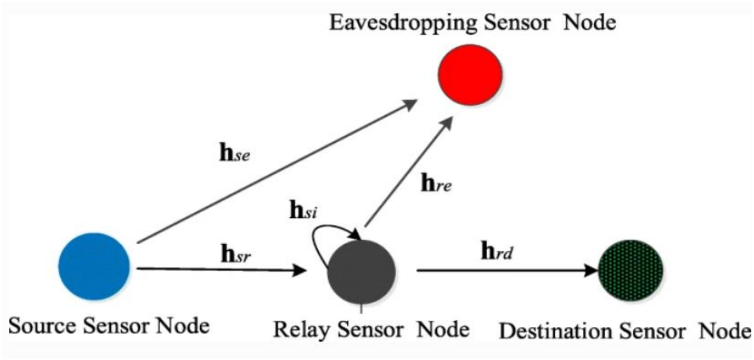

Figure 3: System Model of IoT sensors [15]

The optimal design of the transceiver is extended to the full duplex mode from the half duplex mode. This enhances the balance between the entities of the3 transmitting resistance and power of the source nodes. It aids in solving the sub problems of the PS factor optimisation and transmitter [16]. It can be stated that green communication is one of the revolutions within the data transmission procedure and it requires fewer financial resources to be established and operated [16].

2.3 Relationship Between The Green Radio Communication and Energy Efficiency

Data centres, in the present time frame, play a crucial role in the IT infrastructures of the modern paradigm. The performance metrics regarding green data are being improvised. However, the green communication data metrics are not being much concentrated by the researchers [17]. This is one of the key reasons for not being able to fully incorporate Green Radio communication models within the cellular and other forms of networks. Large data centres are becoming an integral part within the domain of Information Technology. The various cloud-based services are being preferred by almost all the information Technology (IT) vendors and clients. The service providers are being compelled to improvise and renovate the server power consumption infrastructures. It has been noted that data centres and their operational quotients contribute to 2 percent of total carbon emission. Green Radio communication has VM scheduling of DVFS based for higher intensity of distribution of the load among the various servers for the minimisation of the operational temperature. It must be noted that the formulation of any form of selection of data centric function will lead to consideration of lowering of carbon tax, carbon intensity and electricity costs [18].

Total facility power is one of the features of energy efficiency and this aspect is provided by green communication of radio signals. The delivery components of power along with the networking components are highly modified and durable within the equipment of Green Radio

communication. This is a long-term strategic aspect, as it aids in boosting the mixed used model of data emission and signalling [19].

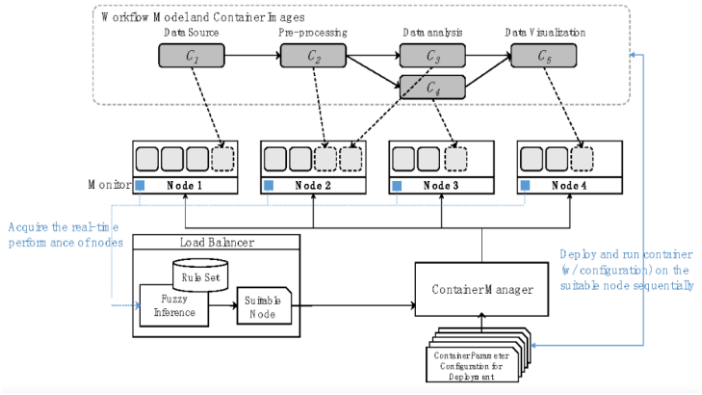

Figure 4: Dynamic resource allocation for computing in container-based model [20])

2.4 Components of the Green Radio Communication Technology and Their Utility

The boom in the 5G has helped the operating entities to be aware of high data, high performance rates and low latency. The new communication technical aspects deal with millimetre range frequency bands. The green communicating network vendors are trying to go beyond the frequency range in THz [21]. The aspect of visible light communication is a great and significant component of Green Radio communication. This form of communication technology has low frequency electromagnetic waves, thus lowering the negative impact on public health. This technology follows the pragmatic approach, instead of the RF technological approach. It has a wider efficiency regarding spectrum and provides high quality connectivity and service to its clients and operators [22]. The enhancement of signal strength is conducted by brag grating, beam swapping and by the "hybrid access technology." It is the social responsibility of every individual to progress towards green communication so that carbon footprints are reduced [22]. The photodiode and the led at the receiver and transmitter parts are the key components of this form of technology. However, it has been argued that RF technology is more cost effective than VLC router technology, which is also one of the prime components of Green Radio communication [23].

The intelligent head cluster selection model along with the spotted hyena optimisation can act as the parametric component in this regard. On the other hand, it can only be utilised by analysing and evaluating the attributes and challenges associated with distance, delay, load and temperature. As stated earlier, the hybrid Sf-SHO is one of the crucial components that can be utilised by the service vendors and operators to mitigate the challenges arising from transmission of functions from RF to VLC [24]. The computing services associated with green

communication are termed as Mobile Edge Computing (MEC). This provides a rich form of computational services, especially near the mobile terminals. This makes it possible to compute intensive tasks at the edge. Renewable energy is the component for supplying power for the MEC servers. Critics argue that unavailability or scarce level of renewable resources will lead to processing delays. This is a critical aspect and can be mitigated by more innovative forms of biogas or other renewable forms of energy.

2.5 Operational Aspects of the Green Radio Communication Technology

According to [25], Green Radio communication technology is the innovative approach that identifies the radio networking solutions which improves the energy efficiency along with the resource efficiency by not compromising the overall quality of the service for the customers. This radio technology enables the energy efficient networks which are wireless. Recent analysis through the manufacturers as well as the network operators have already shown that the present wireless networks are not extremely energy efficient, specifically the base stations through which the terminals across the services from the network. According to [26], green communications have emerged as the strategy which helps in reducing the carbon footprint that is basically produced through the networking sector. There are several advantages of the green technology such as the reduction of the business carbon footprint, reduction of the waste as well as conservation of water and the energy in comparison to the traditional technologies. The green energy sector is basically responsible for the host of the job opportunities on the present market.

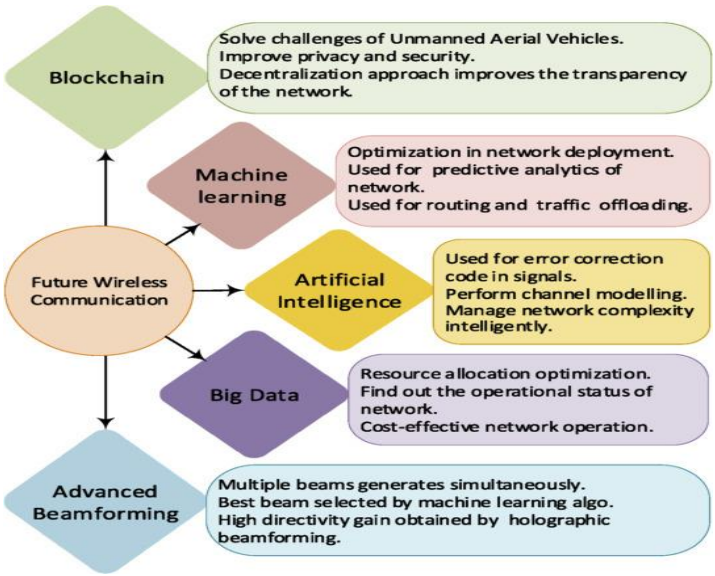

Figure 5: Overview of the Green Radio communication technology [27]

As opined by [27], green communication is basically the practice to select energy efficient communications as well as networking technologies and the resources are used in a minimum manner in all the branches of the communication process. Since the recent years, it has been observed that the green communications networks seem to be extremely necessary because it includes the utilisation of several software as well as hardware techniques regarding minimise the consumption of the energy of the component of networks. Some of the advantages of green technology include the reduction in waste materials, efficient recycling, less starvation as well as reduction in the plastic pollution. Some of the disadvantages of green technology include that some of the organisations may suffer due to less job opportunities. As opined by [28], as the number of the users as well as the utilisation of the telecommunication systems are rapidly increasing which is resulting in the huge demand on the usage of energy. It has been observed that the consumption of energy in the utility phase of the radio networks is considered as the most key factor which creates an impact on the environment.

2.6 Functional Aspects of The Chosen Technology

According to [29], the number of carbon-di-oxide emissions has been increasing in the communication systems along with the growth in the mobile consumers. The present wireless network cannot be termed as energy efficient, specifically the base stations. The rapid growth in the mobile users as well as the increase in the CO2emission basically forces the individuals to use the higher rate of mobile broadband. There is the requirement to restructure the existing architecture of networks. It is also important to control the system in each base station regarding switch the purposes. It describes the innovative as well as promising method regarding enhance the efficiency of energy of the wireless networks. In the case of the network operators the energy efficiency is much more in comparison to the corporate social responsibility. As opined by [30], it is also considered as one of the crucial factors for the successful operations of the large-scale e services of mobile communications. Independence of the source of energy which is utilised for powering the access networks which is achieving highest energy efficiency is extremely important. It applies to the conventional network elements in the larger cities for example- the solar powered base stations to develop the countries without the reliable energy. Efficient energy management is the major requirement regarding obtain the successful as well as profitable operations of the mobile communication networks.

As stated by [31], energy efficiency in the cellular network has received the vital attention from both the industry as well as academia because of the significance of the reduction of the operational expenditure as well as maintaining the rate of profitability of the cellular networks.

For making the networks greener it is important to focus on the base station which is referred to as the primary consumer of energy in the network due to which several efforts have been made regarding study the base station consumption of the energy and regarding find diverse ways for improving the efficiency of energy. The cellular networks have rapidly developed, and this rapid growth is because of increasing the numbers of the mobile subscribers.

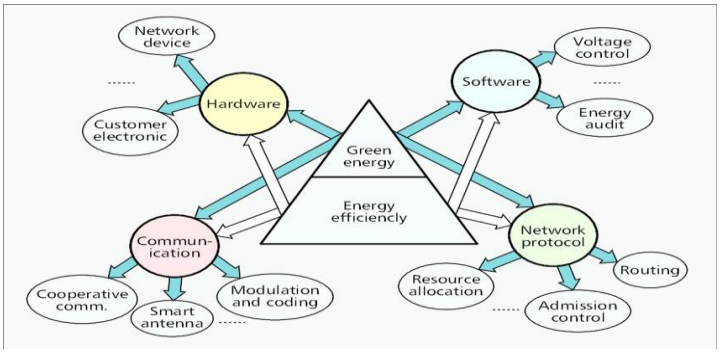

Figure 6: Solutions for the green communication networks [32]

2.7 Analysis Of The Tools Encouraging The Functional and Operational Attributes Of The Selected Technology

According to [33], in recent years, the issues related to the greenhouse pollution as well as consumption of power are associated with the operations of ICT (Information communication technology) devices have imposed a huge amount of the research work in terms of the Green Radio communication. Several power efficient solutions shall help in introducing the cost performance of the trade-offs. The solution of energy efficiency basically takes care of requests of the customers who are using the mobile phones needed for 5G based on greener radio communication. As opined by [34], it is also recognised that the enhanced nodeBs(eNB) are not power sufficient and it is also not suitable for several development scenarios. The (MHR) multichip relay network can be considered as the suitable alternative network for eNB specifically in the cell edges as well as coverage holes. MHR network mainly suffers through the various types of quality issues such as planning of the sites as well as schemes of path selection that shall fail under the conditions of network imbalance. The ultra-dense networks (UDN) which are based on the small cells can be referred to as the promising solution regarding improve the efficiency of energy of the wireless networks. This solution shall also satisfy customers with respect to coverage as well as capacity in terms of dealing with the huge mobile data traffic. As per the opinion of [35], the IT industry has been extensively criticised for the contribution of the carbon emissions as well as the failure to respond to the negative impact on the whole climate. The next generation networks have imposed the challenges in terms of the

provision of the energy efficient solutions which are provided and the transportation of the data along with the vast range of the quality of the services requirement as well as the tolerance of lower optimum services. The applications that might be transmitted all over the next generation networks include the requirements of the real time interactivity as well as the ability for accommodating the slight loss.

2.8 Issues Related to Green Radio Communication Technology

According to [35], energy efficiency is referred to as the most significant metrics beyond the 5G wireless communication systems that are expected for supporting the tremendous or wide range of mobile data traffic to the huge level of mobile devices such as the smartphones, Internet-of things (IOT) devices AND many more. Energy harvesting networks are considered as the wireless networks which are deploying the energy harvesting devices. Several promising techniques are being proposed at present regarding enhance the performance of the energy harvesting networks which are wireless. As opined by [36], in the modern communication process there is an increase in the soaring data as well as energy cost and the environmental problems generally come from the high consumption of energy. Green Radio communication has been introduced regarding solve the issues of energy efficiency. The efforts must be taken by the operators regarding build the mobile network for reducing the carbon-di-oxide emissions as well as the consumption of energy. There are several types of requirements regarding meet all the challenges of 3G technology. The reason is the consumers require the telecommunication network which cannot be found in the 2G technology. The advanced infrastructure for 3G network of communication is required consequently. The bandwidth which is wireless has grown continuously along with popularity of the smartphones which includes the iPhone as well as other smartphones and all the smartphones require the access of Internet regarding form the platforms. As per the opinion of [37], by the application of Green Radio communication technology all the problems can be resolved easily. The 5G cellular networks which are wireless tend to evolve regarding meet the demands of the subscriber soon which is accompanied with the increase in consumption of the energy in the cellular networks. The higher amount of consumption of energy leads to the increase in the emissions of carbon dioxide into the environment along with the exposure to the vast number of harmful radiations of energy. Regarding improve the battery lifetime of the user terminals in the network the architecture including the three layers has been proposed.

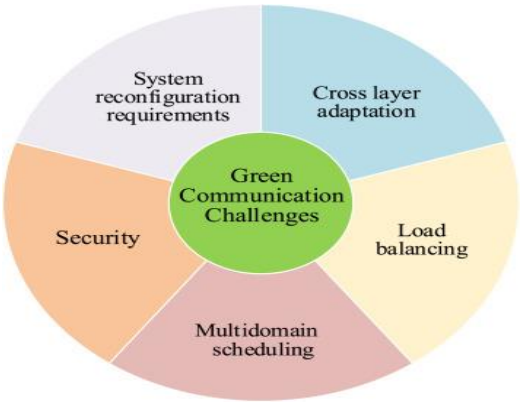

Figure 7: Challenges related to Green Radio communication technology [38]

2.9 Ways to Overcome The Problems Of The Chosen Technology

Green Radio communication is an effective technology that can significantly reduce the environmental impact such as CO2 emission. As [32] states, the issues with the implementation of the technology such as cost, bandwidth and spectrum efficacy can be mitigated by specifying the channels of supportive communication.

Cognitive network is an important wireless communication mode that allows transceivers to detect the problem communication channels. [39] States that the system is an optimal solution that allows energy savings for both networks as well as devices. The positive aspects of this communication system include community cognizance, spectrum sensing, and vicinity attention, requirement analysis of customers as well as language and safety policy. This can efficiently improve the power modulation by exploiting the free available spectrum and contribute to green communication.

Network coding is a technique of networking that allows encoded and decoded data transmission to increase the output. According to [40], the aim of using this technique is to reduce network delays and make it more robust. The main issue of Green Radio communication is bandwidth expansion that requires alterations in the present network. Network coding technology allows removal of the pointers to enhance the network throughput as well as save bandwidth. This in turn will improve the transport speed and contribute to a greener communication system.

Smart grid is a system that consists of multiple operational and energy measuring units. [41] States the issues with the system of electrical grid include high voltage, large scale centralisation and long data transmission. The characteristics features of the electrical grid that contribute to green communication include demand response (DR), Renewable powered base station (BSs), demand side management (DSM), IOT and green wireless sensor network

(WSNs) [42]. This can significantly improve the cost of wireless communication to contribute to Green Radio communication. Figure 8 is an illustration of Cognitive Network Based Smart Grid Communication.

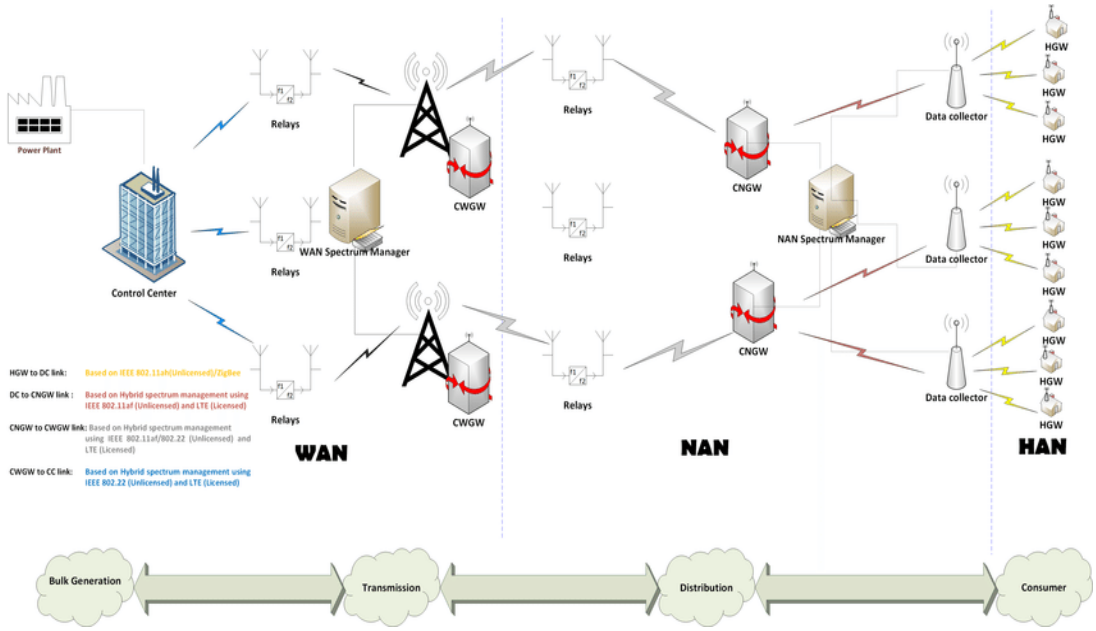

Figure 8: Cognitive Network Based Smart Grid Communication [43]

There are several other technologies under research which can significantly improve the efficiency of Green Radio communication systems. According to [25], these include MIMO and massive MIMO, D2D communication and O-STBC or STTC. MIMO and massive MIMO are data transmission channels that are being devices to reduce energy consumption of signal processing. Cooperative communication or D2D is a communication system that uses "three terminal communication channels" for signalling. STC is a wireless system that has the potential to increase bits of attainable rate.

2.10 Problems Based on Energy Crisis And Its Outcome In Future

Energy crisis may be defined as the issue that highlights the limitation regarding demand supply of renewable sources of energy to power industrial society. [44] Claims population growth is one of the main reasons contributing to the energy crisis aggravation. The key issues of energy crisis include rise in cost of energy, limitations to supply the growing population and environmental impacts of the crisis. Socio Political risks of energy supply is a crucial factor associated with the overexploitation of renewable energy sources. Energy crisis and environmental pollution are two indispensable issues of the modern world. [44] States,

regarding meet the rising demand of growing population energy, are being overused. The overuse of energy is contributing to significant environmental impact such as air, water thermal pollution, climate change and solid waste disposal. As per the views of [45] climate change is the most eminent issue that is associated with the energy crisis. Climate change is being facilitated by the over combustion of fossil fuels. This is posing a serious threat highlighting the limitations in availability of renewable sources of energy for future generations.

Energy crisis implies the overuse of fossil fuels that pose a threat of limitations in their availability. According to [46], the limitation in the renewable energy sources will have a consequent effect on the global economic and political scenario. Overpopulation has contributed to the rise in the demand of these energy sources which will incident lead to the rise in cost of fuels. This can lead to disruption in the global economy and lead to political disturbances over the borders. [47] Claims, renewable sources are a principal factor contributing to democratic energy development. Therefore, energy security is an important aspect of modern-day world politics that implies the patter of energy consumption in the nation.

The global energy crisis is an alarming factor that has the potential to impact the future generations in thorn of environmental economic as well as political stability. The issues of energy crisis are aggravating each day due to the unaltered use of fossil fuels as primary source of energy. Thus, it can be said that the future of fossil fuels as a source of energy is at stake due to the energy crisis.

2.11 Mitigation Of The Issues Of The Energy Crisis In The Future Through This Particular Technology

Energy crisis is an indispensable issue of the modern world and requires effective solutions to mitigate the associated effects. Climate crisis is one of the most prominent effects of the climate crisis. Technologies are being developed to comply with the rising market demands while providing a cleaner and greener source of energy. [48] States, energy and its related infrastructures are the drivers of economic development as well as providing scope of employment for a nation. A low carbon economy is the mitigation mode being targeted to cope with the energy crisis. The use of Green Radio communication technology as an alternative to traditional splay channels can have a significant impact on mitigating the energy crisis.
[49] States technological advancement, population growth and fossil fuel combustion has led to 685 rises in the atmospheric CO2 levels. The cost of energy as a result has also seen a

remarkable rise with the high market demands. [49] States, the methane on reduction of energy cost and reducing the emission of CO2 is leading to an increased focus on greener energy efficient sources. Green commission network has the potential of reducing greenhouse effects as well as decreasing the optional expenditure of energy. [50] States, the use of Green Radio communication can also promote sustainable development reducing dependency on renewable sources of energy. Figure 9 shows cognitive radio network as a means of green wireless communication.

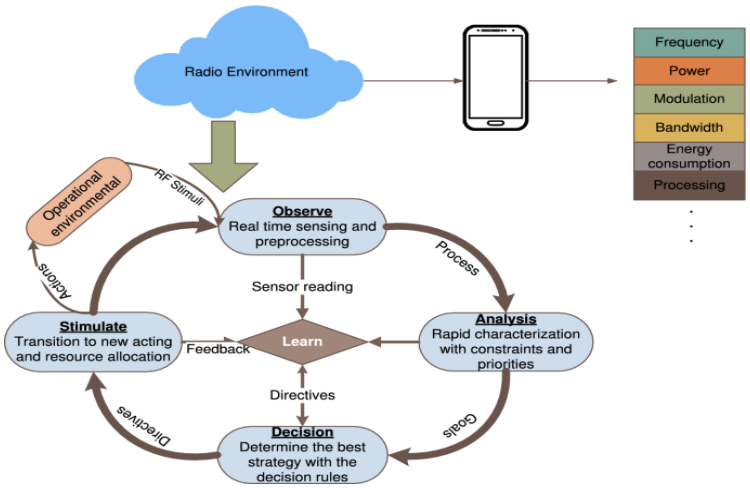

Figure 9: Cognitive Radio Networks as a Means of Green Wireless Communication[51]

The tremendous cellular network and wireless service growth has accelerated the enof energy consumption and emission of greenhouse gases. [51], states the attempt is to harvest the renewable energy sources using cellular data. Cellular base stations are being progressively developed to reduce the energy crisis, carbon footprint as well as dependency on traditional electric grid supply. The conventional energy sources use a high amount of energy that had a significant impact on the energy crisis. The aim of the Green Radio communication technologies is to integrate the use of renewable energy sources with the electric grid system to provide realistic support. As [51] states that the use of Green Radio communication as technology can provide a sustainable and energy efficient mode of use of renewable energy it can Therefore, be said that the energy crisis can be mitigated to an appreciable extent through the uses of Green Radio communication technology.

2.12 Literature Gap

Existing literary articles have limited information on Green Radio communication technology and its energy efficiency. The literature sources indicate the importance of green communication and its environmental impact. However, there is limited information on the target issues being considered in the development of the technology. Data on the components

of the green communication technology mostly highlights the basic features of the technology. However, the importance of these components and their energy efficient operation system in the previous articles. The previous studies have limited information on the energy crisis and they utility of these technologies in mitigation of the issues.

2.13 Conclusion

This chapter was a discussion on Green Radio communication technology and its energy efficiency. The Green Radio communication technology has a significant role in providing seamless connectivity and low latency to wireless networking systems. The operational system of the technology is energy efficient and well equipped to reduce the impact from high usage. There are several issues such as cost, bandwidth and spectrum efficacy that changes the efficacy of the technology. However, new components are being developed to mitigate the issues. The environmental impact form overexploitation of renewable sources of energy and overpopulation can be mitigated using the technology.

3. Research Methods

3.1 Introduction

The research methodology plays a significant role in the whole dissertation because through the appropriate research method relevant information or the data can be obtained. In this research study, the thematic analysis has been considered with the help of the artefacts. Secondary qualitative research methodology has been selected regarding obtain the in-depth analysis related to the Green Radio communication in respect to energy efficiency. Authentic journals or the articles shall be considered regarding collect the information about the Green Radio communications. This section is going to discuss in detail the data collection procedure and analysis technique with artefacts and outcomes.

3.2 Data Collection Procedure

3.2.1 Importance Of Using Secondary Qualitative Data

Secondary qualitative data deals with themes and concepts that constitute the main components of a topic. It is also termed as thematic analysis that uses a set of transcripts to identify the common themes used repetitively. Secondary analysis helps researchers to pursue interests that might be distinct from an original analysis [52]. In other words, through secondary data analysis it is possible to assess the factors that might have hindered the development of the study. Qualitative data sources include notes of researchers, diaries, documents as well as open ended questionnaires [52]. Therefore, the secondary data can be beneficial providing researchers the scope to answer exploratory questions in a research study.

The themes developed to support the analysis helps in diversifying the scopes of a topic. Secondary analysis of qualitative data provides the scope to maximize the utilization of available data [53]. It is essential to consider the explicit descriptions that help in development of accurate themes. Another factor identified as an advantage for the secondary qualitative data analysis is the access to data beyond the knowledge of the masses. Secondary analysis allows time saving in the different processes of research development such as sampling, processing, and collection of raw data [54]. The method provides readily available rich data for projects from trusted institutional research review boards. Therefore, secondary qualitative data analysis is a useful method to utilise data in the development of detailed research study.

The research study uses secondary qualitative analysis to understand Green Radio communication in terms of energy efficiency. ***Five themes*** based on the Green Radio

communication technology have been developed for the purpose of this study. Themes have been developed to understand the concept of energy efficiency of Green Radio communication. The themes have been aligned with the objective of the study to provide support to the data analysis.

3.2.2 Reason Behind The Rejection Of Primary Qualitative And Quantitative Data

The study was an analysis on the energy efficacy of the Green Radio communication technology. The technology is still under research phase and therefore, there are not ample sources to provide opinion on the experience of the use of the data. Primary data is collected through responses of subjects to understand a specific test or issues [54]. In the case of this study the participants are limited for survey or interview. This is because the topic is relatively new and there is not much understanding or experience of the general mass to provide efficient data for study. The purpose of analysing primary data is to answer research questions and provide support or rejection to hypotheses [55]. In this study, the data based on the primary qualitative or qualitative analysis would have been vague due to the lack of adequate pre-existing data for the subjects to refer to. Moreover, this study has been developed to obtain a broader perspective of the utility of Green Radio communication which requires an exploratory approach of analysis. Therefore, instead of a primary method, a secondary analysis of data has been performed to gather information in support of the study.

3.3 Data Analysis Technique

3.3.1 Searching

The searching of the relevant journals for this topic were done with the help of keywords for the development of the five themes that were used in the thematic analysis. Searching with keywords helps in saving time and helps in getting the results that are required [56]. The keywords that were used in the process of searching were Green Radio communication and energy efficiency. Therefore, with the help of searching with those keywords, proper journals were found with rich information that were used regarding create the themes.

3.3.2 Quality Assessment

The process of quality assessment was done with the help of selecting the journal articles that were peer reviewed. Regarding be more precise, the journal articles that were selected were published from authentic journal databases, having a proper digital object identifier (DOI) number, publication date and names of the authors in addition to that, the authors of those articles were renowned in their fields and the information that was collected from those journal articles were genuine and has helped the researcher in conducting thematic analysis.

3.3.3 Data Extraction

The data that was extracted from those peer reviewed journal articles were genuine and high in quality. Those data were collected by the researcher regarding meet the aims and objectives of the research paper with the help of thematic analysis. In addition to that, only the data that was relevant regarding meet the aims and objectives of this research paper were extracted and any other unimportant data was not mentioned in this research paper.

3.3.4 Text Coding

The fourth step of thematic analysis is text-coding, and it is one of the most important steps of thematic analysis because it is helpful for highlighting the valuable information during the data collection process. In this step the relevant information is highlighted so that it can be easily found out when it is required. The comparison between various information cannot be done without finding them during the development of the themes and it is one of the most important aspects to compare between the information that are available in the journal articles so that an authentic outcome can be generated. It is important to compare various sets of data during their interpretation so that a proper outcome can be generated through the process [57].

3.3.5 Theme Generation

Generation of the theme is the ultimate step in the thematic analysis process. In this step the result of comparison and analysis of the secondary data that are collected from the authentic journal articles are depicted. The generation of themes is the process of writing the themes like academic texts with proper analysis, justification, and the required academic references. In this study five themes based on Green Radio communication in terms of energy efficiency have been developed with proper justification and references. The themes are generated with justification regarding the topic area and the contrast between various viewpoints are also discussed here.

3.4 Artefacts zsA

Terms	Linkage and procedure of data search
Dynamic Voltage and Frequency Scaling (DVFS)	DVFS is referred to as the technique which aims for reducing the dynamic power consumption through adjusting the voltage and frequency. This technique is important for Green Radio communication as the consumption of energy plays a key role in the Green Radio communication.

VLC router technology	Visible light communication (VLC) router technology is designed with respect to Green Radio communication because it enables communication in environments which are sensitive to radiofrequency.
RF technology	The concept of radio frequency technology is related to the Green Radio networks which has also paved the way for energy efficiency.
The hybrid Sf-SHO	The famous algorithms such as spotted hyena optimization (SHO) are integrated to form the sunflower -spotted hyena optimization (SF-SHO) through utilising the green communication [58].
Mobile Edge Computing (MEC)	MEC applications tend to address the energy efficiency and the offloading performance of the IoT applications.
Information communication technology (ICT)	ICT plays a significant role in green communication technology because it changes the ways of communication in respect to the environment.
Multi-hop relay network (MHR)	Green network technologies are based on the MHR as it is the network design which is used for minimizing the energy consumption.
Ultra-dense networks (UDN)	UDN is also considered as the new solution through which the communications nodes and the links are diversified.
Network coding technology	Network coding technology is one of the significant issues on the technologies related to the Green Radio communication networks [59]
Smart grid and demand response (DR)	Wireless communication is referred to as the major component on the small grid which is used for communicating through the Green Radio [60]. DR programs are designed regarding affect the consumption of energy in the small grid.
Renewable powered base station (BSs)	Renewable energy (RE) powered base stations (BSs) are also considered as one of the best solutions for addressing the increasing demand of energy in terms of the cellular networks. It can be used for the growth of Green Radio communication technology because it helps in decreasing the emissions of carbon dioxide (CO2).

Demand side management (DSM)	DSM helps in managing the loads regarding obtain the harmony in the ratio of demand and supply which is important for energy management systems.
Wireless sensor network (WSNs)	In this wireless communication era, demand for WSN has been increasing because it is considered as the backbone technology for enhancing energy efficiency.
Cooperative communication or D2D	Through the device-to-device communication, several devices attempt to access the wireless medium [61]. It also helps in making people aware about the communication which can be done through Green Radio communication technology.

Table 1: Artefacts

3.5 Outcome

Regarding make sure proper outcomes of the research study, it is important to select the appropriate topic and its analysis is required for improving the relevance for text coding. Before selecting the research topic, the impact of the subjective area of the research has been analysed effectively for obtaining the appropriate outcome. After the selection of the research topic text coding has been done which has helped in identifying the specific terms as well as variables for the research. The process of the quality assessment has also been done by using the appropriate keyword regarding develop the five themes. The data that has been obtained from the authentic journals or the articles have been used in the research study effectively. Text coding has helped regarding maintain the track of the research study while reading. After the coding to text generation of the artefacts has been made which has been discussed in the above section that is relevant to the Green Radio communication technology.

After the identification of the important terms the identification of the important variables is done regarding understand important aspects of research study. The research methodology plays a crucial role in the whole dissertation and for collecting the information related to research study the secondary qualitative research methodology has been selected and themes have been generated by focussing on the aims as well as objectives of the research study. Themes have also been reviewed by the researcher to ensure proper analysis. After the

collection of the information, findings were interpreted to understand the role Green Radio communication technology performs in energy efficiency. Further, the outcomes obtained from the data collection process is beneficial for the readers to have a deep insight on the Green Radio communication technology.

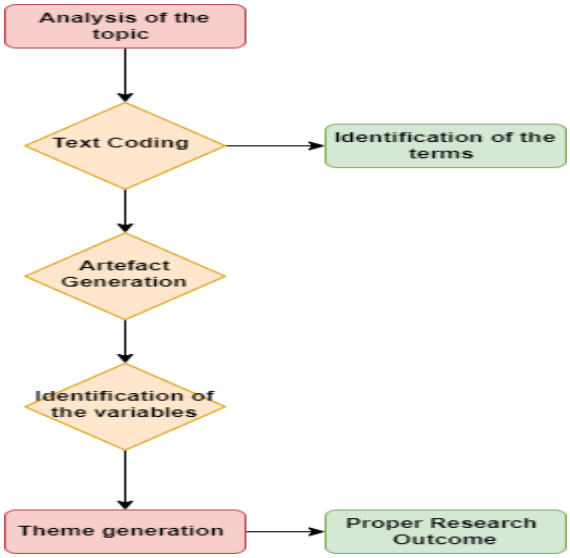

Figure 10: Flow Diagram

3.6 Summary

Based on the above summary it has been observed that Green Radio communication plays a vital role in terms of communication without affecting the environment. The mobility control as well as harvesting of energy can also be considered as the vital results for utilising the Green Radio communication technology. Green Radio communication as well as energy efficiency are interrelated as the data centres play a significant role in the domain of Information Technology.

4. Proposed Approach Of Analysis Using Artefacts

4.1 Introduction

In this chapter of the dissertation, the secondary qualitative information collected for fulfilling the aim and objective of the study are analysed. The secondary qualitative information that are analysed here are collected from peer reviewed journal articles that are available in the authentic databases like Springer, ScienceDirect, Sage pub, Nature and so on. Regarding conduct the thematic analysis artefacts have been created based on relevant keywords.

Regarding develop the artefacts the keywords used in the articles are showcased in the table along with the method that has been used in the articles and the findings of the study are also showcased in the table. The analysis of the findings has been provided under the themes separately. The themes that were developed for completing the chapter are developed based on the objectives of the study so that they can be fulfilled effectively.

4.2 Various Aspects Of Green Radio Communication Technology

Green communication technology is an energy efficient communication and networking tool that helps in reducing the use of resources wherever it is possible in all branches of the communication. The study of [62] shows that VLC router technology is one of the most effective green communication technologies. The power consumption in case of VLC technology both for communication and illumination is much lower than that of the Wi-Fi scheme. It is so energy efficient that the total additive power of the VLC technology is even lower than the power consumption due to the turning on a Wi-Fi AP [62]. Even in the case of the increase of the wall plug efficiency factor for AC signals the increase in the power consumption of VLC technology is negligible. Therefore, it is evident that the traditional RF access like Wi-Fi can be replaced by a VLC system for a much more energy efficient performance [62].

On the other hand, the study of [63], shows that the VLC network typically consisted of LED transmitters for illumination purposes and the VLC system can provide low-cost internet connection, but the hybrid model of VLC and PLC can be helpful for providing better quality communication. However, considering a narrow line of side links that can be used for deployment of dense LEDs is a fundamental challenge for the VLC network. Achieving high-speed VLC lide spatial density which is high is also a challenging aspect because of the higher inter-carrier interference. The dynamic voltage and frequency scaling (DVFS) is used for decreasing the power consumption that is dynamic by means of adjusting the voltage and frequency of the central processing unit [64]. The discrete frequency and voltage setting of the processing units are used for reducing the use of power by the DVFS technology [64]. Therefore, it is evident that this technology can be used for the Green Radio communication for achieving an energy efficient system. As per the study of [65], The use of DVFS reduces the loading time and the DC load is also decreased by 40 to 50% as compared to the non DVFS mode. On the other hand, as per [65], the algorithms that are used for the incorporation of dynamic voltage frequency scaling technique are adhered to the cloud simulator encompassing

the packet level network. From the DVFS mode's point of view, the server receives its initial supply of the task queue through the successful termination of every task in the queue. Therefore, using the DVFS can reduce power consumption, and by doing so, it helps to establish a Green Radio communication by consuming less energy. It appears that integrating DVFS and VLC router technology together can improve communication technology while also reducing power consumption. Therefore, a network that is both more effective and efficient in terms of energy use can be created by combining these two technologies.

Source	Keyword	Method used	Findings
[62]	RF technology, VLC router technology	Secondary qualitative data has been used regarding generate proper outcomes in this study.	The results show that the utilisation of VLC technology is helpful for communication and illumination at the same time. Thereby the use of VLC technology reduces the power consumption. Therefore, the use of a hybrid technology made from both VLC and RF access methods can be helpful for minimising the problem of power consumption.
[63]	RF technology, VLC router technology	The secondary qualitative data is used in this study.	VLC has the capacity to provide underwater communication facility, indoor positioning, however it is also evident that there are challenges regarding receiving the high-speed VLCs.
[64]	Dynamic Voltage and Frequency Scaling (DVFS)		Dynamic Voltage and Frequency Scaling is a technology used for minimising the use of power by using the discrete frequency of the central processing unit and therefore, it can be utilised for developing efficient green communication.
[65]	Dynamic voltage and Frequency Scaling (DVFS)	Experiment has been conducted with green cloud simulator	The result shows that the use of DVFS mode finished all the loading before 47 seconds and no system was withdrawn forcefully. The task is completely consumed by the servers and the average DC load in the DVFS based simulation is decreased by 40 to 50% as compared to non DVFS simulation.

Table 2: Artefact based thematic analysis

4.3 Functional Components Of Green Radio Communication Technology And Its Utilisation In Energy Efficient Outcomes

The core components of the green networking technology are two, namely, energy awareness and energy efficiency. Energy awareness is the ability of the network to measure the cost per packet [67]. Apart from that, identification of power constraints and becoming a limiting force to operate carbon emission in case it goes above the threshold. On the other hand, energy efficiency is the ability of the network to decrease the contribution of carbon from those which were incurred before the application of energy efficiency and thereby extending the lifetime of the network and at the same time maintaining the quality of the network is called network efficiency [67]. As per the study of [68], spotted hyena optimisation and sunflower optimisation (SF-SHO) are the two famous algorithms by using the hybrid meta heuristic concept for optimal selection of cluster head. The most problematic aspect of the IoT is the network delay, consumption of more energy, temperature, and load. However, the use of the hybrid SF-SHO can be helpful for resolving this problem and thereby show the enhanced green communication performance. It is evident that the utilisation of the SF-SHO is very efficient in terms of reducing energy consumption. As per the study of [69], mobile edge computing is one of the most efficient networks that can help in developing an efficient communication network which is more effective than 5G technology. It can increase the data rates and at the same time decrease the latency. The energy consumption is also exceptionally low and the security and privacy that can be provided by this technology is also exceedingly high. As per the study of [70], the use of blockchain technology can be helpful for enhancing the 6G technology by improving the security aspect of the network and at the same time it can also decrease the consumption of energy and thereby it can be helpful in developing an efficient green communication technology. This technology will also be helpful for computing, storage, and resources. As it has been found that the two core components of Green Radio communication technology are the energy awareness and energy efficiency and it is also evident that utilisation of SF-SHO can be helpful for increasing the quality of the network and at the same time increase the energy efficiency, it can be used for energy efficiency in developing Green Radio communication. On the other hand, the study of [70], shows that mobile edge computing is a technology that helps in reducing latency and developing energy efficiency. Based on the perspectives of [71], mobile edge computing is considered as the novel paradigm computing which stipulates a dramatic effect based on the reduction in latency and energy consumption

through the quantification of offloading. Hence, it can be used for energy awareness in the Green Radio communication technology.

Source	Keyword	Method used	Findings
[67]	Information communication technology (ICT)	Conceptual analysis of energy efficiency based on networks.	Network management approach in compliance with the optimisation tactics reduces bit costs through improvement of efficiencies.
[68]	The hybrid Sf-SHO, Mobile Edge Computing (MEC)	Secondary qualitative method	It is evident that green communication technology has two core components. The two core components of Green Radio communication are energy awareness and energy efficiency. Energy awareness helps in quantification of operational cost. On the other hand, energy efficiency helps in reducing operational cost.
[69]	The hybrid Sf-SHO	Secondary qualitative method	Shows that the use of SF-SHO and SHO can be helpful for reducing the consumption of energy and thereby increasing energy efficiency.
[70]	Mobile Edge Computing (MEC)	Secondary qualitative method	The use of blockchain technology as a part of mobile edge computing technology, an efficient 6G network can be developed which will have more security and safety.
[71]	Mobile Edge Computing (MEC)	Secondary qualitative method	Mobile edge computing can decrease latency and enhance power consumption efficiency.

Table 3: Artefact based thematic analysis

4.4 Operational Attributes Of The Green Radio Communication Technology

Green Radio communication technology is built based on using energy efficient forms of network that are wireless and due to this reason, the issue of energy crisis in the future can be resolved. Operate the Green Radio technology of communication, there are certain algorithms that are developed to use the energy garnering wireless networks [72]. In addition to that, mechanical relaying techniques are used in relation to the operational sector in the wireless networks of the Green Radio communication technology as well. For example, according to

the study of [73] mechanical antennas are used to gather data about the ULF frequencies and these mechanical antennas are also much better than the electronic counterparts of them. Furthermore, in the operational section of Green Radio communication, there are few fundamental trade-off systems which are very crucial for the designing and the operational part of the Green Radios for the purpose of energy saving. For example, some of those fundamental trade-off's that are significant for Green Radio are the efficiency of deployment, efficiency of energy, efficiency of spectrum, the power of bandwidth and the delay power.

Green communication helps in the practice of selecting energy efficient communication systems with the technologies of the network along with the usage of minimum resources of energy. Therefore, there are a lot of requirements of hardware's and software's that need to function accordingly regarding minimize the consumption of energy of some of the network components. Therefore, if all the portions of the Green Radio communication technology are working in tune with each other, then it helps a lot in the process of reducing the generation of waste materials. In addition to that, it is quite evident that the number of users of telecommunication systems are constantly increasing and due to that reason, the consumption of energy is increasing as well. Therefore, it is very essential to implement the technology of Green Radio communication technology. It is due to this reason; the usage of Information Communication Technology (ICT) is especially important in the operational process of Green Radio technology and the implementation of Multiple Relay Network (MRN) is also particularly important for the same reason. For example, as per the study of [74] with the implementation of ICT, the energy that is consumed by the data centres and communication servers are reduced by a significant margin which is a great benefit in the process of saving energy for the future. Based on the emphasis of [75], encouragement towards ICT policy making is required in terms of ensuring environmental sustainability with significant development. Diversely, in accordance with [76], operations based on ICT trigger considerable research works in confinement to Green Radio communication and in alignment with the same multihop relay serves to be of best alternative in the cell edges towards producing quality networks. Maximisation of energy efficiency within ultra-dense networks caters towards renewable energy cooperation based on small stations [77].

Sources	Keyword	Method used	Findings
[72]	Mobile virtual centre of excellence	Case studies	Accounting of the embedded energy costs caters towards a higher budget on operational energy at base stations than mobile terminals.
[73]	ULF	Experimentation based on electro-mechanical system	Ultra-low frequency (ULF) entails lower bandwidth, but is immensely reliable and penetrating, which is hard to jam.
[75]	Information Communication Technology (ICT)	The primary quantitative data has been used in this study.	It can be found from the study that the implementation of ICT has significantly reduced the emissions of carbon dioxide (CO2) and it also encourages the practice of environmental sustainability. Furthermore, the implementation of ICT plays a key role in boosting productivity in economies and helps in the practice of energy efficiency. In addition to that, a relative study has been developed which shows that the implementation of ICT helps in the process of mitigating the harmful emissions in this modern age of technological advancements. Therefore, it can be understood that the implementation of ICT helps in the process of energy efficiency in green communication technology.
[76]	Multi-hop Relay Network (MHR)	The secondary qualitative data has been used in this study.	It is quite evident in the study that the green communication technology in relation to the technology of 5G requires solutions that are energy efficient. Additionally, the existing network of enhanced nodeBs (eNB) is not suitable and not energy efficient as well for the purpose of deployment. Therefore, the study shows that the MHR network can be a particularly good replacement of the eNB because it is suitable in the process of cell edges and coverage holes.
[77]	Ultra-Dense Network (UDN)	Primary quantitative method has been used.	The use of UDN in small base stations (SBS) helps a lot in the process of harvesting energy. In this study, Q-learning algorithm has been used and it has been found that NDN helps in the process of optimising the usage of energy and therefore, helps in enhancing the practice of energy efficiency. Therefore, with the help of NDN, the SBSs of green communication networks can also be improved.

Table 4: Artefact based thematic analysis

4.5 Functional Attributes Of Green Radio Communication Technology

The increase of the users in the telecommunication sector has also increased the consumption of energy and has also increased the emission of carbon dioxide gas which is very harmful for the environment. Moreover, the wireless systems that are currently used are not efficient in relation to saving energy and due to this reason, it is of utmost importance to use the Green Radio communication technology and analyse its functional attributes. Network coding technologies and green modulation develops a powerful base of the functional attributes of the Green Radio communication technology to gain energy efficient outcomes. According to the study of [78], the physical coating of the wireless systems of communication are developed with the help of the network coding technologies with this strategy, the high emissions of carbon dioxide can also be reduced. Furthermore, there are some cooperative techniques that are used to carry out wireless communication with the practice of energy efficiency. This is a significant functional attribute in the Green Radio communication technology. According to the study of [79], the analysis of OFDMA networks, relay transmission and MIMO techniques helps a lot in the cooperative techniques of wireless communications in the technology of green communication. According to the study of [80], it can be understood that the process of cooperation technique and the technologies of network coding are significant aspects in the functional attributes of Green Radio communication technology. Moreover, innovative ideas in electrical power engineering can hugely benefit the process of sustaining energy for the future and Therefore, the energy consumption levels can be decreased [81]. Furthermore, the concept of demand response (DR) can be beneficial in the process of reducing energy consumption.

The right implementation of proper functional qualities in the technology of Green Radio transmission makes it easier for network operators to uphold their corporate social responsibility. Additionally, to make cellular networks more environmentally friendly, cellular network operators must concentrate on the fundamentals of the technology and make the necessary functional adjustments. For instance, the base station of the cellular networks must integrate technologies like network coding and cooperative approaches. Additionally, the right integration of these technologies into the cellular network base station will aid in the enhancement of energy efficiency. Because of this, it is necessary to build the functional characteristics of green communication technology using the technologies outlined above, which will produce results that are energy efficient.

Source	Keyword	Method used	Findings
[78]	Network Coding Technology	Experimentation based on energy efficient modulations.	The identification of the level of environmental pollution has been done with the help of ***Wireless Sensor Network*** **(**WSN**)** and with the collection of nodes that are distributed among a wide span of applications.
[79]	ICT	Secondary qualitative method used.	The emissions of greenhouse gases across the globe are on a continuous rise. With the implementation of ICT, the process of reducing the consumption of energy is getting improved and the wireless systems of mobile terminals are also having the benefit of reducing the energy consumption in the development process of batteries.
[80]	Network coding technology	Secondary qualitative method has been used in this study.	Due to the constant increase of users in the network communication sector, there are also many issues that have risen from that process. The main issue that has been mentioned in the study is the environmental issue caused by the increased usage of network communications. The self-adaptive technology of routing in the technology of network coding has been most successful in decreasing the consumption of energy and the space of transmission.
[81]	Smart grid and demand response (DR)	Primary quantitative method has been used in this study.	Smart grid has played an essential role in the engineering of electrical power. It has been found from the study that the energy that is being consumed by people needs to be equal to the amount of energy that is generated. Therefore, the wastage of energy and the consumption of energy can be significantly reduced with the help of demand response (DR) strategy, all the above-mentioned processes can be carried out. Therefore, this technique can be used in the technology of Green Radio communication to reduce the amount of energy consumed by the base servers.

Table 5: Artefact based thematic analysis

4.6 Capacity Of The Green Radio Communication Technology To Reduce The Problems Of Energy Crisis In Future

To overcome the issue of energy crisis in the future is to reduce the dependence on non-renewable sources. Green or renewable energy technologies stand to produce energy by using renewable sources of energy such as solar, water, wind, biomass and the geothermal heat.

Increase in the number of the mobile subscribers eventually results in the increase in the data traffic. As opined by [87], The RE enabled cellular networks are efficient to provide a better networking service on the other hand and decrease the energy consumption on the other significantly. The emission of CO2 can also be reduced by enhancing the energy efficiency by utilising RE enabled cellular networks. Regarding maintain the profitability rate as well as making the cellular networks much greener certain goals are related with the green cellular networks such as there is the requirement in the improvement of the efficiency of energy. It is also important to improve the intelligence of the network by the trade-offs between the consumption of energy as well as the external conditions such as the traffic loads. Another goal is to integrate the infrastructure of the network as well as the services of the network to enable the network to be responsive as well as requiring less power for operating. According to [88], the low utilisation of network and generation implies a significant scope for DSM in contribution to the investment efficiency increment. Demand side management technology is a concept which is used in the energy industry because it is increasing in a trendy way for managing the electronic costs in the countries along with the penetration of the renewable sources and it is also growing the awareness regarding the impact of increasing the utilization of the renewable sources of energy [88].

With the introduction of modern technologies and goals for energy optimization, demand side management technology has evolved into an essential and crucial technique for powering system operations. [89] claims that all the sensors found in wireless sensor networks (WSNs) are battery-powered gadgets with a finite amount of power. It is not feasible to replace each battery that is present in the network regarding energy consumption after the deployment of the sensor devices. Green radio communications are crucial since they are regarded as the newest method of lowering the carbon footprints left by the network industry. The energy consumption of network components can be decreased using a variety of hardware and network strategies. Wireless sensor networks have also become the foundational technology in this wireless communication era, according to [89]. Because of the WSN's crucial function in numerous applications, as well as their deployment and omnipresent nature, demand has been rising quickly. The primary enabling technology for 5G wireless systems, and the Internet of Things is device-to-device (D2D) communication technology (IoT). The D2D technology, according to [89], also offers better resource use, coverage, reduced delays, and power consumption by shifting traffic mostly from centralized infrastructure to direct device-to-device transfers.

Source	Keyword	Method used	Findings
[87]	Renewable power base station (BSs)	The primary quantitative data has been used in this study.	The study shows that cellular networks with RE capabilities are effective at sharply reducing energy use. Renewable energy-powered base stations can also lessen the negative effects of energy use and CO2 emissions on the environment. Studies that examine the viability of base station systems powered by renewable energy for regions were also provided in the paper. As a result, the study suggested using renewable energy as a source of power for network components other than terrestrial base stations.
[88]	Demand side management (DSM)	The secondary qualitative analysis has been used on the study	The study shows that the benefits and drawbacks of demand side management have been examined in relation to the energy grid in the UK. The low network and generation usage suggests that DSM has a substantial opportunity to improve investment efficiency. The main forces behind DSM are aging assets, low-carbon generation technologies, renewable resources, and the development of information and communication technologies.
[89]	Wireless sensor network (WSNs), Cooperative communication or D2D	The secondary qualitative analysis has been used on the study	Information processing technology that uses distributed computing is becoming increasingly important in the twin industry area. To balance network usage over constrained node distance, the study proposes a digital twin calculating technique for precisely finding the remaining cluster head. According to this study, D2D communication is a noteworthy way to use an LTE advanced network's expanded spectrum. A sustainable green communication system can be made possible by D2D's capacity to capture energy and use less energy thanks to nodes that have successive interference cancellation (SIC) capability.

Table 6: Artefact based thematic analysis

4.7 Summary

The chapter analyses the data collated on Green Radio communication systems and discusses the findings in theme format. The themes are developed based on the various aspects that discuss efficiency of the Green Radio communication system. Existing data on the study area has been used to develop themes for analysis. Gathering information from authentic sources has been emphasized in the theme development process. The Green Radio communication

system has been analysed based on its basic aspect, functional component, operational and functional attributes, and capacity to manage energy crisis. RF technology, VLC router technology, Dynamic Voltage and Frequency Scaling (DVFS) have been identified as key components providing efficiency to Green Radio communication. These technologies together enable the radio communication to be an energy efficient alternative through limitation of power usage. It has been found that hybrid Sf-SHO, Mobile Edge Computing (MEC) are the two functional components of the system. Information Communication Technology (ICT), Multi-hop Relay Network (MHR) and Ultra Dense Network (UDN) are identified as the operational attributes of the system. The functional attributes of green radio communications were identified to be Network coding technology and Smart grid and demand response (DR). Therefore, Green Radio communication can be regarded as an alternative to conventional energy systems.

5. Results and Evaluation

5.1 Results

It is found from the artefact analysis that the green communication technology is a networking tool which is efficient energy consumption. It optimises the energy consumption wherever it is possible in each branch of communication. VLC router technology is one of the aspects of green communication technology in which the communication quality can be enhanced on the one hand and energy consumption can be lowered on the other. On the other hand, the DVFS technology is another aspect of the Green Communication technology which helps in discrediting frequency and voltage setting of the processing unit for improving the energy efficiency of the network. In the VLC network LED transmitters are used for providing low cost and highly efficient internet connection. In a hybrid model of VLC and PLC the quality of communication can be made better. On the other hand, the RF access method can be beneficial for enhancing the power consumption aspect in the network is an especially useful aspect of green communication technology because it can even be used for providing underwater efficient networking. On the other hand, the DVFS mode is 40% to 50% more efficient in terms of DC load than the other modes. Therefore, it is evident that utilisation of the DVFS and VLC router technology can be utilised for developing an energy efficient networking system.

It is found from the discussion that green networking technology has two core components and the two core components are energy awareness and energy efficiency. The ability of the network to measure the cost per packet is called energy awareness. On the other hand, the ability of a network to decrease the contribution of carbon and extend the lifetime of the network can be called energy efficiency. The Information Communication Technology (ICT) is one of the approaches in compliance with the optimisation tactics and reduces the bit costs by improving the energy efficiency. The SF-SHO and mobile edge computing are the two aspects of Green Radio communication that helps in quantification of the operational cost. It also enhances energy efficiency and assists in reducing the operational cost. The use of the mobile edge computing through the blockchain technology can be used for developing an efficient 6G network which can have more security and safety as compared to other networks. The mobile edge technology can decrease the latency and improve the power consumption.

The algorithms of the energy garnering wireless networks help in the process of gaining more latency in the wireless communication systems without increasing the consumption of more energy. Furthermore, it has been found that the techniques of mechanical relaying are beneficial in relation to the reduction of high amperage systems of wiring and due to this reason, the

consumption of energy reduces in the case of wireless networks. In addition to that, the cost of the wirings and the switches gets reduced by a significant amount when the implementation of mechanical relaying techniques are done properly. Furthermore, the implementation of Information Communication Technology (ICT) reduces the consumption of energy in wireless networks, and this plays a key role in the technology of Green Radio communication technology. In addition to that, the implementation of ICT also helps in the process of connecting the hardware and software of the wireless technology and making them work accordingly to successfully reduce the energy consumption by communication networks. The implementation of Multiple Relay Network (MRN) helps in the process of keeping track of carbon footprint and with the implementation of ICT along with MRN, the energy that is consumed by base centres of wireless networks of communication can be reduced.

It has been found that with the help of network coding technologies, the emission of carbon dioxide can be hugely reduced and therefore, the green technology of radio communication can become more sustainable. In addition to that, with the help of some cooperative techniques, the wireless communication systems can be run with energy efficient procedures. Furthermore, the OFDMA and MIMO techniques are also a significant aspect of the cooperative techniques regarding run the wireless system of communication with energy efficient processes. Moreover, it has been found that the combined effectiveness of cooperative techniques and the techniques of network coding can result in a rigid foundation in the functional attributes of the Green Radio communication technology. Additionally, the engineering of electrical power plays a leading role in the process of sustaining energy in the technology of green radio communication. It is due to the reason that the electrical wirings in the communication system plays a significant role in the base stations and therefore, innovative procedures in the wirings can be beneficial.

Renewable powerbase enabled cellular networks are very much efficient and it can be helpful for reducing the energy consumption significantly by using this technology. The renewable power generation can also be helpful for reducing the emission of CO2. The renewable energy is a source for components other than the terrestrial base stations. Solar, water, wind, biomass, and the geothermal heat can be the sources of renewable energy and utilisation of the renewable energy for development of cellular network can be helpful for Green Radio communication networks. On the other hand, the demand side management (DSM) is a concept which is used for managing the electronic costs in the countries with the penetration of renewable energy sources.

The technology of Green Radio communication helps in the process of using less energy for the communication purposes and due to that reason, the issue of energy crisis in the future can be mitigated. Therefore, the cellular networks which are enabled with RE are greatly beneficial in the process of reducing the emissions of carbon dioxide and reduces the consumption of energy. In addition to that, the sensors that present in WSN networks are operated with the help of batteries and due to that reason, the power in the batteries are fixed. Therefore, in the green communication system, this is a very essential part because this strategy helps in the limited consumption of energy.

5.2 Evaluation

5.2.1 Various Aspects of Green Radio Communication Technology with Detailed analysis

It has been found that the Green Radio communication technology is an effective networking tool that helps in efficient energy consumption. As per the study of[90], the energy efficiency in the Green Radio communication depends on the network architecture. The utilisation of Green Radio communication technology helps in improving the network architecture and thereby reducing the energy consumption. Hence, it can be said that green communication technology can be helpful in terms of achieving energy efficiency. The findings of the study shows that the VLC router technology is an aspect of Green Radio communication technology which can enhance the quality of communication. The study of [91], shows that the VLC services helps in transmission of data in an extremely fast manner. The LED transmitters that are used for VLC router technology are efficient for both fast data transmission and energy efficiency. Therefore, it is evident that the utilisation of VLC router technology can be helpful for enhancing the Green Radio communication technology. The findings of the study also shows that the use of DVFS technology can be helpful for improving energy efficiency as it can discrete frequency and voltage setting. The study of [92], depicts that DVFS technique can be helpful for enhancing the energy efficiency of the GPUs. As GPUs are used for networking aspects, using the DVFS technology in the GPUs can be helpful for enhancing the energy efficiency and thereby enhancing the efficiency of Green Radio communication technology.

Source	Keyword	Findings
[90]	Energy efficiency, Green Radio communication	It is evident from the study that network architecture plays a key role in green communication networks.
[91]	VLC	The VLC technology is one of the efficient technologies which can be helpful for Green Radio communication. The data transmission rate in VLC technology is fast.
[92]	DVFS	DVFS techniques help in improving the energy efficiency oof the GPUs. As GPUs are used for networking purposes, DVFs can be used for Green Radio communication technology.

Table 7: Artefact based thematic analysis

5.2.2 Functional Components of Green Radio Communication Technology And Energy Efficiency Of The Same

The findings of this study shows that there are two core components of Green Radio communication, the first one is energy awareness and the second one is energy efficiency. The study of [93], shows that the energy efficient communication can be achieved by developing smart communication infrastructure and the energy efficient communication can be developed by utilising Green Radio communication. The findings of this study also shows that the energy efficiency which is one of the core components of green radio communication can enhance the life cycle of the network. The study of [94], shows that the energy efficiency of mobile phones has improved in the last few years, and it helped in increasing the life cycle of the networks significantly. The utilisation of Green Radio communication not only helped in enhancing the network performance, but it has also decreased the carbon footprint. Thereby it is also helpful in improving the environmental performances of the networks. Moreover, the findings of the study have also depicted that the SF-SHO and mobile edge computing are the aspects of Green Radio communication that is helpful for reducing the operational cost of the network on the one hand and enhancing the aspects of safety and security on the other. The study of [95] depicts that SF-SHO is a system that can be used for enhancing energy efficiency and to enhance the efficiency of the network by handling complex algorithms easily.

Source	Keyword	Findings
[93]	Energy efficient communication technology	Generation of smart grid has improved the generation of electricity. The utilisation of the green communication and smart grid can improve the energy efficiency of the networks. It can also reduce the latency and improve the reliability and thereby it can be helpful for handling the workload smartly.
[94]	Energy efficiency	Developing smart communication technology can be helpful for enhancing the energy efficiency on the one hand and the improvement of the network on the other.
[95]	SF-SHO	The SF-SHO can be used for maximum power point tracking. The algorithm used in SF-SHO can be helpful for increasing energy efficiency. On the other hand, it is also helpful for improving the quality of the networks. Therefore, the use of SF-SHO can be used for improving the Green Radio communication networks.

Table 8: Artefact based thematic analysis

5.2.3 Analysis of the tools and operational and functional attributes of the Green Radio communication technology

The implementation of Information Communication Technology (ICT) can be a greatly beneficial tool for the operational and the functional attributes of the technology of Green Radio communication. According to the study of [96], ICT is a tool that needs to be used appropriately to maintain sustainability and practice proper green technologies. In addition to that, with the implementation of ICT in the technology of green communication, the emission of carbon dioxide can be heavily reduced, and functionality of the Green Radio communication can be improved a lot as well. Furthermore, due to the excessive growth of wireless communication networks in these modern times, it is very essential to implement ICT in every base centre of wireless communication systems so that the emission of carbon can be kept at a limit and the practice of green communication can be enhanced. On the other hand, Multi-Hop Relay Network (MHR) is another tool that is highly effective for the operational and functional attributes of the technology of Green Radio communication. As it can be seen from the study of [97], the implementation of MHR has significantly provided an energy efficient solution to the functionality of wireless mobile networks by replacing the enhanced nodeBs. Therefore,

with this strategy, the consumption of energy can be reduced by the data centres of wireless networks and therefore, this is an effective tool in the operational and functional attributes of green communication technology.

Source	Keyword	Findings
[96]	Information Communication Technology (ICT)	It has been found from the study that the implementation of ICT tools helps in enhancing the practice of sustainability. In addition to that, the practice of green technology also gets supplemented with the help of implementing ICT tools.
[97]	Multi-Hop Relay Network (MHR)	The implementation of MHR provides solutions to the wireless mobile networks in relation to the reduction of power consumption in their base centres. In addition to that, it can also be seen from the study that replacing the enhanced nodeBs with MHR has proved to be beneficial in the process of reducing energy consumption by wireless mobile networks.

Table 9: Artefact based thematic analysis

5.2.4 Mitigation of future energy crisis by using the tools and Green Radio communication technology

The modern tools and technologies that are currently being used in the Green Radio communication technology have paved a way to mitigate the crisis of energy in the future. For example, the tool of smart grid and demand response (DR) has had a great positive impact in the process of mitigating future energy crises. As it can be seen from the study of [98], smart grid is playing a key role in the industry of electric power systems and the system of demand response has helped in the process of collecting the data regarding the consumption of energy. In addition to that, the system of demand response can be automated as well regarding gather information about the energy consumed by the base centres of wireless communication networks, and this will prove to be efficient in the process of mitigating the energy crises in the future. On the other hand, another tool that plays a significant role in the mitigation process of

future energy crises is the Information Communication technology (ICT). According to the study of [99], the key role that ICT plays in the mitigation process of energy crisis is that the carbon footprint of the wireless network communication technologies can be monitored efficiently. Furthermore, ICT also provides better approaches to the process of mitigating future energy crises and the data that is required for that process can also be gathered efficiently with the ICT tool.

Source	Keyword	Findings
[98]	Smart grid and demand response (DR)	The tool of smart grid and demand response has provided innovative solutions regarding mitigate the issue of future energy crises. Furthermore, it can also be seen from the study that the DR made a positive impact in the electric power industry and due to that reason, the process of gathering relevant information about energy consumption from base centres has been made easier.
[99]	ICT	It has been found from the study that ICT is the technology that leads by an example in the field of energy efficiency. Furthermore, the study suggests that ICT not only helps in energy efficiency but also helps in the reduction of environmental footprints.

Table 10: Artefact based thematic analysis

5.2.5 Mobile Data Traffic

Since 2010, OFCOM has released an annual statistical analysis of changes in the communications industry from the preceding year (OFCOM, n. d.), which includes per-person mobile data use as depicted in Fig. 11&12. The most recent version of the statistics survey was released in 2019. Mobile data usage has increased more than 30 times per person over the last eight years.

The modernization of communication infrastructure is primarily responsible for the sharp rise in data consumption. better mobile broadband speeds, particularly 4G networks, which has encouraged the usage of data-hogging mobile apps (like TikTok and YouTube). The impact of policies on apps is ambiguous, hence We projected three scenarios for the rise of mobile data: high demand, Low demand and medium (business as usual). Considering the demand for data is increasing at a rate that matches population growth. [103]

In 2021, 5G accounted for about 10% of all mobile data traffic; by 2027, this percentage is expected to have increased to 60 percentage.

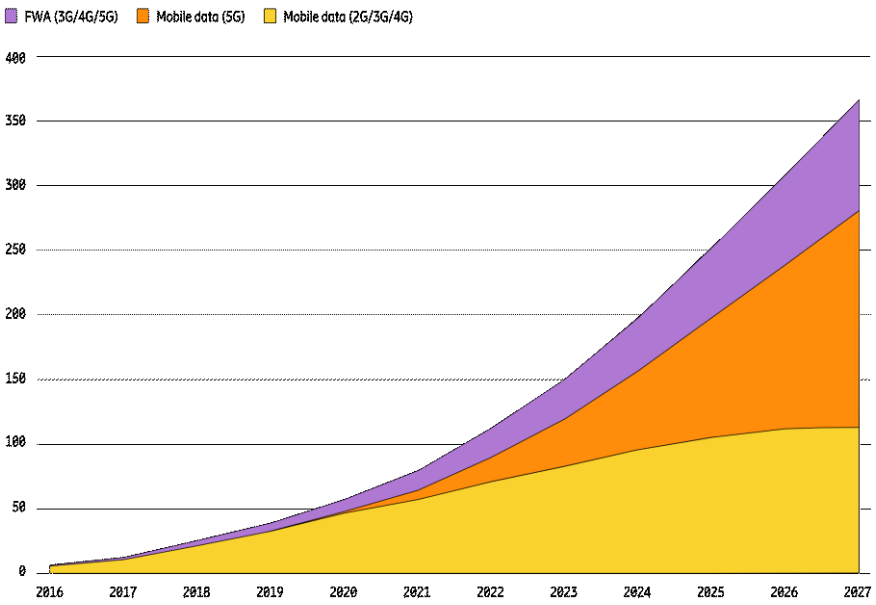

Fig.11. Global mobile network data traffic

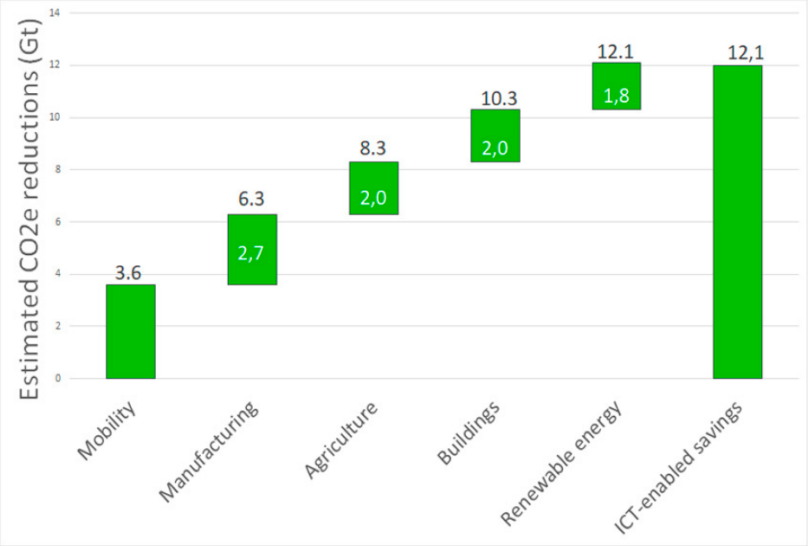

Fig.12 shows how several industry sectors will contribute to the reduction of global carbon-dioxide equivalent (CO2e) by 2030

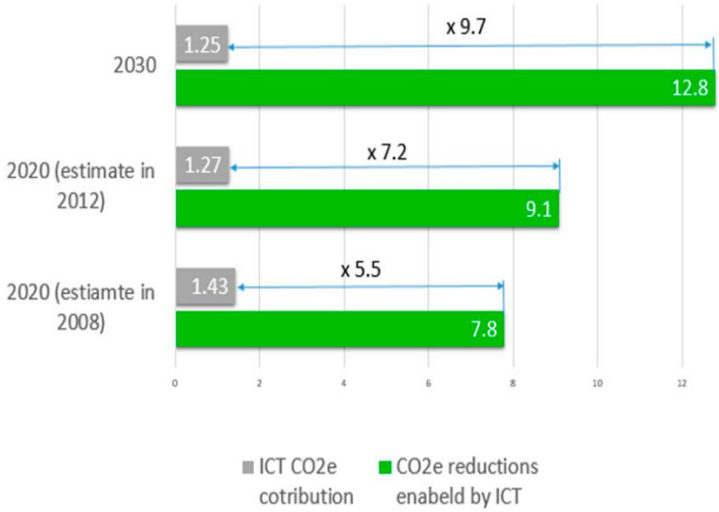

Fig.13 shows how the information and communications technology (ICT) sector will contribute to and enable reductions in global CO2e emissions, expressed in Gt (giga ton) by 2030.

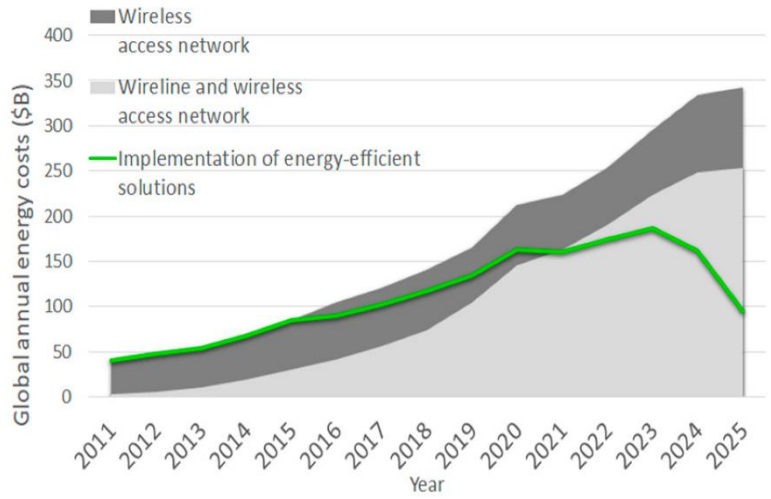

Fig14. Estimated for the world's annual energy use by telecommunication networks between 2011 and 2025

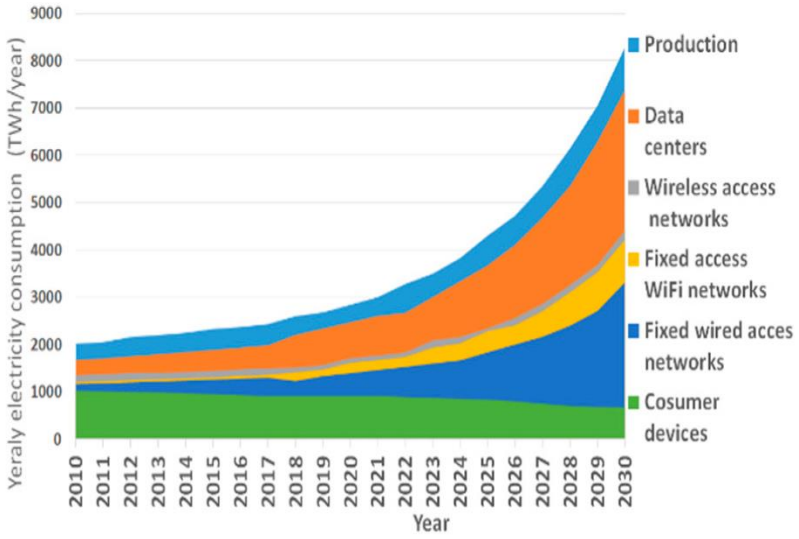

Fig15. Expected annual energy usage totals for various ICT systems between 2010 and 2030.

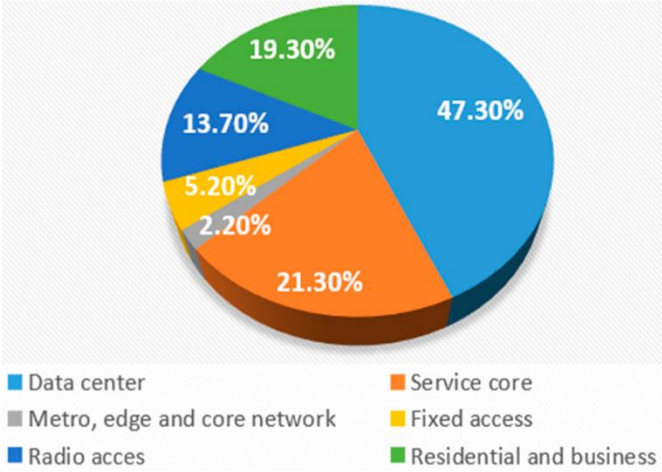

Fig16. projected network energy usage for the primary communication sectors by 2013

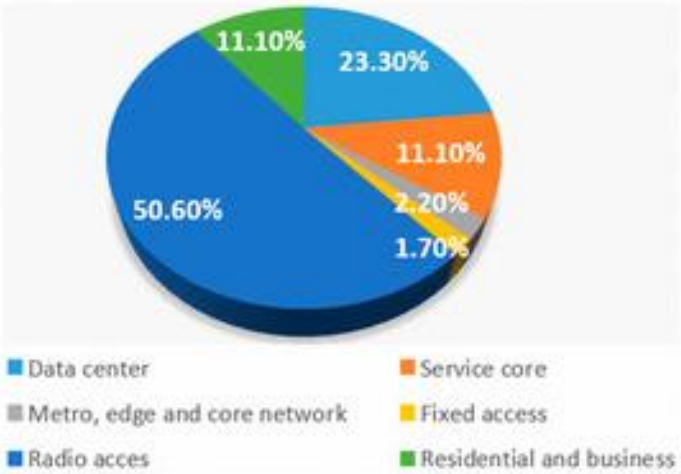

Fig17. shows the projected network energy use for the major communication sectors in 2025.

Each network sector's contribution to the overall yearly energy consumption in 2013 and projections for 2025 are shown separately. Estimates are made assuming the possible advantages of new network topologies and technologies as well as the anticipated growth of IP traffic. However, for an increase in IP traffic to be supported by 2025 in an economically viable and sustainable manner, many technological advancements are needed in each of these industries.

6. Conclusion

The study based on the Green Radio Communications and their implication on the metrics of energy efficiency has been dissected in this research. The discussion has created a massive spectrum of energy conservation as the radio networks have seen an introduction of sustainable measures in its curation to spearhead a new wave of radio communications in the entire industry. The new age industry has an array of new forms of high-speed networks in the form of 3G, 4G and even 5G which have been directly inducing a lot of electrical, electronic, and industrial resources in its production, distribution and setup at domestic venues, industries, and corporate sectors. This is a global rendition with an international relevance and importance as the procurement of such a highly relevant and rather indispensable aspect of modern life necessitates the acquisition of multiple materials, resources, and manpower. It is through the developmental phase that the necessary components of the radio communications and its digital aspects have been witnessing increasingly prolific ingredients and parts for its formulation. Gearing up for the radio communications sector to be digitised is outdated as every radio station now actively and/or passively depends upon the digital injection for a relevant performative promise. The advent of the 21st century has overseen a meteoric boom in the usage of cellular phones, handsets, Personal Computers, laptops with the digital integration of almost every walk of life. With the increase in the digital habituation of the citizens of the world, it was only natural that increasingly base stations were constructed to regulate and process the energy for the consumers. It is understood that all digital and electronic gadgets of today consist of radio networking in some way or the other. This process of accentuating the measurement of radio network has led to legitimate studies that have indicated that the entire chain of events has been eating up a huge chunk of environmental equilibrium as the digital cables and networks have been having adverse effects on the ecology of a place, natural life and animals have been facing anomalies and even human life is being vulnerable to prolonged exposure of these digital avenues. Following the formulation of these conclusions, it has been seen that apart from life risks, the resource pool of the energy and digital world now faces an extreme threat of depletion and lack of alternatives to turn to. It is of utmost urgency that the entire acquisition and usage of the digital energy census gets reduced to a filtered and checked percentage to maintain a social and economic viability for future use and a simultaneous safekeeping of humanity. Processing the said information, this research has formed a stable and strong rationale and statement of problem based on which the academic dissection and even research has been

incubated. The introduction of sustainable energy forms to induce the radio networks and communication has been initiated through Green and sustainable reforms.

The research has oriented a secondary qualitative data collection method in this research to induce an elaborative explanation of the context as well as the scenario in which the radio communication crisis has been panning through. The induction of Green Radio communications has been prolific in terms of new age sustainability measures as the modern technologies of alternative energy sources and consumption procedures have resulted in a much lesser frequency of radio waves to be released which has a lesser impact on the environment and the resources available. The academic intake of selective literatures and the corresponding themes have been utilised in the research as a measure of absolute and unabashed dissection of the issue at hand. It is of utmost importance that the dissolution of the risks and dangers are justified through the research, and it has been done so. The review of literature has led to a massive overturn of information which has established the problem statement of the research. Following the problems of energy crisis, it has been formulated that a profound risk lurks and can be impending in the case of over usage and therefore, has been discussed with pre-emptive resources of literature and past academic journals that materialise the risk into a justified one. Curated materials have been used to discuss the proclivities of energy crisis and its causes related to radio communications, something that forms the crux of this study. Following the elaboration of the importance and relevance of green energy and industrial resources that are growing in valuation and prevalence each day, the components have been linked with the induction in the radio network and communications sector. It has been seen that the radio waves of negative impact have succumbed in their intensity and frequencies in both the industrial and domestic usage metrics, which has been leading a newfound revolution in the sector already. The processing units of radio networks have been diminishing the frequency meters through Hybrid Access Technology as a metric of innovation that can not only supervise the green revolution in this sector but also maintain a strong positioning in terms of business proficiency for further investments. Intuitive renovations have been taking pace in radio base camps, which have created a new array of professionalism in this industry leading to the mainstreaming of this setup. Through the development of an actualised vision and agenda of completely negating the harmful effects of radio communications and the relevant energy dissipation of the forum, the concerned bodies have started to induce ICT principles in spearheading the necessary changes of Green Reforms and sustainability in the radio sector in specific and the energy sector in totality. This has been the research aim and objectives, all summed up for considerable solvency through thematic explanations with constant linkage to the creation of a Green Radio

Communications aspect that will negate all the risks and threats that are imposed by the aged methods. In tandem with the objectives of this research, the qualitative explanation of this topic has been elaborated with complete evaluation.

This research has been constructed with immense attention to details and informative instances regarding the radio industry, communications panel, digital resources, and energy utilisation. The sole aim of inducting green reforms in the sector has been proactively playing a distinctive role in substantially using the research in the sense of providing a set of solutions that will be both viable and relevant for the long haul. However, the research does not include the relevant organs and departments that are present in these sectors which are not at all dependent or influenced by networks and digital components like accounts, Human Resources, and operational bodies. These departments remain unperturbed and instead, undergo an uncalled change which disturbs their proficiency and entire structure. The research has neglected the topic of the subsidiary departments which are unrelated to the networking and communications of radio and have not made an explanation about their situational impact to the proposed solutions. In addition to that, the procurement of primary data in this research has been absent as the secondary qualitative data analysis has been carried out. This has levelled out the possibility of authentic and genuine information from the personnel of the respective sectors and industry of radio communications. Following the inputs made by the primary information from the employees and participants of the industry, the research would have been more relevant and valuable in terms of future academic relevance. Despite the numerous case studies and literary insights that have been used here, the production of statistical analysis and numerical justification is missing from a topic this intricate.

The process of inducing a much better attempt at initiating better research on this very topic can be carried out through numerous angles of improving the procedures, concepts and idealisations that have gone into this attempt. Given the type of research topic and the problem statement that is present, the research can be effectively using a primary quantitative and qualitative data collection and analysis approach of meeting the research objectives. Through the said process, the direct information collected will provide authentication, justification and relevance to the academic learners and researchers for future reference. Through the acquisition of the relevant industries like Internet and Smartphones could have been made as an auxiliary point of reference for this research as the correlation and interdependence between these sectors can provide a much more professional and dissected overview of the research. In lieu of the research process, the development of a confirmed sampling pool for research data collection can help in augmenting not only the quality of the insights but their applicability of their

responses in this research, as the process will cut down on the time taken for information assimilation and lead to a much more proficient version time lengthwise. During the jurisdictional context of producing the necessary reforms in the industry and energy intakes, an ethical consideration can be immensely effective making the process much more seamless and smoother. Following the development of the research aim and objectives, an acute focus on procuring the necessary formalities must be done through routine approach of academic justification to make sure that rest of the research carries on without any disruption.

Up to the year 2030, estimates and evaluations of energy costs and CO2 emissions for various ICT systems are reviewed. According to the studies that have been provided, ICT systems are at a turning point in terms of the amount of energy that telecommunication networks, DCs, and user-related devices are currently and will be consuming. The estimates made here indicate that diverse ICT systems' current technological advancements are insufficient to keep up with rising energy prices and CO2 emissions. The case of wireless networks and DCs, whose energy consumption and CO2 emissions have the biggest increase and contribution to the overall ICT energy consumption, is further explained in this study. Future ICT systems must combine various wired, wireless, and DC communication network technologies and concepts with creative energy-efficiency solutions for user-related and sensor devices to be more power-efficient and environmentally friendly. Only such a strategy can have a synergistic impact that will maintain ICT systems' energy consumption and CO2 emissions as low as possible.

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