ENGINEERING IN ADVANCED RESEARCH SCIENCE AND TECHNOLOGY

ISSN 2350-0174
Vol.03, Issue.02
May-2023
Pages: 904-910

Survey on 5G Coverage Improvement Techniques: Issues and Challenges

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Abstract:

Fifth generation (5G) is a recent wireless communication technology in mobile networks. The key parameters of 5G are enhanced coverage, ultra reliable low latency, high data rates, massive connectivity and better support to mobility. Enhanced coverage is one of the major issues in the 5G and beyond 5G networks, which will be affecting the overall system performance and end user experience. The increasing number of base stations may increase the coverage but it leads to interference between the cell edge users, which in turn impacts the coverage. Therefore, enhanced coverage is one of the future challenging issues in cellular networks. In this survey, coverage enhancement techniques are explored to improve the overall system performance, throughput, coverage capacity, spectral efficiency, outage probability, data rates, and latency. The main aim of this article is to highlight the recent developments and deployments made towards the enhanced network coverage and to discuss its future research challenges.

Keywords: cellular network; network coverage; small cells; device to device communication.

1.0 INTRODUCTION:

Most recently, in three decades, rapid growth was marked in the field of wireless communication concerning the transition of 1G to 4G. The main motto behind this research was the requirements of high bandwidth and very low latency. 5G provides a high data rate, improved quality of service (QoS), low-latency, high coverage, high reliability, and economically affordable services. 5G delivers services categorized into three categories: (1) Extreme mobile broadband (eMBB). It is a no standalone architecture that offers high-speed internet connectivity, greater bandwidth, moderate latency, UltraHD streaming videos, virtual reality and augmented reality (AR/VR) media, and many more. (2) Massive machine type communication (eMTC), 3GPP releases it in its 13th specification. It provides long-range and broadband machine-type communication at a very cost-effective price with less power consumption. eMTC brings a high data rate service, low power, extended coverage via less device complexity through mobile carriers for IoT applications. (3) ultra-reliable low latency communication (URLLC) offers low-latency and ultra-high reliability, rich quality of service (QoS), which is not possible with traditional mobile network architecture. URLLC is designed for on-demand real-time

interaction such as remote surgery, vehicle to vehicle (V2V) communication, industry 4.0, smart grids, intelligent transport system, etc.

2.0 LITERATURE REVIEW

Optimization Techniques for 5G Optimization techniques may be applied to capture NP-Complete or NP-Hard problems in 5G technology. This section briefly describes various research works suggested for 5G technology based on optimization techniques. In **[1],** Massive MIMO technology is used in 5G mobile network to make it more flexible and scalable. The MIMO implementation in 5G needs a significant number of radio frequencies is required in the RF circuit that increases the cost and energy consumption of the 5G network [2]. This paper provides a solution that increases the cost efficiency and energy efficiency with many radio frequency chains for a 5G wireless communication network. They give an optimized energy efficient technique for MIMO antenna and mm Wave technologies based 5G mobile communication network **[3].** The proposed Energy Efficient Hybrid Precoding (EEHP) algorithm to increase the energy efficiency for the 5G wireless network. This algorithm minimizes the cost of an RF circuit with a large number of RF chains. In **[4],** authors have discussed the growing demand for energy efficiency in the next-generation networks. In the last decade, they have figured out the things in wireless transmissions, which proved a change towards pursuing green communication for the next generation system **[5].** The importance of adopting the correct EE metric was also reviewed. Further, they worked through the different approaches that can be applied in the future for increasing the network's energy and posed a summary of the work that was completed previously to enhance the energy productivity of the network using these capabilities. A system design for EE development using relay selection was also characterized, along with an observation of distinct algorithms applied for EE in relay-based ecosystems. In **[6],** authors presented how AI-based approach is used to the setup of Self Organizing Network (SON) functionalities for radio access network (RAN) design and optimization **[7].** They used a machine learning approach to predict the results for 5G SON functionalities. Firstly, the input was taken from various sources; then, prediction and clustering-based machine learning models were applied to produce the results. Multiple AI-based devices were used to extract the knowledge analysis to execute SON functionalities smoothly **[8].** Based on results, they tested how self-optimization, self-testing, and self-designing are done for SON. The author also describes how the proposed mechanism classifies in different orders. In **[9],** investigators examined the working of OFDM in various channel environments. They also figured out the changes in frame duration of the 5G TDD frame design. Subcarrier spacing is beneficial to obtain a small frame length with control overhead **[10].** They provided various techniques to reduce the growing guard period (GP) and cyclic prefix (CP) like complete utilization of multiple subcarriers spacing, management and data parts of frame at receiver end, various uses of timing advance (TA) or total control of flexible CP size.

Limitations of Existing Surveys: The existing survey focused on architecture, key concepts, and implementation challenges and issues. The numerous current surveys focused on various 5G technologies with different parameters, and the authors did not cover all the technologies of the 5G network in detail with challenges and recent advancements. Few authors worked on MIMO (Non-Orthogonal Multiple Access) NOMA, MEC, small cell technologies. In contrast, some others worked on beamforming, Millimeter-wave (mmWave). But the existing survey did not cover all the technologies of the 5G network from a research and advancement perspective. No detailed survey is available in the market covering all the 5G network technologies and currently published research trade-offs. So, our main aim is to give a detailed study of all the technologies working on the 5G network. In contrast, this survey covers the state-of-the-art techniques as well as corresponding recent novel

developments by researchers. Various recent significant papers are discussed with the key technologies accelerating the development and production of 5G products

3.0 5G Coverage Enhancement Techniques:

In this survey, small cells, carrier aggregation, device to device and NOMA, MIMO and 5G optimization techniques are proposed as the 5G network coverage enhancements techniques, which is shown in Figure The existing works of each technique are discussed and its future challenges are explored in this section

Figure 1: 5G coverage enhancement techniques

5G Massive MIMO Multiple-input-multiple-out (MIMO) is a very important technology for wireless systems. It is used for sending and receiving multiple signals simultaneously over the same radio channel. MIMO plays a very big role in WI-FI, 3G, 4G, and 4G LTE-A networks. MIMO is mainly used to achieve high spectral efficiency and energy efficiency but it was not up to the mark MIMO provides low throughput and very low reliable connectivity. To resolve this, lots of MIMO technology like single user MIMO (SU-MIMO), multiuser MIMO (MU-MIMO) and network MIMO were used. However, these new MIMO also did not still fulfill the demand of end users. Massive MIMO is an advancement of MIMO technology used in the 5G network in which hundreds and thousands of antennas are attached with base stations to increase throughput and spectral efficiency. Multiple transmit and receive antennas are used in massive MIMO to increase the transmission rate and spectral efficiency. When multiple UEs generate downlink traffic simultaneously, massive MIMO gains higher capacity. Massive MIMO uses extra antennas to move energy into smaller regions of space to increase spectral efficiency and throughput. In traditional systems data collection from smart sensors is a complex task as it increases latency, reduced data rate and reduced reliability.

Emerging 5G Paradigms and Its Features 5G provides very high speed, low latency, and highly saleable connectivity between multiple devices and IoT worldwide. 5G will provide a very flexible model to develop a modern generation of applications and industry goals There are many services offered by 5G network architecture are stated below:

Massive machine to machine communications: 5G offers novel, massive machine to-machine communications also known as the IoT that provide connectivity between lots of machines without any involvement of humans. This service enhances the applications of 5G and provides connectivity between agriculture, construction, and industries.

Ultra-reliable low latency communications (URLLC): This service offers real-time management of machines, high-speed vehicle-to-vehicle connectivity, industrial connectivity and security principles, and highly secure transport system, and multiple autonomous actions. Low latency communications also clear up a different area where remote medical care, procedures, and operation are all achievable

Enhanced mobile broadband: Enhance mobile broadband is an important use case of 5G system, which uses massive MIMO antenna, mm Wave, beamforming techniques to offer very high-speed connectivity across a wide range of areas

For communities: 5G provides a very flexible internet connection between lots of machines to make smart homes, smart schools, smart laboratories, safer and smart automobiles, and good health care centers for businesses and industry: As 5G works on higher spectrum ranges from 24 to 100 GHz. This higher frequency range provides secure low latency communication and high-speed wireless connectivity between IoT devices and industry 4.0, which opens a market for end-users to enhance their business models

4.0 Machine Learning Techniques for 5G

Various machine learning (ML) techniques were applied in 5G networks and mobile communication. It provides a solution to multiple complex problems, which requires a lot of hand-tuning. ML techniques can be broadly classified as supervised, unsupervised, and reinforcement learning. Let's discuss each learning technique separately and where it impacts the 5G network. Supervised Learning, where user works with labeled data; some 5G network problems can be further categorized as classification and regression problems. Some regression problems such as scheduling nodes in 5G and energy availability can be predicted using Linear Regression (LR) algorithm. To accurately predict the bandwidth and frequency allocation Statistical Logistic Regression (SLR) is applied. Some supervised classifiers are applied to predict the network demand and allocate network resources based on the connectivity performance; it signifies the topology setup and bit rates. Support Vector Machine (SVM) and NN-based approximation algorithms are used for channel learning based on observable channel state information In unsupervised Learning, where the user works with unlabeled data, various clustering techniques are applied to enhance network performance and connectivity without interruptions. K-means clustering reduces the data travel by storing data centers content into clusters. It optimizes the handover estimation based on mobility pattern and selection of relay nodes in the V2V network. Hierarchical clustering reduces network failure by detecting the intrusion in the mobile wireless network; unsupervised soft clustering helps in reducing latency by clustering fog nodes. The nonparametric Bayesian unsupervised learning technique reduces traffic in the network by actively serving the user's requests and demands. Other unsupervised learning techniques such as Adversarial Auto Encoders (AAE) and Affinity Propagation Clustering techniques detect irregular behavior in the wireless spectrum and manage resources for ultradense small cells, respectively.

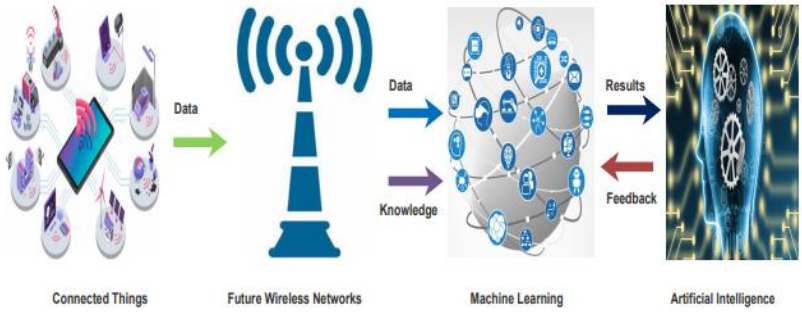

Figure 2: Pictorial representation of machine learning (ML) in 5G.

Table 1: Summary of 5G Technology Based on Above-Stated Challenges

Reference	Study	Discerption
Kaur, J.; Khan [11]	Machine Learning in Beyond 5G/6G Networks—State-of-the-Art and Future Trends	In this paper, we present a brief summary of ML methods, as well as an up-to-date review of ML approaches in 6G wireless communication systems. These methods include supervised, unsupervised and reinforcement techniques
Alawe, I.; Ksentini [12]	Improving Traffic Forecasting For 5g Core Network Scalability	a Novel mechanism to scale 5G core network resources by anticipating traffic load changes through forecasting via Machine Learning (ML) techniques.
Suomalainen, J [13]	Enhancement of Signal to Interference plus Noise Ratio Prediction (SINR) in 5G Networks using a Machine Learning Approach	The proposed method is based on supervised learning using logistic regression. Batch Gradient Descent has been applied as an optimization algorithm for better results. The application of this algorithm helped to obtain minimum loss and great accuracy.
Juhola Bashir, A.K.; Arul [14]	Machine Learning for Physical Layer in 5G and beyond Wireless Networks: A Survey	Review security and privacy concerns in 5G and standard bodies' actionable recommendations for policy makers. Finally, we also discuss emerging challenges and future directions.
Balevi, E.; Gitlin [15]	a comprehensive overview framework on the convergence of Blockchain with AI-enabled 5G networks named Block5GIntell.	To mitigate these dilemmas, Blockchain must be integrated. Blockchain, as a decentralized methodology provides a secure sharing of information and resources among various nodes of 5G environments

Discussions:

- To essential network elements of 6G system architecture and discuss defined issues that current generations of mobile networks are facing; the mobile industry should transition away from traditional strategies and toward some new ones, such as operation in shared spectrum bands, inter-operator spectrum sharing, indoor small cell networks, a large number of local network operators, and on-demand network slice leasing.
- To meet the requirements of the stage where the research results on ML are to be addressed, as well as the methodology used by 5G and 6G for the Internet of Things and energy transmissions. We overview six major categories, including network resource management, security, augmented reality, network scaling, resource allocation, and the smart grid.

- Towards the end, we discuss multiple challenges and research directions applications, issues, research questions, motivation, recommendation criteria, and open challenges of ML usage in incorporating energy and IoT in 5G and 6G.

Conclusion:

This article covers a detailed survey on the 5G mobile network and its features. These features make 5G more reliable, scalable, efficient at affordable rates. As discussed in the above sections, numerous technical challenges originate while implementing those features or providing services over a 5G mobile network. So, for future research directions, the research community can overcome these challenges while implementing these technologies (MIMO, NOMA, small cell, mm Wave, beam-forming, MEC) over a 5G network. 5G communication will bring new improvements over the existing systems. Still, the current solutions cannot fulfill the autonomous system and future intelligence engineering requirements after a decade. There is no matter of discussion that 5G will provide better QoS and new features than 4G. But there is always room for improvement as the considerable growth of centralized data and autonomous industry 5G wireless networks will not be capable of fulfilling their demands in the future.

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