International Journal of Computer Networks and Applications (IJCNA)
DOI: 10.22247/ijcna/2022/214508 Volume 9, Issue 4, July – August (2022)

REVIEW ARTICLE

5G Network: Techniques to Increase Quality of Service and Quality of Experience

Nayeem Ahmad Khan
Faculty of Computer Science and Information Technology, AlBaha University, AlBaha, Saudi Arabia
nayeem@bu.edu.sa

Received: 29 June 2022 / Revised: 25 July 2022 / Accepted: 30 July 2022 / Published: 30 August 2022

Abstract – The rapid growth of interconnected networks and devices inevitably causes the rise of traffic demand and thus pushes the technologies like long-term evolution-Advanced (LTE-A) and mobile multihop relay WiMAX networks technology to move into the fifth-generation (5G). The 5G network was envisioned to be built to encounter the fundamental challenges of quality of services in existing networks, such as allowing higher data rates, enhanced end-user quality of experience, reduced end-to-end latency, lower energy consumption, and higher traffic capacity. In order to satisfy and achieve the vision of the 5G network, extensive debates are in progress about the numerous techniques to be adapted. The objective of this study is to analyze various techniques for 5G networks to achieve the high enhance Quality of Service (QoS) and Quality of Experience (QoE) for users. Moreover, this paper also discussed several combinations of techniques for the upcoming 5G network, such as mmWave with Massive MIMO, D2D with SDN, D2D with mmWave, and D2D with Machine-to-machine communication and NFV and SDN hybrid. This study will be a significant endeavor in choosing possible techniques for 5G networks and further investigating various combinations of such techniques for future works. To make suitable techniques for the emerging 5G network, guidelines and challenges are highlighted to modify the existing techniques.

Index Terms – 5G, Quality of Experience, Quality of Service, Multi-Tier Architecture, Software-Defined Networking, Heterogeneous Networks.

1. INTRODUCTION

Existing broadband technologies, such as long-term evolution-Advanced (LTE-A) and mobile multihop relay and the technology behind WiMAX networks, are maturing and have been put into use [1-9]. Nevertheless, existing 4G broadband technologies are confronting basic challenges with respect to data rates, efficiency, performance, low latency, high energy consumption, and high cost. This is because of the dramatic increase in the volume of data traffic that is being produced by mobile devices in conjunction with the appearance of a variety of high-speed multi-media applications. It is anticipated that evolving cellular networks of the fifth generation, or 5G, would be able to overcome these issues. Researchers and engineers from all over the globe are focusing a lot of attention on the future cellular networks such as 5G. It is projected that 5G cellular technology will achieve a mobile data volume that is one thousand times higher per unit area, a number of connecting devices that is ten to one hundred times higher, a user data rate that is five times lower, a battery life that is ten times longer, and a reduction in latency that is five times lower. The future of 5G technologies will include high performance, a better level of connectivity, and the coverage of cellular networks [10-11]. To achieve this, a new method of technologies will be investigated to replace the previous generation that has low performance and lack of speed of connectivity. Current interest in 5G is motivated by the rapid consumption of wireless data in the network and the emergence of high demand from internet users. According to the UMTS Forum [12] report, it states that the total worldwide mobile traffic will reach more than 607 Exabytes (EB) in 2025, representing a 400 times increase compared 127 EB in 2010 based on the resulting capacity demand prediction. For 5G, the main idea that is being highlighted is technologies to upgrade the network's requirements that will be significantly faster and much smarter and support high user demand [13, 14].

The researchers need the right technologies to unlock the potential of 5G that enable faster data access with high bandwidth and support capacity of the user [15]. Thus, the technology in 5G is a crucially technical challenge for the researchers. Even though it is too soon to provide a precise definition of 5G, recent research trends have shown that the aforementioned lofty goals may be attainable by refining and advancing the technologies used in existing and potential cellular networks. This can be accomplished, potentially, through the implementation of 5G.

Apart from the advantages offered by 5G such faster speeds, lower latency, and better reliability. The disadvantages of 5G are also significant. For example, 5G is not compatible with older devices and infrastructure, which could lead to disruption in the supply of 4G services after 5G has been rolled out. This may mean that people have to buy new devices or upgrade their internet infrastructure if they want access to 5G services.

REVIEW ARTICLE

Several research papers discussed the evolution of 5G technologies, for instance, massive multiple-input multiple-output (massive-MIMO), millimeter-wave (mm-wave) communications technologies, and Device-to-device (D2D) communications, heterogeneous and multi-tier network as well as cooperative communications, network coding and full-duplex (FD). They are proposing more independence for the massive MIMO due to a single base station planted with hundreds of antennas.

In addition, millimeter-wave communication has offered the use of more spectrum in telecommunication and device–to–device (D2D) communication that allows for merging telecommunication with the cellular network. Cooperative communications, network coding, and full-duplex (FD) were the key to physical layer solution to spectrum crunch that gives more bandwidth resources to the cellular network communication [16-26]. However, there is a great need to identify and discuss almost all technologies under one roof with their strength and weaknesses. This paper will explain the obstacles and potential, as well as a perspective on the acceptability of such technologies. The strengths and limitations of the chosen research findings from diverse articles are evaluated after a discussion of the results. The conclusions of this research will provide 5G technological advantages for all parties concerned, particularly operators and users.

The remaining paper is organized as: Section 2 presents the conceptual background of 5G technology and development. In section 3 the taxonomy of 5G technology is presented. In section 4 the analysis of 5G techniques for improving the quality of service is discussed. In section 5 the conclusion, future trends and recommendation are detailed.

2. CONCEPTUAL BACKGROUND OF 5G

2.1. 5th Generation Mobile Networks (5G)

5G is a new standard for wireless broadband that improves the service's data rate, lowers the connection's latency by order of magnitude from the previous standard, and is energy-efficient and cost-effective [27]. Some of the usages of 5G would be for supporting missions such as critical machine communication and the massive machine type of traffic.

The major challenges expected from 5G technology implementation include high data rates, heterogeneous network architecture, ultra-low latency, and flexible spectrum use, a larger number of connected devices, more advanced devices than 3G and 4G, and long battery life for large machine communication [28]. As opportunities for 5G infrastructure will be realized, the challenges [29] for the characteristics of 5G infrastructure that need to be improved from the current infrastructure would be latency, reliability, capacity, spectrum, and network agility.

2.2. Development of 5G

The 5G network is being developed to allow for faster data speeds, improve end-user quality of experience (QoE), decrease end-to-end latency, and reduce overall energy consumption [23]. It should also include device-centric designs, mmWave, massive MIMO, intelligent devices, and native support for machine-to-machine communications, including its features and capabilities [30]. Contrasting to the previous generations of cellular communication, it has to be extremely integrated for a seamless user experience which will tie the air medium for LTE and Wi-Fi [27]. Non-orthogonal multiple access (NOMA) is a technology with a better future, which can tackle certain challenges for 5G. Paralleled to orthogonal multiple access technologies, which are the orthodox method, NOMA can adjust more users via non-orthogonal allocation [31]. The 5G technology focuses on changing from a cell-centric network concept to a device-centric design. The QoE is a method that looks into the users' perspective of the overall system performance [32]. On the other hand, according to [33], some of the challenges faced is to empower element cutting of the systems, end-to-end, to make the particular physical system able to support a much more extensive scope of necessities with the capacity to make a committed network that business clients can control, for example, through self-administration business portals. The arrangement's central component is the capacity to adjust the infrastructure (counting the air interface and supporting networks in the frontal, backhaul, accumulation, and center) to diverse "vertical" application prerequisites. The proposed solution is a codified packet core architecture that is represented in 3 layers: access cloud, regionally distributed cloud, and centralized national cloud [28].

2.3. Device-to-Device (D2D) Communications

According to [34], D2D communication can circumvent the BS and provide service to any adjacent device. In addition, D2D communication enables electronic gadgets to talk with one another directly and independently of any communication infrastructure. D2D communication is on of the fundamental technologies for achieving 5G goals. It performs better than traditional cellular networks [35, 36]. In D2D concept design, the idea is to enable direct communication between devices in proximity [37]. This implementation aims to improve the communication system between devices by incorporating a direct D2D general communication concept [38]. For the implementation of this system concept, there are several objectives that need to be highlighted which include increasing the network coverage for the devices, managing the offloading backhaul, providing a substitute solution, improving the spectrum usage, and lastly providing new services and experiences for a new means of communication [35]. The local network traffic management also obtains the advantage from this

REVIEW ARTICLE

implementation. It will offer the short-distance communication links and decrease the load of traffic and backhaul caused by congested data traffic through the network considerably [39]. Moreover, the traffic management at the central network node will reduce significantly and efficiently [40].

2.4. Millimeter Wave (mmWave) Communications

mmWave based communication is considered as one of the technologies that have a lot of potential for use in 5G cellular networks [35]. A mmWave based communication system has a broad bandwidth, which may be converted into much greater data rates and overwhelming capacity. This is because mmWave systems have many gigahertz. It has been shown that the mmWave band can transmit several gigabits per second in both indoor (through WPA networks, for example) and outdoor (via wireless mesh networks, for example) systems. D2D communications allow for the link to be created between two wireless devices either directly or indirectly via hopping, and the BS enables them in conventional cellular networks. Recent research has focused on local D2D communications as an underlay for LTE-Advanced (LTE-A) 4G cellular networks. This research was prompted by the rising popularity of high-rate local services, such as the distribution of big files among wireless devices located in the same cell. [41].

The mmWave communication has many propagation features that will increase the difficulty in achieving seamless coverage and reduce the reliability of the communications. These features are propagation loss is high, mmWave bands' wavelengths are short, and mmWave signals are hard to penetrate through solid materials [35]. However, those propagation features can bring many advantages in enabling D2D communication over the mmWave network with the use of directional antennas. The mmWave 5G cellular network architecture consists of directional links, wired links, wireless links, 4G BSs, mmWave BSs, and mobile devices. It is the hybrid of 4G cellular networks and mmWave. There is a directional link between the mobile device and mmWave BS to reduce the interference and return high gain links between them [42]. Moreover, the directional antennas replace the fiber links and serve as a wireless backbone for 5G cellular networks to provide high data rate wireless connections between the BS. In short, enabling D2D communications over the mmWave networks can increase the capacity of the network and improve spectrum efficiency [41].

2.5. Cognitive Radio (CR)

Intelligent wireless communication may be achieved via the use of cognitive radio [43]. Users, even though they only have localized information of the circumstances of the wireless network, are expected to consider the operator's rules and preferences when making the ultimate choice [44]. Integration choices are accessible inside the Radio Access Network (RAN), which has an all-encompassing understanding of the radio connection information. It is possible that cross-RAT information exchange between base stations and access points for WiFi will be accessible with the assistance of user equipment (UE), or that an appropriate interface needs to be established between WLAN and the infrastructure of the 3G partnership project (3GPP) [45]. Because of this, it is now possible to manage radio resources in a more dynamic manner, which results in enhanced system and UE performance, reduced WiFi latency, and the absence of severe session interruptions and packet loss. Offload performance is another area that might benefit from some straightforward support information from the radio network [46].

2.6. Software-Defined Network (SDN)

SDN is used in mobile networks to meet communication application challenges while controlling non-related traffic in some environments, such as mobile devices [47]. SDN assigns traffic to network components in the network's distinct data plane [48]. The intelligent network controller enables the controller to generate flow routing rules with the finest granularity for heterogeneous network devices. [49]. SDN can create a QoS, which refers to some kind of methods used to make sure the bandwidth is shared and divided equally among users. Hence, the creation, testing, and deployment of novel network applications can be done in a short period. The SDN application can operate smoothly with the Backhaul concept, which contains:

1) Mobile Backhaul Scaling: It is to optimize and manage the supply of connection for backhaul to Access App from BS [47].

2) Mobility Management App: This tool is to select the device's path.

3) Access App: This App is to do an assignment of IP addresses to the mobile device. The firewall is used in the final admission decision [50]. In addition, The Realm Gateway is used to do traffic admit from legacy Internet [51].

4) Secure Service Delivery App: It is the final SDN App on the communication path. It is to secure the service delivery process.

2.7. Software-Defined Radio (SDR)

The idea of integrating SDR and SDN was proposed as an advanced technology used in developing a 5G network [48]. SDN is commonly known to be an intelligent architecture because it is directly programmable [52]. The control and data plane in SDN architecture are decoupled [53, 54]. SDR is a group of hardware and software technologies. It uses modifiable dynamic software or firmware operating on programmable processing technologies to operate the radio operating function in SDR. The cross-layer controller acts as a vital element in integrating both SDN and SDR layers. It is the decision-maker between the two layers, and because both SDN and SDR are from different layers, the cross-layer controller is needed to allow communication between these layers. It acts as a bridge between the two layers to enable interaction and permit one layer to access the data in another layer to exchange information. Cross-layer signaling is part of the cross-layer controller process. Although it is not defined in the protocol architecture, these signaling methods should consume as scarce resources to reduce overhead.

2.8. Ultra-Dense Network

Ultra-dense deployment is another promising technology for the 5G cellular networks [35]. Ultra-dense deployment is taking the concept of a small cell to develop smaller and more active cells per unit area and Hz in order to increase the network capacity over the cellular networks. The ultra-dense deployment works well with the D2D communications. The small cells are concentrated on offloading the hot-spot traffic, while the D2D communications are concentrated on offloading the proximity services. Although it is clear that UDN is able to self-organize, self-optimize, and save cost [56], at the same time, high-frequent measurement, intolerable handover failure (HOF), and high power consumption have introduced new challenges. Hence, mobility enhancements in the UDN scenario are considered to improve its performance. Consequently, the control plane and user plane split concept is more flexible and allows better service control schemes.

3. TAXONOMY OF 5G TECHNOLOGIES

This section discusses the taxonomy of 5G technologies, as shown in Figure 1. Each paper being discussed is summarized in terms of the problem statement, a technique used to solve the problem, the strength of the technique, the weakness of the technique, and suggestions and recommendations. Combinations of various techniques were also discussed in the paper. As stated in [58], a new network is needed as the current network has demonstrated severe weaknesses in this aspect. With respect to the network infrastructure, the 5G public-private partnership (5G PPP) set up in late 2013 with its Technical Annex of the agreement provides a good overview [59]. The 3GPP [60], which started as an ETSI project, has become the global arena for developing the new standards of mobile communication with participation from all-important regional organizations. The 5G network is being developed to allow for faster data speeds, improve the end-user quality-of-experience (QoE), decrease end-to-end latency, and lower energy usage [32] [61]. Device-centric architectures, mmWave, massive multiple input/output (MIMO), intelligent devices, and native support for machine-to-machine communications should be included in it [39]. Comparing the earlier cellular generations, it has to be highly integrative for a seamless user experience which will tie the air medium for LTE and WiFi [36]. 5G wireless networks have three main requirements, which are [62]: supporting huge capacity and connectivity; carrying a diverse set of services, applications, and users in which the requirements diverge extremely; and using the available spectrum in a flexible and efficient manner, regardless of if it is contiguous or not in order to support various network deployment scenarios.

3.1. Intelligence Incorporation

According to [63], Intelligence should assist in decision-related to 1) cells' configuration, traffic distribution, and resource assignment; 2) handling the situation by activating the proper type of functional or software components and volume required; 3) functional components allocation to the physical elements, and 4) the best interconnections between physical elements and between physical elements and transceivers. In terms of heterogeneous network elements, the introduction of intelligence is expected to assist in decisions associated with the: 1) handling of a situation by involved transceivers; 2) allocation of operated spectrums by transceivers; 3) allowed transmission powers per transceiver; and 4) traffic allocation to the resulting cells which are involved in the situation handling.

3.2. Millimeter Wave (mmWave)

According to the research done by [64] and a team from Samsung, mmWave is one of the alternatives to increase bandwidth because of the flexibility of the frequencies. It enables the redirection of its narrow beam towards a particular direction through an array of various components. Besides that, adaptive array processing would also be able to redirect the direction of the spatial beam and increase the data rates. Radio frequency (RF) capacity estimate for millimeter-wave (mmWave)-based 5G cellular networks was suggested in research by [65] that used field level network modeling. Radio capacity is an important consideration in cellular networks because of its direct influence on the maximum data rates that may be achieved. By using an antenna with a narrow beamwidth for transmission, it is possible to increase the capacity of the microwave. The antenna's beamwidth is reduced from 65 degrees to 30 degrees to increase the capacity of mmWave cellular networks by a factor of three at a distance of 220 meters from the base station (BS). They perform network simulation, which mobile radio operators typically use for cellular planning to determine the level.

The mmWave bands have the potential to become frequency bands for fifth-generation mobile communication systems. These bands are located between 28 and 38 gigahertz (GHz) [65]. In contrast to the 60 GHz and 380 GHz, mmWave bands, the 28 GHz and 38 GHz mmWave bands do not

REVIEW ARTICLE

experience a large contribution to extra route loss from air absorption, making them appropriate for use in outdoor mobile communications. [66-68]. The authors of the study [64] introduced a new design of mmWave cellular 5G systems and conducted various measurements. The team tests the main factor for designing 5G cellular in an urban area. They found that the small-scale fading shows mild changes when receiving impulse response and power from 400 Mbps signals and highly directional antennas. These measurements show that frequencies of 28 GHz and 38 GHz can be used in 5G communication. The instabilities of path and penetration of mmWave bands are the vital problem for this project as the path and penetration loss cause the failure of signal propagation. Besides, the buildings around urban areas can cause the spreading of multipath delay.

Similar to researchers in [67] also conducted several measurements for future cellular systems. They carried out the measurements by considering possible communication scenarios of microcellular and found that path loss is still the problem of the model. They suggested mobile devices should be installed with higher gains antennas in the future to deal with the path loss problem. They added that the leap of frequency from low microwave to the regime of mmWave causes the loss of path. Researchers believed that wide bandwidth would be straightforward and effective method to provide 5G cellular services in the future. They had successfully developed a prototype of mmWave bands for 5G communication.

3.2.1. Massive MIMO-MM Wave Integration

A study by [70] shows that transmission technology uses a dense antenna array. The high-frequency band and an appropriate amount of antennas maximize the functioning of massive MIMO with low complexity. Controlling radiation to unsought directions can reduce co-channel interference. A narrow beam in massive MIMO can lower interference to neighboring cells and boost the number of multiplexing. Thus, massive MIMO effectively increases SNR (Signal-to-Noise Ratio) and reduces co-channel interference. Since a higher frequency band is desirable, a small cell application is suitable for massive MIMO.

3.3. Heterogeneous Network (HetNet)

By 2025, the number of LTE users is predicted to surpass 10.10 billion, and this has opened the industry's eyes to a new reality [71]: the mobile sector must provide greater coverage and performance at a lower cost [72]. Utilizing a mix of innovative network architecture and new terminal capabilities, as well as monetizing the user experience with new services, apps, and possibilities, the strategy is developed.

According to researchers [41], a single cellular connection and a single local D2D connection must share resources. Resource sharing for concurrent D2D communication over mmWave 5G cellular networks may significantly increase network capacity while preserving network connection. Previous research on resource sharing in D2D communications has considered the potential of having just one local D2D connection and one device-to-base-station (D2B) link to decrease interference complexity [73]. In order to maximise the use of available bandwidth in WLAN and WPAN networks, concurrent broadcasts may be permitted [74, 75]. It is necessary to consider the likelihood of interference from omnidirectional antennas while sharing resources for D2D communications. mmWave 5G networks may enable more D2D connections inside each cell by leveraging high propagation loss and directional antennas. This will significantly increase network capacity and enhance spectrum use efficiency. To enable simultaneous D2D discussions over mmWave 5G cellular networks, a unique resource-sharing approach that takes directional interference into account is necessary. According to the debate in [41], resource sharing is the key barrier that must be solved to allow concurrent D2D communications in mmWave 5G cellular networks. As in the distributed model, the mechanism for sharing resources may be decentralised and controlled by the wireless devices themselves, or it may be centralised and managed by the base station. Due to the centralised nature of mmWave 5G cellular networks, the BS is in charge of setting the resource allocation system. This approach takes into consideration the likelihood of D2B and local D2D connections interfering with one another.

3.3.1. Multiple-Input Multiple-Output (MIMO)

3.3.1.1. Massive MIMO

According to [76], Massive MIMO is the main technique in achieving higher capacity in a cellular network and is beneficial for future 5G technology. Massive MIMO is wireless research to do massive on required capacity [77, 78]. It is based on the Multi-user MIMO due to the increase in multiplexing gains [79], and it is related to the 3GPP LTE-A standard. The very large MIMO (VLM) arrays help reach the higher capacity deployed at the BS [80]. This technique helps increase the array size of transmission to implicate various aspects such as inter symbol, coverage, and power budget optimization’s transmission [81, 82]. The Massive MIMO creates a higher capacity in the form of radio heads (distributed) or antenna element’s deployment (higher frequency bands) [83].

3.3.1.2. Very Large MIMO

According to [84], MIMO is a technology that can transmit different signals on the same frequency simultaneously from multiple antennas. In MIMO, the high transmission rate is possible by increasing the number of spatially multiplexed signals according to the number of transmitter antennas. Besides that, this technology is promising in enabling low-

REVIEW ARTICLE

cost services to provide users with a large content volume. However, this requires receivers capable of high-performance signal detection.

3.3.2. Cloud RAN

HetNet architecture had been chosen since it increases the scalability of the network [85], cloud RAN promotes centralization by making use of low latency and high rate network [86], multi-RAT enables overlapping coverage, which appears as a single RAT and can apply for high latency network D2D connection using peer to peer (P2P) connection. Moreover, in order to ensure this implementation's success, several issues need to be solved to improve network efficiency. The issues are interference mitigation [80], an adaptation of Massive MIMO for broader capacity [76], simultaneous connection through multiplexing [87], context-awareness based on network, and devices and spectrum that existed in the 5G technology.

3.3.3. Device-to-Device (D2D) Communication

D2D communication is a kind of technology that allows the devices to communicate with each other directly and does not rely on any communication infrastructure [35]. These days, most researchers are looking forward to the 5G cellular networks, even though the deployment of the 4G cellular networks is still ongoing [88]. This shows the needs and demands of the 5G cellular networks. Both D2D communications and cellular terminals concentrate on the physical layer (PHY) performance metric optimization. The critical performance measured in a 5G cellular network includes reliability and latency. The reliability and latency are both measured by using the delay and packet dropping rate under a bursty traffic model [55]. Bursty data traffic is inconsistent traffic levels, which may consume more power to transmit and indirectly reduce the battery life and increase the interference to the cellular network [36, 89]. Furthermore, D2D communications have a higher degree of freedom because communication between the D2D terminals can be carried out directly, radio resources can be reused, and signaling can be swapped directly [35].

3.3.3.1. Service Discovery Protocol

According to 25], D2D communication bypasses the BS to provide service to local devices. There are several benefits to using this mode of communication. This communication requires a high data rate, unloading of traffic, range extension, proximity service, and social networking. There have been two kinds of service discovery approaches studied. They are reactive (pull) and proactive (push) discovery in a D2D network with infrastructure coordination. As 5G mobile communication expands, D2D communication also gets considerable focus. Since 3GPP presents D2D communication as a solution for a direct access network, it allows sophisticated communication technologies with high transmission data rates, improved efficiency, and network application implementations [90]. The D2D structure necessitates BS cooperation. The purpose of BS is to provide direct communication and assistance amongst users. If no support is obtained from the infrastructure, the user equipment will look for and broadcast to its immediate neighbour. Several strategies have been presented in [91] for maximizing service. In addition, researchers in [92,93] have previously categorized a number of techniques to ensure the service's excellent condition in order to optimise its performance.

In D2D concept design, the idea is to enable direct communication between devices in proximity. This implementation aims to improve the communication system between devices by incorporating a direct D2D general communication concept. For the implementation of this system concept, the are several objectives that need to be highlighted, including increasing the network coverage for the devices (which affects the availability and reliability), managing the offloading backhaul (which affects the cost efficiency), providing a substitute solution (which affects reliability), improving the spectrum usage (which affects spectrum efficiency), the user data rate and capacity per area (which affects capacity density) and lastly providing new services and experiences for a new mean of communications. The local network traffic management also has the advantage of this implementation as it will offer short-distance communication links and considerably decrease the load of traffic and backhaul caused by congested data traffic through the network. Moreover, the traffic management at the central network node will reduce significantly and efficiently. There are several challenges that need to be considered in the D2D system-relevant situations, for example, Device Discovery. The D2D device discovery, which is utilized to know the proximity between devices to create a direct D2D connection, is the main component of allowing the D2D communication. The problem with the detection of new devices within the area can be solved by applying this concept without disregarding the latency and resource efficiency between the Key Performance Indicators (KPIs).

3.3.3.2. D2D Communication in Near Proximity

Communication Mode Selection technical issue is the next technical issue regarding Communication Mode Selection [94]. The communication mode selection in direct D2D link controls the availability of the communication between devices in direct D2D mode or in traditional cellular mode. In direct mode, the device will have the benefit within their proximity and might reuse the cellular resources. In cellular mode, common or separate serving BS is a way of communication [95]. For example, Distributed CSI (Channel State Information) Based Selection Mode is D2D specific, Location-Based Mode Selection, which is based on users'

REVIEW ARTICLE

location information, and Combined Resource Allocation and Mode Selection in Multi-cell, which takes advantage of the different degrees of coordination between the cellular devices and different time scale mode switching based on path loss. The next issue is the Co-existence and Interference Management [96]. This technical concept utilizes resource allocation to handle interference problems [97]. The expanse between the users and from the users for approximating the path losses and the signal-to-interference ratio (SIR) is applied for location-based resource allocation to counterpart the issue. For centralized resource allocation, the distributed resource allocation is important because of the responsive scheduling for D2D in decentralized interference. Power control of distributed iterative is considered, exploiting the measurements implemented by D2D receivers and sending feedback to the respective transmitter to change the transmission power to handle the adjacent band interference.

3.3.3.3. D2D Communication Network

Next, the Mobility management is measured as the D2D communication system is still a new transmission mode. Therefore, optimized mobility management is proposed, which is crucial to the latest D2D handover standard and the older cellular handover criteria. Under these criteria, the number of BS should be in minimum number to deliver efficient usage for the end-users, which lowers the latency during the information exchange among BSs [98].

Thus, two mobility managements are proposed: controlling the D2D handover and cell selection during the mobility of D2D UEs. Based on METIS solutions, there are different forms of D2D relays. The first form is the D2D relay. It is a multiple-stream-based relay where multi-antenna BS and multi-antenna UE are communicated and aided by other multi-antenna UEs as relay nodes [99]. Another form is Relayed D2D, in which the relay station assists the device pairs consisting of two or more communication devices.

The spectrum management and sharing identify the best band or range of transmission for D2D operation that can give performance enhancement for the communication of the whole system [100]. A suitable spectrum can be identified by analyzing the pros and cons and the ways of spectrum sharing.

3.3.3.4. D2D Communication Pricing Technique

According to [101], pricing is the main challenge in implementing D2D practice the network operator must choose how to govern and charge for D2D services. The price models must be created so as to encourage devices to engage in this communication. By providing a secure environment for the sale and purchase of resources between devices, the operator may anticipate payment from the devices. Further discussion on pricing issues and proposed solutions for solving it based on game theory and auction theory are as follows.

3.3.3.4.1. DR-OC

Challenge: Providing sufficient incentives for relaying devices.

Proposed solutions: The quantity of data that customers transmit via their devices might earn them savings on their monthly fees from the service provider. The operators will gain from this approach since it will allow them to deliver service to devices that either do not have coverage or need greater data rates than those available in the macro-cell tier. \

3.3.3.4.2. DC-OC

Challenge: In order to entice users to utilize this service rather than Bluetooth or free Wi-Fi, there has to be an attractive price structure. The formulation of the pricing model is seen as a spectrum trading issue, and the goal of this problem is to maximize the profit for the seller while simultaneously maximizing the utility of spectrum consumption for the buyer. Various suggested remedies: The Auction theory offers a helpful framework of mathematical tools that may be used to create price models. The game theory is an appropriate tool for developing an efficient system for resource distribution in an environment with low disturbance. The sealed-bid-first-price is a suitable tempting pricing scheme for a monopoly market, while Bertrand Game is suitable for an oligopoly market where there exists more than one seller [102].

3.3.3.4.3. DR-DC

The operator cannot anticipate a profit since they have no control over this form of relaying. Since the devices in a closed access DR-DC are familiar with one another, they are able to negotiate a pricing scheme or simply communicate information with one another. In contrast, when open access is provided, users have the freedom to choose from a variety of price models, including market equilibrium, cooperative game, bargaining game, and double auction, among others.

3.3.3.5. Multi-RAT

According to [45], virtual RAN designs will perform an essential part in the development of 5G multi-RAT networks, To accommodate the rising demand for mobile traffic, significant gains in network capacity, as well as improvements in service quality, are required. Gains in interference management and avoidance and improvements in quality of service are brought to light while concentrating on the "timely throughput" [103]. The examination of the results also takes into consideration the findings that have been discussed in [46, 104].

3.3.4. Non-Orthogonal Multiple Access (NOMA)

Non-orthogonal multiple access (NOMA) [32, 105], is a technology that has a promising future and has the potential to solve some of the problems that 5G will face. Compared to

REVIEW ARTICLE

orthogonal multiple access technologies, which are examples of conventional approaches NOMA, can contain a larger amount of users via non-orthogonal allocation [32]. NOMA architecture is based on intra-cell multi-user multiplexing method that makes use of the power domain, as stated by researchers in [84, 106]. The power domain is something that was not completely exploited in the previous standards, including 2G, 3G, and 4G. The user demultiplexing process may be enabled by allocating the considerable power differential that exists between paired users on the transmitter side. On the other hand, the receiver uses a technique called sequential interference cancellation (SIC), which is an entirely new method of multiple access for Future Radio Access (FRA) [70, 107-111]. In NOMA, the superposition of many users with high channel gain differences in the power domain permits the conversion of the multiple users' channel gain differences into multiplexing gains.

3.3.5. Machine-Type Communication (MTC)

Machine-to-machine communication in its present state as well as its potential in the future in relation to 5G networks, was the subject of research conducted by [112]. The authors provide a straightforward mapping between the primary machine-type communication (MTC) service needs and the difficulties that are associated with those requirements. In addition, the path that the currently available cellular technologies will take to become fully MTC-capable in a 5G mobile system is outlined in a roadmap. The study further discusses about communication between two MTC devices as well as communication between an MTC device and a server [113]. They offered a conventional MTC architecture as the foundation for the existing design of an LTE network and various modifications that might be included in 5G mobile systems. It is made up of three distinct components, namely, a network domain, an MTC application domain, and an MTC device domain. MTC devices may link either directly or indirectly to base stations (e.g., eNodeBs) through MTC gateways (MTCGs). By using MTCGs, MTC devices may form capillary networks that can leverage other wired or wireless communication methods. [114] The MTCGs are in charge of data transmission between the cellular and capillary networks. The authors of [115] described a novel 3GPP-compliant architecture that absorbs MTC traffic via a custom-built NodeBS (HeNBs). It significantly reduces the congestion and overburden of both radio access networks and core networks. Support for MTC using upgraded LTE-A [116] is one of the increasing difficulties that cellular network operators must address in order to meet the requirements of 5G wireless networks in the future [117]. Using femtocells with restricted access, the architecture is able to manage ultra-dense MTC across LTE-A networks in an effective manner. The approach that has been provided makes it possible to effectively separate the traffic in a way that satisfies the standards of MTC while having no impact on the performance that mobile users experience. This strategy, which utilizes frequency-separated deployment, ensures that MTC devices will have both decreased complexity and lower costs.

3.3.5.1. Evolved Multimedia Broadcast Multicast Service (eMBMS)

According to [118], both LTE and LTE-A enable eMBMS and LTE broadcast for broadcast. . Using point-to-multipoint transmissions, eMBMS has enabled mobile network operators (MNOs) to partially meet the rising demand for mobile video data. Compared to other broadcast options, the implementation costs of eMBMS are much lower due to the fact that it uses the same frequency carrier as unicast services. Nonetheless, the eMBMS business model is hindered by two factors: the utilisation of dense networks in comparison to terrestrial broadcast networks and the decrease in system capacity for unicast services. According to [119], there were 360 LTE networks deployed commercially throughout the globe by the end of 2014, and this figure is expected to expand to 450 by the end of 2015. This widespread deployment of LTE provides eMBMS, also known as LTE broadcast mode, an edge over its rivals by allowing unicast and broadcast services to coexist with high capacity, bandwidth, and scalability.

3.3.5.2. Future of Broadcast TV (FOBTV)

FOBTV was established in 2012 [120] to determine a common working setting to ensure that the next generation of terrestrial broadcast systems would be able to avoid conflicting standards, overlapping, and the deployment of new services. However, the Advanced Television Systems Committee (ATSC) 3.0 is the most recent breakthrough in the development of future digital broadcast technologies [121]. This timeline depicts the progression of the ATSC 3.0 standard. It is clear from this that the development process includes the physical layer and the management layer, the protocol layer, the application layer, and the presentation layer [122].

ATSC [123] claimed that Qualcomm and Ericsson's ideas were to expand this standard so that fixed and mobile use case applications could be serviced utilizing DTT infrastructure. These enhancements were based on LTE Broadcast. In order to improve the effectiveness of eMBMS from the perspective of radio access, Qualcomm proposed a work item to the 3GPP [124] that uses longer cyclic prefixes (CP) for a large single frequency network (SFN) delay spread environment. Additionally, it adopts MBMS over a single frequency network (MBSFN) dedicated carrier option in order to finish the upper layer support.

However, the 3GPP did not accept Qualcomm's proposal. In addition to this, the DVB forum and 3GPP worked together, and in March 2011, they held a combined session at which both organizations presented their findings. After a period of

REVIEW ARTICLE

two months, a proposal was made to the 3GPP [125] to create a research item that could be utilized in 3GPP mobile communications networks as well as DVB-based broadcasting networks, which constitute the notion of a common broadcasting standard (CBS). On the other hand, this proposal was not accepted since MNOs did not show their support for it. The proposed work by both Qualcomm and CBS will likely go in the same direction, which is completing the definition of eMBMS dedicated carriers and defining longer CPs to address deployment scenarios that use HPHT broadcasting networks. This is because completing the definition of eMBMS dedicated carriers is necessary in order for deployment scenarios to be addressed.

3.3.5.3. Light EPC Integration

Lightweight event-driven process chain (LightEPC), as stated in [20], manages the on-demand generation of cloud-based lightweight mobile core networks devoted to MTC. LightEPC is also used to simplify the network installation method for MTC devices. This simplification is accomplished by the creation of only one NFV MTC function that gathers all of the typical operations together. LightEPC is not only able to build and scale instances of NFV MTC functions on demand, but it also causes an increase in traffic that is created by MTC devices. This is because LightEPC is able to create and scale instances of NFV MTC functions. The findings acquired from the early investigation and the analytical results reveal that LightEPC has the capability to improve and scale congestion in mobile networks with significant numbers of MTC devices.

3.3.6. NFV

According to [126], NFV uses IT virtualization technology to provide a new way of building an end-to-end network infrastructure that SDN can run on rather is a term umbrella [127]. It also allows the association of many HetNet devices onto industry-standard high-volume servers, storage, and switches [128]. A network device’s network function is applied in a software package run on a virtual machine.

This makes the introduction or testing of a new network easier because a software package that is run by the server can simply be upgraded, or new software can be installed. With NFV technology, carriers are able to reduce the power consumption and equipment cost to build and operate a network. New services can also be created, tested, and deployed to market in a rapid manner.

3.3.6.1. NFV-SDN Hybrid

Authors in the study [129] some innovative network infrastructure could be used in 5G, such as a combination of both SDNs and NFV. This combined technique gave the strength, which is the potential to enhance the old way of telecommunication services delivery.

3.3.6.1.1. Edge Computing

Edge computing is a network architecture that allows for data processing to happen closer to the source. It helps with faster data transmission and also with the need for less bandwidth. Edge computing is a new concept in the world of networks. It is an architecture where data processing happens close to the source and not at the central location. This helps with faster data transmission and less bandwidth needed. The edge computing architecture enables more efficient use of resources, such as power, storage, and memory, by performing tasks at or near the edge of a network where they are generated rather than at a centralized location in order to conserve energy and reduce latency. The edge is often defined as the last mile or last few miles of a network before reaching the end user. 5G networks are going to be more reliant on edge computing, since the high data rates and low latency requirements for many applications will need to be enabled. Software Defined Networks (SDN) are also expected to move towards edge computing, where intelligence moves closer to the edge.

SDN layering architecture shows there are three levels of control in the proposed architecture of SDN. The whole idea of design principles comes from the 3G to 4G networks evolution. A study [130] proposed functional and non-functional performance requirements of the supported services, which will affect the network functions implementation to be either centralized or distributed at the edge. The existence of an Orchestration Controller (OC) plays an important role in the whole architecture, consorting the use of cloud computational, memory, storage, and networking [105,131-135].

3.3.7. Software Defined Networking (SDN)

A study by [47] explained SDN by defining that SDN is used in mobile networks to meet challenges in communication applications while controlling non-related traffic in some environments such as mobile devices. According to Open Networking Foundation (ONF) [136], SDN is a network architecture that emerged with a network controller (centralized in the control plane). It helps in traffic allocation towards network elements in the data plane (separated in the network). SDN layering architecture. The task of the control plane is to maintain the work. The network controller can give the best control rules to Heterogeneous Network (HetNet) devices from various places [77]. The network controller provides enough related resources and views to the upper layer of the network application. Open flow [79] is one of the SDN protocols mostly accepted in the southbound interface. In addition, Path Computation Element (PCE) [80] and Forwarding and Control Element Separation (ForCES) [81] are other SDN protocols in the southbound interface which may help in the future 5G network.

REVIEW ARTICLE

3.3.7.1. Link-level Access Cloud Architecture

Large Ethernet Enterprise Networks and Link-Level Mobility are the elements that make up cloud-based architectures that are based on the link level. Both the SEATTLE [137] and Ethane [138] designs are built on Ethernet and make an effort to cut down on the flooding of broadcast packets. The goal of the SEATTLE project is to develop a protocol that does not need any setup and is capable of scaling to very large networks. It accomplishes this goal by putting in place a directory at the network level that uses distributed hash tables (DHT) to keep track of the location of the media access control (MAC) address of each host. Additionally, it avoids broadcast for updating and forwarding tables by using caching in conjunction with a link-state advertising technique that is based on unicast.

Ethane is an additional architecture that tries to define and enforce regulations that apply over a whole network. It does this by outsourcing the processing of the bootstrapping protocol to the controller, which in turn helps to minimize the amount of broadcast traffic and the size of the MAC tables on the switches. The authors in [139] suggest a mobility method for 4G networks that operate on the link level. They noted the drawbacks of the General Packet Radio Service (GPRS) Tunneling Protocol (GTP) of the 3GPP mobile networks and advocated Ethernet and Carrier Ethernet as transport backhaul options. In order to prevent flooding mechanisms for frames with an unknown destination address, they recommended using DHT as a locating service. The core network does not become aware of the handovers within the same network segment because the user id (such as an IP prefix) and user location (such as a base station MAC address) mapping are stored at the customer edge switch. This allows the handovers to go unnoticed by the core network. Even though this proposal is primarily concerned with 4G networks, many of its principles may also be beneficially used in 5G networks.

The majority of researchers working in this field at the moment advocate for service-oriented cognitive networks built atop IP multimedia subsystems (IMS). It indicates that radio channel scheduling carried out on a centralized platform results in a more effective customer service experience. The study on the Markov-chain-based spectrum handoff solution makes it clear that having a more centralized decision-maker is an essential attribute since it may coordinate the information of average throughput and average interference duration. Researchers used Markov chain in order to forecast the actions of single users (SUs), despite the fact that they were working in an environment with multiple single users (Sus). Then there are the channels of spectra that are not blocked in any way, which allows the whole network to achieve higher throughputs while reducing the amount of time spent sensing. These two publications demonstrate the significance of centralized administration and reveal how significant an influence the calculation of spectra has on the network layer.

3.3.7.2. Cross-Layer Architecture

ONF introduced OpenFlow, a communication protocol used in forwarding switches or adding the flow table for traffic forwarding. One major advantage of using OpenFlow switches is handling its own area and reporting it to the controller [48]. The controller will be the leader in conducting the decision-making process and monitoring other network-related functions. OpenFlow has become a representative protocol of SDN in this research. After collecting all the related information, the need for a centralized component to coordinate the request in a fair manner is understood. Hence, SDN and SDR were selected as one the important components to develop a 5G technology and overcome the issue of spectrum and bandwidth [140,141].

3.3.7.3. 3GPP

The newly developed MTC-aware 3GPP network architecture is an important product that contributes to the support of MTC in cellular networks. The MTC device domain, the transport network domain, and the MTC application domain are the three domains that are suggested for use in this architecture. The MTC application domain comprises MTC servers that are managed by either the mobile network operator or a third-party MTC provider, depending on the context.

3.3.7.4. SDN via Backhaul Concept

Some experiments are done to prove that SDN with the Backhaul concept is working, such as Packet Forwarding and Traffic Offloading [142-145]. The SDN is applied in a network of 5G mobile as a way to scale the issue of increase in traffic demand, the number of users and applications, and control level. The lower level of the SDN architecture still needs to be researched to improve this technique [146]. The modeling of 5G as SDN is needed for better performance.

3.3.7.5. D2D Associated with SDN Controller

A mobile cloud system that accomplishes device detection based on the audio data acquired from the UE was also suggested by [147]. The controlled cloud system utilizes a client-server architecture, in which clients send synchronized time-series recordings to a central server. The server then applies a clustering algorithm to the time series in order to categorize the recordings according to the degree to which they share acoustic characteristics.

Cloudlets are a resource computing environment that was suggested by researchers [148] to represent resources placed at the network and in close proximity to mobile users. FlashLinQ is a solution that was presented by authors [149] to carry out tasks such as device detection, channel allocation, and link scheduling in the licensed spectrum.

International Journal of Computer Networks and Applications (IJCNA)
DOI: 10.22247/ijcna/2022/214508 Volume 9, Issue 4, July – August (2022)

REVIEW ARTICLE

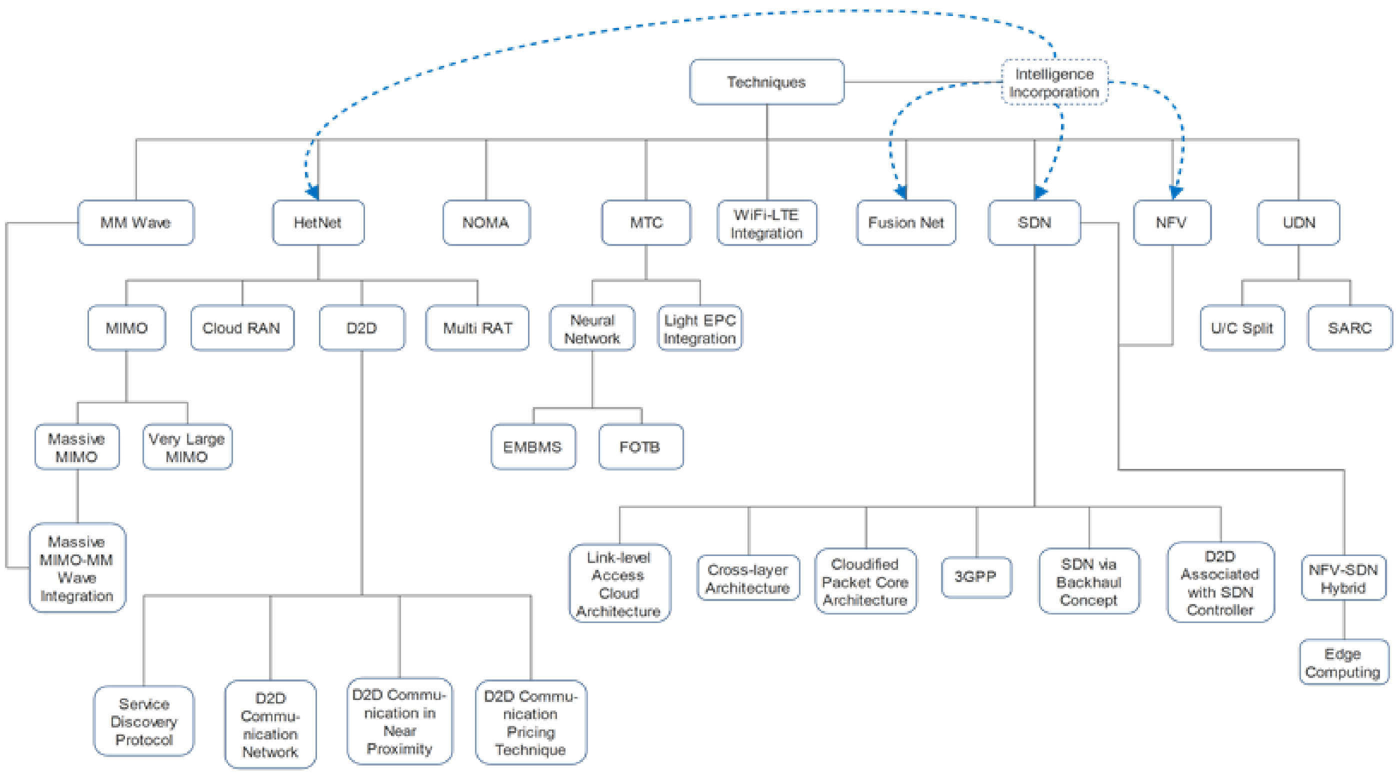

Figure 1 Taxonomy of 5G Techniques/Technologies

This is to deliver considerable gains in comparison to standard IEEE 802.11 systems.

3.3.8. Ultra-Dense-Network (UDN)

3.3.8.1. U/C Split

According to a study by [151], the control plane and user plane (C/U) split is a notion that becomes a reality when distinct cells are responsible for serving the data rate and control signals. When using a C/U split design, the control plane has to be supplied by a continuous and more dependable coverage layer operating at a lower frequency band, but the user plane may be provided by smaller cells with a higher capacity [152]. According to [57], UDN is causing high-frequent measurement, unbearable handover failure (HOF), and enormous power consumption in both the terminal and access network. These issues may be traced back to the fact that UDN is the root cause. Therefore, improving mobility in scenarios where there are a lot of people is becoming an increasingly important challenge [153]. In recent years, the C/U divide has emerged as one of the most promising potential solutions to this dilemma. When using C/U split, the functionality of the C-plane is supplied by a macrocell operating in the low-frequency band [154]. This helps to ensure that strong connection and mobility are maintained. While this is happening, the macrocell also functions as a normal cell, which enables it to handle signaling on both the C-plane and the U-plane. On the other hand, a tiny cell operating at a higher frequency range may give the functionality of a U-plane to increase the user data rate [155]. Nevertheless, the tiny cells are designed to simply transport user traffic. Macrocells are responsible for managing the Radio Resource Control (RRC) connection operations that take place between the user equipment and small cells. A flexible and effective operation is the consequence of a tiny cell's ability to offer a one-to-one connection for user equipment (UE) despite the absence of any cell-specific signals or channels. Because of this, fundamental mobility performance may be maintained despite the use of just a limited number of cells operating at higher frequency bands.

3.3.8.2. SARC

The logical separation of data and control planes, also known as SARC, is a high potential approach that might be used to construct a 5G mobile network architecture that makes effective use of energy [156]. This architectural solution will have an influence on how to build a network that makes optimal use of energy, and it will have that impact because it is an architectural solution. The feature of discontinuous transmission (DTX) and discontinuous reception (DRX) will be made available as a result, enabling traffic adaptability throughout the whole network. At the same time, a high-

REVIEW ARTICLE

strength antenna beam will be generated specifically for the user who is actively transmitting or receiving data. Because of this, the power consumption of the BS will shift, which will lead to an increase in the percentage of energy efficiency. The functioning of the tiny cell may allegedly be improved by separating the control plane from the user plane design [157]. The control plane will provide connectivity and mobility, while the user aircraft will be responsible for providing data transfer. It is possible to generate an efficient energy utilization with variable sleep opportunities in the data plane, and it can decrease the mobility signaling overhead if implemented [158]. These are only two of the many advantages that may be gained by using the SARC. According to the findings of a study [159], one of the two primary ideas about the 5G system that China Mobile has suggested is environmentally friendly. SARC has been seen as one of the promising designs, particularly in terms of energy use efficiency, which is the result of the many different kinds of studies that have been done over the last several years on environmentally friendly communications.

4. ANALYSIS AND DISCUSSION

4.1. Network Functions Virtualization (NFV)

Authors in [63] claimed that the NFV uses IT virtualization technology to provide a new way to build an end-to-end network infrastructure that SDN can run on rather than a term of the umbrella. The strength of this technology is to it provides a new way of building an end-to-end network infrastructure. In addition, the carriers can reduce the power consumption and equipment cost to build and operate a network that is useful in future 5G technology. However, this technique is still unclear on the impact on reliability and performance.

4.2. Software-Defined Network (SDN)

Open Networking Foundation claimed that SDN is a networking computing that allows the network operator to manage the network services through higher-level abstraction functionality. The strength of this technique is to help traffic allocation towards network elements in the data plane (separated in the network) which can help in future 5G technology but has weakness in SDN protocol in the northbound interface. Hence, the northbound interface’s SDN protocol needs to be enhanced by doing more research and experiments. There are several works that take SDN as core architecture for the building of 5G technology. Researchers in [147] said that some innovative network infrastructures might be used in 5G, such as SDN and NFV. This combined technique gave the strength which gives the potential to enhance the old way of telecommunication services delivery. However, this technique has weak network capacity and traffic handling when the number of users increases in the future. We recommend the proposed technique is integrated with the Backhaul concept to handle the traffic growth when the number of users increases to maintain high network efficiency.

A study by [33], proposed architecture design based on SDN architecture. The proposed architecture is a cloud-based packet core architecture consisting of 3 layers: access cloud, regionally distributed cloud, and centralized national cloud. This solves one of the challenges of 5G, namely end-to-end latency. This provides lower latency when implemented. Besides that, the cost of this proposed architecture is cheaper and easy for record evolution and maintenance by enabling the distribution of features on vanilla switches of SDN architecture. On the downside, however, there is a trade-off between latency, cost, and signaling traffic control plane functionalities within the core network architecture. With that, detailed research is recommended to be done to overcome the trade-off. Besides that, based on the architecture proposed by researchers in [48], the idea of integrating SDN with SDR is that the outcome can overcome the issue of spectrum and bandwidth, and communication can be transmitted in a much-centralized manner. The downside, however, is that SDN and SDR are unable to communicate with each other, and to overcome this, further research is required to gain a better understanding between SDN and SDR. In fact, the use of a cross-layer controller also needs to be tested to see if it really works.

A study by [47] came out with a concept called Backhaul, which can provide solutions needed for situations like an increasing number of users, traffic demand, application cost, and control level. The concept had done some experiments that proved visions such as SDN mobile traffic offloading to decrease latency overhead between controllers. Research, however, is needed for the architecture of SDN as the concept of secure service delivery is not likely to be implemented. Recommendations are made to put more effort into the SDN architecture research and to implement and experiment with the concept of secure delivery. Furthermore, R. Guerzoni and Trivisonno [132] came out with an architecture that is based on SDN, NFV, and edge computing. The architecture is able to dispose of the use of tunneling protocol while carrying out multidimensional carrier-grade communication path and reduce end-to-end latency by proactively configuring the SDN-based infrastructure and delay-critical services by ad-hoc virtual link implementation in the flow management module. This, however, is still in the early stages as it is just a “plastic” architecture. To make it a reality, further research and development on this hybrid new concept of an SDN-based network are required so that it can be instantiated easily and grow more maturely.

4.3. Neural Network (NN) into Quality of Experience (QoE)

A study by [20] stated the neural network (NN) approach to QoE is important for future 5G technology. This approach's strength is to give adaptive estimation and classification in 5G

REVIEW ARTICLE

technology automatically. The weakness of this approach is the challenge of implementing it to meet user satisfaction in the overall system because of the increase of smart user devices. Hence, we recommend using QoE's SOF for 5G technology because it can gain QoE self-optimization for 5G technology by the relationship between QoS and the resulting QoE.

4.4. Machine Type Communication (MTC)

The study on 5G has determined that machine-to-machine communication is one of the most significant areas to investigate. According to [160], MTC is more advanced than other communication methods in various qualities: the ability to transmit tiny packet sizes, tolerance of transmission delays, and low frequency. However, a few obstacles still need to be overcome, such as effective scheduling of hybrid aggregators and typical mobile users, improved interface design between devices and aggregators, and RRC signaling optimization for aggregated services. Optimizing DSR performance and relieving the strain placed on networks due to the potentially infinite number of MTC devices are the two proposed solutions. In the study [20], the real-life implementation of LightEPC, which is a novel architecture to enable MTC, was explored.

These strategies are effective in lowering the entry costs for mobile network operators into the MTC market, allowing them to do so with a minimal amount of capital expenditure. It offers distant MTC servers a communication interface that enables those servers to trigger MTC devices or receive MTC data. This is made possible by the fact that it provides this interface. The inability of the eNBs to be modified in any way, despite the fact that they are able to recognize MTC traffic and send it on to the LightEPC instances, is the method's primary shortcoming. Additionally, if there are a large number of attaching requests, MME can become overloaded, which would lead to an increase in queue size and the discarding of certain attach requests. It advises that the internal IDs of MTC devices should use eNBs and that the attached request should have a consistent value. This may be accomplished by making use of one LightEPC request for each MTC group. This will help to keep the number of MTC from fluctuating.

4.5. Evolved Multimedia Broadcast Multicast Services (eMBMS) and Future of Broadcast TV (FOBTV)

A study by [122], stated that the mobile broadcast technologies are Evolved Multimedia Broadcast Multicast Services (eMBMS) technology and the broadcast industry towards Future of Broadcast TV (FOBTV). This technology has strength in handling the opportunities and challenges faced in converging them. In addition, it also gives great hope for the convergence of these two industries in future 5G networks. The weaknesses of the combination for these two industries are still challenges and requirements such as a flexible and scalable broadcast mode that need to be faced and fulfilled. We recommend a better technology needs to be invented that can support the efficiency of the high-definition television (HDTV) services and the wide-area coverage of the high power high tower (HPHT) infrastructure. Besides that, it also needs to be able to constantly change between the unicast and broadcast delivery when required as well as depending on the status of the network.

4.6. Ultra-Dense Network (UDN)

Researchers in [57] claimed that the control plane and user plane (C/U) split concept should be applied to Ultra-Dense Network. The strength of this technique is that it can achieve a much lower handover failure rate and higher energy efficiency as compared with the current LTE system. This technique has a bad side: it does not really select the best local cluster node in clustering. We recommend the selection to choose the best local cluster mode by considering both ideal and non-ideal backhaul situations.

A study by [161] proposed that by applying control and data planes separation architecture (SARC) in designing a 5G network, the potential to gain energy efficiency is higher. Moreover, SARC provides flexibility in mobility management, and due to its ubiquitous coverage characteristic, the inherent drawback of coverage holes and high interference can be voided. But the signaling network in SARC will be complex as flexible mobility management means a higher degree of freedom. A network-aware physical layer needs to be created to provide much more efficient networks to overcome this challenge.

4.7. Millimetre Wave (mmWave)

A study by[162], stated that two aspects are encouraged in mmWave communication system development: the wavelength and the bandwidth. Due to the characteristic of mmWave, it has shown its capability to solve the problem faced by high-speed wireless broadband access, such as supporting the application that needs a high transmission rate. mmWave is one of the efficient solutions in the 5G wireless network. It can uphold the growth of the traffic, which satisfies the rapid increase of data rates and increases the bandwidth up to tens of Gbps in 5G technology. According to a study by [52], the deployment of D2D communications in the mmWave system is to handle local traffic by relaying rather than improving the spectrum utilization efficiency.

On the other hand, researchers [52] also mentioned that its short wavelength has difficulties in diffraction, propagation loss, and weak signal due to the difficulties in penetrating through the solid material. However, the solution for these weaknesses can be resolved by using the high gain antenna in mobile devices and using narrow beamwidth antennas in the BS. As for the BS placement and optimization, the Authors in

REVIEW ARTICLE

the study [163] have discussed the radio network planning in 2015. Throughout the planning process, it will minimize and optimize the locations of BSs for a given geographical area and build up the use of mmWave frequencies in macro and micro BS. The full detail of the calculation for the BSs optimization is provided, but no clear answer exists whether the proposed solution is a good solution for the problem. Therefore, a clear statement to support the effectiveness of the proposed solution in solving the problem should be included.

4.8. Intelligence

A study by [63] stated that the introduction of intelligence towards 5G with consideration of the complex context of operation and essential requirements is required. Intelligence facilitates the decision-making of the cells to maximize energy and cost-efficiency. However, additional costs for adding new or upgrading existing network equipment are required to integrate intelligence. Moreover, the technical proof of the concept is not yet discussed. Hence, further research is required on the simplifying integration of intelligence into the technology and how intelligence impacts the operational and capital expenditure, so that network operators are willing to invest in equipment upgrades to integrate intelligence. Authors in this study also stated Fusion Net could increase heterogeneous network deployment performance with its powerful intelligence properties.

Fusion Net is used to propose a multilayer and MSA technology. The strength of Fusion Net is maximizing the cost and energy efficiency and avoiding over-positioning of resources by using decisions associated with the combination of distribution of traffic to various spectrums and RATs. However, the technical proof of their concept needs to be increased and still needs to be researched. Further research on the technique needs to be done in the technology and how Fusion Net impacts the future 5G technology.

4.9. Radio Access Technologies (RATS)

Researchers in [45] argue that the trend toward integrated use of multiple RATs and networks will be essential for addressing the challenges faced by future 5G networks. The integration of WiFi-LTE within the RAN is needed to address the capacity limitations of the 5G network. The simulation results for Coordinated RAT-Assignment and Cross-RAT Scheduling are also provided. The problem is that the exchange of Cross-RAT information across BSs and WiFi Apps requires user involvement, but the user only has local knowledge of the wireless network conditions. Hence, further research on how and in what way the users are able to help in the exchange of Cross-RAT information are required.

According to Kayama and Jiang [70], Massive MIMO and NOMA are expected to be applied to achieving the 5G target to increase SNR, reduce co-channel interference, and increase throughput gain. In addition, Massive MIMO also created higher capacity in the form of radio heads (distributed) or antenna element’s deployment (higher frequency bands) to handle future challenges, which s including many mobile network users. The downside of massive MIMO and NOMA includes limited coverage of small cells and increased inter-cell interference. The antenna element’s deployment of Massive MIMO still needs to find the most suitable algorithm to acquire fast and coherent signal processing. Phantom cell and network-assisted interference cancellation and suppression (NAICS) can be used to solve the weakness. Furthermore, need to do more research and invent a new processing algorithm and topology to match up the gather of fast and coherent signal processing on Massive MIMO.

4.10. Device-to-Device (D2D) Communication

According to [35, 34], D2D communication provides better service in increasing mobile data volume per unit area, capacity, data rate, and battery life. However, D2D implementation is still facing challenging issues such as the network architecture, physical layer features, and performance requirements of D2D that are yet to be addressed. Also, direct communication is offered between devices in near proximity, leading to the inefficiency of discovering near devices. Recommendations to resolve these weaknesses are intensive research activities on D2D implementation. Meanwhile, at the hardware level, research on increasing the communication range between devices should be carried out in order to resolve the issues encountered.

Authors in [101] stated that the pricing issues in D2D implementation between operators and users can be improved by using game theory and auction theory tools. Although this benefits both operators and users, the proposed tools might not consider the efficiency of a given auction design, optimal and equilibrium bidding strategies, and revenue comparison. Therefore the tools proposed are not efficient and effective. In order to maximize revenue for both operators and users, research on game and auction theory should be carried out in-depth. Ahishakiye and Li [34] stated that in D2D enabled cellular network, BS initiated protocol that is able to handle high traffic requests without generating high control overhead. A disadvantage seen in BS-initiated protocol is that high interference might occur when a BS has a high number of connections simultaneously. However, this can be solved by using directional antennas on BS, each pointing in a different direction. This results in increasing the traffic capacity of a BS and not greatly increasing interference caused by devices.

4.11. Heterogeneous Network (HetNet)

Bangerter et al. stated that the small cell deployment at high traffic regions in HetNet enables the support of wide-range frequency bands for different services with huge network capacity. However, there is high interference between devices

REVIEW ARTICLE

in HetNet. Therefore, enhanced Inter-Cell Interference Coordination (eICIC) is recommended for better interference management.

5. CONCLUSION, FUTURE TRENDS AND RECOMMENDATION

In today's world, wireless network technology has evolved into a requirement for everyday life, and the advent of 5G technology will take it to the next level for a variety of reasons, including service draw, new discoveries made possible by research, and technology, and more. As a consequence of the increased demand, mobile broadcasting technologies such as LTE, LTE-A, and eMBMS have been developed. However, it is probable that the existing wireless communication networks may not be able to operate the 5G devices in an efficient way as these networks were not created to handle frequent short data packets and simultaneous huge demands. On the other hand, owing to the quick expansion of the internet of things, which includes a range of low-cost machine-type communications devices, it is projected that trillions of wireless nodes in IOT may become operational in the fifth generation of the wireless communications system. As a consequence, the mobile type communication architecture (also known as MTC) was established. This design is based on aggregated packet traffic models and data relay mode. It is a platform that makes it possible for machines or devices to interact with one another utilizing the M2M or D2D protocols. The expansion of machine-to-machine (M2M) networks was a crucial contributor in the fast increase of network traffic. It is believed that upgrading MTC with aggregators will reduce some of the load that the possibly billions of MTC devices would have on 5G networks. In conjunction with the intention to provide high data volume, data rates, and high accessibility from mobile with low latency and longer battery life idea of Mobile and Wireless Communications Enablers for the 2025 Information Society (METIS), which promotes a connected information society through an increase in the utilization of mobile devices.

The evolution of 5G technology has produced SDN and NFV) Spectrum sharing, self-organizing network (SON) function, and enhanced networking via the use of terminal measurement input are three areas of emphasis for 5G technology. HetNet is also ideal for 5G technology due to its influence on network effectiveness and overall performance. MIMO (has been the primary method in HetNet architecture used as Cloud RAN for backhaul with high data rates and low latency. Despite the efficacy of the strategies, various factors are considered, such as spectrum aggression, the convergence of LAN, PAN, and WAN, the connection requirements of the internet of things, and increasing network cooperation. Dynamic RAT assignments with virtual RAN architecture may increase system dependability and user QoS via cross-RAT assignment, cross-RAT scheduling, downlink performance outcome, and uplink performance consideration. Radio Access Technology (RAT) enables the transition from LTE to older networks. Future networks' capacity and connection constraints act as a driving force not only to increase the performance of an individual RAT, but also to integrate numerous RATs more tightly. Multi-RAT is also viable for offloading hotspots with proximity services in ultradense small cell deployments. In addition to the use of RAT to accomplish 5G objectives, additional methods for enhancing cost effectiveness and service supply include the reduction of cell size, the deployment of heterogeneous networks, and the use of flexible spectrum management.

The control and data plane separation architecture, also known as SARC, is regarded as a viable paradigm that may help achieve energy efficiency, system-level capacity maximization, interface management, and mobility management. This is important for energy management for the device. The process of shutting things off may also contribute to increased energy efficiency. In addition to this, the design provides more mobility management flexibility by cutting down on the number of handover signals. In addition, there are not many processes necessary to guarantee the dependability of a Device to Device network. In his study, Xuemin Shen suggests that millimeter-wave might be a viable alternative for the development of D2D since it gives less seamless coverage while having a higher degree of stability. Even if its wavelength is extremely short and it is unable to penetrate the object, it is still preferable to use a D2D network rather than a standard one since D2D networks have reduced propagation loss and offer a directed connection, which helps reduce interference. The device-to-device (D2D) connection is made possible by the 5G technology, which takes into account the users, needs, and trends that are now shaping network connections. Device-to-Device, or D2D, communication is made possible by a technology known as D2D. This technology eliminates the need for communication infrastructures like access points and base stations. It will figure out how to make a connection between two devices by taking advantage of their close proximity to one another while still taking into account latency and resource efficiency between the key performance indicators (KPIs). Device Relaying with Operator Controlled link establishment (DR-OC), Direct D2D Communication with Operator Controlled link establishment (DC-OC), Device Relaying with Device Controlled link establishment (DR-DC), and Direct D2D Communication with Device Controlled link establishment are the four different categories of D2D communications (DC-DC). In order to accomplish this objective, the two-tier cellular network will make it possible for users and devices to communicate in ways that include both the macro cell tier and the device tier.

REVIEW ARTICLE

Since D2D communications involve heavy data traffic, hence more energy consumption is expected. Therefore, battery life is easily exhausted, and interference keeps on occurring due to the transmission collision. But with, cross-layer Resource Control under Busty Data Traffic could minimize the problems. Its three function blocks in D2D selection, mode selection, power block, and resource allocation ensure a proper decision to avoid wasting energy and power control and reuse to improve cellular communication. There are two ways for D2D device discovery: Network proximity and Open proximity which the usage depends on either user requirement initiated or base station initiated. Network proximity is a network that provides discovery assistance by enabling user requirements requesting services while open proximity by discovering each possible device in the network. User Equipment initiated, its protocol follows the reactive (pull) principle, which starts with contact with the base station. A proximity service discovery on-demand manner. For Base Station initiated, it follows the idea of a proactive (push) mechanism that is multitasking to an advertisement to all D2D subscribers no matter whether it is with or without request proximity service. Any devices are independent to communicate within their proximity. Bypassing the base station through the D2D link as long recognized by the base station, communication is feasible based on the current location. In addition to that, the base station also will assist in allocating resources and information exchange for discovery success. In conclusion, the reactive protocol performs better if the D2D traffic load is low, unlike the proactive protocol, which is preferable if many D2D user equipment are in the vicinity.

One of the proposed architectures proposed to overcome most of the challenges of the 5G network is SDN. SDN helps to reduce the latency in the network. Besides, it is re-configurable as it allows instantiation of logical architecture and network functions, and the services are implemented in the optimal location within the cloud infrastructure. Other than that, SDN is proposed to support D2D communication. The basic idea of it is that the architecture's controller is associated with the D2D controller. Another proposed future trend is the codified packet core represented in 3 layers: an access cloud, regionally distributed cloud, and centralized national cloud. Besides that, MTC communication architecture is proposed as it enables M2M or D2D communication, and it is expected to reduce the pressure on 5G networks from the potential trillions of MTC devices.

For recommendation:

1. It is important to investigate and define disruptive network architectures in all available network technologies to address the 5G challenges.

- Software-defined Networking (SDN) and Self-organizing Networks (SON) architecture and protocols should investigate
- Existing infrastructure, security measures, and the effective administration of virtualized networks and services are all components of the design procedures that guarantee the co-existence of virtual networks.

2. Networking and virtualization technologies will drive the advances of 5G system components.

- The development of technologies based on particular consumers, services, or network settings is highly recommended. It enables the building of virtual networks in a dynamic and adaptable manner.
- New radio technologies can help us communicate visible light for satellite communications.

3. It will study the system's flexibility and programmability to the fullest extent possible, which will enable us to apply the 5G vision across all of the technologies that have been created.

- It is essential to research both the already operational and planned network installations. It will make possible the sharing of networks on every level.

REFERENCES

[1] S. Hashima, K. Hatano, H. Kasban,& E. Mahmoud Mohamed, (2021). Wi-Fi assisted contextual multi-armed bandit for neighbor discovery and selection in millimeter wave device to device communications. Sensors, 21(8), 2835.
[2] S. Amanuel, & A. Ameen, (2021). Device-to-device communication for 5G security: a review. Journal of Information Technology and Informatics, 1(1), 26-31.
[3] G. Noh, H. Chung, & I. Kim, (2020). Mobile relay technology for 5G. IEEE Wireless Communications, 27(3), 6-7.
[4] A, S, Khan. (2014). "Secure and efficient distributed relay-based rekeying algorithm for group communication in mobile multihop relay network." International Journal of Communication Networks and Information Security 6(3): 189-199.
[5] S. Khan, J. Abdullah, N. Khan, A. Julahi, & S. Tarmizi, (2017). Quantum-elliptic curve cryptography for multihop communication in 5G networks. International Journal of Computer Science and Network Security (IJCSNS), 17(5), 357-365.
[6] A. S. Khan, Y., Javed, R. Saqib, Z. Ahmad, J. Abdullah, K. Zen, & N. A. Khan, (2022). Lightweight Multifactor Authentication Scheme for NextGen Cellular Networks. IEEE Access, 10, 31273-31288.
[7] N. A. Khan, (2022). PKI-Based Security Enhancement for IoT in 5G Networks. In Inventive Computation and Information Technologies (pp. 217-225). Springer, Singapore.
[8] Othman, W., Fuyou, M., Xue, K., & Hawbani, A. (2021). Physically secure lightweight and privacy-preserving message authentication protocol for VANET in smart city. IEEE Transactions on Vehicular Technology, 70(12), 12902-12917.
[9] R. Sharma, & R. Arya, (2021). A secure authentication technique for connecting different IoT devices in the smart city infrastructure. Cluster Computing, 1-17.
[10] Y. Hao, (2021). Investigation and Technological Comparison of 4G and 5G Networks. Journal of Computer and Communications, 9, 36-43.

REVIEW ARTICLE

[11] S. Painuly, S. Sharma, & P. Matta, (2021). Future trends and challenges in next generation smart application of 5G-IoT. In 2021 5th International Conference on Computing Methodologies and Communication (ICCMC) (pp. 354-357). IEEE.

[12] N. Piovesan, A. Domenico, D. López-Pérez, H. Bao, G. Xinli, W. Xie, & M. Debbah, (2021). Mobile Traffic Forecasting for Green 5G Networks. In 2021 IEEE Global Communications Conference (GLOBECOM) (pp. 1-6). IEEE.

[13] R. Sood and A. Garg, "Digital Society from 1G to 5G: A Comparative Study," International Journal of Application or Innovation in Engineering & Management (IJAIEM), vol. 3, no. 2, pp. 186-193, 2014.

[14] A. Dolgui, & D. Ivanov, (2022). 5G in Digital supply chain and operations management: Fostering flexibility, end-to-end connectivity and real-time visibility through internet-of-everything. International Journal of Production Research, 60(2), 442-451.

[15] M. Wang, & Y. Hao, Y. (2021,). Key technologies of green communication for 5G mobile network. In 2021 IEEE International Conference on Electronic Technology, Communication and Information (ICETCI) (pp. 101-104). IEEE.

[16] L. Rao, M. Pant, L. Malviya, A. Parmar, & S. Charhate, (2021). 5G beamforming techniques for the coverage of intended directions in modern wireless communication: in-depth review. International Journal of Microwave and Wireless Technologies, 13(10), 1039-1062.

[17] B. A, A. Osseiran and E. , "Mobile and Wireless Communications Enablers for the 2020 Information Society," FP7 ICT Objective 1.1 Future Networks, pp. 1-2, 2013.

[18] Chettri, L., Bera, R., & Barauh, J. K. (2021). Performance Analysis of 3GPP NB-IoT Downlink System towards 5G Machine Type Communication (5G-MTC). J. Commun., 16(8), 355-362

[19] A. Gupta and R. K. Jha, "A Survey of 5G Network: Architecture and Emerging Technologies," IEEE Access, vol. 3, pp. 1206-1232, 2015.

[20] T. Taleb, A. Ksentini and A. Kobbane, "Lightweight mobile core networks for machine type communications," IEEE Access, vol. 2, pp. 1128-1137, 2014.

[21] El-Shorbagy, A. M. (2021). 5G Technology and the Future of Architecture. Procedia Computer Science, 182, 121-131.

[22] P. Zhouyue and F. Khan, "An Introduction to Millimeter-Wave Mobile Broadband Systems," Communications Magazine, IEEE, vol. 49, no. 6, pp. 101-107, 2011.

[23] E. Hossain and M. Hasan, "5G Cellular: Key Enabling Technologies and Research Challenges," IEEE Instrumentation and Measurement Mag, vol. 18, no. 3, pp. 11-21, 2015.

[24] H.-H. Lee and Y.-c. Ko, "Low Complexity Codebook-Based Beamforming for MIMO-OFDM Systems in Millimeter-Wave WPAN," Wireless Communications, IEEE Transactions, vol. 10, no. 11, pp. 3607 - 3612, 2011.

[25] Y.-D. Lin and Y.-C. Hsu, "Multihop cellular: A New Architecture for Wireless Communications," INFOCOM 2000. Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE, vol. 3, pp. 1273-1282, 2000.

[26] I. Mavromatis, Tassi, A., Piechocki, R. J., & Nix, A. ITS-G5 network for next-generation intelligent transportation systems: design insights and challenges. In Ad-hoc, Mobile, and Wireless Networks: 17th International Conference on Ad Hoc Networks and Wireless, ADHOC-NOW 2018, Saint-Malo, France, September 5-7, 2018. Proceedings (pp. 53).

[27] J. G. Andrews, S. Buzzi, Wan Choi, A. Lozano, S. V. Hanly, A. C. K. Soong and J. C. Zhang, "What Will 5G Be?," IEEE J. Select. Areas Commun, vol. 32, no. 6, pp. 1065-1082, 2014.

[28] D. Soldani, B. Barani, R. Tafazolli, A. Manzalini and C.-L. I, "Software defined 5G networks for anything as a service [Guest Editorial]," IEEE Commun. Mag., vol. 53, no. 9, pp. 72-73, 2015.

[29] J. F. Monserrat, G. Mange, V. Braun, H. Tullberg, G. Zimmermann and Ö. Bulakci, "METIS research advances towards the 5G mobile and wireless system definition," EURASIP J Wirel Commun Netw EURASIP Journal on Wireless Communications and Networking, p. 53, 2015.

[30] F. Boccardi, R. Heath, A. Lozano, T. Marzetta and P. Popovski, "Five disruptive technology directions for 5G," IEEE Commun. Mag. IEEE Communications Magazine, vol. 52, no. 2, pp. 74-80, 2014.

[31] A. Benjebbour, A. Li, K. Saito, Y. Kishiyama and T. Nakamura, "Downlink Non-Orthogonal Multiple Access (NOMA) Combined with Single User MIMO (SU-MIMO)," IEICE Transactions on Communications IEICE Trans. Commun., vol. 98, no. 8, pp. 1415-1425, 2015.

[32] L. Dai, B. Wang, Y. Yuan, S. Han, C.-L. I and Z. Wang, "Non-orthogonal multiple access for 5G: solutions, challenges, opportunities, and future research trends," IEEE Commun. Mag. IEEE Communications Magazine, vol. 53, no. 9, pp. 74-81, 2015.

[33] P. Ameigeiras, J. J. Ramos-Munoz, L. Schumacher, J. Prados-Garzon, J. Navarro-Ortiz and J. M. Lopez-Soler, "Link-level access cloud architecture design based on SDN for 5G networks," IEEE Network, vol. 29, no. 2, pp. 24-31, 2015.

[34] F. Ahishakiye and F. Y. Li, "Service discovery protocols in D2D-enabled cellular networks: Reactive versus proactive," 2014 IEEE Globecom Workshops (GC Wkshps), pp. 833-838, 2014.

[35] X. Shen, "Device-to-device communication in 5G cellular networks," IEEE Network, vol. 29, no. 2, pp. 2-3, 2015.

[36] L. Song and Z. Han, Resource Management for Device-to-Device Underlay Communication, Resource Management for Device-to-Device Underlay Communication: Springer New York :, 2014.

[37] M. Yassein, B., Aljawarneh, S., & Al-Sadi, A. (2017, November). Challenges and features of IoT communications in 5G networks. In 2017 International Conference on Electrical and Computing Technologies and Applications (ICECTA) (pp. 1-5). IEEE.

[38] P. Janis, C.-H. Yu, K. Doppler, C. Ribeiro, C. Wijting, K. Hugl, O. Tirkkonen and V. Koivunen, "Device-to-Device Communication Underlaying Cellular Communications Systems," IJCNS International Journal of Communications, Network and System Sciences, vol. 2, no. 3, pp. 169-178, 2009.

[39] J. Liu, Y. Kawamoto, H. Nishiyama, N. Kato and N. Kadowaki, "Device-to-device communications achieve efficient load balancing in LTE-advanced networks," IEEE Wireless Commun. IEEE Wireless Communications, vol. 21, no. 2, pp. 57-65, 2014.

[40] N. Khan, M. Alzahrani (2018) "Establishing EndVisor and Quarantine Approach in Solving Security Issues of Virtualization", Indian Journal of Science & Techenology vol. 11, no 47, pp. 1-8

[41] J. Qiao, X. Shen, J. Mark, Q. Shen, Y. He and L. Lei, "Enabling device-to-device communications in millimeter-wave 5G cellular networks," IEEE Commun. Mag. IEEE Communications Magazine, vol. 53, no. 1, pp. 209-215, 2015.

[42] T. S. Rappaport, Millimeter wave wireless communications, Upper Saddle River, N.J.: Prentice Hall, 2014.

[43] S. Haykin, "Cognitive Radio: Brain-empowered Wireless Communications," IEEE Journal on Selected Areas in Communications, vol. 23, no. 2, pp. 201-220, 2005.

[44] E. Aryafar, A. Keshavarz-Haddad, M. Wang and M. Chiang, "RAT selection games in HetNets," 2013 Proceedings IEEE INFOCOM.

[45] N. Himayat, S.-P. Yeh, A. Y. Panah, S. Talwar, M. Gerasimenko, S. Andreev and Y. Koucheryavy, "Multi-radio heterogeneous networks: Architectures and performance," 2014 International Conference on Computing, Networking and Communications (ICNC), 2014.

[46] M. Gerasimenko, N. Himayat, S.-P. Yeh, S. Talwar, T. Andreev and Y. Koucheryavy, "Characterizing performance of load-aware network selection in multi-radio (WiFi/LTE) heterogeneous networks," 2013 IEEE Globecom Workshops (GC Wkshps), 2013.

[47] J. Costa-Requena, R. Kantola, A. Y. Ding, J. Manner, Y. Liu and S. Tarkoma, "Software Defined 5G Mobile Backhaul," Proceedings of the 1st International Conference on 5G for Ubiquitous Connectivity, pp. 258-263, 2014.

[48] H.-H. Cho, C.-F. Lai, T. K. Shih and H.-C. Chao, "Integration of SDR and SDN for 5G," IEEE Access, vol. 2, pp. 1196-1204, 2014.

REVIEW ARTICLE

[49] W. Xia, Y. Wen, H. F. Chuan, D. Niyato and H. Xie, "A Survey on Software-Defined Networking," IEEE Communication Surveys & Tutorials, vol. 17, no. 1, pp. 27-51, 2015.

[50] H. Kabir, R. Kantola and J. L. Santos, "Security Mechanisms for a Cooperative Firewall," 2014 IEEE Intl Conf on High Performance Computing and Communications, 2014 IEEE 6th Intl Symp on Cyberspace Safety and Security, 2014 IEEE 11th Intl Conf on Embedded Software and Syst (HPCC,CSS,ICESS), pp. 814-818, 2014.

[51] J. L. Santos, R. Kantola, N. Beijar and P. Leppaaho, "Implementing NAT traversal with Private Realm Gateway," 2013 IEEE International Conference on Communications (ICC), pp. 3581-3586, 2013.

[52] Feamster, N., Rexford, J., & Zegura, E. (2014). The road to SDN: an intellectual history of programmable networks. ACM SIGCOMM Computer Communication Review, 44(2), 87-98.

[53] Aziz, N. A., Mantoro, T., & Khairudin, M. A. (2018, September). Software defined networking (SDN) and its security issues. In 2018 International Conference on Computing, Engineering, and Design (ICCED) (pp. 40-45). IEEE.

[54] Keshari, S. K., Kansal, V., & Kumar, S. (2021). A systematic review of quality of services (QoS) in software defined networking (SDN). Wireless Personal Communications, 116(3), 2593-2614.

[55] V. Shrimali and A. Gaur, "A review on communication infrastructure in 5G cellular networks," Int. J. of Eng. Sci. Invention Research & Develop., vol. 2, no. 2, pp. 94-98, 2015.

[56] A. Bayazeed, K. Khorzom, & A. Aljnidi, (2021). A survey of self-coordination in self-organizing network. Computer Networks, 196, 108222.

[57] J. Zhang, J. Feng, C. Liu, X. Hong, X. Zhang and W. Wang, "Mobility enhancement and performance evaluation for 5G Ultra dense Networks," 2015 IEEE Wireless Communications and Networking Conference (WCNC), pp. 1793-1798, 2015.

[58] M. Z. Shafiq, L. Ji, A. X. Liu, J. Pang and J. Wang, "Large-Scale Measurement and Characterization of Cellular Machine-to-Machine Traffic," IEEE/ACM Transactions on Networking IEEE/ACM Trans. Networking, pp. 1960-1973, 2013.

[59] J. Marquez-Barja, S. Hadiwardoyo, V, Maglogiannis, D. Naudts, I. Moerman, P. Hellinckx, & J. Vandenbossche, (2021,). Enabling cross-border tele-operated transport in the 5G Era: The 5G Blueprint approach. In 2021 IEEE 18th Annual Consumer Communications & Networking Conference (CCNC) (pp. 1-4). Ieee.

[60] N A. Khan. Establishing secure network virtualization in 5g radio access network. (2022), “Journal of Harbin Institute of Technology”, 54(7):111-9.

[61] S. Chen and J. Zhao, "The requirements, challenges, and technologies for 5G of terrestrial mobile telecommunication," IEEE Commun. Mag. IEEE Communications Magazine, vol. 52, no. 5, pp. 36-43, 2014.

[62] A. Osseiran, V. Braun, T. Hidekazu, P. Marsch, H. Schotten, H. Tullberg, M. A. Uusitalo and M. Schellman, "The Foundation of the Mobile and Wireless Communications System for 2020 and Beyond: Challenges, Enablers and Technology Solutions," 2013 IEEE 77th Vehicular Technology Conference (VTC Spring), pp. 1-5, 2013.

[63] P. Demestichas, A. Georgakopoulos, D. Karvounas, K. Tsagkaris, V. Stavroulaki, J. Lu, C. Xiong and J. Yao, "5G on the Horizon: Key Challenges for the Radio-Access Network," IEEE Veh. Technol. Mag. IEEE Vehicular Technology Magazine, vol. 8, no. 3, pp. 47-53, 2013.

[64] T. S. Rappaport, S. Sun, R. Mayzus, H. Zhao, Y. Azar, K. Wang, G. N. Wong, J. K. Schulz, M. Samimi and F. Gutierrez, "Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!," IEEE Access, vol. 1, pp. 335-349, 2013.

[65] A. T. Nassar, A. I. Sulyman and A. Alsanie, "Radio Capacity Estimation for Millimeter Wave 5G Cellular Networks Using Narrow Beamwidth Antennas at the Base Stations," International Journal of Antennas and Propagation, pp. 1-6, 2015.

[66] Y. Azar, G. N. Wong, K. Wang, R. Mayzus, J. K. Schulz, H. Zhao, F. Gutierrez, D. Hwang, T. S. and Rappaport, "28 GHz propagation measurements for outdoor cellular communications using steerable beam antennas in New York city," 2013 IEEE International Conference on Communications (ICC), pp. 5143-5147, 2013.

[67] G. R. Maccartney, J. Zhang, S. Nie and T. S. Rappaport, "Path loss models for 5G millimeter wave propagation channels in urban microcells," 2013 IEEE Global Communications Conference (GLOBECOM), pp. 3948-3953, 2013.

[68] Y. S. Meng and Y. H. Lee, "Investigations Of Foliage Effect On Modern Wireless Communication Systems: A Review," Progress In Electromagnetics Research PIER, vol. 105, pp. 313-332, 2010.

[69] W. Roh, J.-Y. Seol, J. Park, B. Lee, J. Lee, Y. Kim, J. Cho, K. Cheun and F. Aryanfar, "Millimeter-wave beamforming as an enabling technology for 5G cellular communications: theoretical feasibility and prototype results," IEEE Commun. Mag. IEEE Communications Magazine, vol. 52, no. 2, pp. 106-113, 2014.

[70] H. Kayama and H. Jiang, "Evolution of LTE and new Radio Access technologies for FRA (Future Radio Access)," 2014 48th Asilomar Conference on Signals, Systems and Computers, pp. 1944-1948, 2014.

[71] M. Attaran, (2021). The impact of 5G on the evolution of intelligent automation and industry digitization. Journal of Ambient Intelligence and Humanized Computing, 1-17.

[72] R. Azim, A. Meaze, A. Affandi, M. Alam. M., R. Aktar, M. Mia, & M. Islam, M, (2021). A multi-slotted antenna for LTE/5G Sub-6 GHz wireless communication applications. International Journal of Microwave and Wireless Technologies, 13(5), 486-496.

[73] C.-H. Yu, K. Doppler, C. B. Ribeiro and O. Tirkkonen, "Resource Sharing Optimization for Device-to-Device Communication Underlaying Cellular Networks," IEEE Transactions on Wireless Communications IEEE Trans. Wireless Commun., vol. 10, no. 8, pp. 2752 - 2763, 2011.

[74] J. Qiao, L. X. Cai, X. Shen and J. W. Mark, "STDMA-based scheduling algorithm for concurrent transmissions in directional millimeter wave networks," 2012 IEEE International Conference on Communications (ICC), pp. 5221 - 5225, 2012.

[75] C.-S. Sum, Z. Lan, R. Funada, J. Wang, T. Baykas, M. Rahman and H. Harada, "Virtual time-slot allocation scheme for throughput enhancement in a millimeter-wave multi-Gbps WPAN system," IEEE J. Select. Areas Commun. IEEE Journal on Selected Areas in Communications, vol. 27, no. 8, pp. 1379-1389, 2009.

[76] B. Bangerter, S. Talwar, R. Arefi and K. Stewart, "Networks and devices for the 5G era," IEEE Commun. Mag. IEEE Communications Magazine, vol. 52, no. 2, pp. 90-96, 2014.

[77] D. Bast, , A. Guevara, & S. Pollin, (2020). CSI-based positioning in massive MIMO systems using convolutional neural networks. In 2020 IEEE 91st Vehicular Technology Conference (VTC2020-Spring) (pp. 1-5). IEEE.

[78] D. Qiao, Y. Wu and Y. Chen, "Massive MIMO architecture for 5G networks: Co-located, or distributed?," 2014 11th International Symposium on Wireless Communications Systems (ISWCS), pp. 192 - 197, 2014.

[79] D. Gesbert, M. Kountouris, W. R. Heath, C.-B. Chae and T. Salzer, "Shifting the MIMO Paradigm," Signal Processing Magazine, IEEE, vol. 24, no. 5, pp. 36-46, 2007.

[80] F. Rusek, D. Persson, B. K. Lau, E. G. Larsson, T. L. Marzetta and F. Tufvesson, "Scaling Up MIMO: Opportunities and Challenges with Very Large Arrays," IEEE Signal Process. Mag. IEEE Signal Processing Magazine, vol. 30, no. 1, pp. 40-60, 2013.

[81] T. L. Marzetta, "Noncooperative Cellular Wireless with Unlimited Numbers of Base Station Antennas," IEEE Transactions on Wireless Communications IEEE Trans. Wireless Commun., vol. 9, no. 11, pp. 3590-3600, 2010.

[82] A. Pitarokoilis, S. K. Mohammed and E. G. Larsson, "On the Optimality of Single-Carrier Transmission in Large-Scale Antenna Systems," IEEE Wireless Commun. Lett. IEEE Wireless Communications Letters, vol. 1, no. 4, pp. 276-279, 2012.

[83] Y. Lin, L. Shao, Z. Zhu, Q. Wang and R. K. Sabhikhi, "Wireless network cloud: Architecture and system requirements," IBM Journal

of Research and Development IBM J. Res. & Dev., vol. 54, no. 1, pp. 4:1 - 4:12, 2010.

[84] S. Suyama, J. Shen and Y. Oda, "10Gbps outdoor transmission experiment for super high bit rate mobile communications," NTT DOCOMO Tech. J., vol. 15, no. 4, pp. 20-28, 2014.

[85] A. S. Khan, Y. Javed, J. Abdullah, J. M. Nazim, & N. Khan, N. (2017). Security issues in 5G device to device communication. IJCSNS, 17(5), 366.

[86] China Mobile Research Institute, "C-RAN The Road Towards Green Radio," 2011.

[87] U. Ozmat, M. Demirkol, & A. Yazici, (2020,). Service-based coverage for physical layer security with multi-point coordinated beamforming. In 2020 IEEE 25th International Workshop on Computer Aided Modeling and Design of Communication Links and Networks (CAMAD) (pp. 1-6). IEEE.

[88] B. Blanco, J. Fajardo, I. Giannoulakis, E. Kafetzakis, S. Peng, J. Pérez-Romero, & G. Xilouris, (2017). Technology pillars in the architecture of future 5G mobile networks: NFV, MEC and SDN. Computer Standards & Interfaces, 54, 216-228.

[89] H. Jiang and C. Dovrolis, "Why is the internet traffic bursty in short time scales?," ACM SIGMETRICS Performance Evaluation Review SIGMETRICS Perform. Eval. Rev., vol. 33, no. 1, p. 241, 2005.

[90] Y. Cuibo, I. Xiandong, L. Weiyang, Z. Xu, & G. Xuerong, (2015, August). Feasibility study for the LTE-advanced system. In 2015 4th International Conference on Advanced Information Technology and Sensor Application (AITS) (pp. 80-83). IEEE.

[91] 3GPP TR23.703, "Study on Architecture Enhancements to support Proximity Services (ProSe)," March 2014.

[92] A. Thanos, S. Shalmashi and G. Miao, "Network-assisted discovery for device-to-device communications," Globecom Workshops (GC Wkshps), 2013 IEEE, pp. 660 - 664, 2013.

[93] Y. Zhao, B. Pelletier, P. Marinier and D. Pani, "D2D neighbor discovery interference management for LTE systems," Globecom Workshops (GC Wkshps), 2013 IEEE, pp. 550 - 554, 2013.

[94] A. Thanos, "A Study of Network assisted Device-toDevice," KTH Information and Communication Technology, Stockholm, Sweden, 2013.

[95] S. Hakola, T. Chen, J. Lehtomaki and T. Koskela, "Device-To-Device (D2D) Communication in Cellular Network - Performance Analysis of Optimum and Practical Communication Mode Selection," Wireless Communications and Networking Conference (WCNC), 2010 IEEE, pp. 1 - 6, 2010.

[96] A. Osseiran, F. Boccardi, V. Braun, K. Kusume, P. Marsch, M. Maternia, O. Queseth, M. Schellmann, H. Schotten, H. Taoka, H. Tullberg, M. A. Uusitalo, B. Timus and M. Fallgren, "Scenarios for 5G mobile and wireless communications: the vision of the METIS project," IEEE Commun. Mag. IEEE Communications Magazine, vol. 52, no. 5, pp. 26-35, 2014.

[97] C.-P. Chien , Y.-C. Chen and H.-Y. Hsieh, "Exploiting spatial reuse gain through joint mode selection and resource allocation for underlay device-to-device communications," Wireless Personal Multimedia Communications (WPMC), 2012 15th International Symposium on, pp. 80 - 84, 2012.

[98] Nauman, A., Jamshed, M. A., Ali, R., Cengiz, K., & Kim, S. W. (2021). Reinforcement learning-enabled intelligent device-to-device (I-D2D) communication in narrowband Internet of Things (NB-IoT). Computer Communications, 176, 13-22.

[99] P. Baracca, F. Boccardi and N. Benvenuto, "A dynamic clustering algorithm for downlink comp systems with multiple antenna UEs," EURASIP J. on Wireless Commun. and Networking,, vol. 125, no. 1, pp. 1-14, 2014.

[100] B. Kaufman, J. Lilleberg and B. Aazhang, "Spectrum Sharing Scheme Between Cellular Users and Ad-hoc Device-to-Device Users," IEEE Transactions on Wireless Communications IEEE Trans. Wireless Commun., vol. 12, no. 3, pp. 1038-1049, 2013.

[101] M. N. Tehrani, M. Uysal and H. Yanikomeroglu, "Device-to-device communication in 5G cellular networks: challenges, solutions, and future directions," IEEE Commun. Mag. IEEE Communications Magazine, vol. 52, no. 5, pp. 86-92, 2014.

[102] G. Fodor, E. Dahlman, G. Mildh, S. Parkvall, N. Reider, G. Miklós and Z. Turányi, "Design aspects of network assisted device-to-device communications," IEEE Commun. Mag. IEEE Communications Magazine, vol. 50, no. 3, pp. 170-177, 2012.

[103] S. Lashgari and A. S. Avestimehr, "Timely Throughput of Heterogeneous Wireless Networks: Fundamental Limits and Algorithms," IEEE Trans. Inform. Theory IEEE Transactions on Information Theory, vol. 59, no. 12, pp. 8414-8433, 2013.

[104] S.-P. Yeh, A. Y. Panah, N. Himayat and S. Talwar, "QoS Aware Scheduling and Cross-Radio Coordination in Multi-Radio Heterogeneous Networks," 2013 IEEE 78th Vehicular Technology Conference (VTC Fall), pp. 1-6, 2013.

[105] T. Taleb, A. Ksentini, & R.Jantti, (2016). " Anything as a service" for 5G mobile systems. IEEE Network, 30(6), 84-91.

[106] A. Benjebbour, A. Li, Y. Kishiyama, H. Jiang and T. Nakamura, "System-level performance of downlink NOMA combined with SU-MIMO for future LTE enhancements," 2014 IEEE Globecom Workshops (GC Wkshps), pp. 706-710, 2014.

[107] K. Higuchi and Y. Kishiyama, "Non-orthogonal access with successive interference cancellation for future radio access," APWCS2012, 2012.

[108] N. Otao, Y. Kishiyama and K. Higuchi, "Performance of nonorthogonal access with SIC in cellular downlink using proportional fair-based resource allocation," Wireless Communication Systems (ISWCS), 2012 International Symposium, pp. 476-480, 2012.

[109] A. Li, A. Harada and H. Kayama, "Investigation on low complexity power assignment method and performance gain of non-orthogonal multiple access systems," IEICE trans. commun..

[110] K. Higuchi and Y. Kishiyama, "Non-orthogonal access with random beamforming and intra-beam SIC for cellular MIMO downlink," IEICE RCS2012-89, vol. 445, no. 465, pp. 85-90, 2012.

[111] J. Umehara, Y. Kishiyama and K. Higuchi, "Enhancing user fairness in non-orthogonal access with successive interference cancellation for cellular downlink," 2012 IEEE International Conference on Communication Systems (ICCS), pp. 324 - 328, 2012.

[112] H. Shariatmadari, R. Ratasuk, S. Iraji, A. Laya, T. Taleb, R. Jäntti and A. Ghosh, "Machine-type communications: current status and future perspectives toward 5G systems," IEEE Commun. Mag. IEEE Communications Magazine, vol. 53, no. 9, pp. 10-17, 2015.

[113] R. Ratasuk, S. Iraji, K. Hugl, L. Wang and A. Ghosh, "Performance of Low-Cost LTE Devices for Advanced Metering Infrastructure," 2013 IEEE 77th Vehicular Technology Conference (VTC Spring), pp. 1-5, 2013.

[114] K. Zheng, F. Hu, W. Wang, W. Xiang and M. Dohler, "Radio resource allocation in LTE-advanced cellular networks with M2M communications," IEEE Commun. Mag. IEEE Communications Magazine, vol. 50, no. 7, pp. 184-192, 2012.

[115] M. Condoluci, C. Dohler, G. Araniti, A. Molinaro and K. Zheng, "Toward 5G densenets: architectural advances for effective machine-type communications over femtocells," IEEE Commun. Mag. IEEE Communications Magazine, vol. 53, no. 1, pp. 134-141, 2015.

[116] Afrin, N., Brown, J., & Khan, J. Y. (2022). A Multi-Service Adaptive Semi-Persistent LTE Uplink Scheduler for Low Power M2M Devices. Future Internet, 14(4), 107.

[117] D. Astely, E. Dahlman, G. Fodor, S. Parkvall and J. Sachs, "LTE release 12 and beyond," IEEE Commun. Mag. IEEE Communications Magazine, vol. 51, no. 7, pp. 154-160, 2013.

[118] J. F. Monserrat, J. Calabuig, A. Fernandez-Aguilella and D. Gomez-Barquero, "Joint Delivery of Unicast and E-MBMS Services in LTE Networks," IEEE Trans. on Broadcast. IEEE Transactions on Broadcasting, vol. 58, no. 2, pp. 157-167, 2012.

[119] GSA, "Evolution to LTE Report," Information Papers, 2015.

[120] W. Zhang, Y. Wu, N. Hur, T. Ikeda and P. Xia, "FOBTV: Worldwide Efforts in Developing Next-Generation Broadcasting System," IEEE

Trans. on Broadcast. IEEE Transactions on Broadcasting, vol. 60, no. 2, pp. 154-159, 2014.
[121] J. Whitaker, "ATSC Update: New Technologies for Today and Tomorrow - SBE Chapter 24," 2012.
[122] J. Calabuig, J. F. Monserrat and D. Gomez-Barquero, "5th generation mobile networks: A new opportunity for the convergence of mobile broadband and broadcast services," IEEE Commun. Mag. IEEE Communications Magazine, vol. 52, no. 2, pp. 198-205, 2015.
[123] ATSC, "Summaries of Responses to ATSC 3.0 Physical Layer Call for Proposals," 2013.
[124] G. K. Walker, J. Wang, C. Lo, X. Zhang and G. Bao, "Relationship Between LTE Broadcast/eMBMS and Next Generation Broadcast Television," IEEE Trans. Broadcast., vol. 60, no. 2, pp. 185-192, 2014.
[125] DVB Project, "A Cooperation between 3GPP and the DVB Project on a Common Downlink-Only Standard?," in Proc. 6th 3GPP PCG meeting, Kansas City, 2011.
[126] N. Khan, A. Johari, & S. Adnan, (2017). A Taxonomy Study of XSS Vulnerabilities. Asian J. Inf. Technol, 16, 169-177..
[127] N. A. Khan, M. Y. Alzaharani, & H. A. Kar, (2020). Hybrid feature classification approach for malicious javaScript attack detection using deep learning. International Journal of Computer Science and Information Security, 18(5).
[128] "Network Functions Virtualisation – Introductory White Paper," in SDN and OpenFlow World Congress, Darmstadt-Germany, 2012.
[129] J. Mass, S. N. Srirama, H. Flores and C. Chang, "Proximal and social-aware device-to-device communication via audio detection on cloud," Proceedings of the 13th International Conference on Mobile and Ubiquitous Multimedia - MUM '14, pp. 143-150, 2014.
[130] R. Guerzoni, R. Trivisonno and D. Soldani, "SDN-Based Architecture and Procedures for 5G Networks," Proceedings of the 1st International Conference on 5G for Ubiquitous Connectivity, pp. 209 - 214, 2014.
[131] N. Khan, J. Abdullah, & A. S. Khan, (2017). A dynamic method of detecting malicious scripts using classifiers. Advanced Science Letters, 23(6), 5352-5355.
[132] R. Guerzoni, R. Trivisonno, I. Vaishnavi, A. Hecker, S. Beker and D. Soldani, "A novel approach to virtual networks embedding for SDN management and orchestration," 2014 IEEE Network Operations and Management Symposium (NOMS), pp. 1-7, 2014.
[133] A. Alshehri, N. Khan, A. Alowayr, & M. Y. Alghamdi,. (2023). Cyberattack Detection Framework Using Machine Learning and User Behavior Analytics. COMPUTER SYSTEMS SCIENCE AND ENGINEERING, 44(2), 1679-1689.
[134] Cisco System, Inc, "Cisco Visual Networking Index: Forecast and Methodology, 2009-2014," CA: Cisavaco System, Inc., FLGD 12353, San Jose, 2010.
[135] Nokia Solutions and Networks, "Technology Vision 2020, Technology Vision for the Gigabit Experience," Nokia Solutions and Networks Oy, Karaportti 3, ESPOO, Finland, 2013.
[136] A. Alqarni, N. Alsharif, Khan, N. A., Georgieva, L., Pardade, E., & Alzahrani, M. Y. (2022). MNN-XSS: Modular neural network based approach for XSS attack detection. Computers, Materials and Continua, 70(2), 4075-4085.
[137] C. Kim, M. Caesar and J. Rexford, "Seattle," ACM Trans. Comput. Syst. TOCS ACM Transactions on Computer Systems, pp. 1-35.
[138] M. Casado, M. J. Freedman, J. Pettit, J. Luo, N. Mckeown and S. Shenker, "Ethane," Proceedings of the 2007 conference on Applications, technologies, architectures, and protocols for computer communications - SIGCOMM '07, vol. 37, no. 4, p. 1–12, 2007.
[139] N. Varis, J. Manner and J. Heinonen, "A layer-2 approach for mobility and transport in the mobile backhaul," 2011 11th International Conference on ITS Telecommunications, pp. 268-273, 2011.
[140] N. Mckeown, T. Anderson, H. Balakrishnan, G. Parulkar, L. Peterson, J. Rexford, S. Shenker and J. Turner, "OpenFlow," ACM SIGCOMM Computer Communication Review SIGCOMM Comput. Commun. Rev., vol. 38, no. 2, pp. 69-74, 2008.
[141] T. Taleb, K. Samdanis and A. Ksentini, "Supporting Highly Mobile Users in Cost-Effective Decentralized Mobile Operator Networks," IEEE Trans. Veh. Technol. IEEE Transactions on Vehicular Technology, vol. 63, no. 7, pp. 3381-3396, 2014.
[142] R. A. Kantola, "Implementing Trust-to-Trust with Customer Edge Switching," 2010 IEEE 24th International Conference on Advanced Information Networking and Applications Workshops, pp. 1092-1099, 2010.
[143] A. Y. Ding, J. Crowcroft and S. Tarkoma, "a programmable approach toward collaborative mobile traffic offloading," MobiSys '14 Proceedings of the 12th annual international conference on Mobile systems, applications, and services, pp. 368-368, 2014.
[144] A. Y. Ding, P. Hui, M. Kojo and S. Tarkoma, "Enabling energy-aware mobile data offloading for smartphones through vertical collaboration," Proceedings of the 2012 ACM conference on CoNEXT student workshop - CoNEXT Student '12, pp. 487-495, 2013.
[145] J. Korhonen, T. Savolainen, A. Y. Ding and M. Kojo, "Toward network controlled IP traffic offloading," IEEE Commun. Mag. IEEE Communications Magazine, vol. 51, no. 3, pp. 96-102, 2013.
[146] B. Munch, "Hype Cycle for Networking and Communications, 2013," Gartner, Inc., Stamford, CT, Rep. 06902-7700, 2013.
[147] T. Tjelta, G. Millstein, O. Grøndalen, O. Østerbø, P. Lehne, P. Waldemar, P. Grønsund, K. Mahmood and H. Lønsethagen, "Research topics and initial results for the fifth generation (5G) mobile network," Proceedings of the 1st International Conference on 5G for Ubiquitous Connectivity, pp. 267-272, 2014.
[148] M. Satyanarayanan, P. Bahl, R. Caceres and N. Davies, "The Case for VM-Based Cloudlets in Mobile Computing," IEEE Pervasive Comput. IEEE Pervasive Computing, vol. 8, no. 4, pp. 14-23, 2009.
[149] X. Wu, S. Tavildar, S. Shakkottai, T. Richardson, J. Li, R. Laroia and A. Jovicic, "FlashLinQ: A synchronous distributed scheduler for peer-to-peer ad hoc networks," 2010 48th Annual Allerton Conference on Communication, Control, and Computing (Allerton), pp. 514-521, 2010.
[150] Li, J., Nagalapur, K. K., Stare, E., Dwivedi, S., Ashraf, S. A., Eriksson, P. E., ... & Lohmar, T. (2021). 5G New Radio for Public Safety Mission Critical Communications. arXiv preprint arXiv:2103.02434.
[151] O. Onireti, A. Zoha, J. Moysen, A. Imran, L. Giupponi, M. Imran and A. Abu Dayya, "A Cell Outage Management Framework for Dense Heterogeneous Networks," Vehicular Technology, IEEE Transactions, vol. PP, no. 99, pp. 1-1, 2015.
[152] H. Ishii, Y. Kishiyama and H. Takahashi, "A novel architecture for LTE-B :C-plane/U-plane split and Phantom Cell concept," 2012 IEEE Globecom Workshops, pp. 624-630, 2012.
[153] H.-S. Park, Y.-S. Choi, B.-C. Kim and J.-Y. Lee, "LTE Mobility Enhancements for Evolution into 5G," ETRI J ETRI Journal, pp. 1065-1076, 2015.
[154] L. Yan and X. Fang, "Reliability evaluation of 5G C/U-plane decoupled architecture for high-speed railway," EURASIP J Wirel Commun Netw EURASIP Journal on Wireless Communications and Networking, p. 127, 2014.
[155] H. Mounir, Cognitive radio oriented wireless networks 2015, Place of publication not identified: Springer, 2015.
[156] M. Olsson, C. Cavdar, P. Frenger, S. Tombaz, D. Sabella and R. Jantti, "5GrEEn: Towards Green 5G mobile networks," 2013 IEEE 9th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob), pp. 212-216, 2013.
[157] W. Chin, Z. Fan and R. Haines, "Emerging technologies and research challenges for 5G wireless networks," IEEE Wireless Commun. IEEE Wireless Communications, vol. 21, no. 2, pp. 106-112, 2014.
[158] A. Mohamed,, M. Imran, and R. Tafazolli, "ENERGY EFFICIENT 5G NETWORK WITH LOGICAL SEPARATION," 5G Innovation Centre, University of Surrey Guildford, Surrey GU2 7XH, United Kingdom, 2015.
[159] Z. Ma, Z. Zhang, Z. Ding, P. Fan and H. Li, "Key techniques for 5G wireless communications: network architecture, physical layer, and MAC layer perspectives," Science China Information Sciences Sci. China Inf. Sci., vol. 58, no. 4, pp. 1-20, 2015.

REVIEW ARTICLE

[160] I. Chih-Lin, C. Rowell, S. Han, Z. Xu, G. Li and Z. Pan, "Toward green and soft: a 5G perspective," Communications Magazine, IEEE, vol. 52, no. 2, pp. 66-73, 2014.

[161] H. Mustafa, M. Imran, M. Shakir, A. Imran and R. Tafazolli, "Separation Framework: An Enabler for Cooperative and D2D Communication for Future 5G Networks," Communications Surveys & Tutorials, IEEE, vol. PP, no. 99, pp. 1-1, 2015.

[162] V. Bhargava, "Millimetre wave bands for 5G wireless communications," High Mobility Wireless Communications (HMWC), 2014 International Workshop , pp. 2-2, 2014.

[163] W. El-Beaino, A. El-Haji and Z. Dawy, "On Radio network planning for next generation 5G networks: A case study," Communications, Signal Processing, and their Applications (ICCSPA), 2015 International Conference, pp. 1-6, 2015.

Author

Nayeem Ahmad Khan received the Ph.D. degree in computer science from University Malaysia Sarawak, in 2018. He is currently working as an Assistant Professor with the Faculty of Computer Science and Information Technology, Al Baha University, Al Baha, Saudi Arabia. He is an expert on attacks on critical infrastructures and has led many research projects. His research has been published in several reputed international journals and he has presented his research findings at many international conferences. He has several patents to his name. His research interests include cybersecurity, cyber intelligence and analysis, unmanned aerial vehicles, deep learning, and the Internet of Things. He has won many awards, fellowships, grants, and appreciations for his work and has written a remarkable book on malicious JavaScript attack detection using machine learning. He has been a reviewer of many high impact journals and has been the chair and the co-chair for many conferences and technical sessions.

How to cite this article:

Nayeem Ahmad Khan, "5G Network: Techniques to Increase Quality of Service and Quality of Experience", International Journal of Computer Networks and Applications (IJCNA), 9(4), PP: 476-496, 2022, DOI: 10.22247/ijcna/2022/214508.