A Comprehensive Survey of 5G mm-Wave Technology Design Challenges

Article *in* Asian Journal of Computer Science and Information Technology · April 2021

DOI: 10.9734/AJRCOS/2021/v8i130190

7 authors, including:

Subhi R. M. Zeebaree
DPU

Rizgar Zebari

Mohammed A. M.Sadeeq
Duhok Polytechnic University

Amira Bibo Sallow
Duhok Polytechnic University

Asian Journal of Research in Computer Science

8(1): 1-20, 2021; Article no.AJRCOS.68058
ISSN: 2581-8260

A Comprehensive Survey of 5G mm-Wave Technology Design Challenges

Bahzad Taha Jijo[1*], Subhi R. M. Zeebaree[1], Rizgar R. Zebari[2], Mohammed A. M. Sadeeq[1], Amira B. Sallow[2], Sanaa Mohsin[3] and Zainab Salih Ageed[2]

[1]Duhok Polytechnic University, Duhok, Kurdistan Region, Iraq.
[2]Nawroz University, Duhok, Kurdistan Region, Iraq.
[3]University of Information Technology and Communication, Baghdad, Iraq.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJRCOS/2021/v8i130190
Editor(s):
(1) Dr. G. Sudheer, GVP College of Engineering for Women, India.
Reviewers:
(1) Dr. G. Sudheer, GVP College of Engineering for Women, India.
(2) R. Vadivel, Bharathiar University, India.
(3) J. Ramkumar, VLB Janakiammal College of Arts and Science, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/68058

Review Article

Received 20 February 2021
Accepted 24 April 2021
Published 26 April 2021

ABSTRACT

Physical layer protection, which protects data confidentiality using information-theoretic methods, has recently attracted a lot of research attention. Using the inherent randomness of the transmission channel to ensure protection in the physical layer is the core concept behind physical layer security. In 5G wireless communication, new challenges have arisen in terms of physical layer security. This paper introduces the most recent survey on various 5G technologies, including millimeter-Wave, massive multi-input multiple outputs, microcells, beamforming, full-duplex technology, etc. The mentioned technologies have been used to solve this technology, such as attenuation, millimeter-Wave penetration, antenna array architecture, security, coverage, scalability, etc. Besides, the author has used descriptions of the techniques/algorithms, goals, problems, and meaningful outcomes, and the results obtained related to this approach were demonstrated.

**Corresponding author: E-mail: bahzad.taha@dpu.edu.krd;*

Keywords: 5G; millimetre wave; massive MIMO; beamforming; small cells.

1. INTRODUCTION

Information and Communication Technology had substantial effects on human life. Nowadays, most daily life routines can be achieved using Internet services [1]. Fifth-generation (5G) is a mobile networking system intended to have more significant data bandwidth and speeds than the previous Long Term Evolution generation (LTE) [2]. 5G infrastructure provides incredibly low latency and extremely high reliability, allowing revolutionary technologies across different sectors of the industry [3]. Expanded Mobile Broadband (eMBB), central machine-type communications (mMTC), ultra-reliable low-latency (URLLC) communications, and fixed wireless connectivity, such as fiber, are services of this generation [4,5].

Millimeter-Wave communications Bandwidth growth is a successful way to accommodate the rapid rise in data speeds, especially those in 5G devices up to tens of Gbps [6]. Much of the now wholly occupied cellular networks run below 3 GHz [7,8]. The discovery of the rich millimetre wave (mm-Wave) frequency range ranging from 3 to 300 GHz has been inspired by bandwidth shortages [9]. Massive Multiple-Input Multiple-Output (MIMO) is an evolving technology upgraded from the latest technology of MIMO [10]. The Massive MIMO system utilizes antenna arrays containing several hundred antennas, which are frequency slots servicing several thousands of user terminals simultaneously. Massive MIMO technology's fundamental aim is to extract all of MIMO's advantages but on a broader scale [11]. Single-User MIMO (SU-MIMO) has been implemented in Long-Term Evolution (LTE) to improve spectrum utilization in the multiple antenna modes of time division and frequency division. LTE-Advance integrates multiuser MIMO technology with a total of 8x8 MIMO to fulfil the International Mobile Telecommunication Advanced Criteria (IMT-A) [12,13].

Beam-forming is simply a spatial filtering process that generally uses various radiators to absorb or radiate radiation over the aperture in a particular direction. Transmit/receive gain is the benefit gained over omnidirectional transmission/reception [14,15]. Intelligent antenna systems have been implemented by advanced communication systems and can incorporate array gain with variable gain and interference reduction to improve the communication link's power [16]. Using a phased array, a multi-element radiation system with a particular geometric configuration, mechanical beam steering does this [17].

The microcells are named Picocells, femtocells, and small cells occupying 100s to 10s of meters. Particularly in 5G networks, the narrow coverage area as the principal technology gives higher data transfers and offers greater network flexibility for smartphone users [18,19]. For a small cell, the simple concept is to put the access cells as close to the smartphone users as possible [20]. As a result of inadequate coverage, these small cells reach smartphone consumers with low transmission capacity [21]. Therefore, in the streets, on trees, and on lampposts, small cell base stations can be located. Under the small cell principle, the key idea is to maximize the spectrum's reuse to improve network availability [22]. Properties in waves of thousands. Millimeter waves are the generally specified electromagnetic waves in the frequency spectrum of 30 and 300 GHz. The range is usually specified to include the 3–30-G Hz range just below the millimeter-wave range [23].

In this paper, a comprehensive review is performed for the latest and most efficient approaches that have been performed by researchers in the past five years, about 5G in different areas. Also, the details of this method, such as using algorithms/techniques, approaches, and results, are summarized. Furthermore, the researcher highlighted the most widely used approaches.

The remainder of this paper has organized as shown. Section 2 describes Background Theory, which contains an overview of the 5G technology, mm-Wave characteristics, and Benefits and drawbacks of 5G technologies. In Section 3, a Literature Review of numerous facets of recent 5G research studies has included. Section 4 contains a Comparison and Discussion on 5G and finally presents our concluding remarks in Section 5.

2. 5G MM-WAVE TECHNOLOGY

2.1 Evolution of Fifth-generation (5G) Wireless Technology

Mobile networking refers to infrastructure for the support by cellular radios of voice and/or data network communication. Cell telephone is the best-known app for mobile networking. In modern times, however, both speech and data have been transmitted over circuit- and packet-switched systems, mostly using wireless networking to transport voice over a network.

First Generation (1G) 1981 – Launching of the NMT: Analog transmission was the basis for the first handheld networks. They used an inappropriate and unencrypted transmission that resulted in identity defilements and low traffic density via radio, weak voice quality [24].

Second General Generation (2G) 1991 – Introduction of the GSM system: Digital Transmission with various specifications was the basis for the second generation of mobile networks (GSM, ERMES, CT2, CT3, DCS 1800, DECT). The most common format in use today, using 900MMHz and 1800MHz bands, is the GSM (Global System for Mobile) Connectivity. Digital transmission with SIM technology was created by GSM mobile systems to authenticate the customer for identity and accounting purposes and encrypt the data to avoid eavesdropping. TDMA (Multiple Access Time Division) and CDMA One (Multiple Access One Code Division) strategies are used to maximize information transferred through the network. Layer 2, which forbids seamless roaming via heterogeneous access networks and routing regions, is enabled for mobility. This ensures that any operator must protect the whole region or have roaming arrangements in place [24].

Bridge 2 to 3rd generation (2.5G) 2000 – GPRS starts: 2000 GPRS is used as an additional time between 2G and 3G for the growth of mobile networks. GPRS is a data service that allows mobile users to write, retrieve and display emails and images. This makes very common operation rates up to 115 kbit/s which have been improved by EDGE (Enhanced Global Evolution Data Rates – see http://www.attwireless.com), up to a limit of 384kbit/s. Typical GSM data transfer speeds of 9.6 kbit/s were met [24].

2003 3G – First UK 3G launch: 3G First Generation (3G) The third generation of Mobile Networks brings together diverse technologies for mobile infrastructure which uses higher frequency bands to provide data speeds of up to 2Mbit/s in order to enable multimedia services (MMS: voice, video and data). UMTS is the EU standard (Universal Mobile Telecommunication Systems). For billing systems and data encryption mobile systems prefer to use wireless transmission with SIM authentication [24].

WCDMA is used to transmit data (Wideband Code Division Multiple Access). The way of achieving 384 kbit/s to 2048 kbit/s data speeds. For its 'over the air' network with MPLS (multiple protocol label Switching) or IP for its backbone network, some 3G suppliers use ATM (synchronous transfer mode). Layer 2 only supports mobility and thus bans smooth roaming through heterogeneous networks with connectivity and routing realms including 2G. The frequencies of broadcasting bands range from 1900 to 2200 MHz. Both UMTS licensees in the UK retain 20 years' licence, subject to 80% population coverage by 31 December 2007. The current authorized operators of the third generation in the UK can be found below (as at August 2004) [24].

Fourth Generation (4G) 2007+: 4G is still in the field of science. It is built on an ad hoc networking model, in which a fixed infrastructure operation is not essential. Ad hoc networking includes global mobility (e.g. handheld IP) and global IPv6 network access to accept an IP address on any mobile device [25]. With higher data speeds from 2 Mbit/s to 10–100 Mbit/s, seamless roaming can be provided on heterogeneous IP networks (eg. 802.11 WLAN, GPRS and UMTS). Since mobile devices do not depend on a fixed structure, enhanced intelligence is needed for ad hoc networks to auto-configure and routing using a packet-based network [24].

Table 1. Merits and demerits of different networks generations [24]

	Hutchison	Vodafone	O2	T-Mobile	Orange
UK frequency	1,885 – 2,025MHz, 2,110 – 2,200MHz				
UK coverage	60% pop	60% pop	N/A	60% pop	66% pop
UK launch	May 2003	Feb 2004	forthcoming	July 2004	July 2004
3G services	Phone-based voice, Video	Data card	Data card	Data card	Data card

4G can now easily be replaced by 5G with an innovative access technology dubbed Beam Division Multiple Access (BDMA) and Non- and Quasi-orthogonal or Filter Bank Multi-Carrier (FBMC) Multiple Access, with exponential growth in device demand. By considering the situation of the base station interacting with the mobile stations, the theory behind the BDMA technique is clarified [26]. The idea of going to 5G has focused on existing drifts. It has widely believed that 5G wireless networks need to resolve six problems that 4G does not address effectively, i.e. higher bandwidth, higher data rate, lower end-to-end latency, massive connectivity of applications, reduced costs and reliable provisioning of quality of experience [27,28].

Nuclear radiation detection mechanism using millimeter waves as an alternative to conventional detection. It is based on the concept that nuclear radiation causes ionization of air and that if we place a dielectric material near the radiation source, it acts as a charge accumulator of the air ions [29]. It has been found that millimeter waves can interrogate the charge cloud on the dielectric material remotely [30].

2.2 Network Architecture of 5G: [31-33]

1. Radio-links the growth of emerging transmission waveforms and new developments in radio services and various access management.
2. Multi-antenna and Multi-node transmissions explain the highly evolved inter-node management systems and multi-hop and multi-antenna transmitting or receiving technology schemes focused on antenna installation arrays.
3. Network dimension identifies the need for an appropriate intrusion organization method in a heterogeneous network, agility management and traffic control, and various schemes.
4. Spectrum usage the existing working spectrum band and the expanded operating spectrum band have described; the use of each band growth has also described along with this.
5. Direct Device-to-Device (D2D) communication: refers to direct communication between devices (i.e., users) without data traffic going through any infrastructure node, has been widely foreseen to be an important cornerstone to improve system performance and support new services beyond 2020.
6. Massive Machine Communications (MMC): The wide variety of uses for the Internet covers topics such as surveillance services, patient care, vending machines for mobile devices and vehicles.
7. Moving Networks (MN): Connecting theoretically large communities with mutually travelling networking gadgets would strengthen and extend.
8. Ultra-dense Networks (UDN): Expands or attempts to allow efficient use of the under-used spectrum and improve the ability to increase the energy efficiency of radio links. Ultra-reliable (URN) networks can allow a high level of connectivity.

The 5G network architecture has illustrated in "Fig. 1 ".

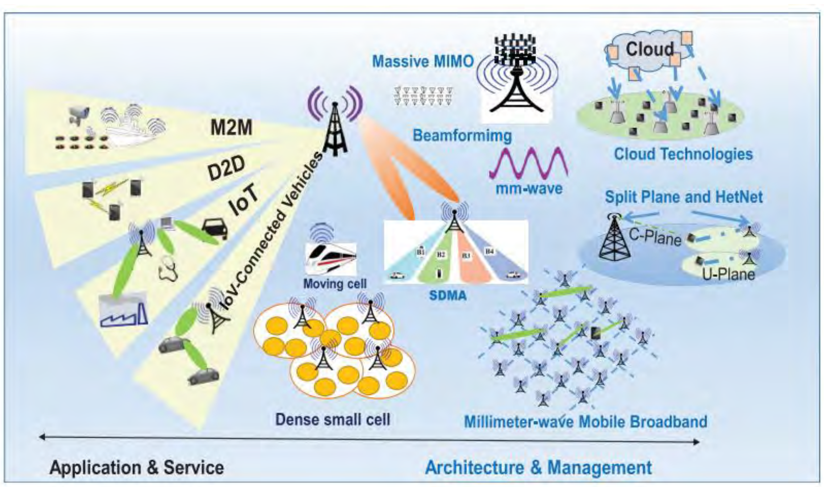

Fig. 1. Schematic diagram of 5G wireless networks [34]

The 5G network architecture mechanism includes the central and local server operation which provides users with quicker content, and low latency applications. The 'Radio Access Network' and the 'Core Network' have two major elements for a mobile network. The Radio Access Network consists of several types of equipment, including small cells, antennas, masts and dedicated building networks and home systems connecting smartphone users and cellular devices to the central network itself. Small cells are a key element of 5G networks particularly for the latest millimeter wave frequencies (mmWave), which have a very limited communication range. Small cells are spread in clusters to provide continuous connectivity, depending on where users need connection which supplements a large-area macro network [34]. 5G Macro Cells can use MIMO antennas, which have multiple elements or links, to simultaneously transmit and receive further data. The advantage for consumers is that more participants will connect to the network at the same time and retain high performance. Where MIMO antennas use very many antenna components frequently referred to as "mega MIMO," the spatial dimension of the antennas in the base station 3G and 4G is identical. Core Network the cellular network for exchanging and managing both telephone voice, data and internet accesses. The 'heart network' has been revamped for 5G to connect better with internet and cloud-based networks, and also incorporates dispersed servers across the network that improve response speed (reducing latency). Many of 5G's innovative technologies such as network features and network slicing can be handled in the heart of a variety of software and services. Examples of local cloud servers that provide faster users (movie streaming) and lower-latency systems for vehicle collision prevention are provided in the illustration below [35].

2.3 Technology of 5G mm-Wave

Features of 5G mm-Wave Technology have described in "Table 2" [10,31].

2.4 Wireless Technology

The developments of wireless technology from 1G to 5G have shown in "Table 3" [36].

2.5 Benefits and Drawbacks of 5G mm-wave Technology

Benefits and drawbacks of 5G mm-wave Technology have demonstrated in "Table 4" [10]:

The most important consideration of the 5G threat landscape is that it includes far more than the volumetric DDoS attacks and signaling protocol-specific hacks of the past. It also includes advanced persistent threats, lateral propagation, web application layer vulnerabilities, API security, and more. As a result, service providers need to ensure that the diverse set of security requirements imposed by this new architecture along with the related use cases and services supported by their core networks can be adequately addressed by their security solutions. And they need to be part of a single security framework rather than a separate, isolated set of solutions that can cause additional overhead as well as issues related to configuration and orchestration. Ensuring that these solutions are fully integrated and automated ensures consistent and effective security to protect infrastructure assets and revenue generating services [37].

Table 2. Description of 5G mm-wave technology

Features	Description
Data rate	more than 10Gbps
Frequency Bands	Bands that range from 30 GHz to 40 GHz to 100 GHz
Bandwidths	Instead of carrier aggregation at 40 GHz and 500 MHz to 2 GHz bandwidth, ten subcarriers of 100 MHz each will have 1GHz bandwidth, without carrier aggregation at 40 GHz.
Distance coverage	Two indoor meters to 300 outdoor meters
Modulation types	CP-OFDMA < 40GHz SC >40GHz
Frame topology	Duplex of Time Division

Table 3. Developments of wireless technology

Name	**1G -1st Generation Technology**	**2G -2nd Generation Technology**	**3G - 3rd Generation Technology**	**4G -4th Generation Technology**	**5G - 5th Generation Technology**
Launched in Year	The 1980s	1993	2001	2009	2020
Switching network	Circuit	Circuit switching and Packet switching	Packet switching	All Packet	All Packet
Technology used	Analog	Digital	CDMA 2000	Wi-Fi, WiMAX	www
Data Bandwidth	2kbps	64kbps	2Mbps	1Gbps	Higher than 1Gbps
Quality of Service (QoS)	Voice	SMS, Digital Voice, high	High-Quality video, audio,	Wearable devices	Devices with AI capability
Multiplexing	FDMA	CDMA, TDMA	CDMA	CDMA	OFDM, CDMA

Table 4. Benefits and drawbacks of 5G

Benefits	Drawbacks
1. Can support more subscribers due to more capacity available. 2. Fast bandwidth in the range of only millimetres such that small cell implementation is appropriate. 3. In the 5G network, sounding qualities have used to avoid error channels to operate appropriately at mm-wave frequencies. 4. Because of their limited physical scale, a considerable amount of antennas may be bundled. This contributes to the ability being strengthened by massive MIMO in AP. 5. 5G mm-wave supports up to four hundred meters of multi-gigabit backhaul and broadband connectivity up to 200-300 meters.	1. Mm-waves suffer various failures, including penetration, rain attenuation, and so on. This restricts the availability of mm-wave range coverage in 5G cellular network deployments. Besides, depending on channel conditions and above-ground AP/eNB height, it supports 2 meters indoors and about 200-300 meters outdoors. 2. supports the dissemination of LOS (Line of Sight). As a result, coverage has limited to LOS. 3. Vegetation degradation is significant at mm-wave frequencies. 4. Because more RF modules due to more antennas, power usage is higher at mm-wave.

5G presents service providers with tremendous opportunities for new business growth in the area enterprise services. However, these new services will require the adoption of virtual and cloud-based technologies that will open up an entirely new set of challenges and risks to the infrastructure and services. To succeed in the highly competitive 5G market, Service Providers will have to adopt a rapid architectural shift to open, virtual, and cloud infrastructure. Securing such a hybrid ecosystem calls for broad, integrated, and automated capabilities only found in a security fabric approach [37].

2.6 Information and Communication Technology

Due to the massive data exchanged among large numbers of connected devices to form the ICT which is the core of IoT, the need to provide extremely increased capacity, high data rate and high connectivity is increased. Thus, 5G wireless networks considered as a key driver for ICT and in turn to IoT. The fifth generation is supposed to make a few crucial improvements: reduce latency (i.e., response time) to allow for real-time communication, as well as improve data transfer, especially upstream speeds [38].

The advancement of education one significant predictor of a country's educational modernization is information and communication technology (ICT) [39]. Rapid social growth in China necessitates the continuous improvement of its education system, which has seen an increase in ICT use [40]. The improved ICT implementation is expected to aid in the modernization of Chinese elementary and secondary education[41]. ICT advancement of education assists the Chinese education system in meeting the demands posed by rapid economic and social change, as well as the growing need for education to be open to everyone [42]. It has been reported that there are issues with the Chinese education system, and that the system needs substantial reform [43]. Curriculum reform is critical in transforming Chinese education, and education ICT will help [44]. With the advancement in modern education ICT, the use of multi-media computers and the Internet in schools is growing, which is conducive to a holistic curriculum change. [45].

Information and communication technologies (ICT) have been tremendously influenced by developing knowledge exchange and the flow of information and communications in our lives (professional, and personal) [46]. Continuous progress of ICT has created countless problems for people [47]. ICT has transformed organizational job structures, causing paradigm changes in the educational area and changing instructional practices for students [48]. The former includes cellular, speech, postal, radio, and television systems and networks, while the latter comprise the hardware and software necessary for collecting, storing, processing and presentation of information [49,50]. Women's liberation and social education have been key sustainability tools and the use of technology in enhanced learning raises women's capacity for contributing to society [51]. The ICT center consists of software, computers, networks, and media, mostly used for the collection, presentation, processing, storage and transmission of information via spoken, documents, text and images. Sustainability 2020, 12, 5052, at www.mdpi.com/journal/sustainability:10.3390/su12125052 2020, 12, 5052 Sustainable 2 out of 18 and other programs. 2 out of 18 The information and communication infrastructure are two components of ICT (ICI and ICT) [52,53]. The use of ICT in technological improved learning infrastructure makes it possible to use ICT technologies and their mechanisms for effective education sustainability. In several countries, the provision of ICT facilities is one of the major educational issues [54,55]. The final impact of ICT on the future of education remains to be found. Improved sustainable ICT education is characterized as the application of ICT in learning and education, which promotes information development, learning and teaching [56]. The use of new ICTs and enhanced technology learning (TEL) instruments in sustainability education, while retaining international standards of training, is a response to this issue. Of course, ICT's commitment to quality education has been enormous [57,58]. This has contributed to improved teaching and learning with dynamically immersive, entertaining content and has opened possibilities for individual instruction [59].

ICT analysis has not provided an overview of the current situation, as it focuses principally on certain advanced countries. Evaluation is, in general, an important part of education, preparation and learning [60]. Evaluation is a vital element in the commitment of students, and it has a critical effect on learning and qualification [61]. Despite the ubiquity of ICT applications, little research has taken place into the contributing aspects of ICT fulfillment in terms of the viability of tertiary education. Satisfaction is the most well-known indicator of teaching efficiency and usefulness [62]. Despite the importance of technology in encouraging effective instructions, it has been shown that students cannot often use technology to optimize its impact on teaching and learning [63]. In these cases, happiness may be one of the reasons why students do not always use ICT for university teaching and study [64]. However, the gratification of teachers in using ICT in the sense of sustainable education is hardly evaluated. Lack of an evaluation would not show how best teachers can be trained and supported in successful integration of technologies in learning and training [65]. Thus, the basis for evaluating and planning technology adoption training is to evaluate the uses and attitudes of ICT among students in order to determine to what degree they follow the available ICTs and are pleased with them [66,67]. Therefore, the thesis aims to research the purpose and happiness of the students to use (SIU-ICT) ICT (SIU-ICT) [68]. This thesis supports literature on the TAM by examining the relationship between TAM factors, SIU-ICT and student satisfaction (SS) with ICT [69].

3. LITERATURE REVIEW

Several experts have discussed the challenges and solutions of 5G in the network infrastructure in recent years. The critical points of some of the most recent research will be discussed in detail in this section.

Chen [70] presented the 5G mm-Wave communication system requirements and the radio frequency (RF) architecture design considerations. For the 5G mm-Wave front-end module, he addressed the challenges of design and growth patterns. He used four antennae (8/16/32/64) hybrid beamforming architecture for mm-wave 5G base station (gNB) and user equipment (UE). He also used a beam-tracking algorithm to enable mobile transmission over 100 Km/hr. The results showed that the highly scalable and versatile millimetre-wave wideband platform developed by the Research Institute of Industrial Technology (ITRI) benefits from the advancement of 5G technologies and the rapid introduction of new technologies realistic solution. Besides, a beam-tracking algorithm has been developed to enable 100Km/hr cell transmissions.

Al-Ogaili and Shubair [71] showed the functionality of the mm-Wave expansion channel, and the key issues were illustrated with the advantages and solutions associated with the use of mm-Waves. To solve the attenuation problem due to atmospheric absorption, rain, and vegetation, they used Ultra-Dense Networks (small cell deployment) and Massive multiple-input multiple-output (MIMO) systems. The findings indicated that the integration of massive MIMO, mm-Wave, and small cells could be considered in the primary technology solutions of 5G mobile communication.

Qi et al. [72] Offered an overview of the Over-The-Air (OTA) measurement problems of the new fifth-generation (5G) wireless system. They also presented various primary 5G OTA measurement technologies that could be used more, including anechoic chamber absorbers, sampling antennas, and transition from near-field to far-field. User equipment, chipsets, and active array systems) for 5G OTA are the primary Devices Under Test (DUT). The challenges of OTA measurements may have a significant effect on electromagnetic compatibility (EMC). For 5G systems, the Radio Frequency (RF) and EMC tests are both definitive. The results illustrated a summary of the 5G OTA test's current success, future directions, and status. The EMC group should therefore be well-positioned to take advantage of the opportunities and difficulties.

Ansari et al. [73] presented a survey of current parts-related methodologies such as network discovery, Device-to-Device (D2D) network protection, disturbance management, and proximity services. They addressed the issues associated with 5G D2D networks that will impact system implementation as mobile device density rises as data rate requirements increase. Coordinated Multipoint (CoMP) technology has used the zero-forcing algorithm to reduce intercom interference between a Cellular User (CU) and a D2D user. The findings showed that the techniques have explored in the sense of a resource-efficient and stable D2D network has provided—moreover, some of the evolving sides of D2D networks.

Zhang et al. [74] introduced the current state of the art, challenges, and research opportunities for mm-Wave communication with Unmanned Aerial Vehicles (UAV). It also presented its modelling problems and showed the features of the Channel. Besides, the potential solutions for UAV mm-Wave cellular networks and issues, including spectrum sharing, UAV-to-base-station, and UAV-to-user communications, were prepared. They used a UAV MIMO system under line-of-sight (LOS) conditions to solve the severe channel difference problems. The emulation results show that the received signal strength (RSS) matches a small number of scatters in the two-ray propagation model. However, in dense dispersions and a high-altitude urban climate, simulation results detect that RSS undergoes rapid changes. This means that in terms of stability durability, durability, and spectral performance, UAV and mmWave communications analysis provides enormous benefits.

Polese et al. [75] presented the most recent standardization activities on Integrated Access, and Backhaul (IAB) clarified and architectures without IAB in mm-Wave implementations. Besides, IAB used end-to-end system-level simulations to illustrate the advantage of cell edge throughput given. To address mm-Wave limitations, such as penetration losses and extreme paths, they used high gain antennas by increasing the connection budget. The results indicated that the IAB provides a viable solution for efficient transport of cell edge traffic, although the benefits for more crowded networks have reduced.

Zugno et al. [76] Provided an analysis of the current standardization efforts at waves for vehicular communications reveals parallels and differences between IEEE 802.11bd and (3GPP NR V2X) 3rd Generation Partnership Project are standardizing next-generation networks for vehicular applications. To address the challenges of expansion from the application layers to the physical layers, they used the End-to-End (E2E) approach to build mm-Wave Vehicle-to-Vehicle (V2V) networks. The results showed that a preliminary E2E execution estimate of the mm-Wave E2E communication system was present, taking into account various spread environments, coding schemes (MCS), modulation, and carrier frequencies.

Yang et al. [77] Explored the importance of numerous hardware constraints. They suggested a new device architecture that can release these hardware constraints while achieving improved performance for future communication systems with millimetre waves. More importantly, these analogue ingredients are typically imperfect because they introduce numerous hardware imperfections and production errors. Additionally, Hardware limitations and vulnerabilities will roughly affect the execution of mm-Wave systems. To address traditional hardware limitations such as phase noise, PA nonlinearities, IQ imbalance, they used the incorporation of a few high-precision phase shifters into the mixed beamforming network. The results showed that the design of the hardware-aided system, which contrasts the consistent relationship between software and hardware units and adaptability, provides greater flexibility for state of art.

Busari et al. [78] introduced the combined influence of the three major Ultra-Dense Network technologies (UDN), massive MIMO, and mm-Wave (and/or terahertz) communications. They also used machine-level emulations with 3-Dimensional (3D) channel models of the Third Generation Partnership Project (3GPP). They estimate the execution of two-tier cellular networks of mm-Wave small cells and mm-Wave macro cells densely deployed. Compared to only large cell environments, the results showed that a much higher capacity could be accomplished with UDNs. The results also show that execution does not scale proportionally by raising the used mm-Wave bandwidth. The consistent increase in noise decreases the Signal-to-Interference-plus-Noise Ratio (because of wider bandwidths) (SINR).

Huo et al. [79] presented the crucial 5G User Equipment (UE) hardware design constraints on circuits and networks and addressed the latest wireless UE hardware design. Besides, a Distributed Phased Array-based MIMO (DPA-MIMO) has been proposed, which is a new highly reconfigurable 5G cellular UE system architecture. To get over the limitations of cell phone design, such as high path loss, human blockage, self-heating problems, they used a novel DPA-MIMO architecture and design process. The results found that the wireless UE based on DPA-MIMO can be executed using state-of-the-art antennas, devices, and circuit technologies. Consequently, this design will ease a peak throughput of more than 10 Gb/s while retaining mobile station devices with a slim form factor.

Zhang et al. [80] explored the problems involved in designing the antenna array structure for future 5 G mmWave systems. In addition to the traditional rectangle, the antenna components can be propagated in the forms of a cross, circle, or hexagon. The critical drawbacks to some outdoor scenarios for the use of mm-Wave technology include communication protection, forests, and hardware growth. In order to overcome these challenges, they used highly dense relays and massive MIMO. The result showed the advantages of the circular antenna array, which has a robust misalignment of the beam and is a flat fluctuation of gain. Besides, optimistic candidate solutions such as multi-hop relaying have discussed, and distributed antenna system solutions have discussed to preserve the connectivity and efficient coverage of mm-Wave networks vulnerable to repeated blockages (DAS).

Feng et al. [81] developed a centred on global and manageable device architecture, a new framework for 5G mm-wave transporters. The system discussed involves ambitious physical layer strategies, such as hybrid beam formation and full-duplex transportation, with higher layer routing and scheduling schemes. Specifically, by providing an optimization study, they solve the challenges of transport channel selection and time distribution in mm-wave transporters and perform the same algorithmic analysis. The outcome showed that the advantages of the design process proposed were beneficial. The routing and scheduling schema, which combines a modern mm-wave physical layer strategy, has shown much higher productivity, shorter lateness and a lower packet loss ratio than the presented 5G backhaul.

Lee et al. [82] defined the general spectrum status for 5G, both below and above 6 GHz, in both the organizer and technical components. In particular, the technological shortcomings of 5G support in the mm-Wave range were addressed, such as the coverage of problems and application aspects. In order to address coverage problems, they used beamforming methods. Besides, through improved hardware design, execution limitations were resolved. The results demonstrated that advanced antenna solutions are significant enablers for both base stations and mobile systems.

Liu et al. [83] The behaviour of the High-Speed Train (HST) channel measurements and advanced HST channel models was defined in numerous circumstances and frequency bands. Besides, a new frequency non-stationary of the HST channel model is being studied. They used the combination of mm-Wave and massive MIMO to resolve the (frequent and quick handover, broad Doppler spread) limitation and provide 5G and beyond HST connections model seamless connectivity. The results revealed that the technologies of opportunity, such as massive MIMO, mm-Wave, and beamforming, are believed to support reliable broadband HST communication services.

Bai et al. [84] displayed the principles and structures of collaborative multi-satellite transport strategies in 5G. Furthermore, two multi-satellite relay transmission systems based on Time-Division Multiple Access (TDMA) and Non-Orthogonal Multiple Access architectures have shown (NOMA). They used the routing algorithm to address significant problems such as resource management and access to achieve higher network capacity for hybrid terrestrial-satellite backhaul networks. The results showed that Maximum Effective Capacity (MEC)-based time scheduling outperformed the other two strategies under any quality-of-service demands. Consequently, MEC-based time management is favoured when requesting high-quality contact in a specific conversation. This suggests that the MEC-based strategy for Multi-Satellite Relay Transmission (MSRT) systems outweighs the TDMA-based strategy.

Chaer et al. [85] explored and highlighted how the blockchain uses 5G networks. Moreover, a blockchain Distributed Ledger Technology (DLT) framework survey was provided along with its main features and supporting elements. Besides, intelligent contracts, decentralized stores, and trusted oracles can be used to enable decentralized 5G applications, services, and ecosystems. Blockchain plays a crucial role in solving the security and scalability problems of 5G networks, such as many Internet of Things (IoT) and the many mobile devices distributed. The findings showed that the value of using the 5G blockchain with high-level technical information concerning device designs and architectures was beneficial.

Davaslioglu and Gitlin [86] explained a massive MIMO (or also referred to as Large-Scale Antenna Systems (LSAS)) energy efficiency aspects, mm-Wave connections, and dense deployment of small cells. Also, the device can be separated, and the high frequency can thus be reused by using beamforming and interference patterns to solve system challenges. The results showed that the grid energy efficiency could be substantially improved during the complementary and robust layout. Massive MIMO, such as modulated interference suppression and spatial multiplexing, provides wide bands not entirely exploited by mm-Wave, reduces communication distances, and mitigates small cell coverage apertures in the diffusion zone.

Liu et al. [87] explained protocols and techniques (Base station (BS) discovery, Beam alignment) and significant premeditation of device design. In comparison, unique technological problems need to be addressed to leverage mm-Wave small cells' capacity fully. In the intended coverage areas, they used beamforming reference signal transport to address efficient consumer BS discovery and beam alignment problems. The results showed applicable instructions for designing the physical layer with mm-Wave waves for small cells. The total number of beam pairs at a BS to cover the 60 ° sector is 128 for comprehensive analysis, and the total number of beams in the hierarchical study is 16.

Li et al. [88] presented technical difficulties in the Channel Reciprocity-based secret Key Generation (CRKG) driven by multiple duplex modes, large MIMO and mmWave communications, and prototypes in the Internet of Things (IoT) strategy. They used beamforming to solve the resulting problems, such as path loss and standard key distribution protocols based on cryptography. The results revealed that in 5G networks and beyond, the three aspiring technologies support exceptionally high data speeds and an overwhelming number of devices.

Martin-Vega et al. [89] discussed the state-of-the-art architecture systems believed for vehicular telecommunications in a holistic view. Then, the primary technologies that will improve the appropriateness of mm-Wave connections for autonomous leadership were discussed. They used the integration of analogue/hybrid beamforming and a location-based beam search protocol, using radio and physical layer full-duplex switch generation to address the problems associated with autonomous driving such as mm-Wave band and the reduction in vehicular techniques of channel measurement operation at mm-Wave. The results showed that autonomous driving could meet the imposed criteria and highlighted its potential advantages such as low latency, high resolution, protection, and unicast and broadcast connection support.

4. DISCUSSION AND COMPARISON

An optical instrument that employs the Fourier optics to modify the configuration of a light beam or another, usually consistent laser light emission, is a spatial filter. Space filters are typically used to "clean" the laser output, remove aberrations in the beam because of defective, dirty or distorted optics or differences in the laser gain medium. This filter can be used to relay a pure transverse laser mode while suppressing other modes issued by the Optical Resonator.

Table 5. Summary of literature review related to 5G technology

Author	Objectives	Algorithm/Technique	Problems	Methods /Tool	Significant Results
Chen [70], 2020	described 5G mm-Wave communication system's specifications and the design architecture (RF)	beam-tracking algorithm	The problems with the mm-Wave front-end module's architecture	MATLAB-based and C++	To allow 100km/hr cell transmissions, a beam-tracking technique has been implemented.
Zugno et al. [76], 2020	explained how mm-Wave operations could be efficiently integrated with IEEE 802.11bd and Generation Partnership Project (3GPP) network V2X systems.	congestion control algorithm	expansion from the application layers to the physical layers	end-to-end approach	present a preliminary E2E execution estimation of an mm-Wave E2E communication system
Zhang et al. [74], 2019	prepared overall overview of UAV mm-Wave	UAV MIMO system under LOS condition	UAV mm-Wave communication.	Pre-coding/ beamforming strategies	UAV and mm-Wave communications analysis provide enormous benefits in stability durability, durability, and spectral performance.
Yang et al. [77], 2019	an incoming system architecture that performance bidirectional channel and dynamic hardware that connects software and hardware constraints	baseband algorithm	Hardware-Constrained Millimeter- Wave Systems	incorporation of a few high-precision phase shifters into the mixed beamforming	a hardware-aided system architecture, which performance the consistent interaction between software and hardware units and adaptability compared and offers better flexibility to state of the art.
Liu et al. [83], 2019	the novel advances in HST channel measurements and technology have reviewed	combining the mm-Wave, massive MIMO and beamforming	(frequent and quick handover, broad Doppler spread) limitation	high-speed train (HST)	possibility technologies, massive MIMO, mm-Wave, and beamforming, are believed to support reliable HST
Chaer et al. [85], 2019	The impact of blockchain on 5G networks has discussed	Blockchain	the security and scalability problems of 5G networks	Blockchain	advantage of using the blockchain 5G with high-level technical details involving system designs and architectures

Author	Objectives	Algorithm/Technique	Problems	Methods /Tool	Significant Results
Li et al. [88], 2019	the feasibility and potential for scaling up of CRKG in support of new air interface technologies have demonstrated	beamforming	the resulting problems, such as path loss and standard key distribution protocols based on cryptography	Utilized duplex modes, massive MIMO and mm-Wave communications	three technologies in 5G networks and beyond support extremely high data rates and an overwhelming number of devices.
Ansari et al. [73], 2018	The idea of 5G technology was led as a futuristic solution for implementation, including high data rate peer-to-peer (P2P) links	zero-forcing algorithm	the issues associated with 5G D2D networks	Coordinated multipoint (CoMp) technology	a resource-efficient and stable D2D network
Busari et al. [78], 2018	combined the three big technologies to corroboration the explosive request for mobile broadband services predicts	combined UDN, massive MIMO and mm-Wave	mm-Wave Broadband issues such as the higher path loss, increased noise, and other additional losses	Use machine level emulations with 3D channel models	a lot higher capacity could be done with UDNs compared to only large cell settings
Bai et al. [84], 2018	described the architectures of two multi-satellite relay transmission systems based on TDMA and NOMA	routing algorithm	problems of resource management and access	two multi-satellite relay transmission systems based on TDMA and NOMA	the MEC-based strategy for multi-satellite relay transmission (MSRT) systems outweighs the TDMA-based strategy.
Liu et al. [87], 2018	protocols and techniques for BS discovery, Beam alignment discussed	Beam-forming	the problems of efficient consumer BS discovery and beam alignment	Base station (BS) discovery, Beam alignment	the total number of beam pairs at a BS to cover the 60 ° sector is 128 for comprehensive analysis, and the total number of beams in the hierarchical study is 16
Martin-Vega et al. [89], 2018	presented a survey of mm-Wave vehicular connections	incorporated analogue / hybrid beamforming with location-based beam search protocol	The problems associated with autonomous driving	mm-Wave vehicular connections	autonomous driving can meet the imposed requirements and highlighted its possibility advantages
Polese et al. [75], 2020	the most recent standardization activities on (IAB) explained	IAB end-to-end system-level simulations	mm-Wave limitations, such as penetration losses and extreme paths	high gain antennas by increasing the connection budget	IAB offers a viable solution for efficient cell edge traffic transport

Author	Objectives	Algorithm/Technique	Problems	Methods /Tool	Significant Results
Lee et al. [82], 2018	a general spectrum overview both below 6 GHz and above 6 GHz from the regulatory and technical aspects have indicated	hybrid beamforming architecture	coverage problems	used advanced antenna solution	the advanced antenna solutions in both base stations and mobile systems are major enablers
Huo et al. [79], 2017	a new distributed phased array MIMO (DPA-MIMO) architecture for 5G UE hardware design presented	adaptive beam tracking algorithms	cell phone design, such as high path loss, human blockage, self-heating problems	DPA-MIMO	the wireless UE based on DPA-MIMO can ease a peak throughput of more than 10 Gb/s while keeping a slim form factor of mobile station devices
Zhang et al. [80], 2017	antenna architecture design and beamforming system that are serviceable for outdoor mmw communication systems have discussed	Beamforming methods	the architecture of the antenna array for 5G mm-Wave	used highly dense relays and massive MIMO	The circular antenna array benefits, which has a robust beam misalignment and is a flat gain fluctuation.
Qi et al. [72], 2017	the EMC community of the 5G presents new opportunities and challenges	the MIMO throughput	OTA measurements	Over-the-air (OTA) measurement	The EMC group should therefore be well-positioned to take advantage of the opportunities and difficulties
Feng et al. [81], 2016	a design framework of mm-Wave backhauls showed by an overview	Analysis algorithm	transport channel selection and time distribution in mm-wave transporters	hybrid beamforming and full-duplex transportation	The outcome illustrated that they fulfil a lot larger productivity, shorter lateness, and a lower packet loss ratio
Al-Ogaili et al. [71], 2016	provided an overview of the 5G cellular systems for mm-Wave as a promising technology	massive MIMO and Ultra-Dense Networks	attenuation problem due to atmospheric absorption, rain, and vegetation	massive MIMO, mm-Wave	incorporation of massive MIMO, mm-Wave and small cells can be considered for the 5G mobile communication's key technology solutions
Davaslioglu [86], 2016	specified the recent advances and quantify how much gain can be achieved by an energy-efficient network design	Beamforming schemes	system challenges	Massive MIMO, mm-Wave and small cells.	during the complementary and robust design, the grid energy efficiency can be significantly improved

Furthermore, the offered 5G technology overcomes the drawbacks of previous works and thus offers the following advantages: Mobile enhanced broadband (eMBB), URLLC, millimeter (mmWave), massive web of subjects (IoT) - mMTC, multiple input massive multi-output (MIMO), quick data transfer and low latency, increased covering and connectivity.

It is clear from the preceding section that researchers have worked in various fields, using various methods and algorithms. Researchers highlighted essential points relevant to the valuation of their suggested methods.

Table 5 shows a comparison of the studies discussed in section 3. The comparison includes five main features that match their trends to check the targets achieved through their 5G technology market approaches. It is evident from the table that the references [80,86-88] were explicitly based on the beamforming technique that utilizes the BS discovery, Beam alignment, duplex modes, massive MIMO and mm-Wave communications for scaling up of CRKG in support of new air interface technologies for scaling up of CRKG in support of new air interface technologies and antenna architecture design and beamforming system that are serviceable for outdoor mm-Wave communication systems, While references [78, 83] used combining the mm-Wave, massive MIMO and beamforming for corroboration the explosive request for mobile broadband services and support reliable HST channel.

The author [72] used throughputs MIMO for OTA measurements. Therefore, the EMC cluster should be well-positioned to take advantage of the opportunities and difficulties. In contrast, [71] used massive MIMO and Ultra-Dense Networks for attenuation problems atmospheric absorption, rain, and vegetation. More so, based on the study [75] used end-to-end simulations of IAB system-level simulations for mm-wave limitations, such as penetration losses and outlying paths, and showed that IAB provides a viable solution for efficient cell edge traffic transport.

On the other hand, the reference [76] used a congestion control algorithm to explained how mm-Wave operations can be efficiently integrated into IEEE 802.11bd and 3GPP network V2X systems. The author [73] utilized the zero-forcing algorithm for implementation, including high data rate peer-to-peer (P2P) links. The author [70] used four antennae (8/16/32/64) hybrid beamforming architecture to enable mobile transmission over 100 Km/hr. In general, based on the literature review, several authors have used mm-Waves, small cells, massive MIMO, full duplexing, and beamforming, as these technologies play a pivotal role in emerging 5G networks and beyond, which it is essential to pay attention to the development of these technologies to reduce the problems arising from them. Finally, in this section, the used machines such as Objectives, Algorithm/Technique, Problems, Methods /Tool and Significant Results are summarized in "Table 5".

5. CONCLUSION

Massive MIMO technology, mmWave networking, machine-type communication, the Internet of Things, and other potential wireless developments have given rise to new security issues for 5G networks. The design of effective, secure transmission systems for 5G wireless communications that harness the propagation properties of radio channels in the physical layer has recently piqued researchers' interest. This method is known as physical layer security in 5G technology. The physical layer's encryption methods are resistant to increasingly sophisticated passive and active eavesdroppers. They are versatile in 5G networks for remote key generation physical layer authentication. Conventional encryption approaches can work together to create a well-integrated security solution that effectively protects 5G networks' sensitive and private communication data with careful monitoring and execution. The most important research related to 5G technology has analyzed and discussed various topics, such as attenuation, OTA measurements, mmWave penetration, extreme path losses o mmWave, antenna array architecture, security, coverage, scalability, etc. Furthermore, the author has used descriptions of the techniques/algorithms, goals, problems, and meaningful outcomes, and the results obtained with this technique were summarized.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Zeebaree SR, Jacksi K, Zebari RR. Impact analysis of SYN flood DDoS attack on

HAProxy and NLB cluster-based web servers. Indones. J. Electr. Eng. Comput. Sci. 2020;19:510-517.

2. Andrews JG, Buzzi S, Choi W, Hanly SV, Lozano A, Soong A. C, et al. What will 5G be? IEEE Journal on selected areas in communications. 2014;32:1065-1082.
3. Ahmad WSHMW, Radzi NAM, Samidi F, Ismail A, Abdullah F, Jamaludin MZ. et al. 5G technology: Towards dynamic spectrum sharing using cognitive radio networks. IEEE Access. 2020;8:14460-14488.
4. Cai Y, Qin Z, Cui F, Li GY, McCann JA. Modulation and multiple access for 5G networks. IEEE Communications Surveys & Tutorials. 2017;20:629-646.
5. Ding Z, Lei X, Karagiannidis GK, Schober R, Yuan J, Bhargava VK. A survey on non-orthogonal multiple access for 5G networks: Research challenges and future trends. IEEE Journal on Selected Areas in Communications. 2017;35:2181-2195.
6. Mezzavilla M, Zhang M, Polese M, Ford R, Dutta S, Rangan S. et al. End-to-end simulation of 5G mmWave networks. IEEE Communications Surveys & Tutorials 2018;20:2237-2263.
7. Cousik TS, Shah VK, Erpek T, Sagduyu YE, Reed JH. Deep learning for fast and reliable initial access in AI-driven 6G mmwave networks. arXiv preprint arXiv.2101.01847; 2021.
8. Shukur H, Zeebaree SR, Ahmed AJ, Zebari RR, Ahmed O, Tahir BSA. et al. A state of art survey for concurrent computation and clustering of parallel computing for distributed systems. Journal of Applied Science and Technology Trends. 2020;1:148-154.
9. Dong P, Zhang H, Li GY, Gaspar IS, Naderi Alizadeh N. Deep CNN-based channel estimation for mmWave massive MIMO systems. IEEE Journal of Selected Topics in Signal Processing. 2019;13:989-1000.
10. Zeebaree SSR, Mohammed AS. Social media networks security threats, risks and recommendation: A case study in the kurdistan region. International Journal of Innovation, Creativity and Change. 2020;13:349-365.
11. Larsson EG, Edfors O, Tufvesson F, Marzetta TL. Massive MIMO for next generation wireless systems. IEEE communications magazine. 2014;52:186-195.
12. Elijah O, Leow CY, Tharek AR, Nunoo S, Iliya SZ. "Mitigating pilot contamination in massive MIMO system—5G: An overview," in 2015 10th Asian Control Conference (ASCC). 2015;1-6.
13. Jungnickel V, Manolakis K, Zirwas W, Panzner B, Braun V, Lossow M. et al. The role of small cells, coordinated multipoint, and massive MIMO in 5G. IEEE communications magazine. 2014;52:44-51.
14. Cai Y, Liu X, Xiong Y, Wu X. Three-dimensional sound field reconstruction and sound power estimation by stereo vision and beamforming technology. Applied Sciences. 2021;11:92.
15. Wang Y, Chen J, Benesty J, Jin J, Huang G. Binaural heterophasic superdirective beamforming. Sensors. 2021;21:74.
16. Sulaiman MA, Sadeeq M, Abdulraheem AS, Abdulla AI. Analyzation study for gamification examination fields. Technol. Rep. Kansai Univ. 2020;62:2319-2328.
17. Kutty S, Sen D. Beamforming for millimeter wave communications: An inclusive survey. IEEE Communications Surveys & Tutorials. 2015;18:949-973.
18. De Jong YL, Herben MH. A tree-scattering model for improved propagation prediction in urban microcells. IEEE Transactions on Vehicular Technology. 2004;53:503-513.
19. El-Dolil SA, Wong WC, Steele R. Teletraffic performance of highway microcells with overlay macrocell. IEEE Journal on Selected Areas in Communications. 1989;7:71-78.
20. MacCartney GR, Zhang J, Nie S, Rappaport TS. Path loss models for 5G millimeter wave propagation channels in urban microcells," in 2013 IEEE global communications conference (GLOBECOM). 2013;3948-3953.
21. Abdulraheem AS, Salih AA, Abdulla AI, Sadeeq MA, Salim NO, Abdullah H. et al. Home automation system based on IoT; 2020.
22. ÇAlhan A, Cicioğlu M. Handover scheme for 5G small cell networks with non-orthogonal multiple access. Computer Networks. 2020;183:107601
23. Bogale T, Wang X, Le L. "mmWave communication enabling techniques for 5G wireless systems: A link level perspective,"

in MmWave Massive MIMO, ed: Elsevier. 2017;195-225.

24. J. community, "Mobile networking: 1G to 4G."
25. Abdulrahman LM, Zeebaree SR, Kak SF, Sadeeq MA, Adel AZ, Salim BW, et al. A state of art for smart gateways issues and modification. Asian Journal of Research in Computer Science. 2021;1-13.
26. Wang CX, Haider F, Gao X, You XH, Yang Y, Yuan D, et al. Cellular architecture and key technologies for 5G wireless communication networks. IEEE communications magazine. 2014;52:122-130.
27. Dino HI, Zeebaree SR, Ahmad OM, Shukur HM, Zebari RR, Haji LM. Impact of load sharing on performance of distributed systems computations. International Journal of Multidisciplinary Research and Publications (IJMRAP). 2020;3:30-37.
28. Popovsk P, Brau V, Mayer HP, Fertl P, Ren Z, Gonzales-Serrano D, et al. EU FP7 INFSO-ICT-317669 METIS, D1. 1 Scenarios, requirements and KPIs for 5G mobile and wireless system; 2013.
29. Dino HI,. Zeebaree SR, Salih AA, Zebari RR, Ageed ZS, Shukur HM, et al. Impact of process execution and physical memory-spaces on OS performance; 2020.
30. Gopalsami N, Chien H, Heifetz A, Koehl E, Raptis A. Millimeter wave detection of nuclear radiation: An alternative detection mechanism. Review of scientific instruments. 2009;80:084702.
31. Busari SA, Huq KMS, Mumtaz S, Dai L, Rodriguez J. Millimeter-wave massive MIMO communication for future wireless systems: A survey. IEEE Communications Surveys & Tutorials. 2017;20:836-869.
32. Gupta A, Jha RK. A survey of 5G network: Architecture and emerging technologies. IEEE access. 2015;3:1206-1232.
33. Osseiran A, Boccardi F, Braun V, Kusume K, Marsch P, Maternia M, et al. Scenarios for 5G mobile and wireless communications: the vision of the METIS project. IEEE communications magazine. 2014;52:26-35.
34. Agiwal M, Roy A, Saxena N. Next generation 5G wireless networks: A comprehensive survey. IEEE Communications Surveys & Tutorials. 2016;18:1617-1655.
35. Salih AA, Zeebaree SR, Abdulraheem AS, Zebari RR, Sadeeq MA, Ahmed OM. Evolution of mobile wireless communication to 5G revolution. Technology Reports of Kansai University. 2020;62:2139-2151.
36. Arcondoulis E, Liu Y, Xu P, Li Q, Wei R, Yang Y, et al. "Experimental application of an acoustic beamforming array pairing method using CLEAN-SC," in AIAA Scitech 2021 Forum. 2021;0214.
37. Nguyen-Duy J. Security challenges facing the shift to 5G. Interconnecting Business and Cybersecurity; 2020.
38. Alsulami MM, Akkari N. "The role of 5G wireless networks in the internet-of-things (IoT)," in 2018 1st International Conference on Computer Applications & Information Security (ICCAIS). 2018:1-8.
39. Zebari RR, Zeebaree SR, Jacksi K. "Impact analysis of HTTP and SYN FLO od DDoS attacks on apache 2 and IIS 10.0 web servers," in 2018 International Conference on Advanced Science and Engineering (ICOASE). 2018: 156-161.
40. Abdullah SMSA, Ameen SYA, Sadeeq MAM, Zeebaree S. Multimodal emotion recognition using deep learning. Journal of Applied Science and Technology Trends. 2021;2:52-58,04/16.
41. Sadeeq MAM, Zeebaree S. Energy management for internet of things via distributed systems. Journal of Applied Science and Technology Trends. 2021;2:59-71,04/16.
42. Sadeeq MA, Zeebaree SR, Qashi R, Ahmed SH, Jacksi K. "Internet of things security: A survey," in 2018 International Conference on Advanced Science and Engineering (ICOASE). 2018;162-166.
43. Srinivasan M, Gopi S, Kalyani S, Huang X, Hanzo L. Airplane-aided integrated next-generation networking. arXiv preprint arXiv:2101.00566; 2021.
44. Abdulazeez AM, Zeebaree SR, Sadeeq MA. Design and implementation of electronic student affairs system. Academic Journal of Nawroz University. 2018;7:66-73.
45. Yusuf MO. Information and communication technology and education: Analysing the Nigerian national policy for information technology. International education journal. 2005;6:316-321.

46. Yazdeen AA, Zeebaree SR, Sadeeq MM, Kak SF, Ahmed OM, RR Zebari. FPGA implementations for data encryption and decryption via concurrent and parallel computation: A review. Qubahan Academic Journal. 2021;1:8-16.
47. Hasan DA, Hussan BK, Zeebaree SR, Ahmed DM, Kareem OS, Sadeeq MA. The impact of test case generation methods on the software performance: A review. International Journal of Science and Business. 2021;5:33-44.
48. Ageed ZS, Ibrahim RK, Sadeeq MA. Unified ontology implementation of cloud computing for distributed systems. Current Journal of Applied Science and Technology. 2020;82-97.
49. Ma Z, Zhang Z, Ding Z, Fan P, Li H. Key techniques for 5G wireless communications: Network architecture, physical layer, and MAC layer perspectives. Science China information sciences. 2015;58:1-20.
50. Maulud DH, Zeebaree SR, Jacksi K, Sadeeq MAM, Sharif KH. State of art for semantic analysis of natural language processing. Qubahan Academic Journal. 2021;1.
51. Shukur H, Zeebaree S, Zebari R, Ahmed O, Haji L, Abdulqader D. Cache coherence protocols in distributed systems. Journal of Applied Science and Technology Trends. 2020;1"92-97.
52. Hu Q, Liu Y, Cai Y, Yu G, Ding Z. Joint deep reinforcement learning and unfolding: Beam selection and precoding for mmwave multiuser MIMO with Lens Arrays. arXiv preprint arXiv. 2101.01336; 2021.
53. Zeebaree SR, Shukur HM, Haji ML, Zebari RR, Jacksi K, Abas SM. Characteristics and analysis of hadoop distributed systems. Technology Reports of Kansai University. 2020;62:1555-1564.
54. Sadeeq M, Abdulla AI, Abdulraheem AS, Ageed ZS. Impact of electronic commerce on enterprise business. Technol. Rep. Kansai Univ. 2020;62:2365-2378.
55. Sallow AB, Zeebaree SR, Zebari RR, Mahmood MR, Abdulrazzaq MB, Sadeeq MA. Vaccine Tracker/SMS Reminder System: Design and Implementation; 2020.
56. Abdulla AI, Abdulraheem AS, Salih AA, Sadeeq MA, Ahmed AJ, Ferzor BM, et al. Internet of things and smart home security. Technol. Rep. Kansai Univ. 2020;62:2465-2476.
57. Saleem SI, Zeebaree S, Zeebaree DQ, Abdulazeez AM. Building smart cities applications based on iot technologies: A review. Technology Reports of Kansai University. 2020;62:1083-1092.
58. Sadeeq MM, Abdulkareem NM, Zeebaree SR, Ahmed DM, Sami AS, Zebari RR. IoT and Cloud computing issues, challenges and opportunities: A review. Qubahan Academic Journal. 2021;1:1-7.
59. Ageed ZS, Zeebaree SR, Sadeeq MM, Kak SF, Yahia HS, Mahmood MR, et al. Comprehensive survey of big data mining approaches in cloud systems. Qubahan Academic Journal. 2021;1:29-38.
60. Ibrahim IM. Task scheduling algorithms in cloud computing: A review. Turkish Journal of Computer and Mathematics Education (TURCOMAT). 2021;12:1041-1053.
61. Alzakholi O, Shukur H, Zebari R, Abas S, Sadeeq M. Comparison among cloud technologies and cloud performance. Journal of Applied Science and Technology Trends. 2020;1:40-47.
62. Sallow AB, Sadeeq M, Zebari RR, Abdulrazzaq MB, Mahmood MR, Shukur HM, et al. An investigation for mobile malware behavioral and detection techniques based on android platform. IOSR Journal of Computer Engineering (IOSR-JCE). 2020;22:14-20.
63. Goldsmith AJ, Greenstein LJ. A measurement-based model for predicting coverage areas of urban microcells. IEEE Journal on Selected Areas in Communications. 1993;11:1013-1023.
64. Ageed Z, Mahmood MR, Sadeeq M, Abdulrazzaq MB, Dino H. Cloud computing resources impacts on heavy-load parallel processing approaches. IOSR Journal of Computer Engineering (IOSR-JCE). 2020;22:30-41.
65. Haji LM, Ahmad OM, Zeebaree SR, Dino HI, Zebari RR, Shukur HM. Impact of cloud computing and internet of things on the future internet. Technology Reports of Kansai University. 2020;62:2179-2190.
66. Abdulraheem AS, Abdulla AI, Mohammed SM. Enterprise resource planning systems and challenges; 2020.
67. Zebari RR, Zeebaree S, Jacksi K, Shukur HM. E-business requirements for flexibility

and implementation enterprise system: A review. International Journal of Scientific & Technology Research. 2019;8:655-660.

68. Shukur HM, Zeebaree SR, Zebari RR, Hussan BK, Jader OH, Haji LM. Design and implementation of electronic enterprise university human resource management system. in Journal of Physics: Conference Series. 2021;012058.

69. Al-Rahmi WM, Alzahrani AI, Yahaya N, Alalwan N, Kamin YB. Digital communication: Information and communication technology (ICT) usage for education sustainability Sustainability. 2020;12:5052.

70. Chen WC. 5G mmWAVE technology design challenges and development trends. in 2020 International Symposium on VLSI Design, Automation and Test (VLSI-DAT). 2020;1-4.

71. Al-Ogaili F, Shubair RM. Millimeter-wave mobile communications for 5G: Challenges and opportunities. in 2016 IEEE International Symposium on Antennas and Propagation (APSURSI). 2016;1003-1004.

72. Qi Y, Yang G, Liu L, Fan J, Orlandi A, Kong H, et al. 5G over-the-air measurement challenges: Overview. IEEE Transactions on Electromagnetic Compatibility. 2017;59:1661-1670.

73. Ansari RI, Chrysostomou C, Hassan SA, Guizani M, Mumtaz S, Rodriguez J, et al. 5G D2D networks: Techniques, challenges, and future prospects. IEEE Systems Journal. 2017;12:3970-3984.

74. Zhang C, Zhang W, Wang W, Yang L, Zhang W. Research challenges and opportunities of UAV millimeter-wave communications. IEEE Wireless Communications. 2019;26:58-62.

75. Polese M, Giordani M, Zugno T, Roy A, Goyal S, Castor D, et al. Integrated access and backhaul in 5G mmWave networks: Potential and challenges. IEEE Communications Magazine. 2020;58:62-68.

76. Zugno T, Drago M, Giordani M, Polese M, Zorzi M. Toward standardization of millimeter-wave vehicle-to-vehicle networks: Open challenges and performance evaluation. IEEE Communications Magazine. vol. 2020;58:79-85.

77. Yang X, Matthaiou M, Yang J, Wen CK, Gao F, Jin S. Hardware-constrained millimeter-wave systems for 5G: Challenges, opportunities, and solutions. IEEE Communications Magazine. 2019;57:44-50.

78. Busari SA, Mumtaz S, Al-Rubaye S, Rodriguez J. 5G millimeter-wave mobile broadband: Performance and challenges. IEEE Communications Magazine. 2018;56:137-143.

79. Huo Y, Dong X, Xu W. 5G cellular user equipment: From theory to practical hardware design. IEEE Access. 2017;5:13992-14010.

80. Zhang J, Ge X, Li Q, Guizani M, Zhang Y. 5G millimeter-wave antenna array: Design and challenges. IEEE Wireless communications. 2016;24:106-112.

81. Feng W, Li Y, Jin D, Su L, Chen S. Millimetre-wave backhaul for 5G networks: Challenges and solutions. Sensors. 2016;16:892.

82. Lee J, Tejedor E, Ranta-aho K, Wang H, Lee KT, Semaan E, et al. Spectrum for 5G: Global status, challenges, and enabling technologies. IEEE Communications Magazine. 2018;56:12-18.

83. Liu Y, Wang CX, Huang J. Recent developments and future challenges in channel measurements and models for 5G and beyond high-speed train communication systems. IEEE Communications Magazine. 2019;57:50-56.

84. Bai L, Zhu L, Zhang X, Zhang W, Yu Q. Multi-satellite relay transmission in 5G: Concepts, techniques, and challenges. IEEE Network. 2018;3238-44.

85. Chaer A, Salah K, Lima C, Ray PP, Sheltami T. Blockchain for 5G: Opportunities and challenges. in 2019 IEEE Globecom Workshops (GC Wkshps). 2019;1-6.

86. Davaslioglu K, Gitlin RD. "5G green networking: Enabling technologies, potentials, and challenges," in 2016 IEEE 17th Annual Wireless and Microwave Technology Conference (WAMICON). 2016;1-6.

87. Liu C, Li M, Hanly SV, Whiting P, Collings IB. Millimeter-wave small cells: Base station discovery, beam alignment, and system design challenges. IEEE Wireless Communications. 2018;25:40-46.

88. Li G, Sun C, Zhang J, Jorswieck E, Xiao B, Hu A. Physical layer key generation in 5G

and beyond wireless communications: Challenges and opportunities. Entropy. 2019;21:497.

89. Martin-Vega FJ, Aguayo-Torres MC, Gomez G, Entrambasaguas JT, Duong TQ. Key technologies, modeling approaches, and challenges for millimeter-wave vehicular communications. IEEE Communications Magazine. 2018;56:28-35.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/68058