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Literature Review

A Survey Study For the 5G Emerging Technologies

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Abstract

5G is the next-generation mobile network, and it has been developed with the purpose of covering the network requirements of today, and the future. 5G has the goal to make network connectivity more accessible, faster, energy efficient, and reliable, all while significatively reducing latency and enabling a denser network capable of handling both consumer mobile devices and massive machine-type communications and leaving space for future innovations. With such an ambitious goal, there come many obstacles and challenges that the industry must face when it comes to the proper implementation of this technology so that it can reach its potential. In this article we will discuss some of the emerging technologies in 5G, presenting an introductory overview of them as well as their benefits, the challenges these present, along with their proposed solutions gathered from recent academic sources.

Keywords: 5G; 5GPPP Architecture; D2D; Mobile Edge Computing; Mobility Management; Broadcast/Multicast; RAN; 5G Core Networks; Radio Access Technologies; RAT

Introduction

The 5G is a brand-new network that connects almost everyone and everything, including machines, objects, and devices. 5G wireless technology is meant to deliver higher multi-Gbps peak data speeds, ultra-low latency, more reliability, massive network capacity, increased availability, and a more uniform user experience to more users. This surveypaper will concern the topics of 5G, 5GPPP Architecture, Device-to-Device Communications and networking, Mobile Edge Computing (MEC), Mobility management, Multicast/Broadcast Services, Multi-Radio Access Networks, Latency challenges in RAN and Core Network, and how 5G as a technology stands in general. In addition, the paper will givean overview of the abovementioned topics, and then go into the discussion about the challenges faced in the rise of this technology, potential problems, potential benefits, andsolutions for 5G requirements as defined by 5GPPP. This article's main contribution will be the meta-analysis of these emerging topics with the use of recently published academicarticles, and the highlighting of the key challenges faced by 5G technologies and their developing or proposed solutions. The remainder of this paper is organized as follows. Section IIpresents a literature review of the 5G topic. Section III drawssome concluding remarks and outlines future work.

Literature Review

5G quick overview and 5GPPP architecture

Before we delve into topics like networking, Mobile Edge Computing, mobility management, and 5GPP architecture asthey relate to 5G networks, it is best to first take a glance intothe big picture and see (or remind ourselves) where these puzzle pieces fit.

5G, as stated by [1], is the fifth generation of mobile networks. It operates using similar mobile networking principles to previous technologies like 4G LTE, and differs in that 5G is based on OFDM (Orthogonal Frequency- Division Multiplexing) to keep interference low, a wider increase in frequency bandwidth size, and the use of standards like 5G NR (New Radio), which deals with how this technology handles radio waves. 5G NR achieves more accuracy and efficiency by, among other technologies, the utilization of millimeter wave bands (mm-Wave), somethingincompatible with preceding technologies like LTE [2].

5G, designed with technologies like IoT in mind, is capable of data speeds in the gigabits, increased availability, reliability and network capacity, and power efficiency, all while managing to significantly decrease latency [1].

In the spirit of providing consumers and organizations newservices, opportunities, and a way to address their specific requirements, 5G Infrastructure Public Private Partnership (5GPPP) among other standardization organizations has declared and developed the principal elements of the 5G architecture. For this purpose, end-to-end network slicing, Software-Defined Networking (SDN), Network Function Virtualization (NFV), and service-based architecture serve asthe backbone to support these emerging use-cases in a more efficient and streamlined way. 5G architecture as proposed by 5GPPP has a structure that is recursive in nature, meaning thatit can be applied repeatedly, giving the ability to build a service out of existing services, improving scalability and automation. On a service level, SDN and NFV enable lifecycle management automation, providing service assurance, fulfillment, and orchestration functions as well asthe ability to program SDN controllers to efficiently executenetwork policies and rules. 5GPPP architecture also providesa common platform that can be accessed by system entities from any level, using access control methods for the access, processing, and transfer of data [3].

Device-to-device communication and networking in 5G

Device-to-Device Communication, as [4] puts it, is atechnology that allows for high-speed, more capable, and more power efficient data transmission by bypassing base stations and traditional signal towers, only using these signaltowers for network control (see Figure 1). This is achieved by letting devices that are close to each other communicate directly instead of using a base station. One of the issues of this technology is interference and resource allocation concerns. Device-to-Device (D2D) when paired with traditional cellular networks creates significant interference between devices. [4] affirms that this has been a problem thatis being studied by many scholars, who have proposed a variety of different resource allocation algorithms to alleviatethese pains [5]. Categorizes D2D architecture functions in a5G network in 3 modes: In-band (or in-coverage), out-band (or out-of-coverage), and D2D relay communication (or relay-coverage).

Figure 1: Conceptual map of D2D communications.

In-band D2D communication refers to the situation in which the devices are being monitored and controlled by a signal tower. This mode requires that the devices be located inside the signal radius, but it has the benefit of, as [5] puts it,better-managed and organized D2D communication. Out-band D2D communication conversely refers to when thedevices are out of the reach of the signal tower. This type of communication works akin to Wi-Fi. It doesn't have the constraint of having to be close to a signal tower, but it meansthat overall management and control over this communicationis harder to upkeep. D2D Relay communication happens whena separate device acts as a relay between the signal tower andthe original device, effectively expanding the reach of the signal tower [5].

Mobile edge computing (MEC) and 5G

In order to introduce the idea of Mobile Edge Computing(MEC) or its updated name, Multi-Access Edge Computing,we must first go over what edge computing is. Edge computing is a framework that allows for small clouds or servers to exist at the edge of a network (end-point networking enabled devices/ IoT), with the purpose of extending the cloud's data handling capabilities at this edge layer for more resource-intensive tasks, leading to improved speed, storage, and latency in relation to a conventional cloud computing approach. The idea of a network edge and how it relates to network infrastructure can be seen in Figure 2.

Before going into Multi-Access Edge Computing, it isnoteworthy to point out that the difference between fog and edge computing is the distance to the end-point devices, withedge computing happening on a local level, while fog computing as you can see in figure 2 would happen farther along the network map [6]. So, if edge computing is the framework, what we call Mobile Edge Computing or Multi- Access Edge Computing is just the practical utilization of theedge computing concept.

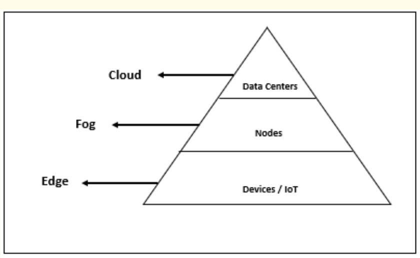

Figure 2: Graphical concept of network edge.

Multi-Access Edge Computing serves as an enabler for multiple 5G goals. With the ability to offload data and process it locally instead of sending it to a distant cloud service right away, 5G objectives such as Enhanced Mobile Broad Band (eMMB), Massive Machine-Type Communications (mMTC), and Ultra-Reliable Low-Latency Communications (URLLC) are becoming possible. There exist many standards that are being made for Multi-Access Edge Computing, here are some of the more important ones:Edge Computing Consortium, Open Edge Computing Initiative, Central Office Re-architected as a Data Center (CORD), and ETSI-MEC [6]. Compounding on these developing standards and initiatives, [6] also discusses how Multi-Access Edge Computing deployment into networks (both traditional and cellular) will be led by the influence of technologies such as Software-Defined Networking (SDN), Network Slicing, Service Function Chaining (SFC), and Network Function Virtualization (NFV). Below we will go over what these technologies mean, and how they relate to and benefit Multi-Access Edge Computing.

Microsoft defines SDN as a way to centrally configure and manage networks and network services such as switching, routing, and load balancing in the data center. SDN can be used to dynamically create, configure, connect and secure networks to the particular needs of the organization. A surveyon Service Function Chaining [7] defines SFC as amechanism that allows various service functions to be connected to each other to create a chain of virtual network services. Service Function Chaining is possible through the use of SDN, and in turn, enables the use of Network FunctionVirtualization.

Network Function Virtualization can be seen as a way of leveraging existing IT virtualization technologies and applying them to network architecture, with the intention of streamlining and consolidating standard networking processes and equipment [7]. Lastly, Network Slicing can be defined as the slicing of a physical network into many virtualnetworks, each configured to fit different roles and requirements [6].

Multi-Access Edge Computing can leverage the aforementioned technologies in the following ways: with SDN, edge computing environment management becomes more flexible and modular when it comes to its functions. NFV allows for fast deployment and flexible scalability of edge computing specifications as well as cost reduction due to virtualization. SFC can be used to optimize the network resource utilization and application performance, and network slicing can be used to assist the deployment of the edge computing network environment on demand [6].

Multicast/broadcast for 5G and Beyond

Multicast/Broadcast in simple terms means the ability fora device to send data through a network in a one-to-many andone-to-all capacity respectively. The ability to do multicast and broadcast has been supported by cellular networks acrosspast generations, starting with 3G being named Multimedia Broadcast Multicast Services (MBMS), and was proceeded by Evolved Multimedia Broadcast Multicast Services (eMBMS) for LTE Networks. For 5G networks, the way thistechnology is implemented is referred to as Multicast Broadcast Service (MBS) [8].

Multicast Broadcast, at least when it comes to cellular networks has been a technology that didn't get much tractionuntil the arrival of 5G and its implementation, with technologies like Digital Video Broadcasting (DVB), Digital Terrestrial Technologies (DTT), Non-Terrestrial Networks (NTN), and Advanced Television Systems Committee(ATSC) being more prevalent in deployment and usage. How5G changes the paradigm of how these technologies are used is that the 5G System architecture supports both 3GPP and non-3GPP implementations of Multicast Broadcast, dynamically leveraging them to gain increased area coverage,mobility support, and spectral and resource efficiency. 5G architecture supports the use of all these previously independent technologies to an increased effect [8].

Within the architecture of Multicast Broadcast Services for 5G networks there are 2 delivery methods declared: Individual and Shared 5GC Multicast Broadcast Service traffic delivery. These methods differentiate from one anotherin that Shared MBS traffic delivery is able to handle multicastand broadcast sessions in which a single copy of the data is sent to the NG-RAN (Next-Generation Radio AccessNetwork), and the NG-RAN then sends the data to the end- point device. Since this method works for both multicast and broadcast, 2 possible ways of sending the data from the NG-RAN to the end-point device are defined: Point-To-Point (PTP), and Point-To-Multipoint (PTM) respectively. For the second method of delivery, 5GC Individual MBS traffic delivery, it is only able to handle multicast connections, in which the MB-UPF (Multicast Broadcast User Plane Function) receives the data, replicates it, and sends it to the individual end-point devices by way of a Protocol Data Unit (PDU) session established between the device and the MB-UPF [8].

Mobility management in 5G

The purpose of 5G and future cellular technologies is to increase the access to wireless communications, making it more widespread all while maintaining the quality and speedof the connection. Mobility Management comes into play when it comes to the handover of devices from one signal tower to the other, to avoid improper use of handover blocking or constant unnecessary handover or switch from one tower to the next, causing network inefficiency and an overall increase in load that can reduce the network's performance.

The main action of a mobility management function is todiscern and follow up on the location of devices connected tothe network in order to determine when to perform the handover of the devices to a signal tower with a more qualityor reliable connection. This handover process can also occurto save on energy or resource load. Figure 3 shows the types ofhandovers that can occur and how they are performed [9].

A fundamental component of a 5G network is its Access and Mobility Management Function (AMF), a function that deals with the registration, connection, and mobility management of devices within the network. Session Management Function (SMF) and User Plane Function (UPF) also relate to this concept. as SMF deals with controlling session context, PDU sessions, etc. and UPFhandles the connection between the network and infrastructure, as well as overall managing of quality ofservice [9].

Types of Handovers	Usage
Horizontal Handover	Between same signal technology. Ex: Wi-Fi to Wi-Fi.
Vertical Handover	Between different signal technologies. Ex: Wi-Fi to LTE.
Intra-frequency Handover	Between 2 access points working on the same frequency band.
Inter-frequency Handover	Between 2 access points working on different frequency bands.
Hard Handover	Connection is broken before end-point device connects to the new signal.
Soft Handover	Connection remains until after the new connection is established.

Figure a: Handover types

The common types of handovers are classified by network type (Items 1-2), by frequency (3-4), and technique (5-6). The information in this table was based on [9].

Best practices and protocols for 5G handover are still being actively researched and developed. Previous generationLTE networks use hard handover, which presents challenges when it comes to mobility management and providing a constant connection, this among other issues makes the current LTE framework not apt for future use-cases where increased data throughput and lower latency will be required.Article [10] released in April 2022 discusses the requirements and challenges that modern mobility techniques for 5G face such as power consumption, mm-Wave drawbacks, signaling, and security.

Multi-radio access networks in 5G

Multi-Radio Access Networks, also referred to as heterogeneous networks is one of the key requirements in 5Gthat could pave the way to increased data rate, reliability, anddecreased latency. Multi-connectivity leverages the use of multiple access points of available Radio Access Technologies (RAT) such as 5G, Satellite, and LTE networkssimultaneously on the same end-point device, increasing datathroughput. One of the challenges faced by this method is how to determine the balance of data traffic going from eachRAT access point to the end-point device [11].

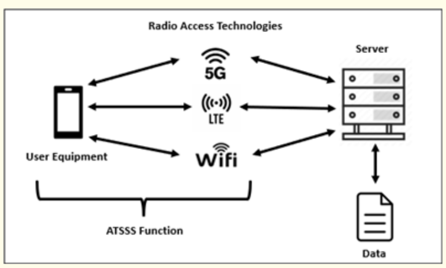

Figure 3: Conceptual map showing how multi-radio access networks work by using the ATSSS (Access Traffic Steering, Switching, Splitting) function.

Multi-connectivity and load balancing are topics that are being actively researched, with multiple proposals on how tobest implement this solution being described in articles [11,12], where they discuss capacity-constrained Wardrop equilibria and the 5G-ALL-STAR solution to multi- connectivity respectively. [11] proposes a dynamicadversarial load balancing algorithm in which the latencies ofthe access points are equalized, while [12] proposes a solutionthat leverages the use of terrestrial and satellite networks to meet the 5G multi-connectivity requirements.

Convergence of RAN and core network in 5G

One of 5G's main requirements is the need for reliable low latency, with the convergence of the core network and the Radio Access Network (RAN) being one of the main contributors to latency. With the intention of reducing latency in this area, articles like [13] discuss various changes and solutions that could be implemented to aid this latency problem. In order to reduce latency in the RAN, changes in the following areas are being proposed: In the frame/packet structure by making changes in the physical and MAC layers, changes in multi-access methods, control channel, modulation and coding schemes, symbol detection, cloud RAN, and others. In addition to changes to the RAN, changes for the Core Network are also proposed, with them being composed of implementing techniques such as SDN, NFV, and Multi-Access Edge Computing to the Core Network architecture.

Conclusion

5G networks have to be capable of ultra-reliable low latency, a wider bandwidth size, significantly increased availability, capacity, data speed, and energy efficiency. 5G iscontinuously evolving, and all of this is possible due to the virtualization of network functions, SDN, network slicing, automation, and emerging topics such as device-to-device communications, multi-access edge computing, multi-radio access networks, as well as innovations in areas like multicast/broadcast and mobility management serving as the backbone that enables this next-generation network. 5G will pave the road for new revolutionary technologies to be made,and in this paper, we have analyzed some of the frameworks,techniques, and technologies that will allow them to be possible while presenting the challenges ahead and going overthe proposed solutions to these issues. Figure b summarizes the5G emergence technologies that we studied in this paper.

For future work, we plan to extend our current 5G securitytest-bed and its related cybersecurity applications [14-50] in the light of the current study to develop an open 5G architecture that supports multi-vendor applications.

Bibliography

1. Qualcomm. "Everything you need to know about 5G".
2. G Vos. "What is 5G NR (New Radio)?". Sierra Wireless, 13 January (2022).
3. S Redana., *et al*. "View on 5G Architecture". 5G PPP architecture working group, June (2019).
4. FA Al-Zahran., *et al*. "Resource Allocation and Optimization in Device-to-Device Communication 5G Networks". *Computers, Materials and Continua* 69.1 (2021): 1201-1214.
5. NO Nwazor and V Ugah. "Device-To-Device (D2D) Data Communications in 5g Networks". *International Journal of Advances in Engineering and Management (IJAEM)* IV.1 (2022): 1151-1154.
6. A Filali., *et al*. "Multi-Access Edge Computing: A Survey". *IEEE Access* 8 (2020): 197017-197046.
7. D Bhamare., *et al*. "A survey on service function chaining". *Journal of Network and Computer Applications* 75 (2016): 138-155.
8. R Kamran., *et al*. "A Survey on Multicast Broadcast Services in 5G and Beyond" (2022).
9. AN Kasim. "A survey mobility management in 5G networks". arXiv preprint arXiv:2006.15598, (2020).
10. S Alotaibi. "Key Challenges of Mobility Management and Handover Process". *International Journal of Computer Science and Network Security* 22.4 (2022): 139-146.
11. F D Priscoli., *et al*. "Capacity-constrained Wardrop equilibria and application to multi-connectivity in 5G networks". *Journal of the Franklin Institute* 358.17 (2021): 9364-9384.
12. F Lisi., *et al*. "Multi-Connectivity in 5G terrestrial-Satellite Networks: the 5G-ALLSTAR Solution". arXiv preprint arXiv:2004.00368 (2020).
13. Parvez A., *et al*. "A survey on low latency towards 5G: RAN, core network and caching solutions". *IEEE Communications Surveys and Tutorials* 20.4 (2018): 3098-3130.
14. Hisham A Kholidy. "Multi-Layer Attack Graph Analysis in the 5G Edge Network Using a Dynamic Hexagonal Fuzzy Method". *Sensors* 22 (2022): 9.
15. Hisham A Kholidy., *et al*. "5G Core Security in Edge Networks: A Vulnerability Assessment Approach". the 26th IEEE Symposium on Computers and Communications (IEEE ISCC 2021), Athens, Greece, September 5-8, (2021).

16. Hisham A Kholidy. "A Triangular Fuzzy based Multicriteria Decision Making Approach for Assessing Security Risks in 5G Networks". December (2021).

17. Kholidy HA and Fabrizio Baiardi. "CIDS: A framework for Intrusion Detection in Cloud Systems". in the 9th Int. Conf. on Information Technology: New Generations ITNG 2012, April 16-18, Las Vegas, Nevada, USA.

18. Kholidy HA. "Autonomous mitigation of cyber risks in the Cyber–Physical Systems". *Future Generation Computer Systems* 115 (2021): 171-187.

19. Hisham A Kholidy., *et al*. "A risk mitigation approach for autonomous cloud intrusion response system". *Computing Journal,* Springer, June (2016).

20. Hisham A Kholidy. "Detecting impersonation attacks in cloud computing environments using a centric user profiling approach". *Future Generation Computer Systems* 115 (2020): 17.

21. Kholidy HA., *et al*. "A hierarchical cloud intrusion detection system: design and evaluation". *International Journal on Cloud Computing Services and Architecture (IJCCSA)* 2 (2012): 1-24.

22. Kholidy HA., *et al*. A Cost-Aware Model for Risk Mitigation in Cloud Computing Systems Successful accepted in 12th ACS/IEEE International Conference on Computer Systems and Applications (AICCSA), Marrakech, Morocco, November, (2015).

23. A H M Jakaria., *et al*. "Trajectory Synthesis for a UAV Swarm Based on Resilient Data Collection Objectives". in IEEE Transactions on Network and Service Management, (2022).

24. HA Kholidy., *et al*. "Toward Zero Trust Security IN 5G Open Architecture Network Slices". MILCOM 2022 - 2022 IEEE Military Communications Conference (MILCOM), Rockville, MD, USA, (2022): 577-582.

25. Hisham A Kholidy and Riaad Kamaludeen. "An Innovative Hashgraph-based Federated Learning Approach for Multi Domain 5G Network Protection". IEEE Future Networks (5G World Forum), Montreal, Canada, October (2022).

26. Hisham A Kholidy., *et al*. "An Experimental 5G Testbed for Secure Network Slicing Evaluation". IEEE Future Networks (5G World Forum), Montreal, Canada, October (2022).

27. H A Kholidy and S Hariri. "Toward An Experimental Federated 6G Testbed: A Federated Leaning Approach". 2022 IEEE/ACS 19th International Conference on Computer Systems and Applications (AICCSA), Abu Dhabi, United Arab Emirates (2022): 1-6.

28. NI Haque., *et al*. "BIoTA: Control-Aware Attack Analytics for Building Internet of Things". 2021 18th Annual IEEE International Conference on Sensing, Communication, and Networking (SECON), Rome, Italy (2021): 1-9.

29. Kholidy HA., *et al*. "Attacks Detection in SCADA Systems Using an Improved Non-Nested Generalized Exemplars Algorithm". The 12th IEEE International Conference on Computer Engineering and Systems (ICCES 2017), December 19-20, (2017).

30. Qian Chen., *et al*. "Towards Realizing a Distributed Event and Intrusion Detection System". The Int. Conf. on Future Network Systems and Security, Florida, USA, Aug (2017).

31. Hisham A Kholidy., *et al*. "A Finite State Hidden Markov Model for Predicting Multistage Attacks in Cloud Systems". in the 12th IEEE Int. Conf. on Dependable, Autonomic and Secure Computing, China, August (2014).

32. Ferrucci R and Kholidy HA. "A Wireless Intrusion Detection for the Next Generation (5G) Networks". Master's Thesis, SUNY poly (2020).

33. Rahman A., *et al*. "Network anomaly detection in 5G networks". *Mathematical Modelling of Engineering Problems* 9.2 (2022): 397-404.

34. Hisham A Kholidy. "Correlation Based Sequence Alignment Models For Detecting Masquerades in Cloud Computing". *IET Information Security Journal* (2019).

35. Hisham A Kholidy. " An Intelligent Swarm Based Prediction Approach For Predicting Cloud Computing User Resource Needs". *Computer Communications* 151 (2020): 133-144.

36. Hisham A Kholidy and Abdelkarim Erradi. "VHDRA: A Vertical and Horizontal Dataset Reduction Approach for Cyber-Physical Power-Aware Intrusion Detection Systems". *Security and Communication Networks Journal* (ISI IF: 1.376), March 7 (2019).

37. Hisham A Kholidy., *et al*. "QoS Optimization for Cloud Service Composition Based on Economic Model". Book Chapter in the Internet of Things. User-Centric IoT, Volume 150 of the series Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering (2015): 355-366.

38. Hisham A Kholidy and Alghathbar Khaled S. "Adapting and accelerating the Stream Cipher Algorithm RC4 using Ultra Gridsec and HIMAN and use it to secure HIMAN Data". *Journal of Information Assurance and Security (JIAS)* 4 (2009): 274-283.

39. Hisham A Kholidy. "Towards A Scalable Symmetric Key Cryptographic Scheme: Performance Evaluation and Security Analysis". IEEE International Conference on Computer Applications and Information Security (ICCAIS), Riyadh, Saudi Arabia, May 1-3 (2019).

40. Samar SH., *et al*. "ICSD: Integrated Cloud Services Dataset". Springer, Lecture Note in Computer Science (2021).

41. Stefano Iannucci., *et al*. "A Comparison of Graph-Based Synthetic Data Generators for Benchmarking Next-Generation Intrusion Detection Systems". IEEE Cluster 2017, Sept 5 2017, Hawaii, USA (2017).

42. Mustafa FM., *et al*. "Enhanced dispersion reduction using apodized uniform fiber Bragg grating for optical MTDM transmission systems". *Optical and Quantum Electronics* 55 (2023): 55.

43. M M Badr., *et al*. "Smart Parking System With Privacy Preservation and Reputation Management Using Blockchain". in IEEE Access 8 (2020): 150823-150843.

44. SA Alansari., *et al*. "Efficient and Privacy- Preserving Infection Control System for Covid-19-Like Pandemics Using Blockchain". in IEEE Internet of Things Journal 9.4 (2022): 2744-2760.

45. S Abdelfattah., *et al*. "Efficient Search Over Encrypted Medical Data With Known-Plaintext/Background Models and Unlinkability". in IEEE Access 9 (2021): 151129-151141.

46. MM Badr., *et al*. "Blockchain-Based Ride-Sharing System with Accurate Matching and Privacy-Preservation". 2021 International Symposium on Networks, Computers and Communications (ISNCC), (2021): 1-8.

47. MM Badr., *et al*. "A Novel Evasion Attack Against Global Electricity Theft Detectors and a Countermeasure". in IEEE Internet of Things Journal (2020).

48. S A Alansari., *et al*. "Efficient and Privacy-Preserving Contact Tracing System for Covid-19 using Blockchain". 2021 IEEE International Conference on Communications Workshops (ICC Workshops), (2021): 1-6.

49. M M Badr., *et al*. "A novel vision to mitigate pilot contamination in massive MIMO-based 5G networks". 2016 11th International Conference on Computer Engineering and Systems (ICCES), (2016): 366-371.

50. M M Badr., *et al*. "A spatiotemporal scenario to mitigate pilot contamination in 5G massive MIMO systems". 2017 12th International Conference on Computer Engineering and Systems (ICCES), (2017): 95- 100.